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Biometric Data Analysis in Digital Game Scenario

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Introduction

The collection and analysis of biometric data play a significant role in understanding the relationship between physical fitness and gaming performance. This research aims to investigate how various physical parameters, such as HRV (Heart Rate Variability), Heart Rate Max, Heart Reate average, Active Sleep and Quality of Sleep, influence a user's performance in a digital game, in this case PUBG: Battlegrounds. The research will also explore the potential of using biometric data to suggest the most suitable settings for different game scenarios. By using wearable technology, which can monitor metrics such as heart rate, sleep, and activity, this study seeks to establish a correlation between the player's physical condition and their performance in a digital game scenario.

The importance of fitness data in this context cannot be overstated. Heart Rate Variability (HRV), maximum heart rate, active sleep, and sleep quality are all essential indicators of a person's physical condition. THese metrics offers a comprehensive insight into the user's physical condition, which can be used to improve their gaming performance.

Heart Rate Variability (HRV): is a measure of the variation in time between each heartbeat, and it is closely linked to the body's stress levels. HRV is widely used as a measure of the body's autonomic nervous system, which controls the body's stress response. A higher HRV is associated with a lower stress level, while a lower HRV is associated with a higher stress level. A research from E. Ortega[2] highlights the importance of HRV in sports science, as a way of understanding the psychological state of atheletes before competions. It found a positive correlation between HRV, self-efficacy, and performance among sport shooters. Advanced shooters demonstrated lower average heart rates and employed mental skills more effectively than less experienced shooters. This suggests HRV as a valuable asset, when tranferring the psychological state of the athlete to the performance in a digital game. It allows for a better understanding of the player's stress levels, and how it affects their performance. This personalized approach can enhance

player experience, and potentially improve their performance in the game.

The Heart Rate Variability measurements typically requires a chest strap, and measurements typically span from 5 minutes to 24 hours, it is commonly used in clinical settings to evaluate cardiac conditions.[3] Short-term HRV analysis lasting less then 5 minutes have been proven to provide more accurate estimations compared to longer measurements.[4] Based on this, the research will focus on short-term HRV measurements, as it is more practical for the user, and it provides accurate estimations. It will be more detailed in the methodology section.

Heart Rate Max: is the maximum number of times the heart can beat in a minute, and it is a measure of the body's cardiovascular fitness. It is an important indicator of the body's physical condition, and it is used to evaluate the body's ability to perform physical activities, reflecting their cardiovascular fitness. In this research, understanding HRmax is vital for assessing participants fitness and endurance. It could indicates how well players can handle stress and maintain their concentration over extended periods of time. By analysing alongside other biometric data this research could uncover valuable insight into optmizing players performance in a digital game scenario.

Heart Rate Average: is the average number of times the heart beats in a minute, and it is a measure of the body's physical activity. It is also an important indicator of the body's physical condition, and it is another measure of the body's cardiovascular fitness. It is used to evaluate the body's ability to perform physical activities, reflecting their cardiovascular fitness.

Active Step: Active steps, as a mesure of physical activity, is an important indicator of the body's physical condition. It is used to evaluate the body's ability to perform physical activities, reflecting their cardiovascular fitness. Counting the numbers of steps taken daily can help track overall physical activity, and it is a good indicator of the body physical condition. It is also used to evaluate the body's ability to perform physical activities, reflecting their cardiovascular fitness.

Quality of Sleep: are important indicators of the body's recovery and readiness for physical activity. Active sleep is a measure of the body's physical activity during sleep, and it is an important indicator of the body's recovery and readiness for physical activity. High-quality sleep, marked by sufficient duration and minimal disruptions, is fundamental for overall health impacting mood, cognitive fucntion. A research that evaluated Sleep and performance in Eathletes [5] uderscores the critical role of sleep in Eathletes performance in Esports, showing its impact on cognitive functions as a crucial factor for competitives success. Adequate sleep improves information processing, visual motor functioning, attention, working memory, and other functions essential for decision-making and reaction time. On the other hand, sleep depravation can significantly impair these cognitive abilities, potentially to poor performance. For this research it proves the

importance of sleep in the context of gaming performance, and how it can be used to predict the player's readiness and tune their performance in a digital game scenario.

Chapter 3

Methodology

This research is geared towards finding a correlation between users' biometric data to their performance in a first-person shooter gaming scenario. The quality of the user data collected was critical in ensuring that the research aims are achieved. For Quality Assurance purposes, a systematic step-by-step approach has been designed for the data-capturing process. An activity monitoring device was distributed to the volunteers in the form of a Polar Watch. The individuals were instructed to use these devices at pre-designated times prior to undertaking a test in the form of a First-Person Shooter Game. Results from the test, was than paired with their biometric data for further analysis.

3.1 Recruitment of Volunteers

The process of recruiting the volunteers was carried out in a way that ensured they satisfied the conditions of the research. The volunteers were required to be students of the Atlantic Technological University (ATU) Galway campus. The volunteers were also required to be over the age of 18 and have no known medical conditions that could affect their performance in the test. A microsoft form was created and distributed to the students of the university to register their interest in the research. A poster 3.1 was created wich contained information about the research and a QR code that linked to the microsoft form.

The form can be found in the appendix 7. For a volunteer to be considered, they were required to fill out the form and submit it. The form was designed to capture the following information from the volunteers:

- How often the participant practices exercises.
- The average duration of the exercises sessions.

Figure 3.1: Volunteers Recruitment Poster

- If the participant owns a activity monitoring device, if so which brand (Polar, Garmin, Apple, Fitbit, or other).
- If the participant plays video games, if so which platform (PC, Xbox, Playstation, or other).
- Which game genre the participant enjoy the most. (First Person Shooter, Third Person Shooter, Soccer, Car Racing, or other).
- Participant should also sign the form as a consent to participate in the research.

3.2 Data Collection

For the purpose of the research, different categories of data was collected from the volunteers through the monitoring device to help achieve the stated goals. As personal data was being collected, an application to the Ethicas Research and Ethics Committee was made to ensure that the data collection process was in compliance with the General Data Protection.

The Taught Programme Research Ethics Approval Application Form can be found on appendix 7. It was an extensive and iterative process with the Ethicas Research and Ethics office to ensure that the data collection process was in compliance with the General Data Protection Regulation (GDPR). Unfortunately, it took

longer than expected to get the approval from the Ethicas Research and Ethics Committee, which lead to an unexpected delay in the data collection process. The data collection process was divided into two main categories:

Biometric Data

For the very first time processing a volunteer, some user information was needed to have them registered with the activity monitoring device and their data was saved to the manufacturer' repository. The Activity Monitoring Device used on this research was the Polar Vantage Smart Watch. The watch is capable of monitoring and capturing user's biometric data and saving the data to a repository where it can be accessed online via an API. The device is commercially available and accessible to the public. The rationale for using the Polar Vantage Watch is because it has been widely used in both academic and industrial research projects and validation. Most importantly, these devices were available to us in such quantity that could satisfy our research needs.

Physical Information

The following physical information was collected from the volunteers, and stored with the manufacturer (Polar) which is GDPR compliant. The data was then accessed through the Polar API.

- Sleep Data: According to the manufacturer's manual [6], the watch is capable of recording the quality and quantity of sleep and also showing how long spent on each stage of sleep. Light Sleep, Deep Sleep, and REM Sleep with the duration of each type of sleep. For the purpose of the research, an aggregated total of the various categories of sleep will be recorded and used. Volunteers were instructed to wear the watch to sleep on the previous night before their scheduled test. Unit of measure used for the sleep data is minutes.
- Daily Activities: According to the Activity monitor manufacturers' manual [6], "Polar device uses an internal 3D accelerometer to record your wrist movements. It analyses the frequency, intensity and regularity of your movements together with your physical information." calories, active calories, active steps and their respective durations are collected from through the device. For the purpose of the research, the active steps was used. Volunteers were expected to wear the device on the previous day for this data to be available. Unit of measure used for the daily activities is count of steps.
- Nightly Recharge: From the Activity monitor manufacturers' manual [6], the Nightly Recharge is recorded as follows: " is an overnight recovery measurement that shows how well your body has coped with overall stress you

have experienced lately." The parameters, measured during roughly the first four hours of your sleep are heart rate, heart rate variability and breathing rate. For the purpose of the research, the following parameters and derived parameters will be used:

- Heart Rate Average (bpm)
- Heart Rate Maximum (bpm)
- Heart Rate Variability (HRV)

Test Data Collection

The test data is generated at the completion of the test session in the Unit Test Application. A test session consists of three categories of tests, which is undertaken sequentially in different stages. For quality assurance, the test was performed in a controlled environment using the same hardware in similar conditions over the course of the trials. For the purpose of the trial, a special designated room has been reserved for the data collection effort. The following metrics for the different tests was then captured and subsequently used for the research effort.

- Audio Test: designed to test users' audio reflexes.
- Average Response Time: this is a measure of how quickly a user is able to react and identify the source of a sound with varying audibility (in decibels) in a 3-Dimensional space.
- Visual Test: designed to test users' visual perception. At the end of this category of test, the following metrics were designed to measure users' performance.
- Average Response Time: a measure of how quickly a user can identify and engage targets.
- Shot Accuracy: a measure of the percentage of successful shots to the number of targets spawned.
- Target Accuracy: a measure of the percentage of successful shots taken to a number of targets hit.
- Fine Motor Test: designed to test users' perception of depth and eye to hand coordination.
- Average Tracking Time: measure of average time it took for a player to successfully track, engage, and eliminate a target.

- Accuracy: measure of the percentage of shots fired to the number of targets hit.

3.2.1 Data Collection Procedure

The data collection process followed the below-listed steps to maximize throughput and minimize the average time spent processing each participant. The whole precdure can be found in the appendix 7.

For this study, participants were required to wear the Polar watch which is referred sometimes to "Activity Monitoring Device" in this text, a day prior to undertaking a gagming test.

Location:

The data collection effort was carried out at the Gym on the Atlantic Technological University (ATU) Galway campus.

Time:

The following weekly schedule was available for the volunteers at various times that best suit their personal schedules.

- Tuesdays: 12:00 - 13:00, 15:00 - 16:00
- Wednesdays: 12:00 - 13:00, 15:00 - 16:00
- Thursdays: 12:00 - 13:00, 15:00 - 16:00
- Fridays: 13:00 - 15:00

Results of the test were then paired with their biometric data for further analysis.

3.3 Prediction Models

- inherited a infrastructure - adapted the infra to our needs - enrolled volunteers - collected data - designed a statistical model to analyze the data -

3.4 Software Development

As a software development methodology for this project, many factors were considered. Initially, a comparison of the different software development methodologies was carried out to determine which would be the most suitable for the project. The comparison was based on the following factors:

- Continuous Stakeholder Involvement: The methodology should allow for continuous stakeholder involvement in the development process. Maitaining a continuous feedback loop with the stakeholders was important to ensure that the project was on track and that the stakeholders were satisfied with the progress.
- Flexibility in Requirements: The methodology should allow for flexibility in the requirements. The requirements for the project were not fully defined at the start of the project. The methodology should allow for changes to be made to the requirements as the project progresses.
- Iterative Development: The methodology should allow for iterative development. The project was divided into different phases and each phase was developed iteratively. This allowed for the project to be developed in a series of small, manageable steps.

After all the considreations, Agile Methodology [1] appeared as the preferred choice over Waterfall, as it allows for continuous stakeholder involvement, flexibility in requirements and iterative development. Unlike the rigid Waterfall methodology [1], Agile allows for changes to be made to the requirements as the project progresses. The Agile methodology also allows for the project to be developed in a series of small, manageable steps. This iterative nature enables continuous refinement and adjustment, ensuring that the project is always on track and that the stakeholders are satisfied with the progress.

Agile - Extreme Programming (XP)

Extreme Programming (XP) is an Agile framework that moves from the traditional software development methodologies by breaking down the development process into smaller and more managebles increments. Instead of extensive planning, analysis, and design upfront, XP focuses on continuous and iterative development. To minimize errors and defects, XP places a strong emphasis on unit testing. This test-driven development approach ensures that the code is always working and that any defects are caught early in the development process. XP also places a strong emphasis on customer satisfaction. The customer is involved in the development process and is able to provide feedback on the project as it progresses.

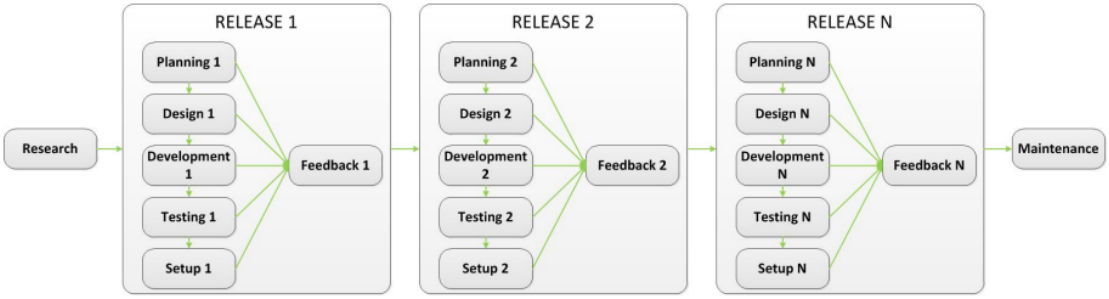

Figure 3.2: Extreme programming methodology [1]

This ensures that the project is always on track and that the customer is satisfied with the progress. [1] Overall, Extreme Programming offers a flexible and iterative approach to software development that is well-suited to the needs of this project.

3.5 Meetings

In this section we will discuss the different types of meetings that were held throughout the project. The meetings were held to ensure that the project was on track and that the stakeholders were satisfied with the progress.

3.5.1 Supervisor Meetings

Weekly meeting were setup with the supervisor to discuss the progress of the project. The meetings were held in the supervisor's office on campus every Tuesday at 12 pm throughout the duration of the project. The meetings were used to discuss:

- The progress of the project.
- Any issues or challenges that were encountered.
- Any changes that needed to be made to the project.
- Any feedback that the supervisor had on the project.

These meetings were important, specially in the early stages of the project, due to various challenges that were encountered. The feedback from the supervisor was invaluable in helping to overcome these challenges and ensure that the project was on track.

3.5.2 Client Meetings

At the beginning of the year we were offered the opportunity to work with a client on a project. In our meeting with the client, we were informed that the project was a research project that aimed to find a correlation between users' biometric data to their performance in a first-person shooter gaming scenario. The aim was to quantify how biometric such as Heart Rate Variation, Heart Rate, active steps taken, quality and quantity of sleep, etc. affect select gaming skills like eye-to-hand coordination, fine-motor skills and reaction time. The client also informed us that the project was a continuation of a previous project and that we would be inheriting an existing infrastructure. For the collection of the biometric data, the client informed us that there was four Polar Vantage Smart Watches available for the project. The meetings were also held to get the devices registered on the Polar API and to get the volunteers enrolled in the project.

The meetings were held in the client's office on the Gym at Unit D, Racecourse Business Park, Ballybrit, Galway.

3.6 Development Tools

3.7 Version Control

Chapter 4

Technology Review

4.1 Executive Dashboard

When it came to developing the Executive Dashboard for data analysis it was crucial to select the tools that could transform data into easily comprehensible information. After conducting research and exploring alternatives Angular and Chart.js were chosen for specific reasons.

4.1.1 Angular

Angular is based on TypeScript and is an open-source framework, and it's a great tool for building client-side web applications. It can be used for single-page applications (SPAs) or for enterprise-level solutions.

Main Concepts: Components, Modules and Services

Angular is composed of three foundational blocks: Components, Modules and services.

Components

Components are like Lego blocks of the application. Each component holds a portion of the user interface and its behaviour. Components serve as the bridge between the application data and what the user experiences on the screen.[7]

Modules

In Angular modules serve as containers that group related components, directives, and services together that can be combined with other modules. It plays an im-

portant role in improving maintainability and re-usability, key concepts of Angular development.[8]

Services

Angular services use typescript classes with injectable decorators. The decorator tells angular that the class is a service and can be injected into other components that need that service.[9]

4.1.2 Angular architecture

Angular uses the Model-View-Controller (MVC) pattern, with a variation known as Model-View-ViewModel (MVVM). The controller is responsible for the interaction between the model and the view.

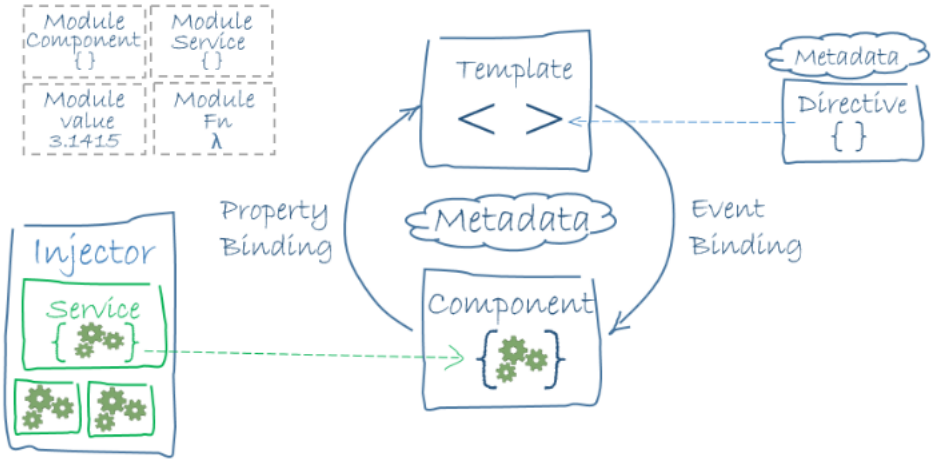

Figure 4.1: Angular application architecture

4.1.3 Advantages of using Angular

Component-Based Architecture

As mentioned earlier in discussions Angular organisess its functionalities into components. These components have the ability to communicate with each other enabling updates to sections without affecting the rest of the application.

Mobile-Friendly Approach

Angular incorporates techniques such, as lazy-loading, which means loading parts of the application (like images) only when they are needed. This ensures that users do not experience long waiting times.

Two-Way Data Binding

With Angular two way data binding data can seamlessly flow between the component and the view allowing for synchronization.

Asynchronous Programming

By utilizing programming executes code in a non-sequential manner and employs multi-threading to enhance performance. This speeds up operations and prevents system freezes, providing users with a seamless experience.

Single-Page Applications

Angular creates a dynamic single-page application which can be navigated without page reloads, improving the user experience with better user interaction and engagement.

Code Re-usability

The component-based architecture of Angular promotes the re-usability of UI components saving development time.

Dependency Injection

With dependency injection in place, Angular allows for the creation of objects that rely on other objects. This improves modularity and efficiency, within the app.

Angular Material

Angular's documentation offers a range of built user interface components and modules that adhere to Google's Material Design principles. This greatly facilitates the developer's work, simplifying the design process and enabling application development.

Angular CLI

Angular command line interface gives the developer the ability to generate Angular projects, modules, services, and components with a single command, this not only saves time but also reduces configuration errors, it gives the developer the freedom to dive into creative aspects of the project, focusing on innovation and functionality rather than getting bogged down by initial setup complexities.

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4.2 Data Visualization

Data visualization is the process of translating large volumes of data into visual representations. It is a powerful tool that allows for the identification of patterns and trends that would otherwise be difficult to identify. It is a key component of data analysis and is used to communicate information clearly and efficiently.

4.2.1 Chart.js

Chart.js is robust, lightweight and open source javascript library that provides features for creating visually appealing charts and graphs that can be embedded into a web page. It is a great tool for data visualization and is easy to use. It is based on HTML5 canvas and is responsive, meaning that the charts will adapt to the size of the container element. It is also compatible with all modern browsers and is supported by a large community of developers. [10] It can be compared like a the artist's toolkit for developers, providing a flexible API to create a variety of chart types, such as line charts, radar charts, pie charts and many more. It also provides a range of customization options, allowing developers to create unique and visually appealing charts. [10]

Table 4.2.1 is showing some of the features of Chart.js[10]:

Feature	Description
Easy to use	Aesthetically charts can be created without the need of extensive configuration. The library follows a declarative approach allowing the developer to define the data and settings of the chart in a single object.
Responsive	Charts generated by Chart.js are responsive, adapting to different screen sizes and devices, ensuring that the visualization remains accessible and readable across various platforms.
Customization	Chart.js provides a high degree of customization. Colors, fonts, and other visual elements can be customized to create unique and visually appealing charts.
Interactivity	Chart.js provides built-in support for tooltips and animation, allowing the user to explore data points, adding a layer of engagement to the project.
Cross-browser compatibility	Chart.js is compatible with all modern browsers, including Chrome, Firefox, Safari, Edge, and Internet Explorer 11.

Table 4.1: Chart.js Features

Chart.js is a reliable and effective tool for data visualization, it is also easy to use and provides a range of customization options. It is also supported by a large community of developers, which is a great advantage.

4.2.2 D3.js

D3.js or Data-Driven Documents is a JavaScript library for manipulating documents based on data. It has the ability ti bind data to the DOM (Document Obect Model) and creates interactive and dynamic visualization. It provides a lower level and more granular approach to data visualization, giving the developer more control over the visualization process.[11]

Table 4.2.2 is showing some of the features of D3.js[11]:

Feature	Description
Data-Driven	D3.js is data-driven, meaning that it can bind data directly to HTML or SVG elements. This type of control is advantageous for creating highly customized visualizations.
Modular	D3.js is modular, composed of many small modules that can be used independently or combined together to create a custom visualization.
Extensible	D3.js is extensible, meaning that it can be extended to support any type of visualization.
Community	D3.js is supported by a large community of developers, which is a great advantage.

Table 4.2: D3.js Features

D3.js is a powerful tool for data visualization, it provides a high degree of customization and control over the visualization process. However, it is more complex and requires more time to learn and implement. It is also not supported by all browsers, which is a disadvantage.

In conclusion, while D3.js is a powerful tool for data visualization, it is more complex and requires more time to learn and implement. It is also not supported by all browsers, which is a disadvantage. Considering the scope of the project and the time constraints, Chart.js was chosen as the tool for data visualization. It is easy to use and provides a high degree of customization, allowing for the creation of unique and visually appealing charts. It is also supported by a large community of developers, which is a great advantage.

4.3 AI module - Data analysis

Ninety per cent of the world's data was generated in just the last two years. In the early 2000s, the amount of data being generated exploded exponentially with the use of the internet, social media, and various other technologies. Organizations found themselves facing a massive volume of data that was very hard to process. To address the challenge, the concept of Big data emerged. Big data refers to extremely large and complex data sets that are difficult to process using traditional methods. [12]

4.3.1 Hadoop

As the volume of data grew rapidly across the globe, organizations needed a way to manage it to gain valuable insights. That's where Hadoop came in. In 2006,

a team of engineers from Yahoo developed Hadoop inspired by Google's MapReduce. Hadoop has introduced a new way of handling data called distributed processing. Now, to process all data it wouldn't use single machines anymore, instead, Hadoop uses multiple computers, allowing large amounts of data to be processed way faster than before. Hadoop has mainly two main components: HDFS (Hadoop Distributed File System) and MapReduce. HDFS stores the into multiple computers, and MapReduce is responsible for processing the data in parallel allowing the organizations to store and process large amounts of data. Hadoop was a great advance in big data processing, however, it had a few limitations. One of the biggest problems was that it relied on storing data on disk. This slowed down data processing because every time a job ran it had to save its data to disk, read it back, process it, and save it back to disk Another problem is that Hadoop processes data only in batches. This means a new job couldn't be submitted before the other job ended. With Hadoop, storing and processing large amounts of data became possible, even with some limitations it was an important step in big data processing.[13]

4.3.2 Apache Spark

As described Hadoop has a few limitations, there was a need to process all this data faster and in real-time. And here is where Apache Spark comes into action. In 2009, researchers at the University of California developed Apache Spark as a research project. At this point, RDD (Resilient Distributed Dataset) was introduced and deemed to be a very powerful concept.[14] RDD is the backbone of Apache Spark, storing the data in memory for faster access and processing. It will not read and write the data from the disk, instead, Spark processes the entire data just in memory. The meaning of memory here is the RAM (Random Access Memory) stored inside the computer. This in-memory data processing of data makes Spark much faster than Hadoop. Spark also gives the ability to write code in various programming languages such as JAVA, Scala, Python and R, along with an optimized engine that supports general execution graphs.

Main components and Features

The Apache Spark ecosystem consists of the following main components[15]:

- Spark SQL: Formerly known as Shark. Spark SQL is a distributed framework that works with structured and semi-structured data. It facilitates analytical and interactive applications for both streaming and historical data which can be accessed from various sources such as JSON, Parquet and Hive table.[15]

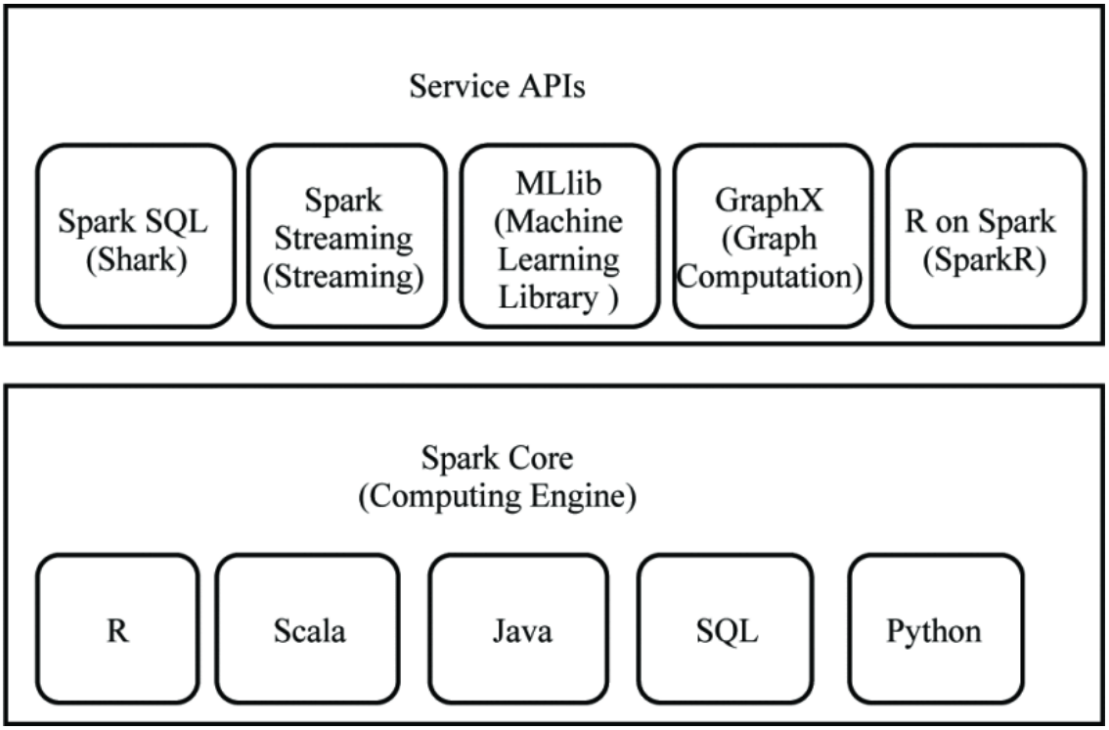

Figure 4.2: Apache Spark Ecosystem

- Spark Streaming: Allows to process real-time data. Is a scalable fault-tolerant streaming processing system that supports both batch and streaming workloads. Spark streaming enhances the fast scheduling capability of Apache Spark by inserting data into mini-batches. An operation known as transformation is then applied to those mini-batches that can be easily obtained from live streams and data sources such as Twitter, Apache Kafka, IoT sensors, and Amazon Kinesis.[15]

- Spark Core: One of the most important parts of the Spark ecosystem is called Spark Core. It helps process data across multiple computers and ensures everything works efficiently and smoothly. Various functionalities of Apache Spark are built on top of the Spark core. It provides a vast range of APIs as well as applications for programming languages such as Scala, Java, and Python APIs to facilitate the ease of development. In-memory computation is implemented in Spark core in order to deliver speed and solve the issue of MapReduce.

- MLlib: It delivers high-quality algorithms with high speed and makes ma-

chine learning easy to use and scale. Several machine learning algorithms such as regression, classification, clustering, and linear algebra are present. It also provides a library for lower-level machine learning primitives like the generic gradient descent optimization algorithm. It also provides other functions such as model evaluation and data import. It can be used in Java, Scala, and Python. [15]

With all these components working together, Apache Spark became a powerful tool for processing and analysing Big Data. Spark manages and coordinates the execution of tasks on data across a cluster of computers.

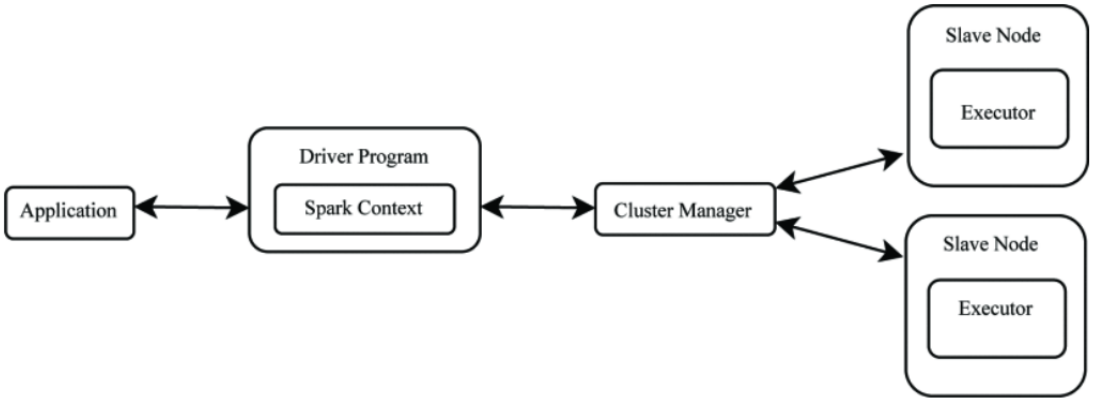

Figure 4.3: Apache Spark Architecture

Figure 4.3 shows the Spark Architecture. It consists of a master node which has a driver program that is responsible for calling the main program of an application, this driver could be the Spark shell or the application, written in Scala or Java, for example. It is basically the entry point and is responsible for creating Spark context, which behaves like a gateway to all of the functionalities of Apache Spark. It allows for communication and coordination with other nodes within the cluster, known as Slave nodes. Within the slave node, there are many numbers of executors which act as workers. Whenever a job is initiated, the driver process will make sure it goes through the Apache application properly. It analyzes the work that needs to be done, divides it into smaller tasks and assigns it to the executors. The driver process is the heart of the Apache Spark application and executors are the real workers, which execute the work assigned by the driver and report back the progress and results of the computation.[15]

Due to the powerful capabilities of distributed computing, large volumes of data can be processed quickly and efficiently. For all these reasons, it was deemed

to be the perfect technology to be used in this project. As the project evolves and more data is gathered from our research volunteers, Spark's performance scales with the size of the data, processing with high speed.

4.3.3 TensorFlow

TensorFlow was developed by Google Brain Team and is an open-source library for numerical computation and large-scale machine learning. It is a powerful tool for machine learning and deep learning, providing a wide range of functionalities for building and training machine learning models. It is also highly flexible, allowing for the creation of custom machine learning models. It is also highly scalable, allowing for the training of models on multiple CPUs, GPUs, and TPUs (Tensor Processing Units). [16]

- **Flexible Architecture**: TensorFlow allows developers to deploy computation to one or more CPUs or GPUs in a desktop, server, or mobile device with a single API, making it suitable for a wide range of applications.
- **Comprehensive Library**: It provides a comprehensive ecosystem of tools, libraries, and community resources that allows researchers to advance the state-of-the-art in ML, and developers to easily build and deploy ML powered applications.
- **High-Level APIs**: TensorFlow includes high-level APIs like Keras, which make it very accessible for beginners by simplifying the process of building and training neural networks.
- **Visualization with TensorBoard**: TensorBoard is a tool for providing the visualization and tooling needed for machine learning experimentation. It enables tracking metrics like loss and accuracy, visualizing the model graph, and much more.
- **Scalability**: TensorFlow's ability to perform computations on a variety of different hardware platforms, and its capacity to scale from a single device to thousands of GPUs or TPUs, makes it fit for large-scale machine learning tasks.
- **Large Community and Support**: Having a vast community, TensorFlow benefits from a plethora of tutorials, documentation, and active community support which aids in solving problems and improving the framework.

Figure 4.4 [17] shows the TensorFlow Architecture. The architecture is designed to be flexible and scalable, allowing for computations on a variety of devices and the ability to handle large-scale machine learning projects.

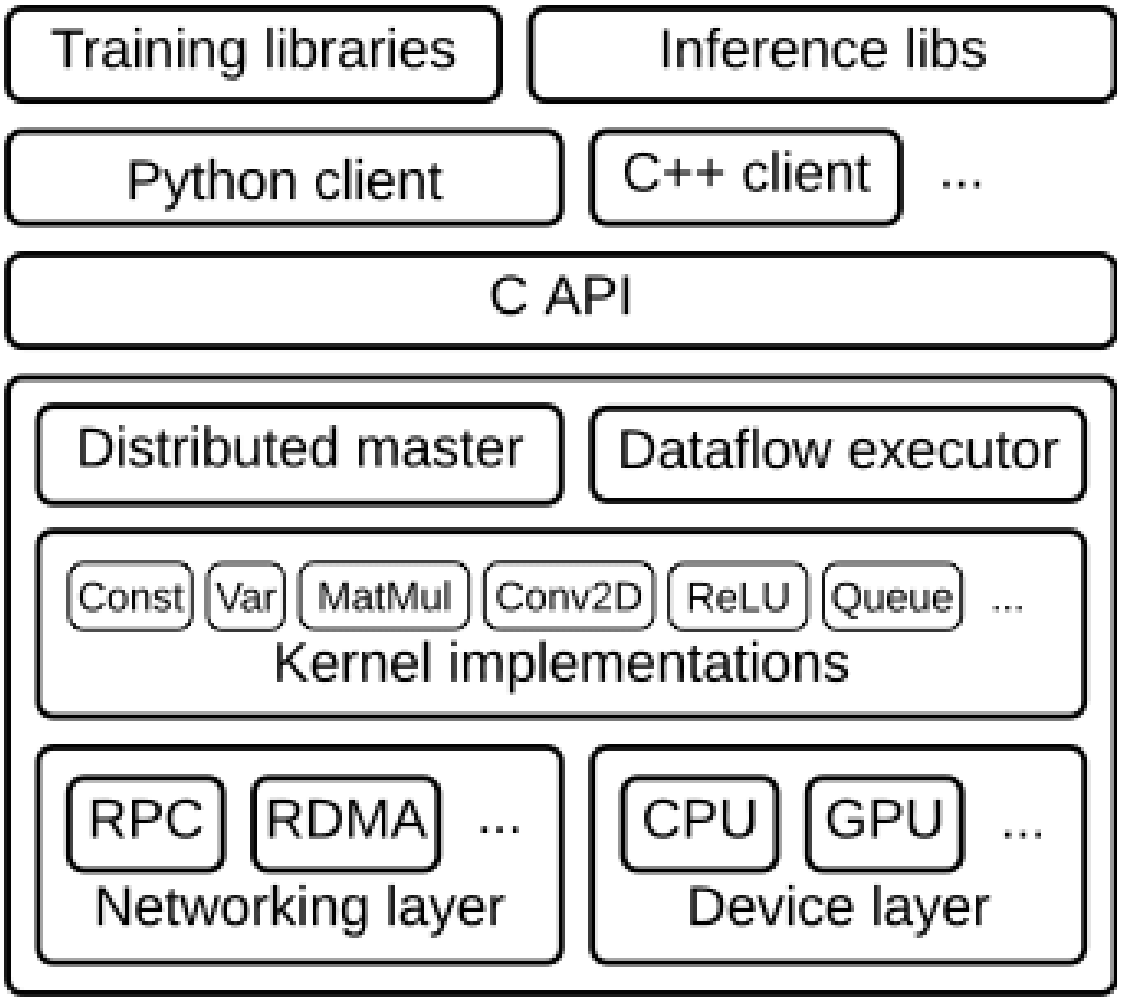

Figure 4.4: TensorFlow Architecture

Given these powerful features and advantages, TensorFlow was chosen to be used in conjunction with Apache Spark, for this project to handle complex machine learning tasks, including but not limited to, neural network design and training. As the dataset grows, TensorFlow's performance scales with the size of the data, processing with high speed.

4.3.4 Node JS

NodeJS is an open-source, cross-platform, JavaScript runtime environment that executes JavaScript code outside of a browser. It is built on Chrome's V8 JavaScript engine and is used to build fast and scalable network applications. It is event-

driven and non-blocking, meaning that it is capable of handling concurrent operations without blocking the execution of other operations. This makes it ideal for data-intensive real-time applications that run across distributed devices.[18] It has solidified its position as a cornerstone of modern web development, with a large community of developers and a vast ecosystem of open-source libraries.

Advantages of Node.js

It is an asynchronous event-driven JavaScript runtime environment that is designed to build scalable network applications. It is lightweight and efficient, making it a great choice for data-intensive real-time applications.[19] One of the primary advantages of NodeJS is that it uses a single-threaded event loop, which allows it to handle concurrent operations without blocking the execution of other operations. Another strength of NodeJS is its vast ecosystem of open-source libraries. The Node Package Manager (NPM) is the largest ecosystem of open-source libraries in the world, with over 1 million packages. [20] This wealthy of modules and libraries greatly facilitates the development process, allowing developers to focus on the creative aspects of the project, rather than reinventing the wheel. NodeJS also benefits from its single programming language across both the server and client sides. This allows for the sharing of code and data between the server and the client, which is a great advantage, reducing the learning curve associated with NodeJS development. [19] Performance wise NodeJS is very fast, it is built on Chrome's V8 JavaScript engine, which is a high-performance JavaScript engine. It is also lightweight and efficient, making it a great choice for data-intensive real-time applications. [19]

Disadvantages of Node.js

NodeJS is not without its criticisms. Critics often point out the callback hell, a situation where the code becomes unreadable due to the excessive use of callbacks. Although it has been largely mitigated by the introduction of Promisses and async/await syntax, it remanins a valid criticism. [21]

Table 4.3.4 is summarizing the advantages and disadvantages of Node.js[19]:

Advantages of Node.js	**Disadvantages of Node.js**
Non-blocking and event-driven: Allows for high concurrency and scalability, making it suitable for real-time applications.	Single-threaded: Node.js is single-threaded, which can lead to blocking if not handled correctly, impacting CPU-bound tasks.
JavaScript as a single language: Developers can use JavaScript for both server-side and client-side development, reducing context switching.	Callback hell: Deeply nested callbacks can make the code hard to read and maintain (though Promises and async/await mitigate this issue).
Large and active community: A vast number of open-source libraries and modules available through npm (Node Package Manager).	Limited support for multi-core processors: Node.js does not fully utilize multi-core CPUs out of the box.
Speed: Node.js is built on the V8 JavaScript engine, known for its high-performance execution.	Less suitable for CPU-intensive tasks: Due to its event-driven, single-threaded nature, Node.js may not be the best choice for CPU-bound operations.
Lightweight and fast startup: Node.js applications typically have lower memory consumption and quicker startup times.	Maturity and stability: Some developers argue that Node.js, compared to more established platforms, may have less maturity and stability in certain use cases.

Table 4.3: Advantages and Disadvantages of Node.js

Considering these noumerous advantages, NodeJS was chosen as the technology for the project. It is lightweight and efficient, making it a great choice for data-intensive real-time applications. It also benefits from its vast ecosystem of open-source libraries, which greatly facilitates the development process, allowing us to focus on the creative aspects of the project, rather than reinventing the wheel. It is also fast and scalable, which is a great advantage.

4.3.5 PM2

PM2, or Process Manager 2, is a production process manager for NodeJS applications. It is a feature-rich tool that provides a wide range of features, including monitoring, load balancing, and error handling. It is designed to simplify the deployment and management of NodeJS applications in production environments and to keep applications alive forever, restart them without downtime and simplify common system administration tasks. The standout feature of PM2 is its

ability to keep processes running in the background indefinitely. This is particular important for web applications that requires constant availability. PM2 automatically resurrects crashed applications, ensuring that system glitches do not result in prolonged downtime.[22] This automatic restart capability is a safeguard against potentially costly application crashes that could otherwise lead to a poor user experience or even lost revenue. [22] PM2 also provides a built-in load balancer that can distribute incoming requests across multiple instances of the application. This improves performance and scalability, allowing the application to handle more requests, evenly distributing traffic across the instances, which can be particularly beneficial when running on multi-core systems. [23] However, PM2 is not one-size-fits-all solution. It is designed for NodeJS applications, and is not suitable for applications written in other languages. It is also not suitable for applications that require a high degree of customization. [22] Despite the considerations, PM2's benefits have outweighed its limitations, and it was chosen as the technology for the project. It is a feature-rich tool that provides a wide range of features, including monitoring, load balancing, and error handling. It is designed to simplify the deployment and management of NodeJS applications in production environments and to keep applications alive forever, restart them without downtime and simplify common system administration tasks. Its installation and setup process is straightforward, requiring minimal configuration. It is also lightweight and efficient, making it a great choice for this project. [19]

4.3.6 Docker

Docker has emerged as a revolutionary tool for software development. It is an open-source platform that allows developers to build, ship, and run applications in containers. It is a lightweight alternative to virtual machines, allowing for the isolation of applications and their dependencies into containers. Containers encapsulate the application's code, libraries, and dependencies in a single object, ensuring that the application runs reliably and consistently across different environments. Due to its simplicity and portability, Docker has become the de facto standard for containerization. It is supported by all major cloud providers, including Amazon Web Services, Microsoft Azure, and Google Cloud Platform. Its lightweight nature compared to traditional virtual machines makes it ideal for cloud computing. Containers share the machine's OS kernel, and do not require an OS per application, which greatly reduces the memory footprint and improves performance. [24]

However, Docker's container model is not without challenges. In the context of this project, the average size of a single Docker image exceeding 400MB presents a concern regarding bandwidth utilization. Continous build and deployment processes involving large container images can consume substantial network resources,

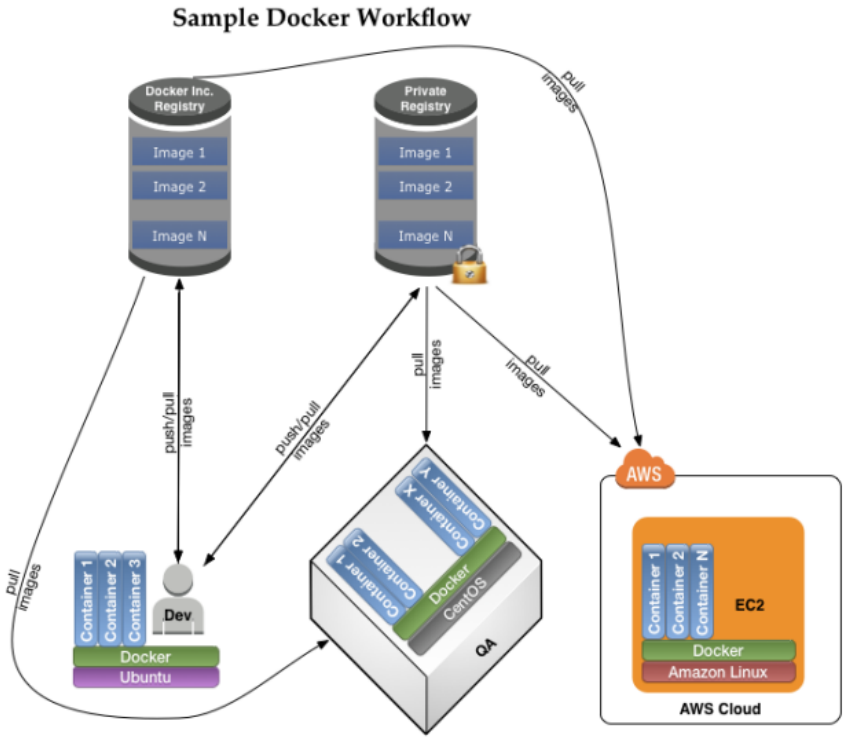

Figure 4.5: Development workflow with Docker

leading to potential cost overruns. [24] Another challenge is the security of Docker containers. Docker containers share the same kernel, which means that a vulnerability in the kernel can affect all containers. [25] While Docker's layering and image caching mechanisms can mitigate some of the network overhead, it is still a concern. In conclusion, Docker is a powerful tool that offers numerous benefits for application deployment, from development to production. However, it is not without its challenges. The large size of Docker images can lead to bandwidth utilization issues, and the shared kernel model can lead to security concerns. Considering the scope of the project, time constraints and budget, Docker wasn't chosen as the technology for the project as the cost would be too high.

4.3.7 NGINX

NGINX is a high-performance web server that can also be used as a reverse proxy, load balancer, mail proxy, and HTTP cache. It is a lightweight and efficient solution that can handle high volumes of concurrent connections. It is also highly configurable, allowing for the customization of its behaviour to suit the needs of the application. It was originally created by Igor Sysoev in 2004, with the goal

of solving the C10K problem, which refers to the challenge of handling 10,000 concurrent connections. [26] It has since become one of the most widely used web servers in the world, often used as load balancer and as reverse proxy in addition to its role as a web server.

Table 4.3.7 is showing some of the features of NGINX[26]:

Aspect	**Description**
Type	Web server software
Primary Use	Serving web content, load balancing, reverse proxy, and more
Performance	Highly efficient in handling high concurrency with low memory footprint
Architecture	Event-driven, asynchronous, and non-blocking which contributes to its ability to handle a large number of simultaneous connections easily
Scalability	Scalable to support growth in traffic and applications
Security Features	Offers robust security features including rate limiting, client request filtering, and SSL/TLS termination
Flexibility	Highly configurable for a wide range of web and mail server tasks
Open Source/Commercial	Available in both open-source and commercial versions (NGINX Plus)

Table 4.4: NGINX Features

Due to its vast capabilities NGNIX was chosen for our project as reverse proxy and load balancer. It is a lightweight and efficient solution that can handle high volumes of concurrent connections. It is also highly configurable, allowing for the customization of its behaviour to suit the needs of the application.

4.3.8 MySQL

MySQL is an open-source relational database management system (RDBMS) that is widely used in web applications. It uses structured query language (SQL) for database access and is known for its speed, reliability, and ease of use. MySQL is a popular choice for both small and large applications and is an essential component of the LAMP (Linux, Apache, MySQL, PHP/Perl/Python) software stack.

Table 4.3.8 is showing some of the features of MySQL[27]:

Aspect	Description
Data Handling	Efficiently manages large datasets, crucial for training machine learning models
Query Performance	Fast query execution, beneficial for data retrieval and preprocessing in machine learning workflows
Scalability	Easily scales with data volume and complexity, supporting the growing needs of machine learning applications
ACID Compliance	Ensures data integrity and consistency, vital for the accuracy of machine learning outputs
Advanced Analytics	Supports SQL extensions for advanced analytics, facilitating machine learning data processing tasks
Data Storage Options	Offers various storage engines, allowing optimization based on the specific needs of machine learning models
Community and Support	Strong community and extensive documentation, aiding in troubleshooting and optimization for machine learning projects
Integration Capabilities	Easily integrates with popular machine learning frameworks and languages, streamlining the development process

Table 4.5: MySQL

In the context of this project, the dataset was originally in a JSON format in FireStore which were found to be of a high complexity while performing compound querying. To facilitate querying and the high complexities involved in FireStore, MySQL was chosen to be the database for the project, where all the data for analysis is sourced directly from it, which is a structured replica of the FireStore Database as obtained from the Legacy System.
By regularizing the data in MySQL, a more standardized and organized dataset was achieved. This standardization significantly simplified the data preprocessing steps in the machine learning workflow.

4.3.9 Express JS

Express.js, commonly referred as Express, is a minimal and flexible Node.js web application framework that provides a robust set of features for web and mobile applications. It is widely used for building server-side applications and APIs due to its simplicity, performance, and scalability. In this project, Express.js was chosen for several strategic reasons, which are outlined below.[28]

Feature	**Advantage for Our Project**
Minimalist Framework	Express.js provides essential web application features without dictating any specific architecture, allowing for flexibility and customization in our project.
Middleware Support	The use of middleware modules enables us to extend the functionality of our application easily and efficiently.
Routing System	Its powerful routing system helps manage requests and responses effectively, a crucial aspect for our project's RESTful API design.
High Performance	Known for its high performance, Express.js enhances the responsiveness and speed of our web application.
Community Support	Being one of the most popular Node.js frameworks, it has strong community support, ensuring access to a wide range of resources and troubleshooting assistance.
Easy Integration	Express.js seamlessly integrates with other technologies and databases, which is vital for the diverse tech stack of our project.
Simplicity	Its simplicity and ease of use accelerate development and reduce the learning curve for new team members.

Table 4.6: Express.js Features

It was chose as a back end web application for this project due to its simplicity, performance, and scalability. It is also widely used for building server-side applications and APIs, which is a great advantage. It also provides a robust set of features for web and mobile applications, which is a great advantage.

Chapter 5

System Design

Provide a detailed explanation of the overall system architecture [**?**], i.e. the HOW of the project. Use UML, system architecture diagrams, screenshots, code snippets and algorithms to illustrate your design.

Legacy Architecture

The entire system architecture, as designed in the previous projects, is visualized in Figure 5.1. This system consists of three modules that interact with both an external API and user devices. These modules are detailed as follows:

- Test Application
  A Unity-designed desktop application on a Windows Platform where users can play tests for different game scenarios.
- Node Js Web Application
  An Express Node JS Web application deployed on Amazon EC2 Virtual machine, serving as a callback endpoint for OAuth 2.0 Authentication for the Polar Flow API.
- Firestore Data Storage
  Permanent storage medium for user's test and Biometric data.

User Devices:

- Smart Watch
- Smart Phone

The actions in the Figure Figure 5.1 can be summarized as follows:

- sync: passing of biometric data to a smartphone from a Polar watch.

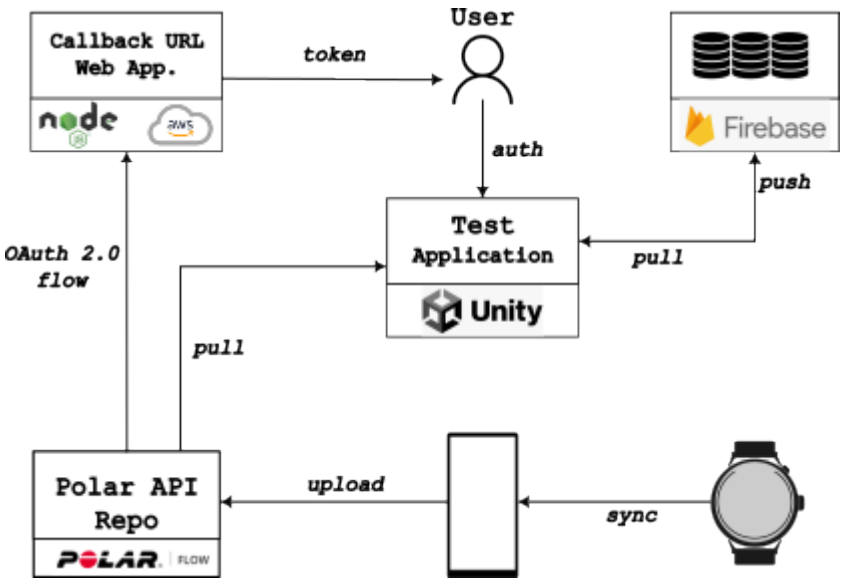

Figure 5.1: System Architecture

- upload: uploading of biometric data to Polar API repository.
- OAuth 2.0 flow: Multi step OAuth 2.0 authentication protocol.
- token: getting verification token from the Callback URL by the user.
- pull (Polar API - Test Application): retrieving biometric data from Polar API by the Test Application.
- auth: The user supplies a token to the Test Application as a final step of authentication.
- pull (Firebase - Test Application): retrieving user test/biometric data for rendering by Test Application.
- push: saving user's test/biometric data to a Datastore.

Proposed Architecture

The final system architecture will include new modules to facilitate data analytics using AI models. The new system calls for a relational database replica of the Firebase storage to ensure data consistency, predictability and structures suitable for relevant statistical analysis. A.I models as a mini-service that performs operations with supplied data and returns the result of the analysis. A Web Application that functions as a Controller that interfaces the data and A.I modules, Executive

Dashboard that renders user data and results from the A.I models and any other information about the system.
Figure 5.2 shows the proposed architectural layout for the System.

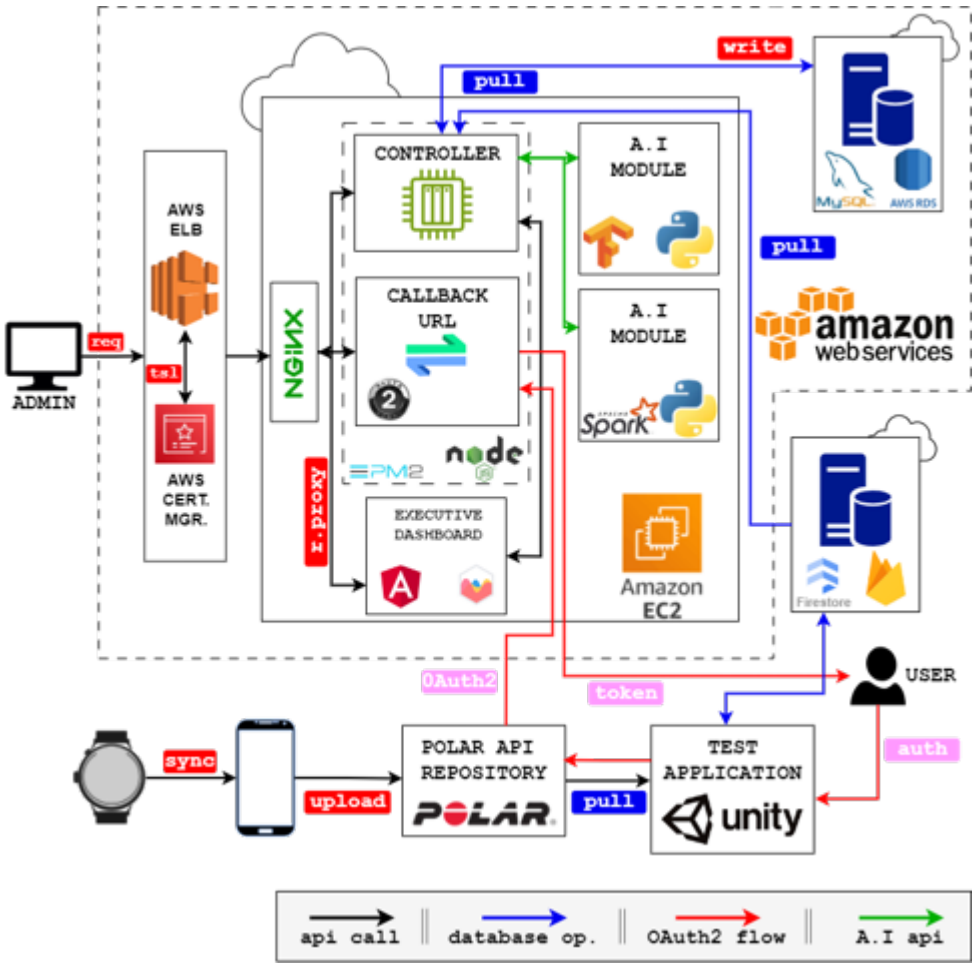

Figure 5.2: Web Application Architecture

Additional modules have been added to the web application namely back end 'Controller' & front end 'Executive Dashboard', and a 'Relational Database'. The functions of these modules are explained below:

- Controller: This module is responsible for coordinating data fetch from the Relational Database and making sure that the Relational Database is always in sync with the Firebase Datastore. It is also responsible for filtering and structuring data being fed into the A.I. Modules and when necessary using the output for an A.I module as input for another A.I module.

- Executive Dashboard: This module provides a Graphical User Interface that displays the working dataset, and offers interfaces to filter, tune and if needed bias the data being sent to the A.I Modules for analysis. This module will developed using the Angular Framework with integration of D3.js or Chart.js for displaying relevant charts. The choice for Angular Framework over other solutions namely ReactJS and Vue is because of the more structured Angular Framework which is more suited for collaborative work.

- A.I Modules: These modules are responsible for running analysis on data. The modules accept input from the 'Controller' and output a comprehensive summary of the results of the analysis done to the 'Executive Dashboard' module. For this purpose, TensorFlow and Apache Spark were chosen for the following reasons:

- Capabilities: Apache Spark is capable of performing linear and logical regression[29] which are common tools used for this class of problem. TensorFlow also has the same capabilities and can perform regression neural network models[30].

- Accessibility: Both tools are open-source and available to the general public[31].

- Python API interface: Both tools provide a Python API. This eases deployment as Python is platform-independent and relatively easy setup in a Ubuntu Virtual machine.

- Large Community: Both have a large community of contributors. Documentation and tutorials are vastly available on the internet.

- Relational Database: Data for the analysis will be sourced directly from this Database which is a structured replica of the FireStore Database as obtained from the Legacy System. The rationale for this Module is to provide a flexible means of retrieving data in various forms and shapes as may be needed for analysis and also overcome the high complexities involved in FireStore for compound queries.

- Chart API: Is responsible for displaying test results and biometric data to the users. This already developed module will be integrated into the 'Test Application' and undergo some modification to be able to display custom data as requirements change.

Chapter 6

System Evaluation

Evaluate your project against the objectives set out in the introduction. This chapter should present results if applicable and discuss the strengths and weaknesses of your system. This is a clear opportunity for you to demonstrate your critical thinking in relation to the project.

6.1 Working with Tables

Table 6.1 can be referenced with the label given to the table, i.e. **ref{table:HexToBin}**. Note that LaTeXwill place the table wherever it deems fit. Don't bother trying to change where a table or figure is placed until your document is ready for final layout.

Hexadecimal to Binary					
Hex	Binary 2	Hex	Binary	Hex	Binary
1	00000001	B	00001011	15	00010101
2	00000010	C	00001100	16	00010110
3	00000011	D	00001101	17	00010111
4	00000100	E	00001110	18	00011000
5	00000101	F	00001111	19	00011001
6	00000110	10	00010000	1A	00011010
7	00000111	11	00010001	1B	00011011
8	00001000	12	00010010	1C	00011100
9	00001001	13	00010011	1D	00011101
A	00001010	14	00010100	1E	00011110

Table 6.1: Conversion from Hexadecimal to Binary

Chapter 7

Conclusion

Briefly summarise your context and objectives. Remind the reader about the overall rationale and goals of the project. Highlight your findings from the System Evaluation chapter.

Appendix

Ethics Application

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Atlantic Technological University

Taught Programme Research Ethics Approval Application Form

Research undertaken by taught students must receive ethical approval unless deemed exempt. This application form may be completed by an individual student or by a Programme Board/Lecturer for a group of similar research projects.

This application is completed by:

Student: ✓ OR Lecturer on behalf of Programme Board: ☐

PART A

Applicant Details	
Name:	Otito Mbelu, Rodrigo Almeida
Student ID:	G00397738, G00377123
Programme Title:	Computing in Software Development
Programme Stage:	Year 4
Research Supervisor's Name:	Dr. Damien Costello

Project Details	
Research Study Title:	Biometric Data Analysis in Digital Game Scenario
Research Study Summary (max 100 words): The main hypothesis of this research is to find if there is any correlation between a user's biometric data and their performance in a first-person shooter game scenario. This research study will try to quantify how biometric data such as Heart Rate Variation, Heart Rate, active steps taken, quality and quantity of sleep, etc. affect select gaming skills like eye-to-hand coordination, fine-motor skills and reaction time.	

Risk Checklist Please answer ALL the questions in each of the sections below – Tick YES or NO			
	Will the research study….?	YES	NO
1	Involve direct and/or indirect contact with human participants?	✓	
2	Involve analysis of pre-existing data which contains personal or sensitive information not in the public domain?		✓
3	Require permission or consent to conduct?	✓	
4	Require permission or consent to publish?		✓
5	Have a risk of compromising confidentiality?		✓
6	Have a risk of compromising anonymity?		✓
7	Collect/contain personal data i.e. any information that relates to an identified or identifiable individual?		✓
8	Collect/contain sensitive personal data e.g. health data, sexual orientation, race religion?	✓	
9	Contain elements which you OR your supervisor are NOT trained to conduct?		✓
10	Use any information OTHER than that which is freely available in the public domain?		✓
11	Involve respondents to the internet or other visual/vocal methods where participants may be identified?		✓
12	Include a financial incentive to participate in the research?		✓
13	Involve our own students or staff?	✓	
14	Take place outside Ireland?		✓
15	Involve participants who are vulnerable or at risk?		✓
16	Involve any participants who are unable to give informed consent?		✓
17	Involve data collection taking place BEFORE informed consent is given?		✓
18	Involve any deliberate deception or covert data collection?		✓
19	Involve a risk to the researcher or participants beyond that experienced in everyday life?		✓
20	Cause (or could cause) physical or psychological harm or negative consequences?		✓
21	Use intrusive or invasive procedures?		✓
22	Involve a clinical trial?		✓

Risk Checklist Please answer ALL the questions in each of the sections below – Tick YES or NO			
	Will the research study….?	YES	NO
23	Involve the possibility of incidental findings related to participant health status?		✓
24	Involve the remuneration of research participants?		✓

If, as a student, you answered **NO** to all the above questions your research supervisor will review, and if in agreement sign below to indicate that this form does not have to be submitted to the Taught Programme Research Ethics Committee.

Name		*Signed*		*Date*	

If you answered **YES** to any of the above questions, you need to complete part B below.

PART B

1	**Project Overview**

Please give a brief overview of the study, including a summary of the aims and objectives.

Help: Describe the purpose of the research and what question(s) the project should answer.

Introduction to PUBG: PUBG, short for Player Unknown's Battlegrounds, is a popular online multiplayer battle royale game developed and published by PUBG Corporation, a subsidiary of Bluehole Studio. In PUBG, up to 100 players parachute onto an island and scavenge for weapons and equipment to kill others while avoiding getting killed themselves. The game features a shrinking safe area to force players into close encounters, promoting tactical gameplay and intense firefights. The last player or team standing wins the game. PUBG became widely popular upon its release in 2017 and is available on various platforms, including PCs, consoles, and mobile devices1. Since its launch in 2017, PUBG has become incredibly popular, with more than 280M active players. People of all ages and from all over the world enjoy playing this game. In PUBG, players need good hand-eye coordination and quick reflexes to compete well against others. The game offers a variety of weapons, and players can customize their controls to fit their preferences. This project builds upon the research done by university students, focusing on collecting biometric data to improve player performance in digital games.

The original project, titled "Biometric Data Collection for Performance Optimization in a Digital Game Scenario", aimed to find out if a player's body data could help them play a video game better. The researchers set up a practice game similar to PUBG: Battlegrounds, with the same weapons and controls in a Unity Desktop Application. Biometric data was supplied by a Smart Watch. In this instance, the only data used to test the application was produced by the developers themselves and from the stakeholders, for this reason, it wasn't necessary an Ethics application as there wasn't a recruitment of volunteers at the time. The goal of the original project was to see if there was a connection between how players performed in the game and their body data. In our third-year project, our team was given the challenge of enhancing the visualization of data from both the test games and the Polar API. To achieve this, we developed a chart API, enabling users to conveniently view all the results on a single page. The chart API was specifically created to present the data collected during the initial research in a coherent and user-friendly chart format, integrating various user data into one unified visual representation. Project Objective The aim of this research project is to overcome the limitations mentioned in previous projects and complete the future development goals of both projects. These include:

• Chart API Integration: Integration of developed Chart API into the test application.

• Offline Data Storage: Provision will be made for offline temporary file storage to improve the overall reliability of the whole system

• PUBG API: Further research on new developments in the PUBG API for better user experience.

And eventually, seek to answer the following research questions:

- Can the user's current physical condition as indicated by their Biometric data, have any direct relationship with their performance in such a gaming scenario?

- Can Biometric and test data help suggest the most suitable settings for different game scenarios?

2	**Methodology**

Please give a description of the methodology, including any data collection and analysis methods.

Help: Give an outline of the study here. If the project is complex, you can also submit the research proposal/protocol (no more than 2-3 A4 sides) if this would help the reviewer's understanding of the project. Include details of your (or the Research Supervisor's) appropriate skills and qualifications to carry out this research. Consideration of how, and for what duration are stored should be provided under Section 7 below.

This research is geared towards finding a correlation between users' biometric data to their performance in a first-person shooter gaming scenario. The quality of the user data collected will be critical in ensuring that the research aims are achieved. For Quality Assurance purposes, a systematic step-by-step approach has been designed for the data capturing process.

An activity monitoring device will be distributed to volunteers in the form of a Polar Watch. Individuals are expected to use these devices at a pre-designated times prior to undertaking a test in the form of a First-Person Shooter Game. Results from the test will be paired with their biometric data for further analysis.

Data of Interest

For the purpose of the research, different categories of data will be collected from the volunteers through the monitoring device to help achieve the stated goals. These data relate to the volunteer's physical information, sleep data, daily activities, and nightly recharge.

For the Test Game, volunteers are expected to play a total of 3 different categories of test to gauge their performance in these tests. The tests are Audio Test, Visual Test, and Fine Motor Test. The tests are designed to be played sequentially and will typically take a total of 15 minutes to conclude.

Procedure

The data collection process is expected to follow the below listed steps to maximize throughput and minimize the average time spent processing each participant.

Location

The data collection effort will be carried out at the Gym on the Atlantic Technological University (ATU) Galway campus.

Time

The following weekly schedule will be available for volunteers at various times that best suit their personal schedule.

· Tuesdays: 12:00 - 13:00, 15:00 - 16:00

· Wednesdays: 12:00 - 13:00, 15:00 - 16:00

· Thursdays: 12:00 - 13:00, 15:00 - 16:00

· Fridays: 13:00 - 15:00

Note: The timing is open for adjustment to suite volunteers

Biometric Data Procedure:

For the very first time processing a volunteer, some user information will be needed to have them registered with the activity monitoring device and their data is saved to the manufacturer's repository.

The Activity Monitoring Device to be used in this research is the Polar Vantage Smart Watch. The watch is capable of monitoring and capturing user's biometric data and saving the data to a repository where it can be accessed online via an API. The device is commercially available and accessible to the public. The rationale for using the Polar Vantage Watch is because it has been widely used in both academic and industrial research projects and validation. Most importantly, these devices are available to us in such quantity that can satisfy our research needs.

Physical Information

These are the first group of data to be collected about the individual to register the Monitoring device manufacturer. The data is stored with the manufacturer (Polar) which is GDPR compliant.

Sleep Data

According to the manufacturer's manual, the watch is capable of recording the quality and quantity of sleep and also showing how long spent on each stage of sleep. Light Sleep, Deep Sleep, and REM Sleep with the duration of each type of sleep. For the purpose of the research, an aggregated total of the various categories of sleep will be recorded and used.

Volunteers are expected to wear the watch to sleep the previous night before their scheduled test

· Sleep (minutes)

Daily Activities

According to the Activity monitor manufacturers' manual, "Polar device uses an internal 3D accelerometer to record your wrist movements. It analyses the frequency, intensity and regularity of your movements together with your physical information." calories, active calories, active steps and their respective durations are collected from through the device. For the purpose of the research, the active steps will be used.

Volunteers are expected to wear the previous day for this data to be available.

· Active Steps (count)

Nightly Recharge

From the Activity monitor manufacturers' manual, the Nightly Recharge is recorded as follows: " is an overnight recovery measurement that shows how well your body has coped with overall stress you have experienced lately." The parameters, measured during roughly the first four hours of your sleep are heart rate, heart rate variability and breathing rate. For the purpose of the research, the following parameters and derived parameters will be used:

· Heart Rate Average (bpm)

· Heart Rate Maximum (bpm)

· Heart Rate Variability (HRV)

Once again, volunteers are expected to wear the watch to sleep the previous night before their scheduled test.

Test Data Collection

The test data is generated at the completion of the test session in the Test Application. A test session consists of three categories of tests, which will be undertaken sequentially in different stages. For quality assurance, the test will be undertaken in a controlled environment using the same hardware in similar conditions over the course of the trials.
For the purpose of the trial, a special designated room has been reserved for the data collection effort. The following metrics for the different tests will be captured and will be subsequently used for the research effort.
Audio Test: designed to test users' auditory precision. This test is expected to generate.
`Average Response Time`: this is a measure of how quickly a user is able to react and identify the source of a sound with varying audibility (in decibels) in a 3-Dimensional space.
Visual Test: designed to test users' visual perception. At the end of this category of test, the following metrics were designed to measure users' performance.
`Average Response Time`: a measure of how quickly a user can identify and engage targets.
`Shot Accuracy`: a measure of the percentage of successful shots to the number of targets spawned.
`Target Accuracy`: a measure of the percentage of successful shots taken to a number of targets hit.
Fine Motor Test: designed to test users' perception of depth and eye to hand coordination.
`Average Tracking Time`: measure of average time it took for a player to successfully track, engage, and eliminate a target.
`Accuracy`: measure of the percentage of shots fired to the number of targets hit.

3	**Main Ethical Considerations**

Please give a brief description of the main ethical considerations involved in the study.

Help: Highlight here the main ethical considerations for the study (which may concern, e.g., the type of participants, the sensitive nature of the study, the data collection process, and security-sensitive research) and advise how the main issues will be addressed. If the project is funded, give details here, and whether there are any potential conflicts of interest involved in the study. NB: Section 5 below addresses: recruitment; voluntary participation; consent; and, the right to withdraw. Those details need not also be entered here.

There are no conflicts of interest, and the project is not funded.

4	Human Participants

If the study includes Human Participants (or their data), please give a description of who will be included.

Help:

- Please note this should include sample size/number of participants, whether the project will focus on any particular groups/individuals, if it will include any at risk or vulnerable participants, participants aged 16 years or under, etc. Please also specify the rationale for including/excluding groups of participants.
- If the research involves secondary data not in the public domain, give details in this section.

For the research, physically active individuals that participate in work out activities at a minimum of 3 days a week are desired. Furthermore, the participants are expected to be regular console game players.

We expect a minimum of 4 participants to make the research viable and a maximum of 20 volunteers which will be separated into a control group and intervention groups.

5	Recruitment, Voluntary Participation, Consent and Right to Withdraw

If the study includes Human participants, please give a brief description of the recruitment process, how voluntary participation will be ensured, if (and how) informed consent will be obtained prior to participants taking part in the study, and the right of withdrawal from the research process.

Help:

- This should include clear information on how participants will be identified, approached and recruited; whether the study will include any covert research or deliberate deception; whether help is required from a third party/ gatekeeper to access participants; what information will be given to participants, etc.
- If expenses or any incentives are to be offered to participants, give full details.
- If research involves students, colleagues and/or other employees then specify the rationale for this and how issues of coercion or feelings of obligation will be addressed.
- If data is held on participants, research using that data may require permission from the participant.
- Regarding withdrawal from the study, discuss the different stages/dates a participant could withdraw or withdraw their data, and how they could do this.

The poster below will be printed and placed around the ATU Campus. It will also be sent through email to all students registered on Galway Campus. The poster contains an electronic form that volunteers will be prompted to fill out when scanning the QR code from the poster or accessing the link https://forms.office.com/e/EmhfampDUT.

Once volunteers register interest the email address will be kept as stated in the form and then we will contact them through their registered email.

6	**Risks and Benefits**

Please give a brief description of how, when and where the research will take place and whether there are any risks and/or benefits involved.

Help:

- This should include information on what participants will be required to do, the rationale for this and the level of risk involved.
- When considering risks, please refer to risks to the participants (e.g., for research in sensitive areas, where there is a balance of power), the researcher, any other parties to the research; and also any health and safety issues for anyone involved (e.g., for lone researchers carrying out fieldwork).

The research is a software project that analyses data and does not involve the volunteers performing any physical activity other than does in their normal routine.

Volunteers are expected to wear a biometric data monitoring device that records physical activities.

The volunteers are expected to play a game that will be installed on their computer. On average the game is expected to last for 15 minutes.

Data from the game and device monitor are collected during gameplay and stored in a secured database.

Regression and Correlation analysis are done using these data.

7	Personal Data, Anonymity and Confidentiality

Please specify what type of information/data will be collected/analysed and the source(s). In addition, specify if and how the anonymity of participants will be ensured, and information be kept confidential.

Help: This should include information on whether new information/data are being collected or uses data that are already in the public domain; whether the data includes personal data; whether the data includes sensitive personal data e.g. health data, sexual orientation, race, religion; how the data will be processed and stored; who will have access to it; who it will be shared with; how long data will be retained; how it will be destroyed; the Data Protection requirements for any sensitive personal data, etc. In addition, include whether there may be any requirements for disclosure of information to other parties due to professional practice or legal reasons. If there are limits to confidentiality, explain clearly how the participants would be advised about these limits and possible outcomes.

There are basically two categories of data to be collected which are:

- Game test data that are generated during gameplay.
- Biometric data is obtained from a biometric data monitor (watch).

Specifically, the data to be collected from the Biometric data monitor are exhaustively listed below:

- Maximum Heart Rate
- Average Heart Rate
- Active Steps
- HRV
- Sleep (hours)

To get a volunteer setup for data collection, the volunteer will have to register with the activity monitor manufacturer (i.e. Polar Flow). Such information like height, weight, etc will be taken to ensure the accuracy of data being collected by the activity monitor as advised in their documentation. These data are not of interest to the research and will be stored with the Activity monitor manufacturers.

Volunteer's data collected will be stored in a Firestore database through Firebase which is a secured Backend-as-a-Service Cloud service that provides encryption, security, and availability. Individual user-specific data are stored with the alias/username they choose to register with.

** It is important to note that no data will not be traceable to any individual as their data will be annotated with their chosen alias/username.

8	Reporting and Dissemination

Please give details of the planned dissemination and specify if the findings from the research will be published and whether any permission is required for this.

Help: This should include information on the methods of dissemination (e.g., dissertation/thesis) and/or what will be published and where (research papers, conference presentations). Specify if any permission is needed (e.g., from participants, clients, gatekeepers, etc.) prior to publication, and whether there are any potential issues relating to Intellectual Property Rights when creating or using materials.

As indicated in section A. There are no plans at the moment to publish the research.

9	Location of research

Will the research take place outside of Ireland?

YES ☐ **NO** ☐ **If yes, give details below.**

Help: If yes, please specify where the research will take place. Research must comply with the laws of the country where it is taking place and also comply with local Data Protection and Intellectual Property legislation: you must confirm that your research is compliant with local requirements and how you have ascertained this. Advise if the project requires ethical approval in-country and how this has been ascertained. If approval is required, a copy of this should be included in the application or details of the process of how it will be obtained. Please make reference to insurance and indemnity cover for the project where relevant.

Note: If data is to be processed or stored outside the EEA contact dpo@atu.ie

NO

10	Collaborative Projects

Is the research a collaborative project (i.e., it involves more than one institution)?

YES ☐ **NO** ☐ **If yes, give details below.**

Help: If yes, please specify the other institutions involved and if ethical approval needs to be / has been given by them. Please also specify what procedures have been put in place to ensure ethical compliance from all partners.

Note: If personal data is being shared between institutions then a data sharing agreement must be in place. Contact dpo@atu.ie

NO

11	Any other permission or external ethical approval required to undertake the project

Please specify if the project requires any other ethical approval or permissions not mentioned previously in this application and how and when these will be obtained.

Help:

- Other permissions: ethical approval does not give the right of access to the Institute's students, staff or the use of Institute premises to carry out research, and you may need to contact an appropriate Institute gatekeeper for agreement to approach potential participants or for the use of premises, so please give details.
- Gatekeepers: permission of a gatekeeper for initial access to participants may be required or to carry out data collection on their premises.
- If the project requires approval from an external ethics committee, this should normally be obtained prior to submitting this application.
- If a Disclosure and Barring Service check is required due to the specific participant group, give details.
- Regarding insurance and indemnity cover, some projects will require individual confirmation of cover. See the Research Ethics Procedures document for more details.

NO

SUPPORTING DOCUMENTATION: what to submit with the application

For projects involving human participants, you must submit, where appropriate, the Participant Information Sheet/s and consent form/s. You must also submit every communication a participant will see or receive. Failure to do so will cause delays to the application.

DECLARATIONS AND SIGNATURES

STUDENT			
I confirm that I will undertake this project as detailed in Part A and Part B of the application. I understand that I must abide by the terms of this approval and that I may not make any substantial amendments to the project without further approval. I understand that research with human participants or their data must not commence without ethical approval.			
Signed	Rodrigo Almeida Otito Mbelu	*Date* *31/10/2023*	

RESEARCH SUPERVISOR RECOMMENDATION FOR STUDENT PROJECT					
I confirm that the committee has considered part A and part B of the application. The project is viable and the student has the appropriate skills to undertake the project. Where applicable, the Participant Information Sheet and recruitment procedures for obtaining informed consent are appropriate and the ethical issues arising from the project have been addressed in the application. I understand that research with human participants must not commence without ethical approval. I recommend this project for approval.					
Name		*Signed*		*Date*	
Comment(s): E.g. if similar research projects have been previously approved.					

LECTURER ON BEHALF OF PROGRAMME BOARD			
I confirm that the project will be undertaken as detailed in stage one and stage two of the application. I understand that I must abide by the terms of this approval and that I may not make any substantial amendments to the project without further approval. I understand that research with human participants or their data must not commence without ethical approval.			
Signed		*Date*	

PROJECTS APPROVED BY THE RESEARCH ETHICS SUB-COMMITTEE					
I confirm that this project was considered by the Taught Programme Research Ethics Committee and has received ethical approval.					
Chair		*Signed*		*Date*	

This form will be retained for the purposes of quality assurance of compliance and audit for THREE years

Ollscoil Teicneolaíochta an Atlantaigh

Atlantic Technological University

PARTICIPANT INFORMATION SHEET

Biometric Data Analysis in Digital Game Scenario

We are Rodrigo Almeida and Otito Mbelu and we are students in Bachelor of Science (Honours) in Computing in Software Development at ATU Galway City. We are recruiting volunteers to take part in a research study. The aim of this study is to answer the following research questions:

- Can the user's current physical condition as indicated by their Biometric data, have any direct relationship with their performance in such a gaming scenario?

- Can Biometric and test data help suggest the most suitable settings for different game scenarios?

This participant information sheet outlines what the study involves and what will be required of you if you choose to volunteer to participate.

What is the purpose of this study?

The main hypothesis of this research is to find if there is any correlation between a user's biometric data and their performance in a first-person shooter game scenario.

This research study will try to quantify how biometric data such as Heart Rate Variation, Heart Rate, active steps taken, quality and quantity of sleep, etc. affect select gaming skills like eye-to-hand coordination, fine motor skills and reaction time.

What will be required of you?

For this study, you will be required to wear the Polar watch which is referred sometimes to "Activity Monitoring Device" in this text, a day prior to undertaking a test.

Location
The data collection effort will be carried out at the Gym on the Atlantic Technological University (ATU) Galway campus.
Time:
The following weekly schedule will be available for volunteers at various times that best suit your personal schedule.

- Tuesdays: 12:00 - 13:00, 15:00 - 16:00
- Wednesdays: 12:00 - 13:00, 15:00 - 16:00
- Thursdays: 12:00 - 13:00, 15:00 - 16:00
- Fridays: 13:00 - 15:00

Note: The timing is open for adjustment to suit you

Results from the test will be paired with their biometric data for further analysis.

What will happen to the information that is collected about me?

The information gathered from the study will be handled in complete confidence and cannot be traceable back to you. These data are stored in an encrypted database system with everything relating to a user linked with the alias (username) they choose to register with. When the study is finished, information will be kept on the researcher Luke Smyth.

What are the benefits?

The benefit of taking part in this research is that if such a correlation is found between your biometric data and your performance in the game you can use the results to improve your own performance when setting up in any First-shooter game. You may benefit by taking part in seeing how a final year project is run you may take some valuable knowledge and apply it to your own studies if applicable.

What are the risks?

There will be no risks as this study is based on the volunteer's normal activities and playing a game in a controlled environment.

What if you change your mind during the study?

Please be aware that individuals who volunteer to take part in the study have the right to withdraw from the project at any time without the need to provide a reason or notice period. Should you feel at any stage that you want to stop taking part in the study, then this is dealt with in a sensitive and confidential manner.

What happens at the end of the study?

At the end of the study, the data gathered will be disseminated for the purposes of a written academic report and submitted to ATU for assessment purposes. A summary of the results can be provided to you, upon request. All data will be held securely, in line with GDPR regulations, for a period of ten years, as per the ATU records retention policy.

What if you have more questions or do not understand something?

It is important that you feel completely at ease during the research. If you do not understand any aspect of the research, please contact us or my research supervisor to discuss any questions that you might have. Alternatively, you may contact the Head of Department, if you wish to speak to someone independent from the study.

Research Supervisor: Dr. Damien Costello

Head of Department: Dr. Gareth Roe

Thank you for taking the time to read this. I would be grateful if you would consider participating in this study.

Yours sincerely,

Student Name: Rodrigo Almeida, Otito Mbelu

Student Signature:

Date: [*Insert date of circulation of this document here*]

Contact Details: G00377123@atu.ie or G00397738@atu.ie

Ollscoil Teicneolaíochta an Atlantaigh

Atlantic Technological University

PARTICIPANT CONSENT FORM

Effects of Post-Action potentiation on sprint performance

Please tick the appropriate boxes

	YES	NO
1. I have read the Participant Information Sheet for this study and understand what's involved.	☐	☐
2. I have been given the opportunity to ask questions about the study.	☐	☐
3. I agree to take part in the study under the conditions set out in the Participant Information Sheet.	☐	☐
4. I understand that my taking part is voluntary and that I can withdraw my consent at any time before my data is de-identified or amalgamated with other data.	☐	☐
5. I understand that, in any report on the results of this study, my identity shall remain anonymous.	☐	☐

Signature of Participant: **Date:**

Signature of Student: **Date:**

Appendix D: Participant Withdrawal Form

PARTICIPANT WITHDRAWAL FORM

Reference Number:

Participant name or Study ID Number:

Title of Project: Biometric Data Analysis in Digital Game Scenario

Name of Principal Investigator: Rodrigo Almeida and Otito Mbelu

Name of the person to whom this form should be submitted: Gary Flynn

Participant to complete this section. Please initial one of the following boxes:

1. I confirm that I wish to withdraw from the study before data collection has been completed and that none of my data will be included in the study.	
2. I confirm that I wish to withdraw all of my data from the study before data analysis has been completed and that none of my data will be included in the study.	
3. I confirm that although the results of the study have already been produced and cannot change, I wish to be forgotten and that all of my personal data is deleted from verification records maintained by the university about the study. I understand that this means that only those data identifying me will be deleted.	

Your name is required to verify that you have withdrawn your data from the study as specified above. In the case of (3), above, we will need to retain this form until…….

It may be necessary to share this information with internal examiners, external examiners, and / or journal editors for the purposes of verification of findings and tracing results of studies to the raw data used.

This form will be stored securely until ……, when it will be destroyed, and will not be shared with anyone else.

Signature of participant:	Date:
Signature of person who will ensure that the stated data have been deleted:	Date:

Microsoft Form for Volunteer Recruitment

Research Participant Needed

Join our study exploring the link between biometric data and gaming performance. Help us understand how your body's responses impact your gaming abilities. Your input is crucial for our research. Thank you for participating!

* Required

* This form will record your name, please fill your name.

1. How many times a week do you exercise? (Select one option) *

- ◯ 1-3 times/week
- ◯ 3-5 times/week
- ◯ 5+ times/week
- ◯ I don't exercise

2. What is the average duration of your exercise sessions? *

- ◯ 30 minutes/session
- ◯ 45 minutes/session
- ◯ 60 minutes/session
- ◯ 75 minutes/session
- ◯ 90 minutes/session
- ◯ 90+ minutes/session

3. Do you own an activity tracker (E.g. fitness watch)? (Select one option) *

- ◯ Yes
- ◯ No

4. Do you play video games? (Select one option) *

- ◯ Yes
- ◯ No

5. What gaming platform do you use most frequently? (Select one or more options) *

- ☐ PC
- ☐ Xbox
- ☐ PlayStation
- ☐ Other

6. What kind of games do you enjoy the most? (Select one or more options)

- ☐ First Person Shooter
- ☐ Third Person Shooter
- ☐ Soccer
- ☐ Car Racing
- ☐ Other

7. What brand is your activity tracker? *

- ◯ Polar
- ◯ Garmin
- ◯ Apple
- ◯ Fitbit
- ◯ Other

8. I consent to be contacted by the researchers about my participation in this project and my data might be kept for the purpose of this research and will not be shared with any third parties.
(You have the right of withdrawal at anytime, by emailing G00377123@atu.ie) *

- ◯ Yes
- ◯ No

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