Biometric Data Analysis in Digital Game Scenario

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Chapter 1

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[1] 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.[2] Short-term HRV analysis lasting less then 5 minutes have been proven to provide more accurate estimations compared to longer measurements.[3] 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 [4] 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 2

Methodology

Describe the way you went about your project. Was your approach to the problem valid? You need to discuss both your software development methodology and your research methodology.

Chapter 3

Technology Review

3.1 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.

3.1.1 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.[5]

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.[6]

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.[7]

3.1.2   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.
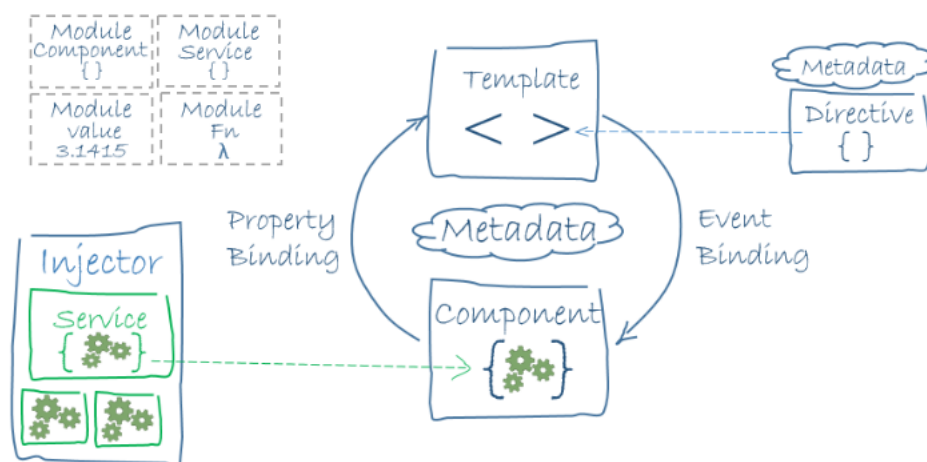

Figure 3.1: Angular application architecture

3.1.3   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.

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.

3.2   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.

3.2.1   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. [8] 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. [8]

Table 3.2.1 is showing some of the features of Chart.js[8]:

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 3.1: 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.

3.2.2   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.[9]

Table 3.2.2 is showing some of the features of D3.js[9]:

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 3.2: 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.

3.3   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. [10]

3.3.1   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.[11]

3.3.2 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.[12] 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[13]:

- 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.[13]
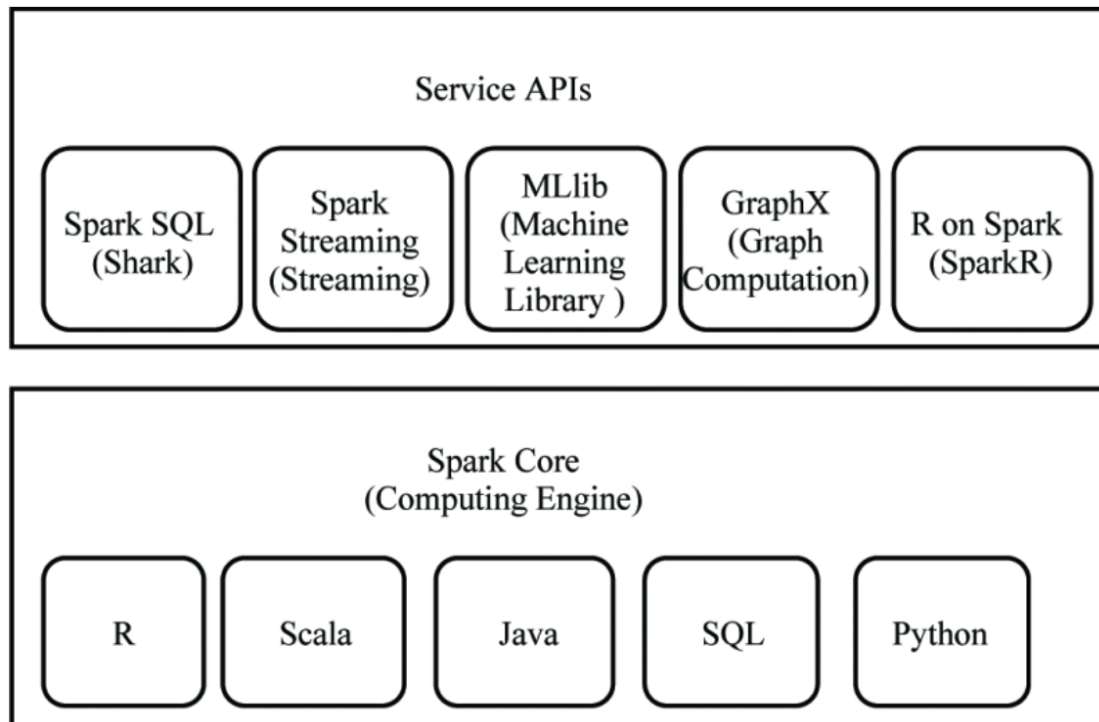
Figure 3.2: Apache Spark Ecosystem

- 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.[13]

- 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. [13]

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.
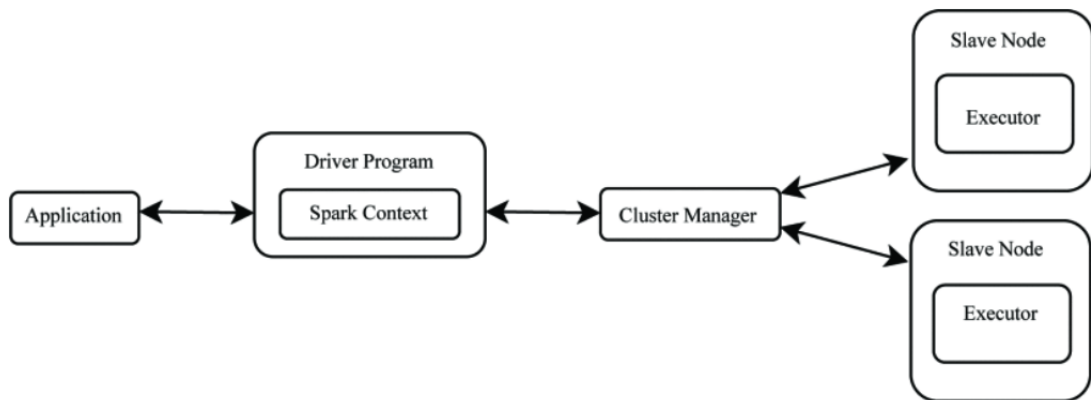

Figure 3.3: Apache Spark Architecture

Figure 3.3 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.[13]

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.

3.3.3   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). [14]

- **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 3.4 [15] 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.
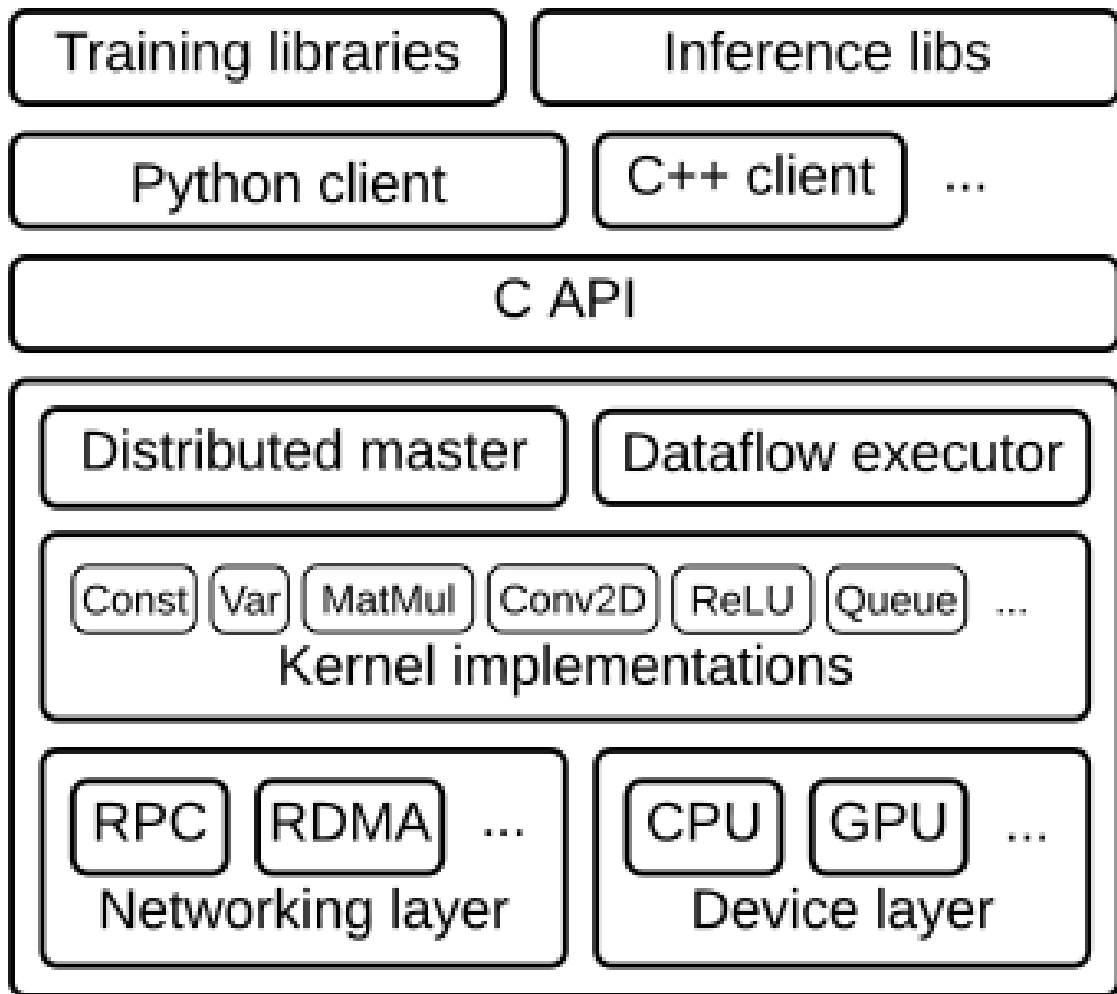
Figure 3.4: TensorFlow Architecture

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.

3.3.4   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.[16] 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.[17] 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. [18] 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. [17] 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. [17]

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 Promises and async/await syntax, it remanins a valid criticism. [19]

Table 3.3.4 is summarizing the advantages and disadvantages of Node.js[17]:

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 3.3: 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.

3.3.5 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.[20] 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. [20] 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. [21] 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. [20] 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. [17]

3.3.6   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. [22]

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,
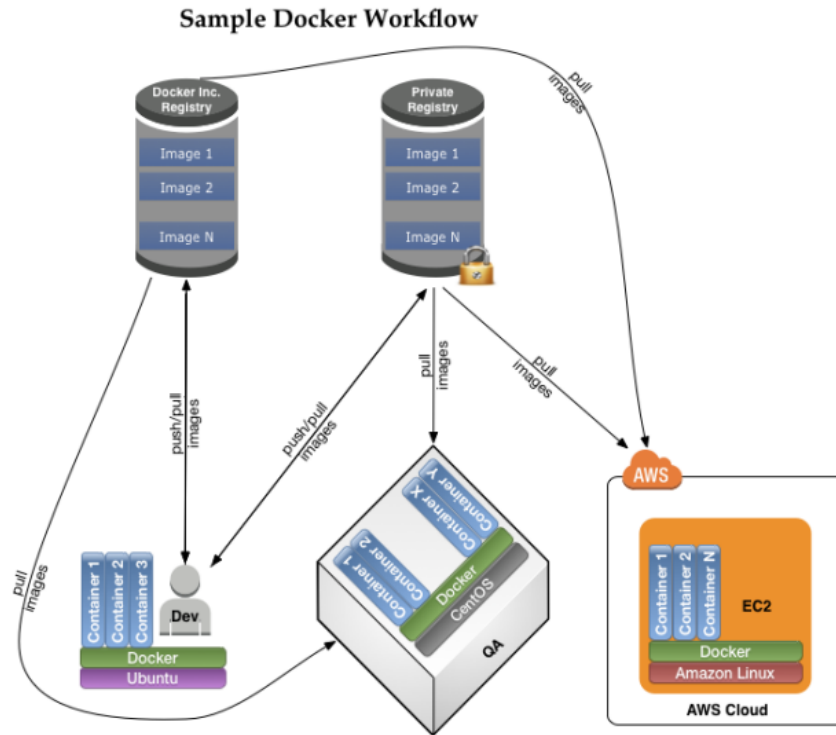
Figure 3.5: Development workflow with Docker

leading to potential cost overruns. [22] 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. [23] 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.

3.3.7   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. [24] 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 3.3.7 is showing some of the features of NGINX[24]:

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 3.4: 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.

3.3.8   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 3.3.8 is showing some of the features of MySQL[25]:

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 3.5: 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.

3.3.9   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.[26]

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 3.6: 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 4

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 4.1. 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 4.1 can be summarized as follows:

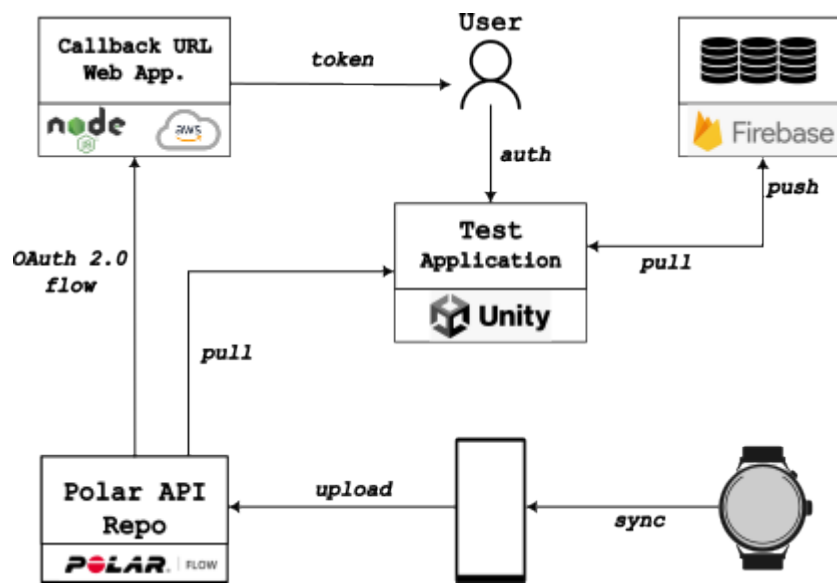- sync: passing of biometric data to a smartphone from a Polar watch.

Figure 4.1: 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.

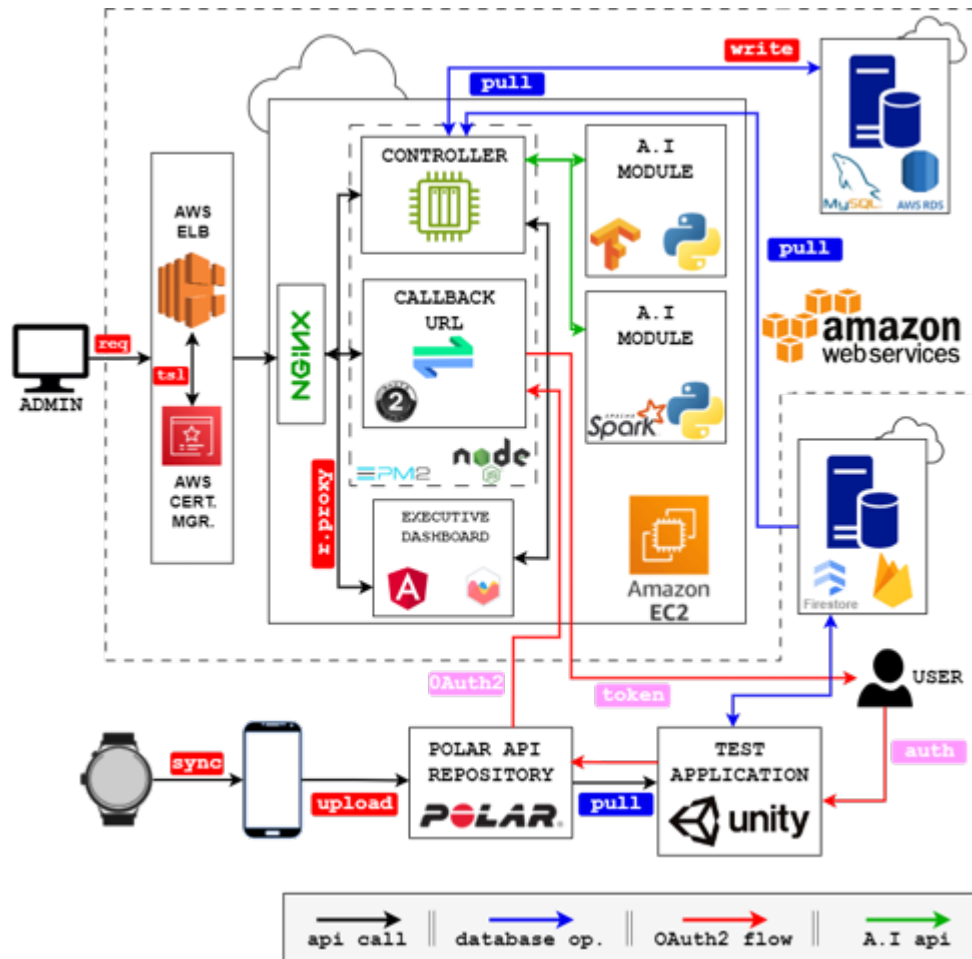Figure 4.2 shows the proposed architectural layout for the System.

Figure 4.2: 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[27] which are common tools used for this class of problem. TensorFlow also has the same capabilities and can perform regression neural network models[28].

- Accessibility: Both tools are open-source and available to the general public[29].

- 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 5

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.

5.1 Working with Tables

Table 5.1 can be referenced with the label given to the table, i.e. **\ref{table:HexToBin}**. Note that LaTeX will 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 5.1: Conversion from Hexadecimal to Binary

Chapter 6

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.

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