# IoT System – Assignment 1

# Architecture

# 1.1 Architecture Diagram

A diagram of a computer

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Figure 1. High Level Architecture Diagram

Figure 1 demonstrates the IoT sensors and actuators that will be used in my solution, as well as the Data Processing and Mobile Application connectivity. The solution makes use of four sensors: a camera sensor with a view of the court, a gyroscopic sensor and accelerometer physically connected to the racket, and a pressure sensor over the racket grip. The camera sensor will be used to identify and track player movements around the court. The gyroscopic sensor and actuator will provide data on the racket’s direction and movement, the combination of which will allow the system to identify the location of the racket and track it throughout practices and games. The pressure sensor will measure the force applied by the player when gripping the racket.

Sensor data is passed to an IoT gateway, and then sent via Bluetooth Low Energy(BLE) to a centralized edge compute server. BLE is beneficial to this system as the distance between ‘things’ does not exceed 100m, and it provides low latency, which is essential to the actuator mechanisms. An edge compute server is a server located on premises, which handles the data analytics processing and machine learning capabilities of the system. Due to the edge servers proximity to the IoT sensors, there is low latency in responses, this is needed for the actuators to provide real-time feedback. The system makes use of two actuators: a projector, which projects onto the court the range of area that the ball is likely to bounce in; and a haptic motor, which is physically connected to the racket, and provides haptic feedback in response to the quality of the player’s swing.

The edge compute server processes data from the IoT sensors using predictive analytics, and then passes the computed insights to the actuators to feedback to the player. The edge compute server also communicates with a cloud server for the storage of non-latency-dependent data. Both the data stored on the cloud server and the processed data insights from the edge server are sent to a mobile application, through which a player can track their performance and access a dashboard of data-driven metrics.

# 1.2 Sequence Diagram

A screenshot of a computer screen

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Figure 2. Sequence Diagram

The Sequence Diagram in Figure 2 presents a detailed view of the communication between the sensors and actuators in the system and the IoT gateway and the edge compute server. In particular, this sequence diagram is concerned with the use case of the player swinging their racket and hitting a shot. When the player swings their racket, the Gyroscopic sensor and accelerometer connected to the racket sense the change in velocity and direction of the racket, this sensed data is read by the IoT gateway, and then sent to the edge compute server.

The edge compute server uses the data from the sensors to compute the correctness of the swing. To do this, the server will make use of a learned machine learning model to quantify the correctness of a tennis swing. In parallel to this computation, the edge server will begin to compute a prediction for the location that the ball will bounce on the other side of the court. While these computations take place, more data is being captured by the sensors and transmitted through the IoT gateway to the edge compute server, this further data contributes to the Machine Learning based computations to improve their accuracy. When the computation for swing correctness is complete, the result is sent from the edge server to the IoT gateway, read by the gateway, and passed to the haptic motor actuator. The motor performs the simple logical operation to check if the swing correctness is below a defined threshold i.e. the swing is incorrect enough, the haptic motor activates, sending a haptic vibration to the player’s hand.(The threshold for correctness is pre-defined in relation to the ML model that calculates correctness and the mobile application).

Once the ball prediction computation is complete, the result is sent from the server to the IoT gateway and is passed to the projector. This actuator then projects onto the court the cone-shaped region in which the ball is likely to bounce. This diagram is a simplification in that it shows a discretized subset of the data that is sensed by the IoT sensors throughout the players swing. In reality, data is continuously captured by the sensors and sent through the gateway to the edge server to inform the predictive calculations.

# Use Case Diagrams

A diagram of a software application

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Figure 3. Mobile Application Use Case Diagram

Figure 3 highlights how different stakeholders of the system will interact with the mobile application. All stakeholders are able to log in, these logins are separate, and login details are verified by the cloud server to grant access to the application. The main stakeholder of the system is the player.

The player can choose to view detailed statistics about their tennis technique and strategy. When the player chooses to view statistics, the statistics are fetched from the cloud server and displayed in a readable format. The player can also choose to view their improvements, included in this are two options: viewing technique improvements, and viewing improvement drills, when the user selects one of these options, the cloud server displays the relevant improvement data through analysis of the data captured previously by the IoT sensors. The player also has the option to configure the court actuators, they can configure the projector by changing the threshold value for the ball location estimation to refine the region that is displayed. They can also configure the force, frequency and duration of haptic feedback during the swing. If the player changes settings during this process, the edge compute server alters the output of the on-court actuators.

The coach shares similar use cases to the user, except for the actuator configuration, as this is ultimately the players decision. The third stakeholder in the system is the Tennis Ranking Association and media organizations. In addition to the login, these outlets can view high level statistics, abstracted and aggregated to a higher extent, thus removing the detriment to the player.

A diagram of tennis court

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Figure 4. Smart Tennis Court Use Case Diagram

Figure 4 highlights the physical interaction between the player on the court and the IoT sensors and actuators. The user can swing their racket, this is sensed by the racket IoT sensors. The racket IoT sensors here is a logical group of the sensors physically connected to the racket, including the accelerometer, gyroscope and pressure sensor. The sensed data is sent to the edge compute server.   
The player can also react to the haptic feedback felt through the racket. This haptic feedback motor is activated by the edge compute server if the user’s swing technique is incorrect, computed by the received sensor data.

# Requirements

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| Functional Requirements | Non-Functional Requirements | Usability Requirements |
| The mobile app must show the distribution of spin that a player uses | The haptic motor must vibrate with enough magnitude to be unquestionably registered by the user. | The mobile application must not require more than 3 clicks to navigate to any given page |
| The mobile app must show the maximum, minimum and average power a player hits shots with | The haptic motor must vibrate only in the period between when the player’s swing has started and ended. | The racket must be easy to hold and swing with while the sensors are attached. |
| The mobile app must show players maximum, minimum and average movement speed | The haptic motor’s vibration must vibrate proportionally to the incorrectness of the swing. | The pressure sensor grip must be comfortable to hold and grip with the normal force used to grip a racket. |
| The mobile app must show the players maximum, minimum and average racket preparation time. | The projector must project the region of likely locations for the ball to bounce within 50ms of the ball being hit. | The application must be able to be navigated through using one hand. |
| The mobile app must show the players maximum, minimum and average racket grip strength. | The gyroscope and accelerometer must fasten securely to the racket. | The projection must be clearly visible to the player whenever it is displayed. |
| The mobile app must show the player’s maximum, minimum and average serve speed | The accelerometer, gyroscope and pressure sensor tape and their attachments must not weigh more than 30 grams | The players statistics should be visible clearly on the home page of the application |
| Coaches and Trainers must be able to access data and insights for multiple players they coach. | The player’s personal data must be stored securely, in accordance with GDPR regulations. | Physically connecting the pressure sensor grip must be of equal difficulty to applying a grip to the racket. |
| The mobile app must break down the shown statistics in the four quarters of the court. | The mobile app must support a range of screen resolutions | Physically connecting the gyroscope and accelerometer must require little force |
| The mobile app must provide suggestions for practice drills based on the player’s statistics. | The projection must be compatible with and adapt to a variety of court colours and surfaces. |  |
| The player must receive haptic feedback when they use an incorrect swing. |  |  |
| A projection of likely locations for the ball to bounce must be displayed after the user hits the ball. |  |  |

# Evaluation

Evaluation can take place throughout the development and utilization of the system.

Formative Evaluation

During the design and development of the system, formative evaluation will take place, this will be done through examining the feasibility of technical processes and their integration, as well as the creative objectives of the system in relation to its original purpose and requirements. Furthermore the target users’ needs must be considered through the development process, to guarantee that features cater to the audience of which the system was built for.

To perform formative evaluation, focus groups will be conducted in the early stages of design and development to gain an insight into user needs and key functionality. Then, as the system is developed, prototype testing will take place, in which players will test early versions of the system and feedback areas of technical quality and deficiency. This type of evaluation ensures that modifications can be made throughout the design and development process, reducing mistakes and increasing the system’s quality.

Summative Evaluation

Summative Evaluation will also be utilized, however this will take place once the system has been developed and is being used by target users. Summative User Acceptance Testing will be used to gain quantitative and qualitative feedback in regards to the system’s impact on the players’ tennis game, as well as how well the system functions overall, and how well each of the sensors and actuators individually operate. This feedback will be analysed and compared to the functional, non-functional and usability requirements, so that the development team can gain a view of the most useful aspects of the system, as well as problem areas in the system’s functionality, technical operation, and its usability from a player perspective.