

Foil Performance Monitoring Vest; An Interactive Training System for the Olympic Sport of Fencing

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Fencing is a well-known sport where two opponents use swords and protective gear. The addition of technology into this sport has been attempted, but results are often not feasible. This work provides a simple and novel approach to assist players in practicing foil fencing where the target area consists of eight main strike zones on the torso. A training session can be started by a coach to allow embedded technology in the gear to collect data regarding the player's performance and transfer it by means of Bluetooth to an android phone where analysis of the data is carried out and a summary of the performance is displayed. The final prototype can be scaled down to grant the feel of the stock fencing gear in which players compete. This novel work aims to introduce smart training gear in sports and to make the sport accessible to everyone.

Key words: *Android; fencing; IoT; technology.*

1. Introduction

The current technology era has introduced a new, virtual world where people are able to accomplish various tasks without the need for physical interaction. A popular outcome of technology is online courses. They are available in multiple forms, from simple text on a screen to an interactive system adopting examples, quizzes, instructional videos, and sport activities.

Some researchers have shown an interest in combining technology with sports. An implementation of a self-training system was introduced to ballet (Wang et al., 2017). Blank et al., (2015) presented a system for the detection and classification of the strokes for table tennis based on sensors. Sharma et al., (2017) described an engine that analyses the serve performance and gives feedback for the players to enhance their technique and to prevent potential injuries.

Wang et al., (2016) proposed a training system for the sport of badminton that is based on a network of body sensors. The system can recognise a variety of badminton strokes done by the players.

The assessment of an athlete's performance is an important objective in fencing, as well as in other elite sports, to facilitate detailed analysis. Efforts of implementation of robotics were used to detect the player's speed and accuracy when hitting a target, or by means of electrically connecting the weapon and sensing electrical pulses (Laurenson et al., 2012). Implementing automatic methods to detect and recognise sport specific movements would overcome the limitations associated with the manual performance analysis methods (Cust et al., 2019). FencingVis would assist analysts find the tactical patterns hidden in fencing bouts, as well as the tactical and technical characteristics of the player (Zhang et al., 2019).

Fencing is an Olympic sport played by two opponents. It has three different types; Foil, Epee and, Sabre; each type has its own sword and target area. In this study we will address the Foil hoping to enhance the training efficiency and the fencers' performance. The guiding principle of all fencing is to hit without being hit. The hit at foil is made with the tip of the sword. The sword in Foil is a thrusting weapon with a flexible rectangular blade (Rogers, 2013).

A hit needs to be delivered accurately to the target, namely the torso – that includes the flanks, shoulders and back as well as the more obvious chest and stomach areas. Fencing is a game of speed, action, reaction and strategy in which the winning stroke is the one correctly employed at the appropriate moment. To be successful, a hit needs to be delivered at the precise moment that the opponent is incapable, hesitant or distracted; when they are preoccupied and unready; or when they have lost the initiative (Smith, 2007). Such a winning stroke, although unique to that moment, is also the culmination of the practice of all the technical and tactical content of fencing that was undergone before.

The player scores a point when hitting the valid target area with the tip of the sword.

Fencing, as a sport, is taught in specialised schools where trainees practice a set of moves and techniques. Routinely executing the lessons learned develops into an intuitive motion which in turn enhances posture, speed, and accuracy. The presence of a tutor for examining a student's performance has always been necessary. Feedback is a crucial part in any learning and practice process (Rogers, 2013). Technology can be utilised to aid the training process to drastically reduce the need for constant supervision. This allows a single tutor to train more students within a training session.

Foil fencers wear a lamé during a combat or a training bout; A lamé is a jacket that is electrically conductive, it defines the scoring area (Rogers, 2013), the aim of this study is to design the Foil Performance Monitoring Vest (FPMV). An electronic jacket divided into eight

cells worn by players, it detects a hit on the FPMV and determines the precise location during a training bout. The collective number of detected hits in each cell are saved, giving a rough idea about the spatial distribution of the hits on the lamé. Additional information and statistics of each players' previous performance and records can be registered in the system. This study is a preliminary effort to combine technology with the Foil/Fencing sport to pave the way for a self-training and monitoring system in this sport. The achieved design of the FPMV has three main components; (1) the vest (including sensors and a microcontroller), (2) the Bluetooth (Transmitter/Receiver) where the transmitter is on the vest (connected to the microcontroller and the receiver is in the phone), and (3) the Android application.

The vest is an electronic jacket responsible for sensing hits throughout eight cells (sensors). Each cell consists of six push buttons. It is designed thoroughly to guarantee the players' proper protection during the bout and is made of flexible material to withstand the sword's impact. During the training bout between two foil players, each player wears a vest. Both vests calculate the number of hits on each cell. Upon completing the game, each vest transfers raw data to the coach's mobile phone using Bluetooth (Transmitter), allowing the phone to collect and analyse the data instantaneously. The Android application on the coach's phone receives the data, store it to each respective player's online database and then displays each player's in-game performance.

This work presents a novel, cost efficient approach that is simple and might be adapted. Output data of the FPMV enable both players and coaches with insights into their performance. The FPMV can be implemented for Epee and Sabre, to analyse the players progress in training exercises and tournaments, as well as providing match statistics. This is the first paper that discusses a wearable FPMV system for Foil/ Fencing sport, and our future work aims at using the presented prototype to build a complete FPMV.

2. Background

Technology has no limits; it can be introduced to any field to produce significant performance improvements. Sports are one of the largest industries in the world and it unites nations across the globe. It is undoubtedly in a huge need of technology. It should be intertwined with IoT to aid the development of the industry using technological equipment. Such equipment can be used to grant sports players more experience and a faster pace in improving their skills to achieve their goals. Also, the availability of technology allows the involvement of everyone interested in the game (Buning, 2020).

Researchers design new projects using different techniques. Rapid developments in technology have encouraged the use of smartphones in physical activity research, although little is known regarding their effectiveness as measurement and intervention tools. The range of novel and engaging intervention strategies used by smartphones, and user perceptions on their usefulness

and viability, highlights the potential such technology has for physical activity promotion (Bort-Roig et al., 2014). Kirwan et al., (2012) stated that using a smartphone application as an additional delivery method to a website-delivered physical activity intervention may assist in maintaining participant engagement and behaviour change.

Blank et al., (2015) presented a sensor-based table tennis stroke detection and classification system. They attached inertial sensors to table tennis rackets and collected data of 8 different basic stroke types from 10 amateur and professional players. Sharma et al., (2017) described a serve analytics engine that provides feedback to players for enhancing their serve performance while preventing potential injuries. By utilising the information of inertial sensors from the wrist of a player and using serve kinetics. Wang et al., (2016) proposed a badminton training system based on body sensor networks. The system may recognise different badminton strokes of badminton players.

The design of Liang et al., (2006) is a robot that moves forward and backwards, mimicking the movement of a fencing player. It has a wired connection to the computer and helps training by dividing the torso into 16 zones, each having a sensor and an LED. The training consists of lighting a pattern of LEDs and the trainee would have to hit the designated area. The data is then transferred to the computer.

Weichenberger et al., (2015) designed a training robot similar to the previous design with some differences and improvements; flexible movements are added to the robot itself and controlled by the computer. The number of zones was decreased to ten zones. It is controlled by an external computer. The computer is connected to the robot's parts via Bluetooth through a CAN bus.

Projects containing similar features, such as connectivity, were reviewed (Laurenson et al., 2012; Oakley and Lee, 2014; Tadoju and Mahesh, 2015). Although the main purpose is not related to fencing such as the home automation system, built using PIC18F2550, is installed and connected to the GUI on smartphones using a low cost "Cytron Bluebee" Bluetooth module. The Bluetooth module is connected to a voltage regulator and PIC18F2550 (Oakley and Lee, 2014). By clicking the "Connect" button in the GUI connects the main control board or other laptops/PCs to the smartphone via Bluetooth; the Android GUI interface allows the user to choose the desired Bluetooth connection: Bluebee for the main control board, or directly to another PC/Laptop.

In the design presented by Laurenson et al., (2012) robotics were also used to detect the player's speed and accuracy when hitting a target; the idea deploys LEDs in a specific area where the player should aim and hit the target within a specified time frame. Then the data is sent using RFID technology to the computer. The hits on strike zones are transferred via Bluetooth

technology to the mobile app on the smartphone where the application contains a database for the player.

FencingVis is an interactive visualisation system for fencing competition data. FencingVis can help analysts find not only the tactical patterns hidden in fencing bouts, but also the technical and tactical characteristics of the contestant (Zhang, 2019).

Despite the differences between their work and our objectives, previous efforts provided us with wider insight to develop and improve our prototype, by knowing what options may be used, and providing valuable technical information regarding what other researchers achieved in similar situations. In accordance with Liang, et al., (2006) our suggested prototype would provide quantitative evaluation of the training performance, assist the coach to better understand the different elements affecting the training purpose, and customise the training plan to achieve better results. Movshovich and Lobanov (2018) suggested that competitive results of beginning fencers at the start of their sports' career can be improved if the trainer makes the specific changes to training.

3. Method and Design

3.1. FPMV Design Methodology

This work focuses on the target area of Foil. It consists of the torso, from shoulders to groin in the front, and to the waist in the back. A Foil player who hits the target successfully gains one point. New trainees often start training in foil fencing where the torso is divided into eight sections in the front, as depicted in figure 6. Therefore, the purpose of the FPMV design is to sense any hit made within these eight sections. This is achieved by implementing a network of sensors within the vest. To ensure that the vest is safe and comfortable, layers of foam are added. This way the sensors withstand the impact of the weapon while the vest retains the required flexibility, allowing supple movement.

The sensor network was connected to a micro-controller unit (MCU) for data processing. The results can then be fed into a wireless device for transfer to a mobile phone. The mobile phone is capable of analysing the data and presenting it in a user-friendly manner. The material and circuitry added to the vest is light in weight to retain the feeling of the stock vest, and the setup is wireless to allow freedom in movement. The vest can either be mounted on a dummy for target practice or worn by two trainees in a training match.

3.2. *FPMV design requirements*

- 3.2.1. *Hardware Requirements*: The lamé will be equipped with several sensors, and data will be collected and processed by a microcontroller which will then transmit the results to a smart phone.
- 3.2.2. *Software Requirements*: An application for the smart phone will be developed to handle the collected data and visualise statistics for both the coach and players. The application will be developed using Android Studio software.

3.3. *FPMV design constraints*

- The hardware should fit on the lamé and retain flexibility for the players to wear and move comfortably.
- Reliability: the hardware should withstand shocks mainly from foil hits.
- Safety: The system should conform to the game's safety regulations.
- Price: The FPMV must be affordable and accessible to as many people as possible.

3.4. *Technical Details*

3.4.1. *Hardware Design*

Many MCUs that have serial ports can fulfill collection, processing and transmission of the data required for the mobile application. Popular MCUs are PIC and Arduino; their low cost and small size tend to be the most attractive features. A PIC16F877A sufficiently fulfills the required functionality. The sensors used to detect weapon hits were push-buttons. They are simple, lightweight, reliable components with low cost. In foil, there should be a noticeable hit on the vest to be counted as a point. Therefore, the “push” is what we aim for when we want to sense the collision between the sword and the vest. The type of push button was chosen based on its spring flexibility and area. Six buttons were put into each of the eight vest sections to cover the areas in a way that would ensure that wherever the sword hits, the buttons would sense it. The buttons were covered with a plate for protection and to divide the pressure of the hit. The second-best option to use for sensing was the MPR121 but was dismissed due to its need for I2C connection and extra ports. The sensors were punctured into a sheet of high-density polyethylene that covers the torso, as in Figure 6A, covered with layers of foam to cushion the hits and protect the wires and hardware connections from ripping apart,

The microcontroller chosen for this design is Microchip’s PIC16F877A which can fulfill collection, pre-processing and transmission of the data required for the mobile application using the Bluetooth module HC-06. The pushbuttons of each section are connected in parallel to the controller through PORTB pins. Therefore, PORTB is used for sensing hits and recording

them. The Bluetooth module HC-06 has four pins: Tx is connected to Rx (Pin 26) of the PIC, and Rx is connected to Tx (Pin 25) of the PIC. The module operates on 3.3V which is regulated internally in its breakout board, so the VCC pin is connected to VPP (Pin 1) of the PIC which is in turn connected to the output pin of the 5V voltage regulator with 9V input. OSC1 and OSC2 (Pin 13 and 14) are connected to an 8 MHz Crystal Oscillator. The connections are illustrated in Figure 7.

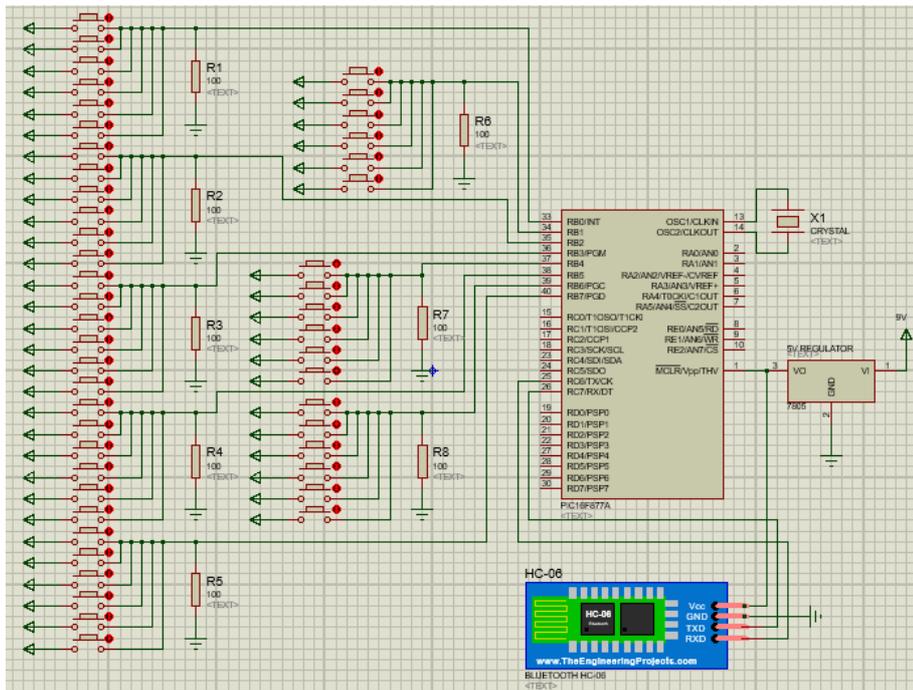


Figure 7. Schematic outlining circuit connections for the FPMV

Finally, an investigation was carried out on the available transceiver options before choosing the HC-06 Bluetooth transceiver. Wireless transmission to a mobile phone can be achieved using a Bluetooth module or a Zigbee. Zigbee was not chosen due to its larger size, insufficient official libraries and the need for an external adapter (IOIO), as well as the higher cost compared to Bluetooth. Bluetooth is attractive for its high transmission speed within small distances and its convenience; every smart device contains Bluetooth. The final decision was between either Bluetooth RN-42 or Bluetooth HC-06. Both models can be used as slave transceivers, and the project does not require a master transceiver; HC-06 can only be used as slave, and therefore does not require any additional configuration. Both HC-06 and RN-42 have changeable pairing pins in command mode, but the command mode in HC-06 is easier to access than in RN-42. Therefore, Bluetooth HC-06 was used for transmission.

3.4.2. Software design

As seen in the flowchart in Figure 8, the PIC microcontroller first initialises the Bluetooth device and then it remains idle until it receives a Start signal from the mobile application, denoted by the letter 'S'. Once 'S' is received, it starts counting hits and storing them in unsigned integer counters. However, the counting stops in two cases: 1. The letter 'P' is received indicating that the coach wants to Pause the game and resumes only after 'S' is received again. 2. The letter 'E' is received, indicating that the game has ended. The data is sent to the application as soon as the game ends.

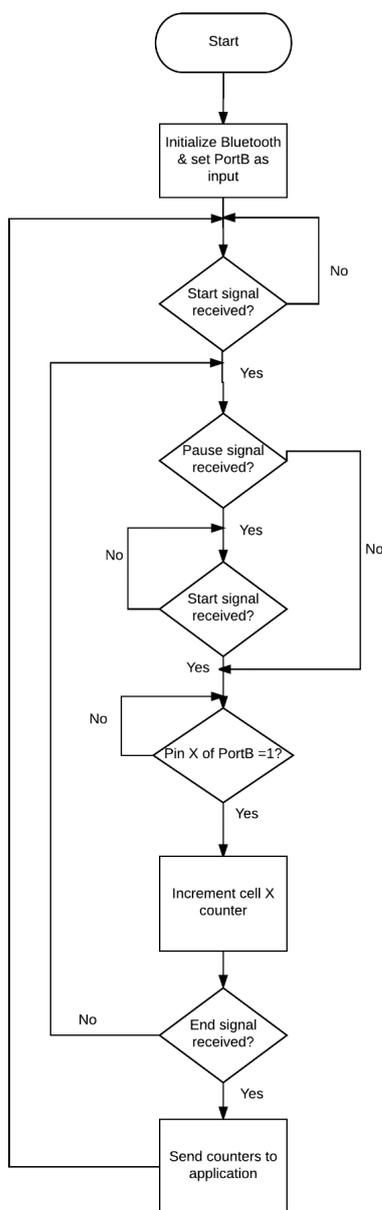


Figure 8. Flowchart outlining the procedure of the PIC

3.4.3. Application

The mobile application is created using Android Studio and contains two parts of code: Java and XML. The design of the application consists of multiple activities as shown in Figure 9.

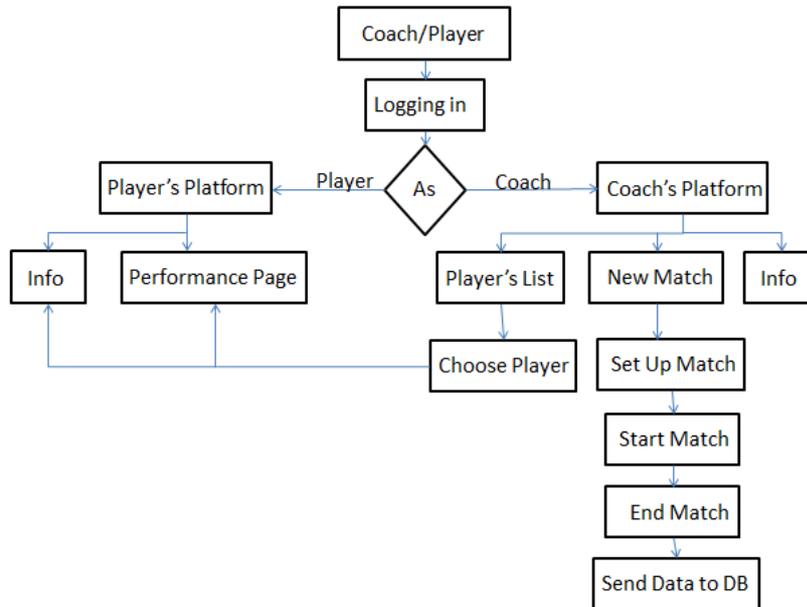


Figure 9. Overview of application features

3.4.4. Database

The database is designed based on the needs of the application, Figures 10 and 11 show the Enhanced Entity-Relationship (EER) diagram of the database and the tables that need to be implemented.

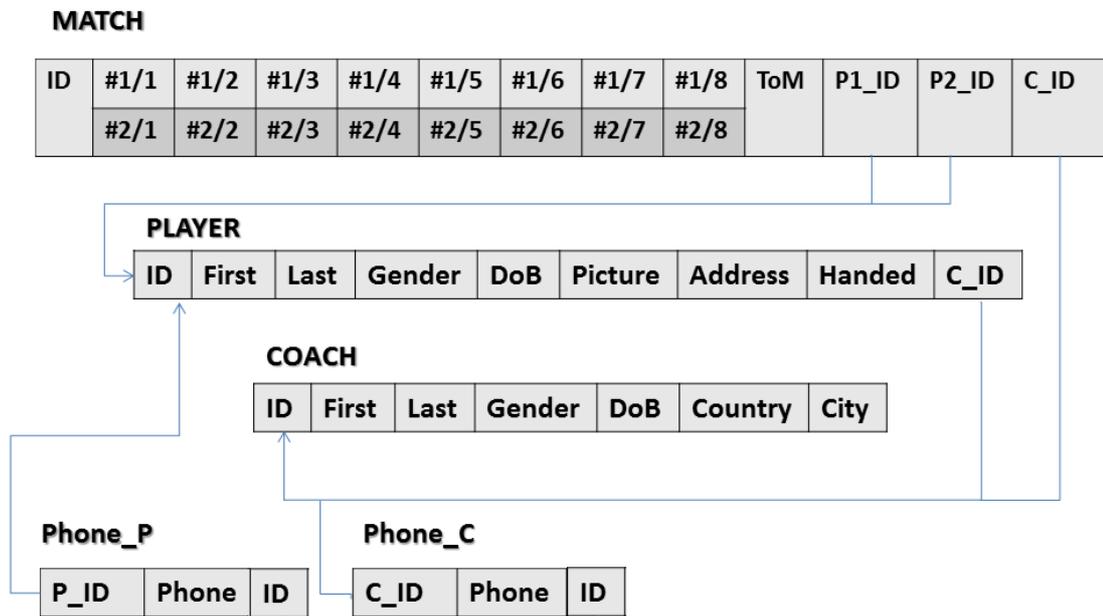


Figure 10. Enhanced Entity-Relationship (EER) model

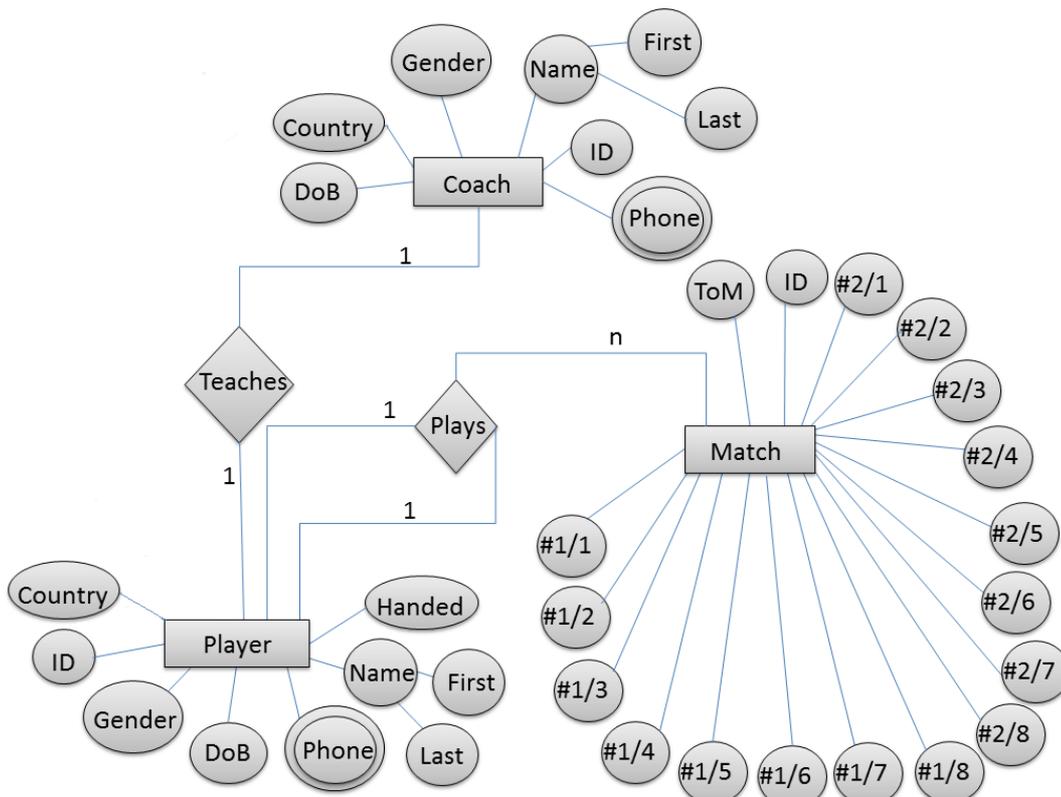


Figure 11. EER diagram



- Mobile Application Activities Storage (JAVA)

Storage is used to store the user's username, ID, and type (coach or player). There are also two variables used to save the id and username of the player that a coach chooses to view.

- Web Request Helper (JAVA/PHP/SQL)

The web request helper includes all the functions used throughout the application: adding data to the tables, modifying them and retrieving stored information. It consists of over 3000 lines of code and all functions use a URL including the PHP file. The PHP files were uploaded on a server using FileZilla. The PHP files connect to the database and execute SQL commands to either return or send values to the database.

- Sign up (XML/JAVA)

The sign-up page first inquires whether the user is a player or a coach, followed by the remaining information that may be entered according to the first choice. If the user is a coach, the information requested are: 1. Picture, 2. First and last name, 3. Username, 4. Password and confirmation. 5. Gender, 6. Location, 7. Phone number, 8. Date of birth. However, if the user is a player, the application additionally requests the following information are requested: 9. Main hand (Left-handed or Right-handed), 10. Coach ID.

Of course, some of the information may be skipped, while others are mandatory. The mandatory fields are: 1. First name, 2. Username, 3. Password, 4. Gender, 5. Coach ID (for players only).

Once the user signs up, the Java function first verifies the availability of the username and whether mandatory information was inserted. Afterwards, the user's information is stored in the database to be used when needed. Thereafter, the application takes the user to their information page.

- Sign In (XML/JAVA)

The sign in page contains a linear, vertically oriented layout; two linear layouts are included; each horizontally oriented and including a label in text view and an edit text to enter the username and password. It can be noted that the password is hidden for security and privacy purposes. A radio button group is available for users to select whether they are a coach or a player. To create a new account, a user may opt to sign up using the sign-up button that would redirect the user to the sign-up activity.

The sign in button calls a function as an asynchronous task from the Web Request Helper to validate the username's existence in the database and verify the password associated with the account.

- List of Players (XML/JAVA)

The design of this activity is very simple, it is a text view and a list view inside of a linear vertically oriented layout.

The functions from Web Request Helper are used to retrieve the players' information through a synchronous task. There are two possibilities that may occur after the user selects a player, depending on whether the user navigated from "Match" or "Players" from the menu:

1. In case of "Match", clicking on a player would retrieve the Player ID
2. In case of "Players" from the menu, clicking would send the user to the player's information page.

The activity includes a menu which can send the user to either "Coach Information" or to the "Match" activity; on selection we use intents to start the other activity.

- Player Info (XML/JAVA)

This activity lists all the information for the coach: 1. ID, 2. Username, 3. Name. 4. Gender, 5. Location, 6. Date of birth, 7. Main hand, 8. Phone numbers.

Linear with vertical orientation is the layout for the activity. A text view for the title of the activity "Player Info" is placed with a differing font, size, and colour. Inside the activity's linear vertical layout, six linear horizontal layouts are added; each including a text view for labelling and another text view for displaying information. A margin of 20dp was added for enhanced visibility. Unlike the other information, phone numbers were placed in list view since the coach may have multiple phone numbers.

In the java file, the data is retrieved from the database using the functions written in Web Request Helper. Calling the function must take place in the background using an asynchronous task and applying necessary changes in the GUI afterwards.

A menu is included in the activity which can send the coach to either "Players List", "Match", "Coach info" or "Performance" activities, and sends the player to the "Performance" page. Upon selection, intents are used to start the other activity. If the user selects "Performance", additional information to the player's ID is sent, and if "Players List" was chosen, an indicator that this is the page where the user came from is displayed.

- Edit Info (XML/JAVA)

Two activities list all of the information for either the coach or player:

1. ID, 2. Username, 3. Name, 4. Gender, 5. Location, 6. Date of birth, 7. Main hand. (player activity only), 8. Phone numbers.

The layout for the activities is for the player here is linear with vertical orientation. A text view for the title of the activity “Edit Info” is placed with a differing font, size, and colour. Inside the activity’s linear vertical layout, over 10 linear horizontal layouts were added; each including a label and text box and a button for editing the information in the database. A margin of 20dp was added for enhanced visibility. Extra phone numbers can also be added to the database.

- Match (XML/JAVA)

The layout for the activity is linear with vertical orientation and a scroll view in case the phone’s screen is too small. It includes a text view for the title and a combination of linear horizontally oriented layouts. When the coach clicks on the button “Find in List”, the app sends the user to the “List of Players” activity to fetch the player’s ID. Afterwards, the coach should select the “PAIR” button to pair the vest to the application and assign it to the selected player.

When clicking the pairing button, the pairing process starts. The application first scans for available Bluetooth devices and then shows a list of those devices. Once the coach selects the desired Bluetooth device, a dialog appears requesting the coach to either: enter a pairing pin and await confirmation or simply pair with the remote device using a random pairing pin and await the pairing request to be accepted.

After both players are chosen and their vests are ready and paired, the coach starts the game which would connect to the first vest, send the “start” command for the vest to accumulate the hits, disconnects. The procedure is repeated with the other vest.

When “pause” is selected, the application would connect to the first vest, send the “pause” command then disconnect. The procedure is repeated with the other vest. The button changes from “pause” to “resume” and selecting it would connect to the first vest, send the “resume” command, disconnect, and repeat for the other vest.

The “end match” button would connect to the first vest, send the “end” command, retrieve the number of hits calculated during the game, disconnect, and reconnect to the other vest to collect the required data. After receiving the match’s information, the application saves the data in the database as a new match entry. It then sends the user into the “Match Performance” activity.

- Coach Info (XML/JAVA)

This activity lists all available information for the coach: 1. ID, 2. Username, 3. Name, 4. Gender, 5. Location, 6. Date of birth, 7. Phone number. The layout for the activity is linear with vertical orientation. It has a text view for the title of the activity “Coach Info” with different font, size, and colour. Inside the activity’s linear vertical layout six linear horizontal layouts are added. Each includes a text view for labelling and another text view for displaying the information. A margin of 20dp was added to enhance visibility. Unlike other information, phone numbers are inserted into a list view since the coach may have multiple phone numbers.

In the java file, the functions written in Web Request Helper were used to retrieve the data from the database, ensuring that calling the function happens in the background using an asynchronous task and then applying necessary changes in the GUI afterwards.

The activity includes a menu which can send the user to either a “Players” or “Match” activity. Upon selection, intents are used to start the other activity. If the user selects “Players”, additional information is sent to identify the page where the user came from.

- Match Performance and Performance (JAVA/XML)

To aid the training process, the application keeps building on the database by adding more data into it. This allows a more accurate analysis of players’ performances. The performance of each player is seen in the “Performance” page which is shown as a bar chart with the strike zone names on the x-axis and the number of hits for each area on the y-axis. The page has three features:

1. Shows a player’s performance: This feature is used when a player or a coach wants to check the number of times the player successfully attacked their opponent and number of times the player failed to defend a specific area on a specific date; each cell has 2 bars, one for defences and one for attacks.
2. Shows a player’s performance compared to another player’s performance: Both the player and the coach can compare a player’s performance to another player’s performance if the other player’s ID is available. If another player’s ID is inserted and “SHOW PLAYER2 PERFORMANCE” is selected, another bar chart appears with four bars per cell. Two of the bars represent the first player’s defences and attacks, and two more represent the other player’s defences and attacks. This feature makes it easier for the coach to decide the strengths and weaknesses for both players.
3. Show the difference in performance between two players: This feature is used to make the comparison between two players easier. If the ID of the other player is inserted and “PERFORMANCE DIFFERENCE” is selected, the bar charts change to two bars per cell. The first bar shows the difference between the attacks of the two players; a positive value

on the attacks difference bar means that PLAYER1 is better than PLAYER2 in attacking. The second bar shows the difference in defences between the two players; unlike the attacks, a positive value on the defences difference indicated that PLAYER2 is better.

After a match between two players ends, the coach will be able to see the difference between the two player's performances; MP Android Chart library was used to create the bar charts.

- Prototype Setup

The next two steps should be followed before starting the game:

Step 1: Players should put on their equipment including the electric vest.

Step 2: The coach must have an account on the application, if not he should open it, press sign up, and register himself. Players should do the same using the same application on their phones making sure that the coach supervising them is registered as their coach on their accounts.

- Experiment/Simulation Setup

To start any game and collect data, the next steps must be followed:

Step 1: the coach should sign in to his account and choose "Match" from the menu.

Step 2: Both vests are turned on and ready, the coach should pair their vests and choose their names from the lists of players. The vests should be correctly paired to the corresponding player.

Step 3: The coach can start the game. During the game he can pause and resume it as seen fit. At the end of the match the coach should press the "End" button.

Step 4: When "End" is pressed the coach is sent to the match performance page so he can observe the performance of the players in the match. The vests should also be turned off to conserve power.

Step 5: After having some match data in the database for the players, the coach can easily check for the performance of his players at the "Performance Page", choosing daily, monthly, or yearly, and comparing him to another player if needed.

4. Data Analysis

Testing for Validation of requirements and constraints

The project met all design requirements and realistic constraints as seen in Table 1 and Table 2.

Table 1. Validation of Requirements

Requirement	Achievement	Action Taken
Sensors on the lamé	Achieved	The lame is divided into eight sections with six push buttons covering each section. The purpose of the push buttons is to sense the hits and register them.
Collecting and processing data with a microcontroller/computer	Achieved	PIC16F877A is used to collect the number of hits from the push buttons and process the data to send it to the mobile application.
A user-friendly application	Achieved	A user-friendly mobile application is developed using Android Studio, to be used by both the coach and the player. The application receives the data from the microcontroller using Bluetooth technology, stores it in a database and uses it to analyse the players' performance.

Table 2. Validation of Constraints

Constraint	Achievement	Action Taken
Size and Flexibility	Achieved	Polyethylene plastic is used to attach the push buttons to the vest and the circuit is built using a small PIC microcontroller.
Reliability	Achieved	The push buttons are covered with a special layer of foam, and the same foam is used for noise isolation in buildings, which is cheap in price, and able to provide enough protection to the vest from the foil hits.
Safety	Achieved	The bottom part of the vest is covered with a layer of foam to protect the player from any physical injury from any part of the circuit.
Price	Achieved	The entire project costs less than 200 JOD (equivalent of 280 USD).

5. Experimental Results

This work aims to assist the training process. The performance of a player is seen in a “Performance” page as a bar chart, showing the number of hits on each area against the eight vest strike zones, as shown in Figure 27. Players can then refer to this result to gain insight into their accuracy. This is especially helpful when practicing back-to-back hits on the vest at high speeds. The MP Android Chart library is used to create the bar charts. The prototype vest was worn to examine the comfort and flexibility. Some stiffness was noted due to the bulky nature of the push buttons used. However, this is not critical since the buttons can be easily scaled down into tiny contact sensors. Likewise, the foam layers can be scaled down into thinner layers in the production phase. The thinner layers would also conform to the minimised contact sensors, achieving better vest performance, comfort, and flexibility.

6. Conclusions & Future Work

This study aimed to design and develop a prototype of FPMV; the vest may contribute to detecting and analysing the hit frequency and accuracy of a novice foil fencer. The FPMV integrates many technologies, such as the sensors and microcontroller in the vest, the Bluetooth (Transmitter/Receiver), and the Android application. The vest is paired to a mobile phone using Bluetooth, and a user-friendly application provides insight into a player’s performance during their training sessions.

The implemented prototype can be scaled down to provide a legitimate feeling of the stock fencing vests. The costs are minimised by using components that are widely available in the market; an application for android mobile phones analyses the data collected from the vest to provide insight into a player’s performance during a training session.

At present, the prototype of FPMV has obtained the desired effect from the authors. We need future studies to widely investigate and validate the FPMV prototype, and to study whether the proposed would improve the training process and the fencer’s learning. Previous literature in sport psychology and motor learning proposes possible success of such a project. It will undoubtedly strengthen children's motivation to engage in this sport (Movshovich and Lobanov, 2018). Potential stakeholders should be involved in developing such a project in the future.

A significant addition to the vest would be a health indicator that can measure a players’ blood pressure, temperature, and heartbeat. These measurements would be able to ensure that a player maintains good health while training. Multiple sensors would be required for this implementation, resulting in a higher complexity of the system’s design and consequently a higher cost.



Data is currently stored on a user's phone. An improvement would be to store it in a secure server, providing large data storage for each player with enhanced performance analysis over long periods of training. This would also allow players to connect as enthusiasts of the sport and share their statistics with certified coaches that are able to review and assist with the training process remotely. However, such a procedure will require the addition of strict privacy policies to comply with international laws.

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