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Are You for Real? Engineering a Virtual Lab for the Sports Sciences Using Wearables and IoT †

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Abstract: In tertiary education, disciplines such as sports science that require experimental components in their courses represent a significant challenge for online and distance education. This paper demonstrates the design and construction of an enriched experiment, together with the prototype software solution which can all be operated remotely using a web-based client. It presents research that investigated how to visualise data from internet of things (IoT) sensor devices (inertial sensor) used for tracking football sideline throw-ins. In this simple experiment, data was collected from one footballer, fitted with a single inertial sensor. A two-dimensional (2D) video, three-dimensional (3D) motion capture system and inertial sensor were all used to detect the release point of a sideline ball throw-in. In this project, inertial sensor data was used to create a 3D model using web graphical language and three.js.

Keywords: IoT; visualization; virtual technology; augmented technology; wearable technology

1. Introduction

With the growth of the sports industry, professional sporting people are expected to maintain a high level of performance over their careers while maintaining a positive attitude towards injury, pain, exhaustion and fatigue [1]. This normalisation regarding the quality of performance athletes must achieve means that coaches are now expected to train athletes harder and tougher to achieve a perfect performance. With technology rapidly evolving, there is a growing demand in the sports world for equipping coaches, other sporting professionals, and players [2,3] with faster, smarter communication. Furthermore, in a country such as Australia, where there are vast distances that often impede a student from attending a class, distance learning is not uncommon. In the sports science program at Charles Darwin University in the Northern Territory, more than 80% (sometimes over 90%) of students are distance learners. Offering realistic learning environments can be challenging.

The internet of things (IoT) is a collection of internet services enabling communication capability between computing devices and people through the world wide web [4]. With increasing adoption into sports sciences, the IoT may provide a means of enhancing sports science education and athletic performance. However, before this can be achieved, sports science students need to understand how to analyse and interpret IoT performance data. For distance learners, extended reality technologies (virtual and augmented) may provide a platform to supplement actual classroom activities.

In a sports science context, inertial sensors are devices that contain microsensors that can measure various outputs [5]. Accelerometers, gyroscopes and magnetometers are now typically found in inertial sensor devices. A device can have various forms, from smart phones and watches to devices specifically manufactured for movement analysis. Depending on the device and subsequent

application, an inertial sensor can be part of an IoT system. Data obtained from IoT sensors is often difficult to decipher and there is a need for data visualisation and education to equip the industry better. Data visualisation, a technique for creating images, diagrams or animations [6], is used to interpret data obtained from a device and output it in a form where end users can accurately discern and understand the data.

The aim of this research was to investigate how IoT may be used in education to enrich the student experience as well as to prepare students for future trends in the industry. In this initial phase of research, IoT sensor (time series) data from a specific context of a football throw-in was examined and visualised with the intention of prototyping a process for developing future interactive technologies in the virtual, augmented and IoT realms as teaching tools for sports scientists who may later become analysts for coaches and athletes. The specific focus was the kinematics of elbow extension during a ball throw-in activity. The throw-in was chosen due to the nature of the action. This action enables a single joint and body segment to be isolated for assessment. Adding to this, most of the movement (elbow flexion/extension) is in a single orthogonal plane [7], with a small amount of forearm supination in a second plane. Therefore, a small but manageable amount of complexity, enough to challenge the visualisation model, was present in the system of interest.

2. Materials and Methods

One experienced male football player performed a series of ball throw-in simulations (five throws in total) (Figure 1). The participant was required to stand and throw a soccer ball from a static position. Each trial was recorded via a single two-dimensional (2D) video (HDR-PJ240E. Sony Corporation, Minato, Japan) and a 10-camera three-dimensional (3D) infrared motion capture (MoCap) system (Optitrack. NaturalPoint, Inc. Oregon, United States of America). These recordings were aimed to track forearm movement, specifically the elbow.

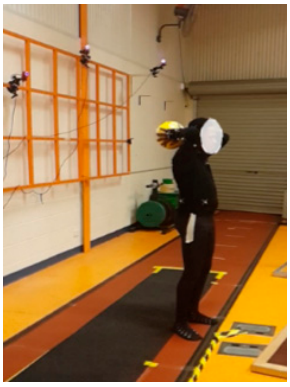


Figure 1. Ball throw-in experiment using infrared Optitrack cameras.

Synchronisation was carried out where a clear sharp impact on the wrist was detected in the three capture systems used. This was followed by the throw. A second impact was made prior to stopping recording. This enabled each throw to be identifiable between the impact boundaries something akin to a clapperboard effect in both camera systems and sensor data. Furthermore, this simple and effective synchronisation method has been validated and reported previously [8].

Using this data, an iterative human centred approach [9] was used to build a web application to visualise the data. To ensure that the end user (a coach or sports science student) would be able to use the software visualisation, personas were created to represent these end users (a persona is a fictional representation of the real user based on research) [10]. Personas provide developers with a clear representation of a typical user that may use the web application. The 3D web visualisation design in this application targeted coaches, players and analysts. Visualisation of a player's performance helped identify areas of performance improvement. Dam & Siang [10] wrote that a persona with an assigned role addresses the needs, goals and behaviour pattern of the user.

"Andrew" was the persona created to gain an understanding of what is expected from a 3D performance visualisation from a coach's perspective.

Agile software development was used to develop the visualisation and included six sprints. After each sprint, testing the software output with users of the application allowed the developer to quickly gain insights on how a coach may understand, perceive and use the football throw-in as a visualisation tool for coaching, therefore a teaching tool with real life applications. Feedback from this guerrilla user testing [11] was assessed in three categories: effectiveness, efficiency and satisfaction of the coaches when using the 3D model in a real-life application. This included a 3D visualisation of a ball throw-in that would be useful for real world use. The visualisation model allows simultaneous visualisation of the player's performance. Therefore, the coach can fix a player's ball throw-in technique immediately. Correcting a player's technique to improve performance is extremely crucial in a game environment [3,5]. From these observations it was concluded that it was important to provide a 3D visualisation model that best communicated the biomechanics. This critical understanding was reinforced through a chance conversation with an elite football coach.

Prior to visualising the data, the software development process needed to extract the data from the sensors so that visualisation development could occur. The process of data extraction is illustrated below (Figure 2). Biomechanical data was captured from the inertial sensor during the ball throw-in movement and plotted to help understand the significant data that may be used for visualisation. This data was then incorporated into a 3D model to be visualised through a WebGL based development. The software environment used Atom as the HTML text editor, Blender as the animation and rendering software, and WebGL and three.js were selected as the graphical language for developing the 3D ball throw-in model. A suitable graphics card at a medium range price with powerful rendering capabilities, the AMD Radeon RX 580, was used to render the 3D graphics.

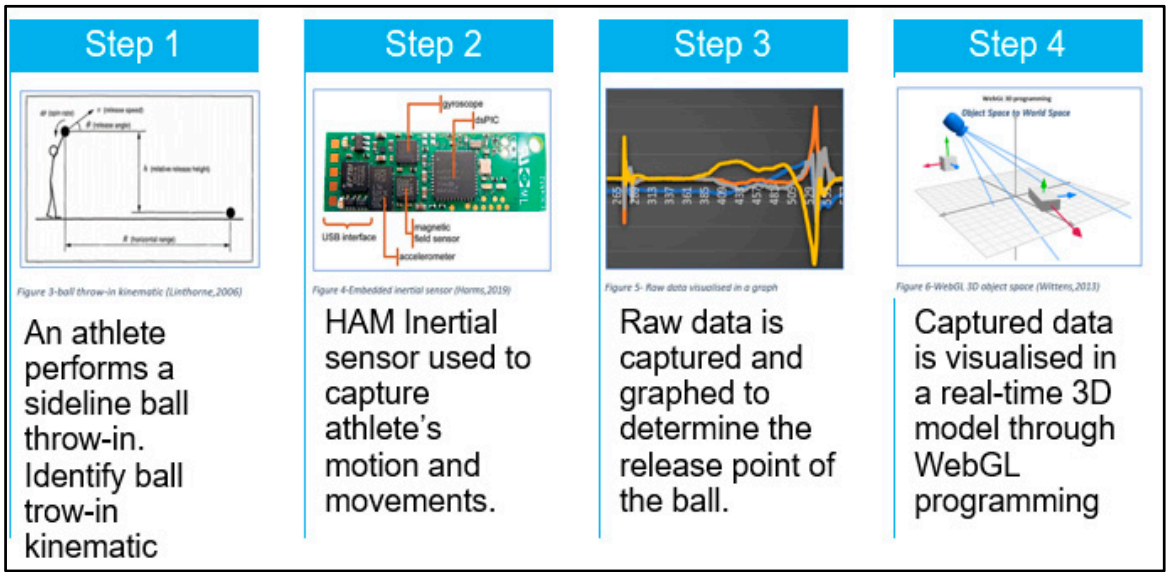


Figure 2. Development phase that demonstrates the process of data extraction from the throw, to comparative data capture systems.

3. Results

To facilitate the educational aims, this research developed a 3D visualisation model as a primary aid for students to understand technological methods, which in turn may assist coaches to best visualise a player's performance. When coaches are looking for a competitive advantage over their opposition [3] the 3D visualisation model attempts to offer clear visual data that may improve the way data is currently interpreted. This section discusses experimental results of biomechanical data obtained through observations of kinematics of elbow extension during a ball throw-in activity. Using the MoCap and inertial sensors, data was captured through video and graphical analyses of the athlete's avatar. A comparison of the video and graphical sensor data was used for accurate

examination of the biomechanical data. Additionally, the software development processes are elaborated describing the approach used to develop a suitable 3D visualisation model of the ball throw-in activity. The 3D implementation process outlined successes and failures and many of the decisions that needed to be made as this area of software development (3D data visualisation) and compatible development hardware was explored. Potential changes to the processes used were addressed, including relevant literatures, resources and tools that further support the development of 3D visualisation model.

3.1. Experimental Data

Nine degrees of freedom (9DOF) of accelerometers, gyroscopes, and magnetometers sensor data were observed during the experimental stage through video capturing and graphical avatar data. This process of examination through video capture and graphical sensor data allowed the detection of the arm movements from starting to stopping point. Events in the graphical data which matched the video capture were examined to identify the initiation of the throw and release point of the ball. Events in the biomechanical data of the ball throw-in activity through infrared MoCap data validated the ball throw-in activity. By observing a 2D graph of sensor data, the rotation of the arm and the release point of the ball was identified. Additionally, both experiments provided critical analytical data to construct a data visualisation model, to best communicate the ball throw-in activity to the coaches. Experimental results obtained serve as a platform for developing future interactive technologies in the field of virtual, augmented and IoT realms as teaching tools for sports scientists who may later become analysts for coaches and athletes.

3.2. Software Development Processes

Software development of the 3D visualisation model of the ball throw-in was undertaken using six sprints with varying degrees of success. Initially, identifying appropriate hardware and software compatibility for efficient software development was required. The solution was the use of an AMD Radeon RX 580, a powerful mid-class rendering graphics card. To be able to use the data produced by the sensors, three different software development technologies (Blender, WebGL and Three.js) were combined. However, identifying the correct software took significant time, as 3D visualisation programming is a new field of learning. The approach taken to successfully identify suitable software was based on research, installing and testing the software and completing software tutorials. Software development processes for 3D visualisation models required further software research and experimentation. The combination of reviews of relevant literature and the experimentation phase enabled growth in the understanding of the fundamental concepts underpinning the biomechanics of sports as well as specific understanding of the IOT and sensors. This domain of knowledge was important to be able to create accurate and detailed software visualisations. As a result, this approach created a concurrent, efficient and effective workflow that helped develop a 3D visualisation model. Another aspect that worked well was the combination of multiple software development technology and tools. This was a strategic approach which aimed at facilitating the development process, coding with more efficiency, and therefore accelerating the learning curve to still be able to produce a product at the end of the project.

4. Discussion

The aim of this research was to investigate how the IoT may be used in education to enrich the student experience as well as to prepare students for future trends in the industry. As a result, a range of resources, development approaches and literatures were identified in the development of this research that were not implemented or used to better the development process. Usability validation of the 3D ball throw-in visualisation model is an approach suggested by Eldar & Fisher-Gewirtzman [12]. The usability validation approach selects a specific part of the 3D model or the entire 3D model, states a hypothesis for the usability of the 3D model and then takes the problem to experts of that field for assessment. The experts assess the usability of the 3D model through a list

of evaluation heuristics and determine whether that visualisation model serves its intended purpose and if the alternative is appropriate for the problem driven visualisation task. Free3D is another resource that could have been used to facilitate the development of the software. Free3D offers a free avatar model framework, that could have been used instead of reinventing the wheel. Hence, the development process of the 3D football sideline throw-in may have drastically improved through additional research on more resources, development approaches and literatures that could simplify the development process.

However, the software development approach had some aspects that could be improved in a fuller implementation. Trade-offs due to the time constraints, the complexity of 3D development and the associated learning curve were areas where further development is warranted. The current development approach did not take into consideration the complexity of the development: however, using a software sprint methodology allowed a trial and error approach to identify the software tools and learn the technology. The first development sprint was allocated to gaining in depth technical understanding of specific tools such as Blender, WebGL and Three.js. Merino et al. [13] support the approach of the first sprint as a learning sprint through their study on overcoming issues of 3D software visualisation. Consequently, incorporating learning sprints, using insights from the literature would have possibly reduced time spent in the first phases of software development, establishing software skills and appropriate technologies, making the development process more efficient.

This research demonstrated that inertial sensors can be integrated into an IoT system with the intention to further develop the processes into a teaching tool. The complexities in time series data are essentially still there. However, this research concept has been tested through a persona model that in a real scenario may give a sports scientist a quick analysis tool for performance feedback. Therefore, in a teaching environment, this can be replicated for sports science students to effectively learn how to gather and interpret the data.

In a virtual or augmented sense, the IoT phase should be implemented to build the infrastructure that enables these realities to be utilised. Educating off campus students will be possible where technologies facilitate an online learning environment that mirrors a sports science laboratory class. Students will be able to remotely access the system at any time and manipulate the environment for a learning experience that replicates an actual laboratory. Therefore, students will be able to measure kinematic data, and in the case here of a soccer ball throw (e.g., joint angle displacement, velocity, and acceleration, tangential and centripetal accelerations, angle of ball release, velocity of the ball after release). Furthermore, assessment of competency and application will also be possible. This will ultimately bring the learning and skill development for off campus, distance-based sports science students closer in alignment to their in-class peers.

5. Conclusions

This study reports the first phase of research to design and develop a sports science teaching tool that incorporates wearables, IoT, augmented, and virtual technologies. The ultimate outcome will contribute to more digitally skilled sports industry professionals. This phase of the project focused on how to capture and present 3D data visualisation of a sideline ball throw-in. This solution can now be the basis for development into other sports and activities. While this phase was IoT focussed, it enabled the road-mapping of the wider educational goals of the project. Through literature reviews and interviews, several findings emerged identifying current IoT technologies and an associated data visualisation system based on biomechanical kinematics. The following phases will take the IoT knowledge and apply it to virtual and augmented realms for effective online teaching capabilities to distance learners, a trend recently predicted to have a greater focus during the next decade of tertiary education [14].

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Conflicts of Interest: The authors declare no conflict of interest.

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