Construction of a Virtual Environment to Measure the Evolution of Kendo Athletes

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Abstract: The use of technology applied in sports comes each year becoming a great tool to help athletes train. Moreover, the post-pandemic world is undergoing dramatic changes in the way of thinking and acting, with new ways of exercising emerging, but without leaving home. Thus this paper describes the development of a platform for training, focusing on Kendo practitioners (Japanese fencing) using virtual reality tools to allow athletes and training the distance. Through the use of a HMD (Head Mounted Device), *kendōkas* will be able to practice blows and improve their reflex by a gamified experience in a virtual environment.

1 INTRODUCTION

The application of technology in sports is an area that has seen constant renovation in the past few years and has since become a great auxiliary tool in the training of athletes. In relation to this market, some of the technologies used include computer modeling, data acquisition and analysis, mobile computers and information technology networks (Baca et al., 2009). Currently, high-level athletes have adopted the use of technological devices that collect data on their physical and mental abilities, with the aim of improving their abilities and sports performance (Liebermann et al., 2002) (Petri et al., 2018).

Among the technical resources used in sports training, virtual reality (VR) is a technology capable of imitating real scenarios in a way that seems familiar to human cognition, creating a virtual environment. The user is inserted into this environment and their movements are represented virtually, causing an enhanced feeling of immersion, a perfect setup for creating training environments.

Martial arts and combat sports can also benefit greatly from this kind of technology. Kendo, a martial art of Japanese origin and the main style represented in this paper, can be described as a match between two opponents. Its setup resembles Olympic fencing, however practitioners wield bamboo swords and wear a special set of armor and clothing that is settled down by traditional customs. Moreover, Kendo is a sport that has high-performance, world-class championships, but a very small amount of research in the West about it, mainly in the field of technology. When compared to Football, which is an Olympic sport and relies on generous technological investments, it is estimated that Kendo has a great deficit in scientific works devoted to it. Even so, in the years 2016 to 2020, there has been a remarkable increase in experi-

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ments that employ technology to improve the training of Kendo practitioners (also regarded as “kendoka”). Some of the themes found were a study of the kinematics and dynamics of Kendo kata (Konyukhov and Yeniavci,), a study to determine the factors to reduce the attack time of the men (Murase et al., 2017), the development of a “kote” Kendo glove to analyse parameters (Jeong et al., 2018), a Kendo support system (Takata et al., 2019), and detection of attack activity (Torigoe et al., 2020). Most of the recent articles are related to the field of health sciences or the study of Kendo as a martial art in general.

In view of this, virtual reality will be used to carry out movement execution training for Kendo athletes. The use of this technology in sports is applied in different modalities, several studies have already tested and observed whether the use of virtual reality in sports helps the practitioner’s performance, concluding that the use of this technology in parallel with the usual physical activity is beneficial for the practitioner. (Neumann et al., 2018),(Stinson and Bowman, 2014),(Bideau et al., 2009).

2 JUSTIFICATION

Since the start of the COVID-19 pandemic, the public was faced with an increasing need to find new ways to exercise, since gyms were temporarily closed all over the world. In addition to that, due to safety precautions, a substantial portion of the population had to stay in their homes. Ahead of this situation, the Brazilian Kendo Confederation (Confederação Brasileira de Kendo – CBK) prepared a calendar of online events for training and refereeing directed at the Brazilian public, highlighting the ”Online Children’s Suburi Championship” of Kendo Jidai International magazine, which had the participation of athletes from all over the world. This event united sports practitioners in an extremely difficult time for humanity. In this perspective, in the post-pandemic context, the practice of physical exercises with Internet tools remains a widely adopted modality, becoming a new way of practicing exercises and sustain social contact, albeit remotely. Thus, performing these activities in online settings facilitates training and makes knowledge in different areas of Kendo much easier to share.

Following this line of reasoning, it seems fair to state that people in the whole world should reconsider the conditions in which, until quite recently, many commonplace activities, such as physical exercise, occurred. When governing bodies of many countries throughout the world understood that the institution of ”lockdown” measures was necessary, it suddenly seemed clear that health authorities needed to come up with public health strategies that must include the creation and implementation of interventions in popular habits and customs, with a focus on promoting safe physical activity and reducing sedentary lifestyle. With these measures in mind, it is possible to prevent major health crises should similar extreme situations be experienced by humanity ever again (Stockwell et al., 2021).

Given the situation, virtual reality resources, especially Head Mounted Display (HMD) devices, would offer an immersive and realistic environment. In contrast to the real environment, these devices allow free manipulation, which provides greater autonomy for instructors and developers, in addition to creating favorable frameworks for the progress of athletes. Consequently, virtual reality technology helps improve the accuracy of strikes and reduce the reaction time of athletes, focusing on the growth and improvement of Kendo practitioners, preparing them for competitions. Furthermore, it is imperative that this technology can be distributed easily and quickly, aiming at its dissemination among different dojos and isolated practitioners, making it an integral part of the kendokas training routine.

3 THEORETICAL REFERENCE

3.1 Kendo

Kendo, often translated as ”way of the sword”, is a martial art of Japanese origin in which practitioners (kendōka) learn to fight with bamboo swords (shinai) while wearing traditional clothing and protective armor (kendōgu or bōgu) . It is also an elegant traditional combat sport that can be enjoyed from early childhood well into late seniority. It emphasizes correct execution of techniques as well as correct demeanor from teachers and students alike, nurturing a prospering environment of healthy and safe exercise based on mutual respect and fair-play, owing much to its martial origins and sportive leanings. According to the All Japan Kendo Federation (AJFK), the concept and purpose of kendo are as follows: concept - ”Kendo is way of disciplining human character through the application of katana principles”; purpose - ”To shape mind and body. To cultivate a vigorous spirit and, through correct and rigorous training, to strive to import the art of Kendo. To have esteem for human courtesy and honor. To associate with other in sincerity. And always seek self-cultivation. Thus a person will be able to love his country and society; contribute to the development of culture; and promote

peace and prosperity among all peoples" (Salmon, 2013).

Futhermore, Kendo's list of valid strikes is composed of four basic attacks that can be used to score points in a match. They are: *men* (attack to the top of the head), *kote* (attack to the forearm), *dō* (attack to the torso) and *tsuki* (throat thrust). All of these attacks are made on areas of the armor the competitors wear, and are usually named after the part of the armor that is being hit. Competitors advance in a match if they score two valid points (datotsu or ippon) that are considered satisfactory by the three standing referees, or if they score one point and time runs out, or yet if their adversary is disqualified for receiving two fouls (hansoku).

Besides the competition setting, Kendo training involves basic body exercise focused on developing good movement and coordination, traditional exercises such as *suburi* (swinging the sword reapeatedly, as if cutting the air), *kirikaeshi* (repeated cuts or strikes in a set pattern against a training partner), *uchikomi keiko* (training of strikes as allowed in competition) and *kata* (predefined forms of both classical and modern influence that represent the most significant aspects of Japanese swordsmanship).

3.2 Virtual Reality in Training

Technology has become an amazing tool for high-performance sports since its use in training for competition comprehends much of the new methods for improving athletes, especially in sports centered on the constant monitoring of the evolution of their practitioners (Fleming et al., 2010). Among the various technologies used for this purpose, virtual reality stands out for "transporting" the athlete into the possible scenario that will be faced by him in the day of the competition, bringing him closer to the real situation. In addition to this, there is also the possibility of inserting unexpected variables that cannot be reproduced so easily in real-life training, enabling the athlete to be prepared for any type of unforeseen event that may occur during competition (Wang, 2012).

In view of this, athletes and technical committees can take advantage of virtual scenarios and positioning technology as a sort of training partner, aiming at improving and monitoring the evolution and performance of practitioners, thus improving their skills and allowing better performance in competitions (Craig, 2013).

Kendo, as a martial art and combat sport, requires a constant training routine from the practitioner, as the score depends on the execution of the strikes and the accuracy of each blow against the opponent. In this sense, similar to the present work, there is an article that aims to use immersive virtual reality to improve the training of Karate athletes, aimed at improving their CRT. However, it seems that the way in which the VR technology is used in that trial ends up making it impractical for use in other Karate commissions, as it does not use an standalone device. What that means is that, for the project to work, it is necessary to connect the VR device to a computer, making it dependent of another component to work, reducing its portability and ease of use (Petri et al., 2019).

4 MATERIALS AND METHODS

The choice for the HMD for this project was determined by the immersiveness that the equipment provides to the user. It also provides movement monitoring capabilites and has several integrated sensors, in this sense bringing the virtual environment closer to the athlete, making the experience even more immersive. Besides, it is a stand-alone device, which means it does not require a cable connection with a computer. It is a virtual world mirrored in the real world, helping with the proximity of movement and training space. According to Doctor Cathy Craig (Craig, 2013) the structure of the HMD contains an inside-out tracking technology, using a headset and cameras while connected to a computer, without the need to organize external towers in the room, since the Meta Quest 2 allows the user to define the shape and size of the limits of his virtual space.

For the development of this work, the hardware device used was the Meta Quest 2. For the software part, the Unreal Engine version 4.27, together with the HTTP Request For Blueprints Plugin, a Web API using Express framework and a Postgresql database. The Meta Quest 2 was chosen in this work due to the immersiveness that it provides since it allows following the athlete's movements within the virtual environment, beyond the fact it is a stand-alone device, which results in more freedom of movement for the athlete. Unreal Engine 4 is a 3D application development platform designed by Epic Games that offers a wide range of tools that enable the creation of cutting-edge content, interactive experiences, and immersive virtual worlds. The version 4.27 of Unreal Engine was chosen instead it latest launched version, the Unreal Engine 5, its due the fact that at the beginning of project development, the Unreal Engine 5 was not fully stable, and also presented errors at Android OS exporting. Although this engine is geared towards games, its application goes far beyond this area. Thus having prominence in research and interactive proto-

typing. Among the options that Unreal Engine 4 allows us, those that were used by the team are support for VR, importing 3D models, remote control protocol and external plugins, which can be found on the official Unreal Engine 4 website.

HTTP Request For Blueprints is a plugin developed by King Wai Mark that makes it possible to perform REST requests to a server efficiently, used to communicate between the virtual environment and a remote API. To create a project with VR interaction, we used a template from Unreal Engine 4 called "Virtual Reality." This template provides a character who has already implemented the movement mirrored with reality.

With this character in the project, we created a new map where the virtual training environment will be created. To create the environment, we used an asset package from Synty Store called Samurai Pack. We also used a shinai 3D asset model, a bamboo sword used in Kendo, to be handled by the player, as shown below in the figure 1.

Figure 1: Holding Shinai.

The shinai was programmed to have three collision areas, as shown in the figure 2, representing the three shinai parts: *bo*, *satsu* and *sei*. Depending on the shinai area hit, the score changes. Additionally, a socket has been added to the base of the shinai's skeletal mesh, to ensure that whenever the player uses the gripping action on any part of the shinai, the base is fixed to the player's hand, ensuring a correct grip. However, a double grip was not implemented, since the player is not holding a unique equipment, the hands movement is totally free, which could confuse the player when trying to use both hands grip on shinai.

The training protocol was implemented placing targets to be hit on a samurai 3D model, in the positions of the *men*, *kote* and *do* strikes, respectively, the head, forearm and tummy positions, as shown in

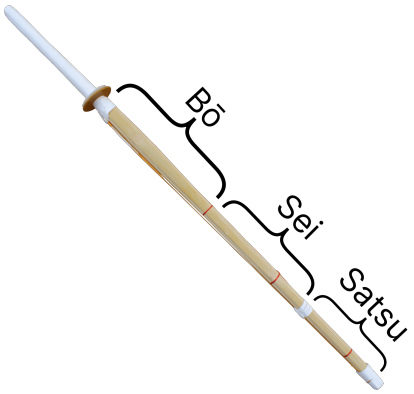

Figure 2: Shinai areas.

the figure 3. As shown in the figure below, the targets are highlighted areas over the samurai. These targets light up one at a time, as well the samurai animation, indicating where the athlete should hit simulating an opening for a hit. Furthermore, a timer is shown to indicate how much time the user is taking to hit the area.

Figure 3: Highlighted area in red.

For the targets to start lighting, the athlete must maintain a distance from the target similar to the fighting distance between kendokas in real life, which is represented by a cylinder highlighted area. In Kendo, all strikes are trained by both beginners and seniors, with the exception of the Tsuki that only more seniors practice because of its risk.

To ensure that the strike will be executed correctly, we use a collider above the athlete's head, which verifies if the athlete has raised the shinai to the correct position to execute the strike. Once the athlete reaches that position, the message signals the possibility of executing the strike. After the execution of the strike, the highlight goes out and a short audio track is played, representing audible feedback for the user to know if the hit was successful or not, and the samurai animation returns to the initial position, then the reaction time is computed between the moment

Figure 4: Initial position.

when the target lit and the end of the execution of the strike. This process is repeated a predetermined number of times during a training session.

Figure 5: Message indicating permission to attack.

At the end of the session, we generate a JSON with all the data acquired, storing the athlete id, the session date, duration, score and information from all the executed strikes, saving the shinai area hit, the samurai part hit and the reaction time necessary for the execution of that strike. After all that, the data of the executed strikes are sent to a remote API through the HTTP Blueprint plugin, to store the information about the user training session on a database.

For the development of this API, the Node js was used together with the Express framework and Prisma Object-Relational Mapping (ORM) to develop a system that can work online. Using Node js, Express framework and Prisma ORM, you can create an API that can communicate with a database, which allow us to create, update and read data from it. This means that we can abstract real data in a way that the system understands and is free to manipulate. The Prisma ORM is responsible for designing the entities, which

Figure 6: JSON data format.

are abstracted to objects in a model. Therefore, we can think of a training session as an object model that has relevant data. This object would have, for example, an identification number, the strokes given by the student, his reaction time, among other relevant data. Like the session, other entities need to be abstracted before they can be stored. They also need to be related to the aspect of athlete training. They are:

- User
- User Session
- User Session Statistics

In Node, to implement this abstraction, you need to create a model for each of these entities. With the models created in the 'schema.prisma' file, Prisma ORM itself can generate the database for immediate use, by using a tool called Prisma Migrate. Models, like their real entities, have relationships with each other. For example,

An athlete can do a series of training sessions. A training session is done when an athlete performs a series of strikes. All of these relationships must be represented and implemented according to real cases. These relationships can be more easily seen in the class diagram:

Now having all the models placed and associated as necessary, you must now create and manipulate this data. It is at this point that Unreal's HTTP Request for Blueprints plugin is used to make requests to the API, as in the representation below:

Now with the data processed and sent to the API, it is possible to observe, based on this database, some aspects of the athlete's performance in each training and its progression.

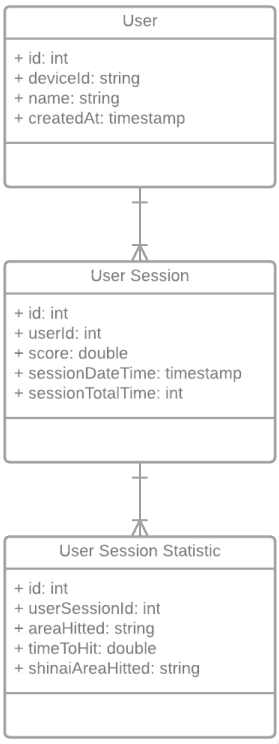

Figure 7: Class Diagram of API Models.

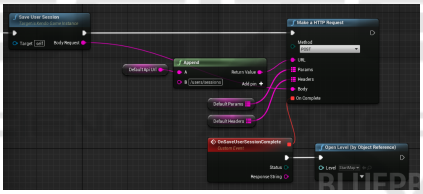

Figure 8: HTTP Blueprint Node.

5 CONCLUSION

The aims of this paper include the development of a training platform focused on improving the performance and technical improvement of Kendo athletes. With the development of the platform and the ease of distribution of the HMD technology (through the Meta Quest 2 VR headset), it is possible to disseminate the use of this platform to other dojo practitioners who are distant from the nearest teachers and schools, providing a more accessible tool for their technical growth and inclusion. Furthermore, during the construction of the project, the team was faced with the difficulty of representing the weight in the simulated environment, some of the methods used do not meet the needs of the project, leading to the conclusion that it would be better to remove the weight simulation of the application, and that this decision would not affect the athlete's practice.

6 FUTURE WORKS

In this way, once this work is concluded, it is intended to add analysis of the athletes' reaction time, with the objective of following their evolution. That said, this parameter will be used in a dashboard, composed of several graphs aiming at monitoring the collected information, allowing coaches to adapt training to the needs of the athlete.

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