Real-time Evaluation System for Top Taekwondo Athletes: Project Overview

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Abstract: Assessing athletes' performance is a constant challenge for coaches, whatever the sport is. In some sports there are no technological solutions to assist coaches in this task. This is the case of Taekwondo, where currently the methods used are mainly manual. Following this trend, this article presents the work developed in a PhD project whose main objective is the development of a friendly and low-cost system for assessing the performance of Taekwondo athletes in real time. Thus, the system uses a 3D camera with depth sensor (Orbbec Astra), a computer and software developed for data collection and processing. The system also provides the inclusion of Inertial Measurement Units (IMUs). The system allows an accurate feedback for the correction or improvement of the athlete's techniques, enabling an increase in the athlete's performance in a shorter period of time. In all, the project contributes to the evolution of the techniques used during Taekwondo training, as well as to the technological development in the practice of Taekwondo.

1 INTRODUCTION

Technology plays a major role in everyday life across the spectrum of society. Its use has been increasing, as an integral part of the daily routine, becoming something natural and often imperceptible. In different areas of society and science, the use of technology is possible through the combination of information processing and the continuous use of tools, extended through computing devices, known as ubiquitous computing (Baca, Dabnichki, Heller, & Kornfeind, 2009).

One of the areas in which research and development of technological solutions has obtained an active participation from the scientific community is motion analysis. It is currently possible to analyse the movements of humans in a natural environment of activity, without the need for markers on the human body. The result of these new methods of motion analysis contributes to the creation and availability of accessible and easy-to-use motion capture solutions (King & Paulson, 2007).

In sport, the evolution in movement analysis has allowed the development of technological solutions that help athletes, coaches and referees in certain tasks (Thomas, Gade, Moeslund, Carr, & Hilton, 2017). These technological solutions are divided in two main groups. The non-optical systems, which uses sensors placed on the athlete's body to obtain movement information. And the optical systems, with or without markers. The optical systems with markers show better results combined with a higher cost and complexity of implementation, as well as higher intrusiveness, and systems without markers are easier to implement, being less intrusive (Pueo & Jimenez-Olmedo, 2017).

Assessing the performance of athletes is a complex and difficult task in any sport. The inclusion of motion analysis in the practice of sport, through the systems developed, came to assist in this task. Some of the systems developed to perform the evaluation allows to obtain relevant information of the athlete's performance like velocity, acceleration, force, displacement, among other characteristics (Arastey,

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2020) (Cunha, Carvalho, & Soares, 2018) (Nadig & Kumar, 2015).

In Taekwondo martial art, the evaluation athletes' performance is still carried out by traditional methods, that is, by viewing videos of the training sessions or in loco of the athletes' movements in real time. This is time consuming for the coach and delays the feedback for improvements to the athlete (Pinto, et al., 2017).

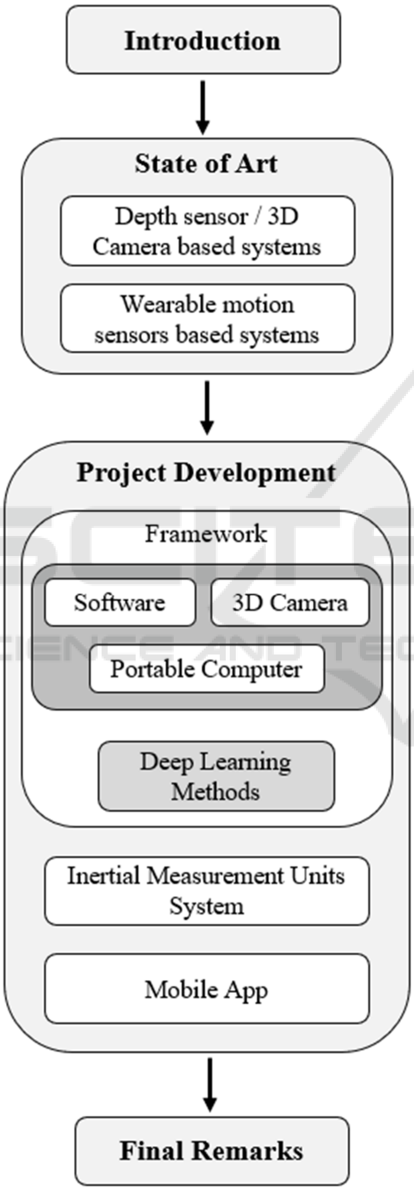

Figure 1: Paper flowchart.

This paper intends to present a project whose objective is to assess the performance of Taekwondo athletes in real time. The study performed during the project aims to contribute with a new method of identifying and quantifying the movements performed by the taekwondo athlete during training sessions using deep learning methodologies applied to the data collected from the taekwondo athletes' movements in real time.

This paper is organized into four chapters as described by the flowchart presented in figure 1. The second chapter presents the state of the art; in the third chapter, the work and study performed on the tasks that make up the main project are described; and in the fourth chapter are presented the final remarks along with the future work in the project development.

2 STATE OF ART

Along the development of technology, several devices have emerged that enable the monitoring and analysis of movements performed by the human body. Taking advantage of this, in Sports area has been conducted a large number of researches aiming to contribute to the improvement of athletes' performance and help in the prevention of injuries.

For trainers and athletes, motion analysis is of great importance when applied in the training because it allows to provide technical skills improvement by correcting the trainee's body motion in order to perform correct and most efficient movements in any sports.

Regarding motion analysis some of the research carried out aims to study the hands movements and localization. As the case of the study that presents a survey where they summarized the techniques used for hand localization and gesture classification (Suarez & Murphy, 2012).

Despite a growing increase in image resolution, traditional video cameras are conditioned by the luminosity and colours present in the environment making it difficult to obtain the correct digital analysis of the image. Depth cameras appear as the suitable alternative for image collection when these situations occur, collecting depth images, not dependable on orientation or intensity of illumination, or from the colour scheme of the environment. One of the most used depth sensors in scientific research regarding gesture classification and hand localization is the Microsoft Kinect (Microsoft, 2020); mainly due to its low acquisition value, portability, not requirement of markers, ease to set up, and creation of 3D images. It allows to develop affordable 3D video motion systems that are used to human movement kinematics analysis of body joints and segments in several areas.

A Microsoft Kinect camera used to collect data from whole human body movements was presented in a study for human gesture recognition using data mining classification methods in video streaming of twenty body-joints positions of the human body (Patsadu, Nukoolkit, & Watanapa, 2012). The study recognized gesture patterns as stand, sit down, and lie down. The classification methods adopted for comparison were backpropagation neural networks, decision trees, support vector machines and naive Bayes. The results obtained allowed to conclude that backpropagation neural networks show superior performance compared to the other classification methods, recognizing human gestures with 100% accuracy. The average accuracy of all classification methods was 93.72%, confirming the efficiency of the Kinect camera when used in human body recognition applications.

Also, with Microsoft Kinect, a study was carried out where compared the Microsoft Kinect displacement measures with the Peak Motus marker-based system displacement measures. The results allowed to conclude that the Microsoft Kinect, for being a mark less system, was more favourable during the setup, data collection and analysis stages as compared to the Peak Motus (Zerpa, Lees, Patel, Pryzsucha, & Patel, 2015).

A real-time evaluation approach that uses a Microsoft Kinect and image processing techniques to recognize and record the number of occurrences of a movement in Taekwondo training environment is presented by Pinto, et al (2017). The recognition of the movements was obtained through the calculation of the angles between human body joints and comparing them with the correct values of each movement previously saved in a database.

In (Cunha, Carvalho, & Soares, Development of a Real-Time Evaluation System For Top Taekwondo Athletes SPERTA, 2018) it is presented a system to evaluate the performance of Taekwondo athletes during training sessions. The 3D camera used is the Orbbec Astra that comparing with Microsoft Kinect 2 is smaller, has less weight, with a higher maximum reach distance. The system allows to save information about the athletes and about the movements. Regarding movements the data obtained are relative to Cartesian coordinates in the real world of the human body joints. Providing athlete hands and feet joints movements data in Cartesian coordinates numeric values, Cartesian coordinates line chart and speed line chart, all in real-time.

Still further studies are needed, so that it can be confirmed the reliability and validity of the Microsoft Kinect for human movement kinematics analysis (Polak, Kulasa, VencesBrito, Castro, & Fernandes, 2016). However, some studies verified and agreed that marker less systems would be a major revolution in the analysis of human motion making possible the application of human motion capture studies (Robertson, Caldwell, Hamill, Kamen, & Whittlesey, 2004) (Corazza, Mundermann, Gambaretto, Ferrigno, & Andriacchi, 2010).

Other studies follow a different approach, where movement data is collected using motion sensors used by athletes. These wearable devices are valuable instruments for the improvement of sports performance. However, the existing systems are still limited (Li, et al., 2016).

In (Camomilla, Bergamini, Fantozzi, & Vannozzi, 2018) the authors agreed that magneto-inertial technology is a reliable tool to improve athlete's performance, the training specificity and to prevent injuries. These sensors measurements can be used to estimate temporal, dynamic and kinematic parameters.

Smart sensors and sensor fusion allow to study the impact suffered by the athlete. In (Mendes Jr, Vieira, Pires, & Stevan Jr, 2016), the authors demonstrated the use of smart sensors and sensor fusion in biomedical applications and sports areas, promoting a reflection about techniques and applications to process physical variables associated with the human body. The application can be used in areas related to rehabilitation, the athlete's performance development, among others.

In (Amaro, et al., 2017), the authors agreed that the impact signals combined with IMU may be a reliable way of scoring, whilst heart rate measurement enables monitoring of the athlete's physical state. The technique used consists in integrating a "non-invasive" sensor system into Taekwondo clothes. The impact is measured using pressure sensors, thin film piezo resistive force and accelerometers. The communication between the sensor and the computer is based on Bluetooth and it was discovered a limitation of bandwidth using this transmission protocol.

3 PROJECT DEVELOPMENT

The project from which this study derives aims to contribute with a technological solution that allows the assessment of the performance of Taekwondo athletes in real time during training sessions. In order to achieve the objective, several tasks have to be completed, each one contributing with elements necessary for the development of the system.

Thus, the main outputs of system will be statistics, biomechanics and motion analysis. The statistical analysis, will be made with the results obtained through the identification and quantification of the movements performed by the athlete, allowing to assess the evolution over time of the training sessions. And the biomechanics and motion analysis, will allow to calculate acceleration, velocity and the applied force of the athlete's movements.

In this chapter these tasks will be presented, referring to their role in the functioning of the final system.

3.1 Framework

The developed system is composed by a 3D camera Orbbec Astra, a computer and by the software, as presented in figure 2. The option for the 3D Camera Orbbec Astra is due to the fact that it is smaller in size, weighs less, does not require external power and has a higher maximum range system, compared to Microsoft Kinect 2, the most used depth sensor in research (Cunha, Carvalho, & Soares, Development of a Real-Time Evaluation System For Top Taekwondo Athletes SPERTA, 2018).

Figure 2: Framework system architecture (Cunha, Carvalho, & Soares, 2018).

The system allows to collect data on movements performed by taekwondo athletes during training sessions, calculating and presenting the values of speed, acceleration and applied force of the athlete's hand and feet in real time (Cunha, Carvalho, & Soares, Development of a Real-Time Evaluation System For Top Taekwondo Athletes SPERTA, 2018).

3.1.1 Software

The software of the framework was developed in C# with Visual Studio 2017 IDE (Integrated Development Environment) for build up the interface and the main features, along with Structure Query Language (SQL) to add the database where the data is stored. In order to obtain athletes movements data, the Nuitrack™ SDK was integrated. Nuitrack™ is a 3D skeleton tracking gesture recognition solution middleware that allows to obtain the athletes joints cartesian coordinates relative to the range of the 3D camera Orbbec Astra.

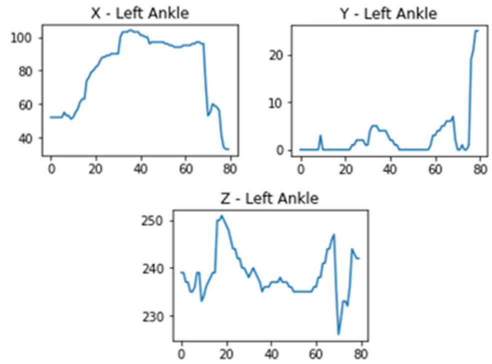

Figure 3: Raw data from Left Ankle Joint.

The development of the software had as initial objective to create a dataset with the data of the movements that the athletes perform during the practice of Taekwondo. The dataset consists of several classes, each referring to a movement, in which the cartesian coordinates of the athlete joints for each class are stored. The values of each joint refer to the X, Y, and Z coordinates in a tri-dimensional environment.

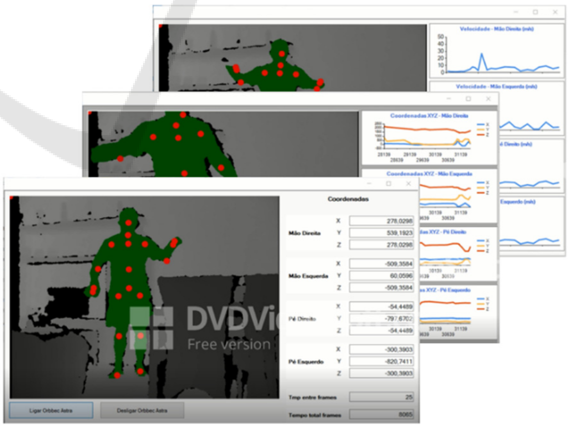

Figure 4: Depth sensor, cartesian coordinates and speed data output in real-time (Cunha, Carvalho, & Soares, 2018).

It is intended to integrate the software with the functionality of identifying and quantifying the movements performed by Taekwondo athletes during training sessions. For that, motion analysis will be performed according to skeleton-based action recognition, through deep learning methodologies.

The main propose of the developed dataset is to gather information about the taekwondo athletes' movements aiming to use on training of deep learning classification methods. The dataset obtained consists of four classes (front leg bandal, rear leg bandal, jirugui and front leg miro), in which each class represents a movement performed by the taekwondo athlete, with about 200 samples per class. The data acquisition and treatment were performed to identify and quantify the athlete techniques.

In order to select the deep learning method that best fits the type of data, several deep learning were studied and tested, such as, Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), Graph Convolution Networks (GCN), CNN+LSTM and a LSTM with embedded Convolution (ConvLSTM), figure 5.

Figure 5: Deep learning methods testing system diagram.

During the tests, the classification validation accuracy was 80% for the CNN model, 88% for the LSTM model, 93% for the CNN+LSTM model, and 92% for the ConvLSTM model. The results obtained allow to realize that convolutional layers models achieve the best results. Both CNN+LSTM (figure 6) and ConvLSTM, managed to get results above 90% on accuracy validation, placing these models as the ones that best fit the characteristics of the Taekwondo athlete's performance evaluation system.

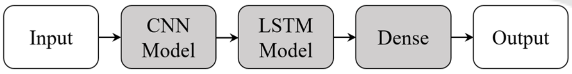

Figure 6: CNN+LSTM Network Architecture.

3.2 Inertial Measurement Units (IMUs)

For the movements data acquisition, as presented above, was used a system data extract the body joints coordinates in a tri-dimensional environment. Although this method allows data to be collected efficiently, sometimes, due to a rotation of the athlete or overlapping of a limb, there is occlusion. In order to overcome these occlusions, the addition of motion sensors, more specifically the inertial measurements units, was foreseen. They will be positioned on the extremities of the upper and lower limbs, hands and feet. For this purpose, custom-made containers were designed to accommodate the various hardware components, which will be fixed to the athletes through a velcro system.

As Taekwondo is a sport in which the athlete performs fast and wide movements, with a greater incidence of the lower limbs, the size and weight of the motion sensors must be considered. The solution developed should be the least intrusive as possible, not interfering with the athlete's movements and with adequate comfort for use during training sessions. Along with the characteristics related to the intrusiveness of motion sensors, the value and ease of acquisition of the components were also considered.

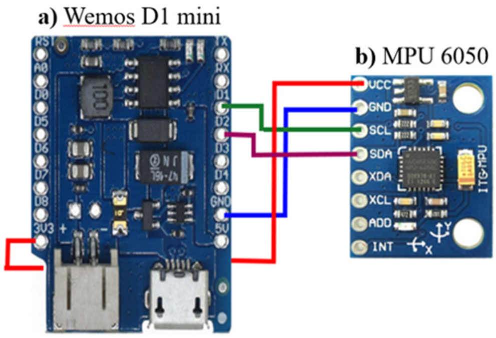

Figure 7: Wemos D1 mini Wi-Fi board (a) and the GY 521 MPU 6050 (b) connection diagram.

Thus, for data processing and transmission it was selected the Wemos D1 mini a Wi-Fi board based on ESP-8266, with 11 digital input/output pins and 1 analogue input, as seen in figure 7 a) (LOLIN D1 mini, 2020).

The sensor chosen to obtain the acceleration and gyroscope data was the GY 521 MPU 6050 (figure 7 b)), which is a three-axis gyroscope and acceleration module, with standard communication I2C. The acceleration range is between ±2 and ±16 g and the gyroscope range is between +250 to +2000 °/s (MPU6050 - Accelerometer and Gyroscope Module, 2020). The motion sensors system also includes a battery shield (Battery Shield, 2020) which allows to choose between powering the system through a battery or through a USB charger, as well as enable to charge the battery when the system is being powered by the USB charger.

The system presented in figure 8 measures the displacement and acceleration of the upper and lower limbs, transmitting this data through a Wi-Fi communication, stored in the computer belonging to the system.

For this, a program was developed that allows the reading of the IMUs and the transmission of data through the UDP protocol.

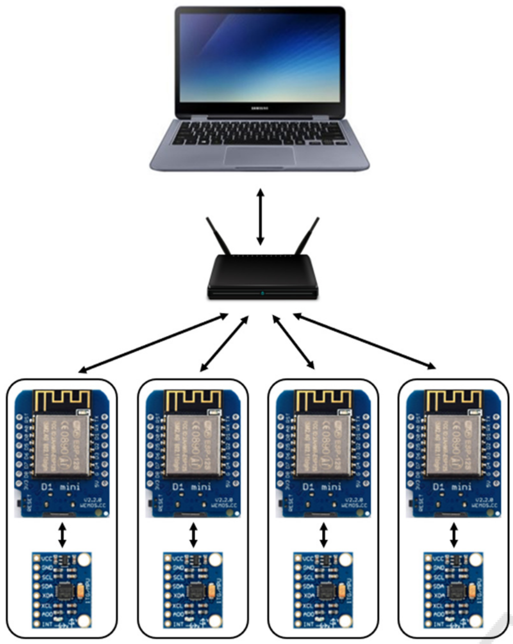

Figure 8: Motion sensors system architecture diagram.

3.3 Mobile APP

Mobile devices are a constant presence in everyday life, and some devices currently have processing capacity comparable to computers. Therefore, they are also used as a tool to perform various tasks.

Taking this into account, together with the development of the framework presented above in which the data processing fell on a portable computer with Windows operating system, an app was developed for Android and IOS devices.

The app is intended to be a friendly tool that can be used by the trainer during training sessions. It will allow to manually enter the movements performed by the athlete, with the objective of providing a fast feedback to the coach and athletes so that they can analyze, correct and adapt the training method to improve their performance.

The app makes it possible to enter athletes' data, such as name, weight category, step and club, saving this information in a database to add to training sessions and consultations.

After filling in the training data, when selecting "Start training", the menu displayed in figure 9 appears, where: in a) it is possible to select the movements to be performed. A maximum of 10 types of movements will be allowed per training session, which can be leg and/or arm movements; in b) the type of movement (arms or legs) can be selected; in c) the duration of the training is presented; in d) the buttons to start or end the training are available; in e) four additional buttons are available for each movement where the user (trainer) can specify the type of movement: right front (1st column), right back (2nd column), left front (3rd column), left back (4th column)); in f) there is a button available to indicate whether the movement was successful.

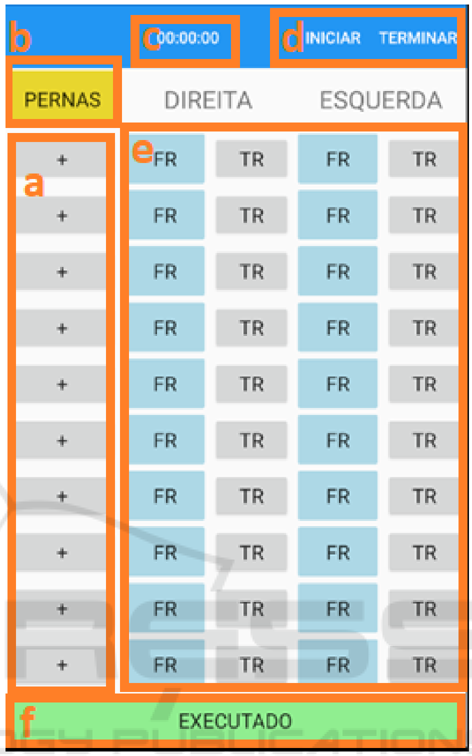

Figure 9: App training session interface.

After the training is finished, a small summary of the training is presented, indicating when the training started and ended and its duration, the number and type of movements performed during the session, which movements were performed with or without success.

4 FINAL REMARKS

The purpose of this paper is to present the project under development, whose main objective is to design and implement a friendly and low-cost system for assessing the performance of Taekwondo athletes in real time. The system should have the lowest level of intrusion to athletes during the practice of Taekwondo.

A framework for the acquisition of movement data was developed, which allowed the creation of a dataset with data on the movements of Taekwondo athletes. With this dataset it was possible to conduct a study on deep learning methodologies in order to define which method has the best performance in identifying athletes' movements.

With the intention of promoting the inclusion of technological tools in Taekwondo training sessions and taking advantage of the easy access to mobile devices, a mobile App for Android and IOS was developed. This App allows the trainees to add information about the athletes and manually collect data about the movements performed by the athlete in a training session, saving them in the application's database. Afterwards, the saved sessions can be consulted, allowing to analyse the evolution of the athlete's performance.

As future work, we intend to include the deep learning model to identify the athlete's movements in the developed framework and the integration of the data acquisition system through motion sensors based on IMUs in the framework.

Then, tests of the overall system will be performed with athletes in a training environment, in order to assess the impact of the system developed in the practice of Taekwondo training and its contribution to the assessment of the performance of Taekwondo athletes.

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