3D Interactive Environment Applied to Fencing Training

Carla P. Guimarães[1], Vitor Balbio[1], Gloria L. Cid[1], Maria Isabel V.Orselli[3], Ana Paula Xavier[2],
Augusto Siqueira Neto[2] and Sônia C. Corrêa[2]

[1]*National Institute of Technology, Rio de Janeiro, Brazil*
[2]*LACEM, Presbyterian University Mackenzie, São Paulo, Brazil*
[3]*Franciscan University, Rio Grande do Sul, Brazil*

Keywords: 3D Digital Platform, Biomechanics, Eye Tracking, Fencing, Training.

Abstract: The purpose of this study was to present a 3D interactive environment - a Digital Platform to help in fencing training. The first fencing motion described and analysed at the 3D platform was lunge in epee fencing. The platform was able to show kinematic variables of upper and lower limbs and the center of mass that characterized a good performance in epee fencing. The platform also incorporates a digital database of eye track motions of the fencers. An OptiTrack motion capture system was used to capture the lunge motion of five skilled amateur fencing athletes in the presence or not of a static opponent and an Eye Track System Tobbi II was used to track the eye movements of the fencers when performing a lunge attack with a target. The 3D platform was developed using Unity3D and can present some interesting results to improve available information to coaches. That highlights the importance of visualization biomechanical results based on coach criteria in a more understandable way to help athletic training.

1   INTRODUCTION

It is interesting to appoint that there is a big gap between scientific knowledge and coaches. It happens all over the world. There is a lot of knowledge being developed in the labs but it does not reach the coaches. The languages are very different. The coach usually does not understand the graphics and data that the biomechanics researchers generate and the coaches need something that they really can use in their daily practice. We intend to work in this gap, trying to fulfill the coaches' needs but bringing the precision and reliable data that we can provide.

The use of interactive system is interesting and can fill this gap communication between coaches' and researchers. The Ergonomic Laboratory researchers of National Institute of Technology (Guimarães et al, 2015) have been working in this approach in other projects that involve combat sports as Jiu-jitu and also in ergonomic study applied to education and training of caregivers.

In general, publications of biomechanical parameters applied to fencing and martial arts are reduced (Roi and Bianchedi, 2008, Correia and Franchini, 2010). The consequence is the lack of specific knowledge to give support to teaching and coaching in these sports. Another important parameter that on which there is a lack of studies is the gaze behavior, which can be used to identify search strategies and differences between skilled and less-skilled athletes (Oliveira, et al, 2008). The lack of access of teachers and coaches to the human movement science laboratories can be a possible reason.

Based on this scenery the purpose of this study is to develop a 3D interactive environment and platform to help in fencing training, which also incorporate the identification of the most common human body structures focused by high-level fencing athletes during their practice.

The first selected fencing motion to be studied was lunge because it's the basis of most attacking motions and one of the first movements to be learned in fencing. We studies this in the presence and absence of a target to be hit.

2   METHODOLOGY OF DEVELOPMENT

In this session it will be presented the methodology

of data acquisition and software development used in this project.

2.1 Motion Capture

For this project we evaluated 5 skilled epee's fencing athletes (3 female and 2 male, four of them (2 male and 2 female) were part of the Brazilian Olympic Team in 2016. The subjects perform a lunge attack at their best, from a static en garde position in two different experimental conditions: first, without the presence of any target to be hit and second, having their coach's chest as the target. For each condition, the task was repeated at least four times. Before data acquisition, the athletes had a time to get used to the task, which included, for the second condition, find the proper athlete to coach distance.

The athletes' whole body motion was captured with an eighteen-camera optoelectronic system (Prime 13, Optitrack, 240Hz sampling frequency) by placing retro-reflective markers in anatomical landmarks at their legs, arms, pelvis, trunk and head. After each repetition, the coach qualitatively evaluated the athlete performance according to his own criteria and corrected the gesture if necessary. Motive software (Optitrack, version 1.8 and 1.10,) was used for motion capture, reconstruction and preliminary data processing (namely, fill trajectory gap through cubic spline interpolation, in case of marker occlusion). (Figure 1).

Figure 1: Lunge motion captured using Optitrack system.

Data from the best-executed lunge attack of each athlete in each condition, as judged by the coach, was selected for inclusion in the digital platform. Body pose during the lunge attack period was, thus, exported, for animation purposes, using Biovision Hierarchy format (bvh). In addition, the tri-dimensional coordinate of each retroreflective marker in the corresponding period, was exported in c3d format, for kinematic analysis purposes. All the relevant kinematic quantities calculation, as well as the necessary data processing, were done with the Visual 3D software (5.01 version, C-Motion). The variables selected for analysis were based on the criteria used by the coaches to judge the athlete performance (Correa et al, 2015).

We used the Calibrated Anatomical System Technique (CAST; Cappozzo, 1995) to calculate the body segments instantaneous position and orientation. The 3D joint rotations (joint angles) were computed via Euler angles using the Cardan sequence (flexion-extension, abduction-adduction, axial rotation). Inertial characteristics of each body segment were estimated according to the Zatsiorsky-Seluyanov model modified by deLeva (deLeva, 1996).

The following variables were selected to analyse the lunge: the foot angle relative to the anterior-posterior direction (toe in-out angle); the angle between the longitudinal axis of both feet; base length and width; horizontal position of the centre of mass (CM) relative to the unarmed (back) heel; each segment, as well as whole body, CM displacement and velocity in the forward, vertical and lateral directions; the 3D angular displacements and velocities of the upper and lower limb joints for both, armed and unarmed, sides; pelvis and trunk angular motion in the sagittal plane. The time series of those variables were filtered using a 4th order, zero leg, low-pass Butterworth filter, with a 6 Hz cut off frequency. (Klauck and Hassan, 1998).

The digital platform allows the user to visualize the time series and instantaneous values of biomechanical variables, by selecting the corresponding joint or segment at the movement animation. At the present, the following variables are allowed for visualization: ankle, knee, hip, wrist, elbow and shoulder joint angle at the frontal (abduction-adduction) and sagittal plane (flexion-
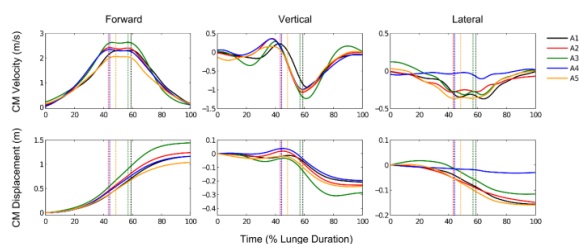

Figure 2: Whole body center of mass (CM) displacement and velocity in the forward, vertical (upward positive) and lateral (unarmed side, positive) directions, during a lunge attack without the presence of any target to be hit, at the best performance of each one of the five athletes analyzed. Vertical lines indicate the instant at which CM achieved the higher forward velocity.
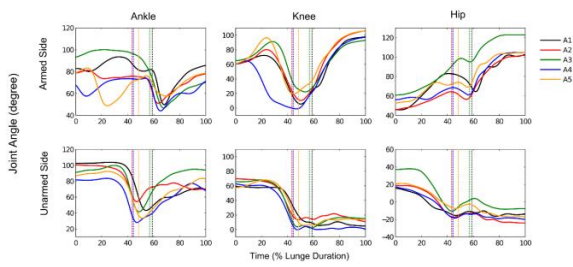
Figure 3: Joint angle in the sagittal plane for the armed side and unarmed side lower limb joints, during a lunge attack without the presence of any target to be hit, at the best performance of each one of the five athletes analyzed. An increase in joint angle means joint flexion. Vertical lines indicate the instant at which the athlete's CM achieved the higher forward velocity.
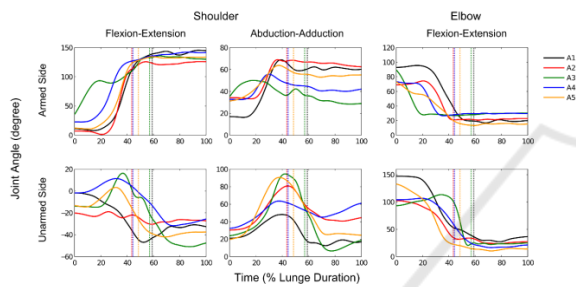

Figure 4: Joint angle in the sagittal plane (shoulder and elbow) and frontal plane (shoulder) for two of the armed side and unarmed side upper arm joints, during a lunge attack without the presence of any target to be hit, at the best performance of each one of the five athletes analyzed. An increase in joint angle means joint flexion and abduction, respectively. Vertical lines indicate the instant at which CM achieved the higher forward velocity.
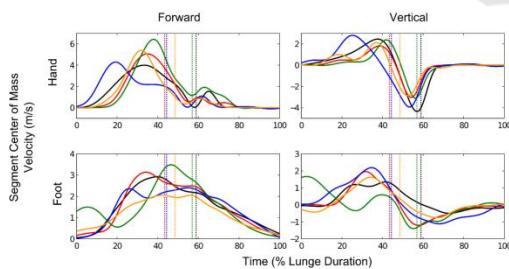

Figure 5: Foot and Hand center of mass (CM) velocity in the forward and vertical (upward positive) diraction, during a lunge attack without the presence of any target to be hit, at the best performance of each one of the five athletes analyzed. Vertical lines indicate the instant at which CM achieved the higher forward velocity.

extension), as well as the CM linear displacement and velocity for the whole body, pelvis, trunk, head, upper and lower arms, hands, feet, shanks and thighs. An example of the data feeding the platform can be seen in the figures. The data for the 5 athletes (A1-A5) are shown together just for illustration purposes. (Figure 1,2,3,4,5).

2.2 Visual Tracking Collection

The same fencing athletics were evaluated with regard to their gaze behavior during their training practices. For that, the athletes performed their training section using an eyetracking (TobiiGlasses 2) under their protective masks. This device has 4 cameras to monitor the retinal movements and a camera that records the images seen by the subject. Data were analyzed with the TobiiGlassesAnalyzer (version 1.16). (Figure 6).
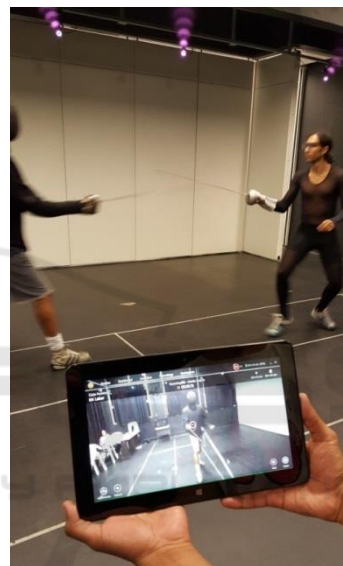

Figure 6: Athletes using Eye tracking device.

Three main areas of interest (AOI) were identified in the subject field of view, which were: the opponent's
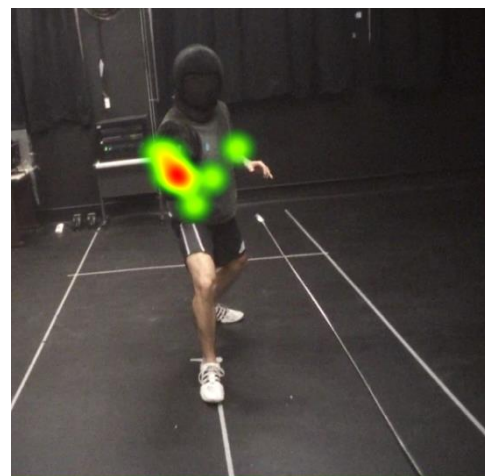

Figure 7: Colour mapping that shows the areas of interest.

arm, trunk and face (mask). The frequency the athletes focused on each AOI were calculated. (Figure 7).

The results of these steps were inserted in the 3D Digital Platform or 3D Interactive Environment.

3 PLATFORM DEVELOPMENT

The Virtual Platform was developed using mostly "game technologies" since they are currently the best available tools for virtual scenes 3D. The core system was based in Unity3D (www.unity3D.com) with addition of some add-ons such NGUI (http://www.tasharen.com/) and others. The system was split in modules to better organization of the development and it components are presented in Figure 8.

Figure 8: System Module Diagram.

- Core System: Is the main framework where all the systems are integrated. It includes menus, 3D viewport, graphs, skeleton reconstructions and other interfaces.
- Animation System: Present the captured animation using a skeleton reference where you can select bones or joints.
- Graph System: Synchronized with the animations we present some graphs related to the captured movements. This include Bone Rotation, Position and others.
- Eyetrack Database: Here, the Eye Track data collected were made available.

The interface of the system was planned to be easy to use and understand, an important feature since mostly of the users may not have fluency in digital applications. In the Figure 9 you can see the main interface of the Mobile version, the desktop layout is yet in development.

During the development was implemented a process to insert all the data in the platform, it follows some tasks:

- The model captured in BVH format is imported in Blender (www.blender.org) (Figure 10)
- It animations are converted to a metric scale of 0.001, that way the model gets 1:1 scale when imported in Unity.
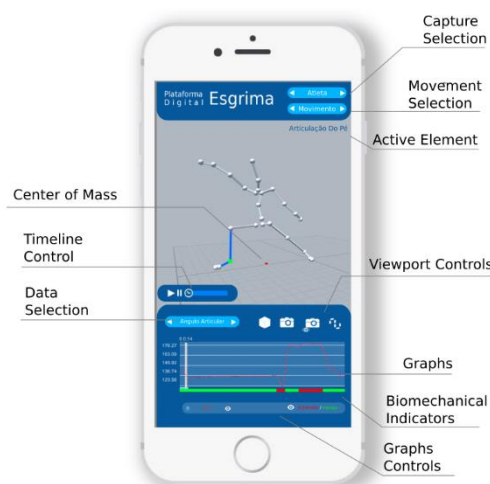

Figure 9: Main Interface of the mobile version.

- All the animation poses are cleaned for wrong keyframes and the correct segment that represents the movement of interest.
- All the segments (bones and joints) are renamed for a correct standard that we can read in the platform. It's used to the skeleton reconstruction.
- All the data are imported and converted to a XML file. That way we can read it in the platform and plot the Graphs.
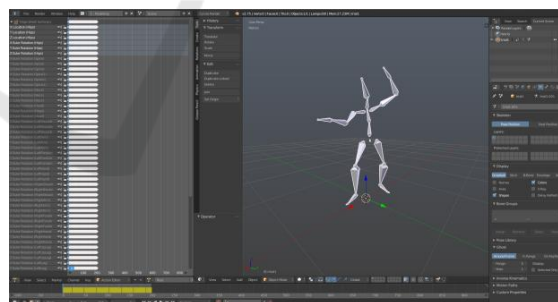- The model is exported as FBX format that can be read by the platform

Figure 10: Clean-up and Name Fixes Process in Blender.

3.1 Graph System

The Graph System shows selected data from elements of interest of the model. It can be a data of a Segment, a Joint or not necessarily associated to a skeleton element as a gravity center e.g. the figure 4 shows the Desktop version of the platform using the Graph system. (Figure 11).
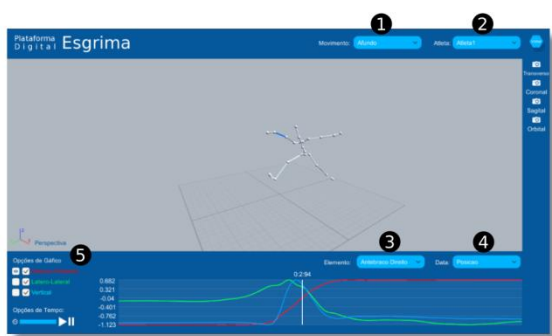
Figure 11: Desktop Platform with the Graph System.

1. To select the Movement to Analyze
2. To select the Athlete
3. To select the Element to Analyze
4. To select the Data to show the Graph
5. To select options as Axis and Scale to Show

3.2 EyeTrack Database

Inside the EyeTrack Database we can find all the data collect from the eyetrack system of the athletes. It commonly contains 3 files:

- .tsv file with the RAW data of the Eyetrack
- .xlsx file with a more accessible data that can be read in Excel
- .mp4 video with the Eyetrack mirroring what the athlete sees during the execution of the movement

The image above shows the usage of the eyetrack database. (Figure 12).

Figure 12: Eye Tracking Usage.

4 CONCLUSIONS

The 3D digital platform is an attempt to approach fencing coaches and researchers in order to explore biomechanical factors and visual aspects that may lead to an improvement on epee fencing technique, as well as in teaching and training methods. Its support to mobile and desktop highlights the importance of visualization and interaction of the coach with results on the biomechanical parameters and visual search strategies in a more understandable and relevant way to training.

Based on coach's criteria, it was identified the importance of the upper body and center of mass kinematic variables to lead to a good lunge performance. Another aspect of the research is the identification of what is the most relevant visual information to predict the movement of the epee and opponent.

ACKNOWLEDGEMENTS

REFERENCES

Capozzo, A., Catani, F., Della Croce, U., & Leardini, A. 1995. Position and orientation in space of bones during movement: anatomical frame definition and determination. *Clinical Biomechanics*, 10, 171.

Corrêa, S. C., Orselli, M. I. V. , Xavier, A. P., Salles, R. J. D.,Cid, L.G., Guimaraes, C. P.2015 . Kinematics fencing's analysis based on coach's criteria. In: 33 International *Conference on Biomechanics in Sports, 2015, Poitiers. Annals of the 33 International Conference in Biomechanics in Sports.*

Correia, W. R., Franchini, E. 2010. Produção acadêmica em lutas, artes marciais e esportes de combate (in Portuguese). *Motriz*, 16, 1-9.

de Leva, P. 1996 Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. Journal of Biomechanics. Vol. 29 , nº 9, pp: 1223-30.

Guimaraes, C. P., Balbio, V., Cid, G. L. Zamberlan, M. C. Pastura, F., Paixao, L. 2015. 3D virtual environment system applied to aging study - Biomechanical and anthropometric approach, Proccedia Manufacturing 3, pp: 5551 – 5556.

Klauck, J, Hassan, S.E.A. 1998. Lower and upper extremity coordination parameters during the fencing lunge. In *Proceeding of the 16th International Symposium on Biomechanics in Sports.*

Oliveira, R. F., Oudejans, R. R. D., Beek, P. J. 2008. Gaze behavior in Basketball shooting: Further evidence for online visual control, *Research Quarterly for Exercise and Sports*, vol. 79, nº3, pp: 399-404.

Roi, G., Bianchedi, G. 2008. The Science of Fencing: Implications for Performance and Injury Prevention. *Sports Medicine*, 38, 465-81.