INTERACTIVE GAMES FOR PRESERVATION AND PROMOTION OF SPORTING MOVEMENTS

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ABSTRACT

In this paper we describe two interactive applications for capturing the motion signatures associated with key skills of traditional sports and games. We first present the case for sport as an important example of intangible cultural heritage. We then explain that sport requires special consideration in terms of digitization for preservation as the key aspects to be digitized are the characteristic movement signatures of such sports. We explain that, given the nature of traditional sporting agencies, this requires low-cost motion capture technology. Furthermore we argue that in order to ensure ongoing preservation, this should be provided via fun interactive gaming scenarios that promote uptake of the sports, particularly among children. We then present two such games that we have developed and illustrate their performance.

***Index Terms*—** Low cost motion capture, motion comparison, virtual reality, digital preservation

1. INTRODUCTION

Sport stimulates the development of basic human motor skills, but equally importantly, it is a clear expression of a societys identity and their evolution. In fact, sport is a key part of cultural identity, and a mechanism for the protection and promotion of cultural diversity. Traditional Sports and Games (TSG) lie at the very foundation of our cultural traditions. European examples include Gaelic games (hurling, football, camogie, handball) in Ireland, Basque Pelota (and local variants) in Spain, Longue Paume in France, Tamburello in Italy among many others. Such TSG form the backbone of a community and many elements of traditional culture such as language, cuisine, dress, music, dance, the arts. Thus, retaining knowledge of our traditional sporting practices is vital in terms of preservation and promotion of sport as an expression of *Intangible Cultural Heritage* [1].

Despite their social and cultural background, TSG are currently under threat. Many have disappeared as the result of neglect, or in the past due to repression. In Eastern Europe, traditional sports are often viewed as old-fashioned, obsolete, reactionary, separatist and incompatible with the desire to be modern in all things. Some have been absorbed into the world of competitive sport, losing their social and community value and, in some cases, have become mere commercialised passive sports. Others have been forced to accept the limited role of helping to promote some other objective, such as physical education in school or as part of the training programme for some other sport.

1.1. Promotion and preservation of TSG

Clearly, TSG are a key target for digital preservation. In this context, it is pertinent to consider how best to preserve TSG into the future. The preservation challenges are very different from, say, digitizing an ancient manuscript or analog film. Sporting apparel and implements can be digitized thanks to recent progress in 3D scanning equipment techniques [2]. However a key aspect of what makes these sports unique is the characteristic sporting movements that have to be mastered and performed in order to take part and it is these motion signatures that require digitization and preservation. Motion capture is a mature technology [3] with high-end optical capture systems such as Vicon[1] considered to be the gold standard. However, such systems tend to be very expensive and out of the reach of most sports clubs. This is particularly true in the case of TSG which are typically run by amateur organizations that rely on volunteerism. Thus, what is required is a much cheaper alternative that is potentially within reach of any sports club or association. Whilst a low-cost motion capture system is part of the solution for digital preservation of key TSG movements, it is only one consideration. Such a system potentially provides for digitization in the "here and

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[1]See: http://www.vicon.com/

now". An equally valid question, however, is how to ensure that the very existence of TSG continues into the future. The approach espoused in this paper is promotion of TSG via enjoyable and educational computer games as an effective mechanism to ensure their long-term existence.

1.2. Children as future custodians of TSG

Sports clubs tend to be one of the first structured environments in which children 'act out' their future roles as adults, take on positions of responsibility, gain confidence as individuals, and form positive and open relation-ships with adults (beyond their immediate family) who they respect, admire and consequently 'aspire to mimic'. It is well established that a childs interest in sport is stimulated by creating opportunities for them to engage with their national or local hero. One approach is to teach children the skills of a sport using a hero to demonstrate the technique, and then to biomechanically compare the correctness of the child's technique to that of the hero over repeated attempts .

2. PROPOSED APPROACH

Motivated by the considerations above, we propose two low-cost game applications for teaching TSG skills to children. The applications leverage widely available and popular consumer electronics and interaction/visualization channels, such as the new generation of computer game controllers (e.g. MS Kinect) and immersive virtual environments that mimic already familiar gaming scenarios. The games are based upon the idea of teaching a TSG skill in a fun interactive environment, whereby the young user's performance of the skill can be compared in real-time to the same skill as performed by a local/national hero, providing positive reinforcement in an engaging and enjoyable manner.

Recent research results indicate that the technology required is either already available or starting to mature. Low-cost motion capture is now possible using cheap sensor devices, such as MS Kinect. The Kinect can be used not only to track motion but also a way to create full 3D mesh-based reconstructions of humans that can start to approach the quality of full body scanners [4]. Comparison of human motion has been the subject of multiple ACM Multimedia Grand Challenges [5]. As mentioned above 3D scanning is now a mature technology with even desktop products now available at reasonable cost[2] and could feasibly be used for sport implements (e.g. racquets, balls, etc) and apparel in the near future. Virtual immersive environments are increasingly being leveraged in cultural heritage applications. To date, this has mainly focused on museum or archeological applications [6] [7].

[2]E.g. NextEngine 3D Laser Scanner, See: http://www.nextengine.com/

3. GAMES FOR PROMOTION OF TSG SKILLS

The two game applications developed are essentially variations on a theme: the first targets a hand-based TSG skill, whilst the second targets a foot-based skill. In the future, both will be integrated into the same platform. Furthermore both currently target a single TSG, corresponding to Gaelic football, but other sports will be targeted in the future. Gaelic football, a native sport in Ireland, can be considered to be a hybrid of soccer, rugby and basketball[3]. Both applications share a common set-up as shown in figure **??**. The user is in front of a projection (e.g. TV or projector screen) with a Microsoft Kinect sensor underneath, which in turn is connected to a computer. For rendering the open source Unity 3D[4] engine is used. The over-arching objective is the natural interaction between the game engine and the user, in order to immerse the user in a reproduction of a playing environment allowing him/her to act as a professional athlete [8]. To engage the user as much as possible, the virtual environment chosen for the application is Croke Park, the national stadium that is considered to be the "home" of Gaelic football and which has a special place in Irish history from a socio-political as well as sporting perspective [9]. The user is located on the pitch within this prestigious stadium – see Fig. 2(a).

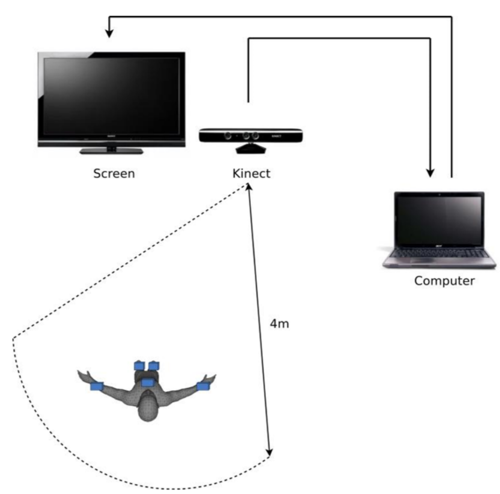
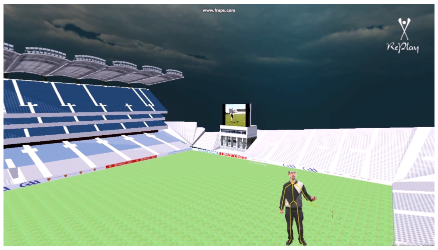


Fig. 1. The setup of the two applications

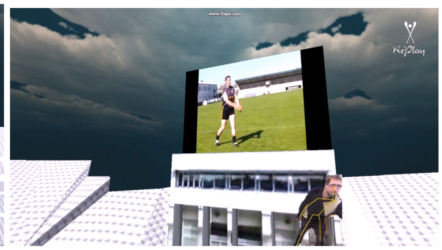
3.1. Hand-based skill

In this game, the user tries to reproduce a Gaelic football skill termed a 'Fist pass'. The Fist Pass is used in Gaelic football to pass the ball to a team member over a short distance. The technique involves supporting the ball with one hand, and striking with the closed fist of the free hand.

[3]See: http://www.gaa.ie/about-the-gaa/our-games/
[4]See: http://unity3d.com/



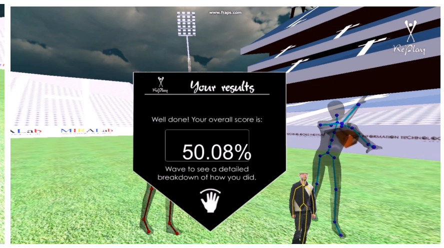
(a) Virtual sports stadium



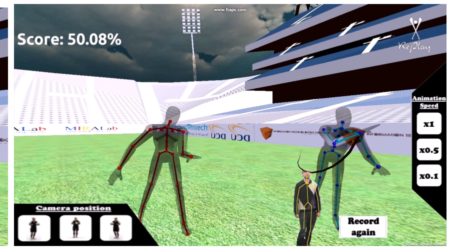
(b) View video of skill to be learnt

(c) View the skill from multiple angles

(d) Capture child's motion



(e) Score based on motion comparison



(f) Feedback on motion performed

Fig. 2. A virtual environment and fun game for mastering the fist pass in Gaelic football

3.1.1. Application Overview

The application was developed in C# based on the Unity 3D engine. External data such as 3D avatars and animations, 3D reproduction of Croke Park Stadium were integrated using the FBX format. The user is tracked using Microsoft Kinect and Microsoft Kinect SDK. It also uses an external C++ plugin to improve tracking quality based on Inverse Kinematic system. Navigation through the application, i.e. moving from one step to the next, is performed by very simple hand gestures (e.g. waving, option selection). The application is divided into the following steps.

1. First the user is provided with a 2D video visualization of the skill to be performed which is played on the virtual stadium's giant video screen – see Fig.2(b)
2. Then the user has the opportunity to view the skill being performed by a 3D avatar that resembles a hero located directly beside the user on the pitch – see Fig. 2(c).
3. The user then has the opportunity to perform the skill whereby the application guides him/her to the correct starting position and to perform the motion – see Fig. 2(d).
4. Immediately after completing the movement, a score is provided to the end user based on a motion comparison algorithm (see section 3.1.3) – see Fig. 2(e).
5. Finally, the user has the possibility to replay the motion he/she performed and view this motion in comparison to the hero's motion via synchronized playback of the two skeletons.

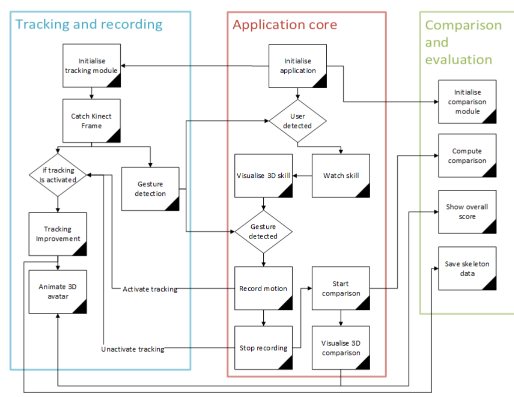


Fig. 3. Application flow

3.1.2. Implementation details

The application is composed of three main modules (see Fig. 3). The *application core module* controls and interacts with the 3D engine and the other modules. It controls camera position and animation, avatar animation, Graphical User Interface control and communication with other modules. This module is based on a finite-state machine described in Fig. 4.

The tracking and recording module is composed of three programs:

- C# scripts that collect depth sensor data, analyze and recognize user gestures (wave hand and hand cursor manipulation).
- A dynamic library built in C++ which improves tracking quality using a Sequential Inverse Kinematics system

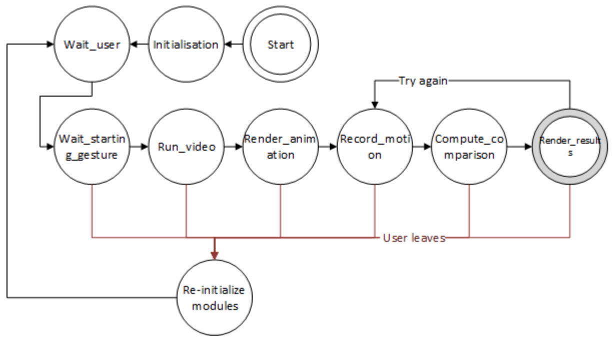
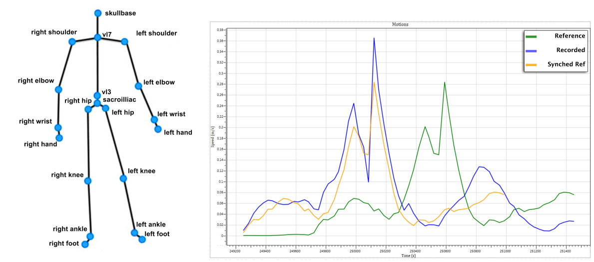


Fig. 4. Application finite-state machine



(a) 20 joints of the human body (b) Plot of the speed of the motion over time: reference (green), recorded (blue) and synchronized (orange) motions.

Fig. 5. The joints used in motion comparison and an example of synchronisation

[10]. It includes the core functionalities for kinematical structure handling, i.e., joint hierarchy management, posture correction through inverse kinematics, biomechanical constraints and motion filtering.

- A C# script that includes the functionalities for transferring and applying results of Sequential Inverse Kinematics system to the 3D avatar.

The comparison and evaluation module processes the data sequences and calculates the similarity between two trials, the pre-recorded reference motion of the athlete and the recorded motion of the user. The recorded motion is captured and stored in the same format as the reference one. The utilized information includes the 3D position and orientation of 20 human body joints (see Fig. 5(a)) in every frame. The skeleton structure follows the well known H-Anim standard [11].

3.1.3. Motion comparison algorithm

The information required to evaluate the user's trial are the angle, the angular velocity and the linear velocity of the joints during the motion. It is necessary to transform and to synchronize the data of the recorded motion in order to produce a correct spatio-temporal alignment of the two skeletons, allowing for a consistent comparison of trials. The synchronization is performed by detecting and matching of maxima and minima peeks of the data – see Fig. 5(b).

Skeleton alignment is achieved by calculating the quaternion $Q_C = Q_A * Q_B^{-1}$in every frame. Q_A and Q_B are the quaternions of the torso joint angle of the reference motion and the recorded motion respectively, after the synchronization. Q_C is used to transform the positions and the angles of the recorded motion to align the new skeleton with the reference one. The average of the normalized difference of three different metrics are used to represent the distance between the two motions and are used as a negative score. The total distance of the motion, M_{total}, is calculated as:

$$M_{total} = \frac{w_1 * \sum_{n=1}^{k}(\sum_{n=1}^{m} \triangle\theta_n) + w_2 * \sum_{n=1}^{k}(\sum_{n=1}^{m} \triangle\omega_n) + w_3 * \sum_{n=1}^{k}(\sum_{n=1}^{m} \triangle u_n)}{k}$$

where $w_1 + w_2 + w_3 = 1$ and w_1, w_2, w_3 are the weighting coefficients of the metrics, $\triangle\theta_n$ is the difference of the angles, $\triangle\omega_n$ is the difference of the angular velocities, $\triangle u_n$ is the difference of the linear velocities, m is the number of the joints and k is the number of frames. The weight coefficients depend on the confidence of the data. Given that the joint positions are the most accurate, the weights were set to $w_1 = 0.6$, $w_2 = 0.2$ and $w_3 = 0.2$. The final score S_{Final}, is:

$$S_{Final} = S_{perfect} - M_{total}$$

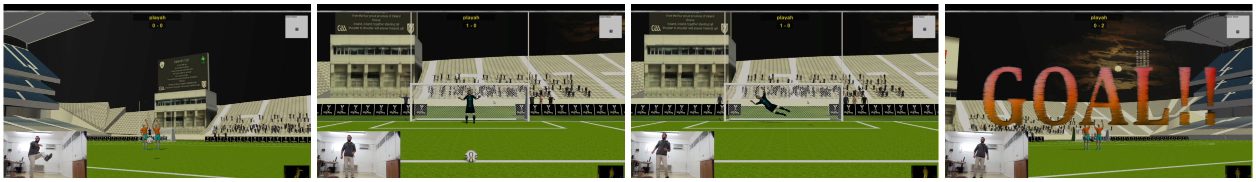
where $S_{perfect} = 1$.

3.2. Foot-based skill

In Gaelic football, both the hands and the feet can be used to impel/strike the ball. A key skill is the "Free Kick" which is awarded to a team after a player from the opposing team has committed a foul. In general it is taken from the location where the foul was committed. If within sticking distance of the goal posts, the objective is to kick the ball over the bar but between two uptight posts to be awarded a point. If the foul was sufficiently close to the goal posts, a penalty (like in soccer) is awarded, where the objective is to kick the ball under the bar, beating a goal keeper, to be awarded 3 points. In this game the user kicks a virtual ball in order to score against an autonomous goalkeeper. The user is allowed to make 4 attempts and the total score is calculated based on Gaelic football scoring rules.

A virtual ball is placed in front of the user and its precise position is marked on the floor. During the attempt, the Kinect-based skeleton tracking returns the positions of 15 joints at a frequency of 30 Hz. The retrieved information enables the calculation of the necessary metrics [12], which are the position, the velocity and the angle of the feet, that allows to estimate the power and the direction of the foot that kicks the ball, at that specific time-point. The results of these calculations, in combination with the game engine, provide the final simulation of the kick and the ball trajectory.

The applications development required the use of a physics engine in order to realistically simulate a kick. This



(a) Typical free kick location (b) Penalty kick location (c) Goalkeeper reaction (d) A goal is scored

Fig. 6. A fun game for mastering the free kick in Gaelic football

engine sets the gravity, the collisions, the friction and the forces in the environment, in order to simulate the circumstances of the real world [13]. The physics for the reaction between the skeleton and the ball were calculated based on Newton's laws of motion. The motion of the foot that kicks the ball is analyzed and the velocity is calculated when the virtual ball is kicked. As a result, the ball is moving towards the direction that the user defined with the foot while shooting.

An autonomous goalkeeper tries to prevent the user from scoring. The goalkeeper was designed to randomly choose one out of six candidate save movements. The goalkeeper moves, once the system recognizes that the virtual ball is hit. Collision detection techniques are then employed in order to simulate the save, in case the ball hits any part of the goalkeeper.

4. CONCLUSION

The applications have been showcased in a number of public events, such as Researcher's Night 2013 in Thessaloniki, Greece, in ICT 2013 Vilnius, Lithuania, and in the BT Young Scientist 2014 exhibition Dublin, Ireland. In all cases, the applications have been a great success with many children and teenagers excited to try out the games. For example, in Dublin over 300 people (the majority of whom were children) tried the games over two days. The excitement/interest of the targeted group shows that such interactive TSG simulation applications can be used in order to promote TSG in wider audiences and could potentially be used to transmit important heritage to new generations.

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