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Online-Gym: a 3D virtual gymnasium using Kinect interaction

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Abstract

Synchronized online gymnastics may provide new possibilities for enhancing the physical and social well-being of people with restricted mobility. We propose a prototype platform for this – Online-Gym – which allows users to interact using a Microsoft Kinect and participate in on-line gymnastics sessions.
In this paper we present the Online-Gym concept and a first iteration of the platform architecture that allows interaction in OpenSimulator or Second Life virtual worlds with movement captured by a Kinect device.
The exploratory work done so far provides evidence that this approach is viable and that such scenarios may be pursued.

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1. Introduction

The widespread availability of high-bandwidth Internet access, which now is common even for groups such as the elder and people with special needs, enables the emergence of novel cooperation services for social interaction and gaming.

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It has been known that platforms for sustaining physical activity can promote the physical well-being and mental health of older people [1]. The possibility of conducting those activities online enables the participation of experts such as trainers and counselors. Therefore, it can contribute to engage populations with these professionals, who might otherwise not do so [2]. In parallel, recent developments in the videogame area allowed the low-cost access to technologies for motion capture, such as Microsoft Kinect [3, 4].

The key challenge in realizing the opportunity of bridging motion capture (mocap) with those online platforms lies in the online virtual environment synchronization of captured movements on the terminals of the users. This leads to the creation of a 3D platform for virtual worlds that allows users to interact with the system through the use of a motion capture device, such as Microsoft Kinect. In practice we envisage an "online gymnasium", which corresponds to a virtual three-dimensional space where different users, physically apart, may attend a workout session coached by a monitor. Users will be connected over the Internet and represented by avatars directly animated by the movement captured on the Kinect device connected to each personal computer.

In this paper we present some of the theoretical basis supporting the idea and the exploratory approach used in the early prototype of the Online-Gym project, the concept idea, and the intended goals. We also present the architecture of the prototype system. The thorough analysis of the existing interaction systems between Kinect and virtual world platforms is not addressed in this paper.

To conclude, we sustain that the technological developments currently ongoing in this area of integration between virtual 3D platforms and motion capture devices, and our early experimentation, allow us to state that the approach is viable, even if the margin for improvement is huge; but there is potential for development and deployment of such a service.

2. Interactive technologies and physical activity

There are several approaches developed and implemented to promote physical activity in the last decade [5]. Among others, we highlight the use of broadcast media or consumer products (flyers, videos, etc.), because they have the potential to reach large numbers of individuals [6]. One of the limitations occurring in the use of such media to enhance the level of physical development is that in most cases the content is generic and feedback obtained is minimal – an issue when one considers that these strategies intend to promote individual changes in the level of physical activity [7].

Therefore innovative approaches are needed that are able to more efficiently reach groups of people and at the same time enhance accessibility and personal relevance [6]. The level of customization and personalization necessary may be attained using advanced information and communication technologies such as the Internet, personal digital assistants, and mobile phones, among other interactive technologies [8, 9].

One of the interactive and technological areas that have a high potential to promote physical exercise are videogames [9, 10]. With the possibility of emergence at a low cost of perception and actuation technologies, rose a new class of games - exergames (EXG) [10, 11]. Such games focus on the development/leverage of the sensory and motor skills of players, thanks to the possibility of perceptual emulation, and by the mechanisms afforded by virtual reality and tracking technologies [12, 13]. Some examples currently available in the market of systems that provide platforms for EXG are the Nintendo Wii [14], Xbox with Kinect [15] and PlayStation Move [16, 10].

As Staiano & Calvert [17] state in their research, "exergames are enjoyable tools that increase energy expenditure during play, motivate players to become more physically active, promote social interaction, and enhance cognitive performance". The cited authors conclude by stating that "playing exergames could become one of the most popular, engaging, and health-promoting homework assignments of the twenty-first century" [17].

Our Online Gym approach is targeted at older people, who may not be able to participate in regular training sessions outside their homes, when living in lower-density areas or complex urban neighborhoods, since that may require expensive or troublesome travel. It is hard to motivate oneself to exercise regularly alone at home [18], so EXG may help to motivate elderly to exercise more, providing social interactions with online technologies [3, 18, 20].

Castronova, on his paper titled "The right to play" [37] has defined two possibilities about working "within virtual worlds: virtual worlds as play spaces and virtual worlds as extensions of the Earth". Morgado et al. [38] put forward the possibility of using these online multiuser spaces to combine on-the-job training with professional traineeships, since spaces like our intended Online Gym become the place of real activities, not just simulated ones. These 3D platforms, which are multi-user, collaborative, and shared virtual environments, can bring to a higher level the users' experiences and bring the "being there" presence [21].

In summary we think that if we can combine the potentialities of the interactive technologies like EXG and emerging motion capture devices with the ability of 3D virtual worlds for socialization and context, we can produce a platform to promote the physical activity of its users, which leverages its potential.

3. Motion Capture Devices

There are several devices with advanced motion capture capabilities, many of them are even used in movie making, however the acquisition costs and technical complexity are high, which renders them unviable as a mainstream product [22]. With the appearance of the low-cost motion capture devices for the home market, numerous opportunities sprung for the target audience that we want to reach. The relevance of these interfaces is mainly due to two factors. The first is the issue of economic factors, because they reduce the cost of acquisition. The other factor is usability, because their setting up is minimal and their use is highly intuitive [23].

According to Steinberg [23] devices such as these simpler motion capture ones, which present the following characteristics, are deemed to be natural user interfaces (NUI): intuitive (the devices allow us to use their interface with little or no training, because they are the result of common experiences, activities or gestures); flexible (the devices allow us to adapt the interface to better meet our needs); fluid (the devices allow us to interact with the interface almost without realizing that we are using it).

There are several motion capture devices with these characteristics, such as: Microsoft Kinect [15]; PrimeSense Sensor [24]; ASUS Xtion [24]. These systems have cameras that capture full-body movements directly, and include depth sensors for 3D data acquisition, unlike infrared-based motion detection as found in the Wii Remote [14] or the Playstation Move [16].

The latest advances in 3D depth cameras, such as those used in the Microsoft Kinect, made the Kinect a relevant 3D sensor that has received much attention due to its fast recognition of body pose and its low cost, reliability, and speed of 3D measurement [25]. These were the factors that led us to perform this analysis with the Microsoft Kinect.

Technologically, besides other components which are not relevant to the present work, Kinect "contains a depth sensor, a camera, and a color array of four microphones that provide capture the movement of the entire body 3D facial recognition and even voice recognition capabilities" [26]. This allows the software tools to use and work the data sent by Kinect to track the movements of different parts of the human skeleton, including legs, arms, hands, and head (see Fig. 1) [27].

Fig. 1 - Skeleton model (left) with data generated by the Kinect (right)

According to the World Health Organization [28], physical activity or exercise is important for every individual. It's very difficult to maintain a strict exercise regimen for any person, but particularly for the elderly it becomes even more challenging. As Ganesan & Anthony [29] defend, using the Kinect has a high potential to encourage older adults to maintain an exercise regimen.

4. The Online-Gym project

Online-Gym is an exploratory project based on an online 3D virtual worlds platform that allows users to interact with the system through the use of a motion capture device such as Microsoft Kinect [15] (see Fig. 2). It aims to create an "online gymnasium ": a virtual three-dimensional space where different users, physically apart, attend a shared workout session coached by a monitor, all of them connected over the Internet and represented by avatars directly animated by the movement captured on the Kinect devices connected to each personal computer. This scenario will provide the experience of a joint participation in a group gymnastics session.

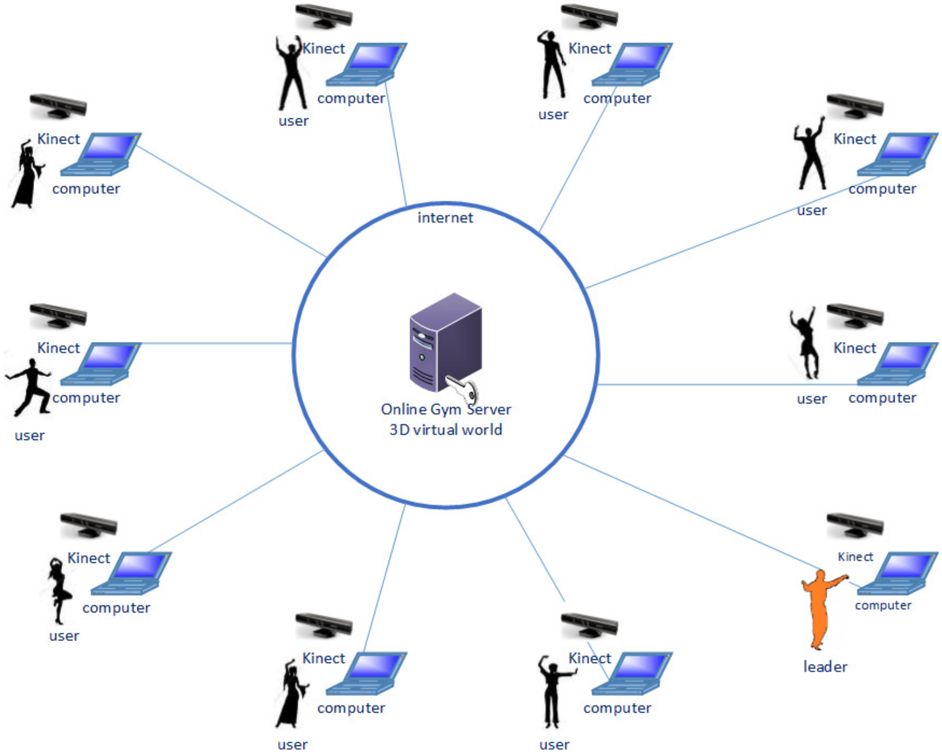

Fig. 2 - Online-Gym scenario

To realize this scenario, we explored three currently available platforms that allow interaction within 3D virtual worlds using Kinect-based mocap technology: RINIONS, FAAST, and NUILIB. All of them use middleware known as NUI libraries, which deal with the processing of the Kinect data streams and make them available to higher-level software. There are two such libraries: the Microsoft Kinect SDK provided by Microsoft and the OpenNI, provided by a not-for-profit consortium formed to standardize the compatibility and interoperability of natural user interfaces [30].

4.1. RINIONS

This is a software package which allows the remote reproduction of movements performed by the user using the Kinect in viewers for virtual worlds like Second Life or OpenSimulator (Fig. 3). This software requires a modification at the source code level in OpenSimulator/Second Life viewers. It is provided as open source albeit without documentation. It does not provide synchronization features for multiuser movements [31].

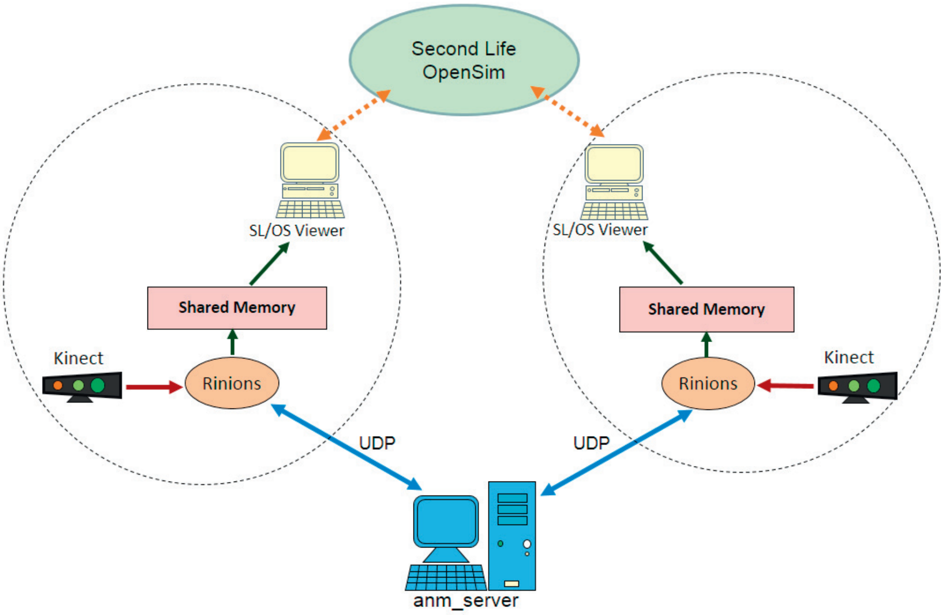

Fig. 3 - Architectural Model of the Rinion software (adapted)

4.2. FAAST

This is a piece of middleware that interprets gestures captured by Kinect or other motion detection systems, matching them to predefined animations (Fig. 4), which has announced the release of its source code, but is currently still closed source. It enables the results to be sent to servers, without regard for synchronization. It is appropriate to scenarios in which the movements are from a predetermined set [32].

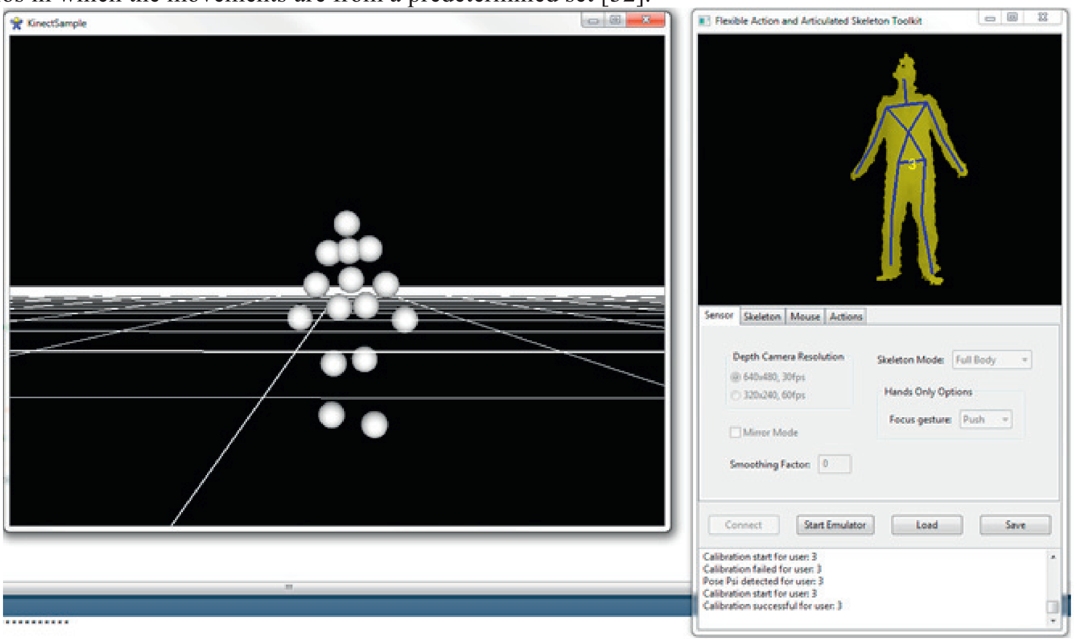

Fig. 4 - Screen Capture of FAAST Software [32]

4.3. NUILIB

This is an open source library of applications for integration into NUI devices, such as the Microsoft Kinect. It provides a high layer of abstraction, based on specific data structures, aiming to simplify the process of using gestures in applications [33]. Associated with this library there is a sample viewer for the Second Life/OpenSimulator platforms, called Armadillo (Fig. 5). This viewer reproduces in these virtual worlds a set of predefined movements identified through NuiLib.

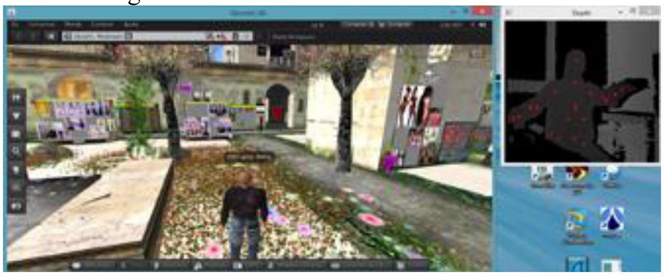

Fig. 5 - Screenshot from Armadillo viewer that uses the NuiLib library

5. System architecture

To accomplish the goals of an Online Gym, and considering the feature set of existing projects (FAAST, RINIONS, NUILIB), we plan to implement a two-server architecture: a virtual worlds server and a movements server (Figure 7). This approach aims to solve the issue of motion-tracking and broadcast in a way that is independent from the technology used for 3D rendering. A particularly relevant issue that no current project tackles is that of synchronization of the movements made by users (see Fig. 6), an issue which will be dealt with in the movements server. This server is also responsible for: receiving, recognizing, synchronizing, and replicating gestures to all users; controlling the access to the platform; and identifying the leader/monitor (responsible for the session).

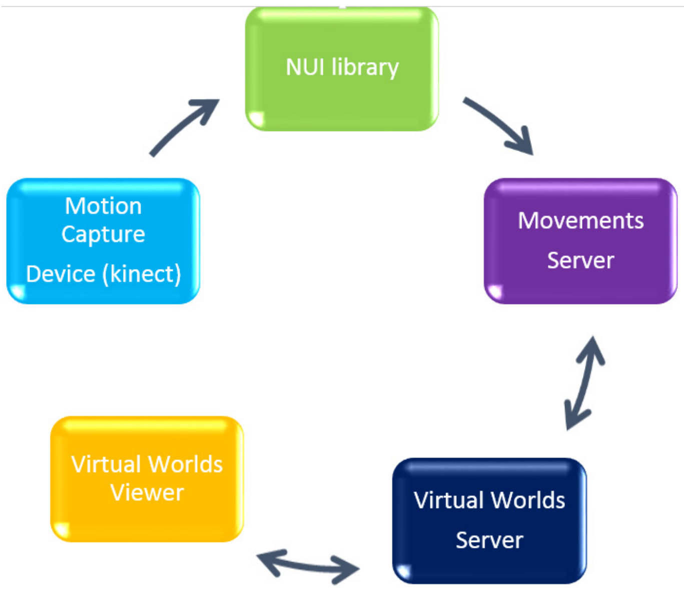

Fig. 6 - System flow of motion data

5.1. Receiving, recognizing, synchronizing, and replicating gestures

The movements server must be able to receive all the gestures sent by users in the gym session. It needs to constantly calculate the network latency of each user and place the gestures on a queue, from where they will be sent to all users. This queue will act as a time buffer for synchronization, to provide a stable latency experience for all users, isolating them from network latency variations. At a later stage, should it be necessary to reproduce "ideal" gestures rather than the exact motions of users (for instance, for participating in choreographed dances or theatre plays), the movements server will also have to recognize individual users' gestures and convert them into those "ideal" gestures (predetermined), replicating them.

5.2. Controlling the access to the platform

The movements system can control the Online Gym decision-making, including access, rendering the 3D platform as a mere visual engine for all the users registered on the session.

5.3. Identify the leader/monitor

To realize an online session the system must know that it's about to begin. So the platform must have a mechanism to identify start and end of session. This means that the leader (user responsible by the gym session) must be identified by the system, in order to use a custom interface to initiate and terminate the session. At the same time, all the remaining users must clearly see who coordinates the session and the gestures that he is carrying out, without having to move the camera all the time.

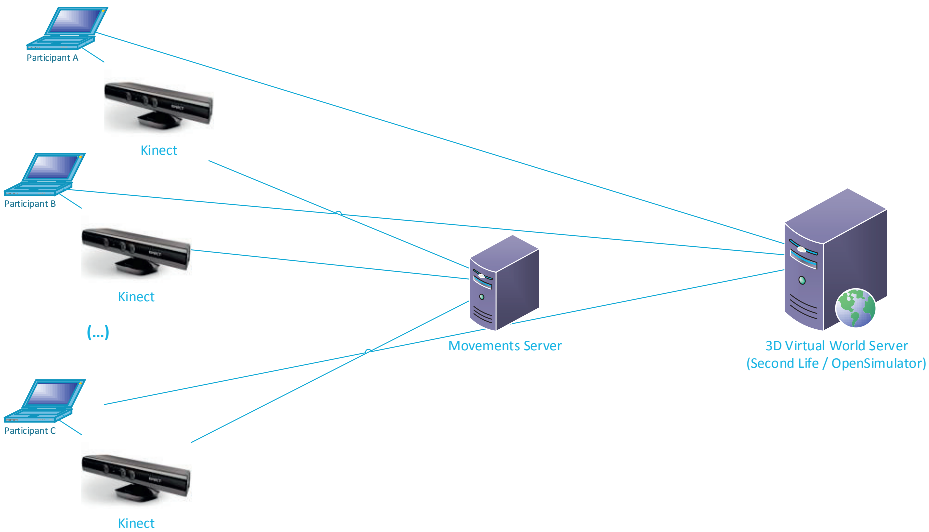

Fig. 7 - Physical perspective of the Online-Gym system

6. Conclusions

As outlined throughout this article, we conclude that the Online-Gym project has a theoretical basis sustainable in the scope of a technology platform based on Internet and has features relevant for users who are isolated, dispersed geographically or with reduced mobility, e.g., the elderly. It aims to render them able to participate in group gymnastics activities. Remote assistants/facilitators may support these activities, rendering such a service available even in locations where a physical presence in a gym is not available or implies complex travel costs or logistics.

The experimentation carried out within this project, towards the architecture of such a system, pointed out that its implementation should take into account some requirements stemming from existing systems integration, particularly in the synchronization of the movements and their impact on the network for other users, but also regarding the need to have a clear identification of the leader/monitor and custom controls for him/her.

To conclude, we may state that the technological developments currently ongoing in this area of integration between virtual 3D platforms and motion capture devices render this project viable, albeit with a huge margin for improvement, meaning that there is the potential for the development and deployment of such services.

7. Future work

Throughout the work carried on this ongoing project, other challenges on the topic of integration capabilities between the service platforms and the motion capture devices emerged.

A first challenge is the need to further study the solutions for remote transmission of gestures made in front of the Kinect. This subject was addressed, albeit very lightly, in the scope of the current project, but needs further development before it can be integrated into a commercial service online platform.

On the other hand, it is also necessary to experiment with a variety of approaches to find out how one can synchronize the movements made by each user physically distant, that is, taking into account the different characteristics of the network, such as latency, propagation delays, speed, variability, and so on. It is necessary to achieve a systematic mechanism that will synchronize the movements produced by the different users, while keeping the local synchronization with the actual movement being performed.

Finally, there is the issue of independence. It is a major topic to establish how to easily integrate this interface mechanism in various types of virtual worlds, since there are various platforms that use completely different technologies. While the software technology of the Second Life and OpenSimulator are similar, other platforms (Jibe [34], CloudParty [35], Unity [36], and so on) are quite different, and the existence of a tool to easily transpose/transcode the real-time motion capture data among platforms would certainly make these class of scenarios and services even more interesting and attractive. We intend to pursue the path pointed out by other teams [39].

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