VIRTUAL REALITY & SPORT

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This applied session deals with the design of immersive environments for human motion performance analysis. In a first part of the session, a theoretical presentation describes the aims and scopes of such type of experiments. In a second part of the session, a review of the available immersive systems will be exposed. Finally, a practical framework will be designed in real-time with the attendees: a low-cost immersive environment based on a Microsoft Kinect, a Razer Hydra and an Oculus Rift Head Mounted Display device. We will develop an experiment to analyse perception-action coupling in soccer with simulated virtual opponents enabling to analyse the decision-making of a real goalkeeper.

KEY WORDS: Virtual Reality, design of immersive experiments, interactions.

INTRODUCTION: Virtual Reality (VR) is now commonly used in many domains to train people in performing tasks in dangerous (such as aircraft pilot training) or very expensive (such as plant maintenance) environments without taking risks. In addition to the secure aspect, VR above all provides a standardized and controlled environment that allows analyses and experiments that cannot be done in real situation. For instance, it helps understanding the link between the performance of a player and the information perceived, such as on his opponent's kinematics or on a ball trajectory for instance. These experiments were previously made with videos. However, in videos, the viewpoint is fixed to the camera position during recording. This prevents interactivity, something extremely important if the player wishes to move so as to better pick up key information. Moreover, video playback depends on which actions took place at a given time. Owing to improvements in technology and processing power, virtual reality (VR) can overcome these limitations by providing numerical simulations and immersive, interactive environments (Vignais et al. 2015).

STATE OF THE ART USING VR IN SPORTS: In sports, it has been demonstrated that VR offers a unique standardized environment to analyse perception-action coupling, such as duels between two players in handball (Bideau et al. 2004) or in rugby (Brault et al. 2010) or the perception of a goalkeeper in soccer (Craig et al. 2009), as shown in Figure 1. It has also been used to train learners in complex motor tasks, such as juggling or rowing (von Zitzewitz et al. 2008; Ruffaldi and Filippeschi, 2013). This unique standardized and reproducible environment indeed offers advantages such as the ability to control the stimuli and the virtual world (including virtual opponents), the adaptation of viewpoint thanks to head tracking system and the ability to have stereoscopic vision. Nevertheless, VR systems have also disadvantages that can modify the behavior of the immerse subject by altering his perception and/or actions. The VR solutions must thenbechosencautiously.

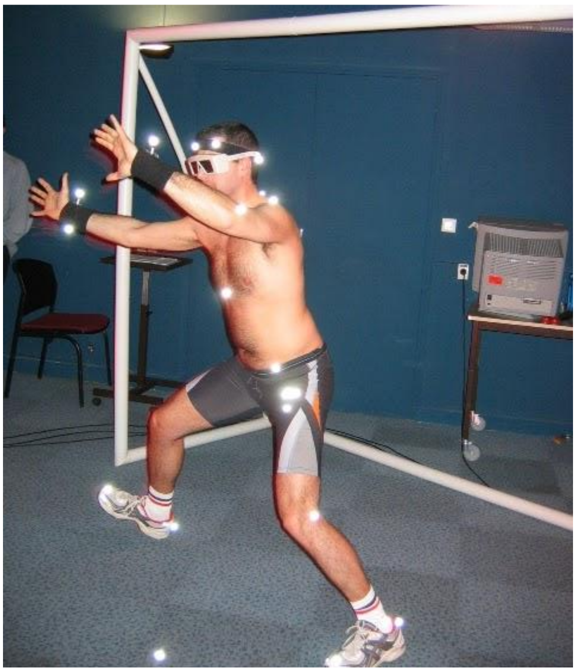

Figure 1: Experiment developed in VR to analyze perception-action coupling in handball.

REVIEW OF TECHNOLOGICAL VR SOLUTIONS: Although a lot of improvements have been done to virtual reality systems, VR is still in its early days. One of the main implications is the existence of a plethora of hardware systems having its own advantages and disadvantages. Hardware devices can be grouped in two main groups, hardware systems that enables us to gather information about the state and actions of the athlete (input devices), and systems that allow the athlete to perceive (e.g. see, feel) the virtual environment (output devices). In this section we want to provide a glimpse about the different technological choices that are required when designing virtual reality systems focusing on sports. More precisely, we discuss the different choices currently available in terms of hardware. Although the choice of the software it is also important, in this section we will mainly focus on hardware components as a full example of the required software components will be presented during the live demo.

The core of a VR system is typically determined by the tracking system (input) and the display system (output). While the tracking system is able to capture the user's movements which are feed to the VR simulation in order to account for the user's actions, the display system enables the user to perceive the current state of the virtual environment which enables the user to adapt their actions to be coupled with the state of the VR simulation. However, in the real world, we are used to have a "perfect" control of our body, the actions we perform have an instantaneous and "predicted" behavior and all our senses are stimulated. In contrast, in VR, the accuracy of our actions is constrained by the accuracy of the tracking system and our perception is constrained by the limits of the output devices.

For example, if our feet are not tracked, no matter how we move them, their movement will not influence the VR simulation. Another example is precision and latency, while in the real life interactions are limited to the biomechanical constraints of our body in VR the precision and latency are determined by the tracking system. Motion tracking systems range from inertial-based systems which are inexpensive but inaccurate and prone to drift, image-based solutions as Kinect-based systems which require minimal setup (the user does not have to wear any marker/device) but still inaccurate, till high-end millimeter-accurate optical tracking systems which require the user to wear reflective markers and are invasive (camera setup).

When choosing the tracking system, we have to take into account the requirements of the application in terms of accuracy and control.
Regarding the display systems, in addition to low latency which is the main requirement and has to be kept as low as possible (< 60ms), other relevant characteristics are the field of view and field of regard, here we are only considering stereoscopic systems. The field of view (FoV) is the size (in degrees) of the viewing frustum at a given time while the field of regard (FoR) is the size (in degrees) of the viewing frustum that can be observed. The human FoV is almost 180º horizontal and 135º vertical while the FoR is 360º (by moving our head we can explore the environment in all directions). Head-mounted displays (HMD) can provide fields of view around 90º horizontal (Oculus Rift) with a field of regard of 360º. In contrast, projection-based displays (PBD), can achieve a higher FoV at the expense of more complex and expensive systems (see Figure 1) but typically provide a lower FoR.
Nevertheless, the final choice has to be done according to the requirements of the experiment/training procedures. If our application requires high accuracy measurements high-end optical tracking systems must be used. On the other hand, if the tracking system will be used only to enable the user to interact with the system, less expensive solutions can be employed. Moreover, low-cost VR systems are more and more used based on devices initially developed for video games, such as the Nintendo BalanceBoard and the Microsoft Kinect systems to measure the foot pressure and the motion of the user respectively.

LIVE DEMO: This applied session aims at exposing potential applications of such a technology in sports, and to exchange with the attendees on the advantages and limits for future developments. To this end, we will expose a short state of the art of applications of VR in sports. Then, we will review the various technological solutions already available and their limits in such research domains. The setup of each component of a virtual reality system such as the stereoscopic vision, the head tracking, the interaction with the virtual world and the motion capture will be demonstrated with low-cost systems. Finally, the setup of the virtual environment will be demonstrated on a sport application: a global framework to analyse perception-action coupling in the soccer free kick. More concretely, we will use this experiment to determine the influence of the wall configuration on the goalkeeper's performance (see Figure 2). A final discussion with the attendees will help to clarify the required technological skills and solutions needed to perform such an analysis, and the limits of such an approach.

Figure 2: Experiment developed during the session: a soccer goalkeeper facing free kicks (an HMD will be used instead of an immersive room to demonstrate the experiment in live).

CONCLUSION: The main goal of this applied session is to make a point about modern and low-cost immersive systems, and to examine to which extend they could be used to analyse human physical activity. The demonstration will show the various theoretical and practical steps needed to prepare such an experimentation with cheap commercial immersive systems. We wish to generate discussion and desires to encourage researchers in biomechanics in sports to work on this promising approach. Several open problems have to be addressed: automatic biomechanical evaluation of the performance of the user, design of more natural interaction devices to ensure natural interaction with the simulated environment, simulate credible/natural virtual humans, compute appropriate multi-sensory feedback, and help to evaluate the relevance of such a system in sports to transfer skills trained in VR to real practice.

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