Paralympic VR Game

Immersive Game using Virtual Reality and Video

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ABSTRACT

In the last few years, the interest in virtual reality has been increasing partially due to the emergence of cheaper and more accessible hardware, and the increase in content available. One of the possible applications for virtual reality is to lead people into seeing situations from a different perspective, which can help change beliefs. The work reported in this paper uses virtual reality to help people better understand paralympic sports by allowing them to experience the sports' world from the athletes' perspective. For the creation of the virtual environment, both computer-generated elements and 360 video are used. This work focused on wheelchair basketball, and a simulator of this sport was

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created resorting to the use of a game engine (Unity 3D). For the development of this simulator, computer-generated elements were built, and the interaction with them implemented. User studies were conducted to evaluate the sense of presence, motion sickness and usability of the system developed. The results were positive although there are still some aspects that should be improved.

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INTRODUCTION

Virtual reality (VR) has a wide range of possible applications. It can even be applied for social purposes. This work is part of a project in collaboration with iNOVA Media Lab of School of Social Sciences and Humanities, NOVA University of Lisbon. The project intends to allow people to gain a better and fairer understanding regarding the paralympic sports. Through the use of virtual reality techniques, an immersive experience that allows people to see from a new perspective, experiencing things differently and potentially even changing opinions, was created. Concretely the experience allows someone to witness and/or take the place of an athlete, granting the chance to perceive the sport from his/her perspective. This way people are expected to see beyond the athlete's disability and see him/her as any other sports competitor. It is expected that this project may also help promote and value paralympic sports. The work done so far was focused in wheelchair basketball and had the collaboration of the Portuguese Handicap Association of Lisbon (*Associação Portuguesa de Deficientes de Lisboa*), who provided help with insight on the sport and in the evaluation of the system developed.

RELATED WORK

As previously mentioned, VR has a wide range of applications. It is, for example, used in sports for reasons such as entertainment, athletes training, and others. A potential problem for VR in sports where the athlete can move in a large play area is that the effective space in which a user will be able to move in the VR system will be much smaller than the real space. Different techniques can be used to face this issue. Interrante et al. [3], for example, explored a metaphor for walking-based locomotion - the Seven League Boots. The intention of this method is to let each step that the user takes in the real world appear to have the same consequence as that of taking seven steps in the virtual world.

Several sports' VR simulators have been created throughout the years. Ribeiro et al. [6] created a realistic boccia [1] game simulator adapted for people with disabilities or motor disorder.

In early 2018, IMG Studio [2] launched a virtual reality wheelchair basketball game [2] with the goal to help recruit players, serve as a training tool for athletes, and increase awareness of paralympic

[1] Indoor paralympic sport

[2] https://theimgstudio.com/

sports. When playing, the user uses touch controllers to shoot the basketball from the perspective of an actual player, seated in a sports wheelchair. However, in this system the user does not seem to be provided with a full virtual body and the way to move the wheelchair is not how a person would do in real life. Both aspects were had in consideration in Paralympic VR Game.

Several wheelchair simulators have also been created with a variety of goals in mind. Sørensen and Hansen [7] developed a prototype of a low-cost manual wheelchair simulator that consists of a stationary platform on top of which a real wheelchair is placed. However, for manual wheelchair simulators, force feedback and the stimulation of the vestibular sensory system are of great importance to avoid motion sickness. Sørensen and Hansen prototype does not provide that, unlike Challenging Environment Assessment Laboratory (CEAL) of Toronto Rehabilitation Institute's simulator [1].

The use of a physical wheelchair simulator with a platform, however, makes it harder for the game to be easily accessible for any user to try from anywhere. In this work, so far, the focus as been on creating an entirely virtual wheelchair simulator.

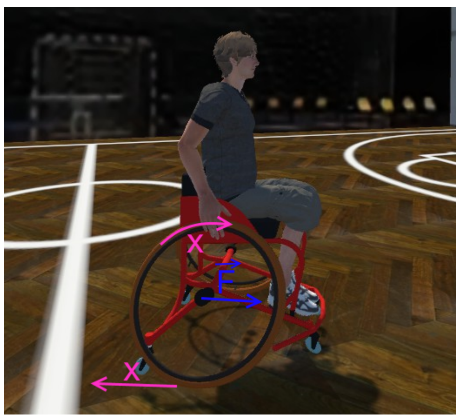

Figure 1: Maneuvering of the wheelchair. The displacement of the wheel (x) is used to calculate the force ($\vec{F}$) applied to the wheelchair.

SOLUTION

The Paralympic VR system is being developed using the game engine Unity and is meant to be displayed using the head-mounted display (HMD) HTC VIVE. With this, the user has a headset and two controllers that are used to track his/her movements.

As already mentioned, the work so far is focused on wheelchair basketball. Therefore, the virtual environment (VE) created represents a basketball court. For the development of this VE some 3D elements were created using Blender. Videos and photos of a real court were also used for the creation of a more realistic environment.

In the game, the user has a virtual body which is a character sitting in a virtual wheelchair that represents an athlete. The user sees the VE from this body's perspective and is able to control its movements, which leads the user to have a sense of ownership over the body and feel like he/she truly is an athlete. The body mimics the movements the user makes in real life while playing.

The user can also interact with a ball, grabbing it and throwing it so that he/she may attempt to score, and move through the VE. This locomotion may be done by interacting with the virtual wheelchair, pushing it around the court as one would do in reality. A wheel is attached to a player's hand when he/she attempts to grab it, being later detached once the wheel is released. The game is designed so that when the user moves one of the wheelchair's wheels, the velocity and length of that wheel's displacement will be used to calculate the force that should be applied to the wheelchair, on that wheels' side, as a result of that movement (fig. 1). The two wheels move independently, hence, the user can push one forwards and the other backwards simultaneously and, as a result, the wheelchair will turn. This work is also a study of the peoples' response to a VE in which the locomotion is not

Figure 2: NPC defending its backboard.

[3]Video available at: https://goo.gl/SjRCXy

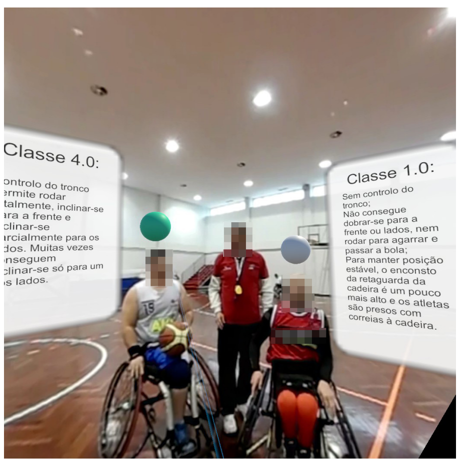

Figure 3: Example of use of video integration. Placement on top of athlete's heads of computer-generated elements with which the user can interact, making information boxes appear.

done through walking or running, which leads to new questions relative to the movement and its perception.

Besides the character controlled by the user, another is also present in the VE, a non-player character (NPC). Currently, this NPC is programmed to defend the backboard considered as his from the user (fig. 2). However, every time he catches or grabs the ball he will pass it to the user, giving him/her, once again, a chance to score. When neither the user nor the NPC are in possession of the ball, the NPC will move towards it and try to grab it. The movements of the NPC's body result from animations.

Three different basketball practice scenes are available in the game - the wheelchair, the throws, and the full practice. As the name suggests, in the throws practice the user can train his/her throws, having an infinite number of balls easily available and not being able to move the wheelchair, managing only to choose one of the specific available spots to throw from. In the wheelchair practice the user can practice moving the wheelchair. Finally, in the full practice, the user can both train the throws and wheelchair control and play together with the NPC.

Besides the practice scenes, the game also includes scenes with 360 video, one of which is the *Paralympic VR 360 video-prototype* video[3] by Caroline Delmazo of School of Social Sciences and Humanities, NOVA University of Lisbon, which was created in the scope of this project.

The integration of computer-generated elements with 360 video is present in all scenes. To achieve this integration different techniques were applied: fading from video to virtual, use of videos as textures, and the placement of computer-generated elements onto tracked 360 video (fig. 3). For the later, a color detection algorithm had to be implemented in order to track a mark throughout the video frames to know the position in the video that the computer-generated element must overlay in each frame. By combining these two elements, this work intends to contribute for a new singular media type, which may lead to new interfaces and a new user experience which could be used, for example, in a journalistic context.

EVALUATION AND RESULTS

There were two test stages in the development of the system. In both, user tests were performed to evaluate the system and detect aspects to improve. The evaluation was accomplished through passive observation of the user playing the game, and a posterior questionnaire and interview. The questionnaires mainly evaluated the sense of presence and the feeling of motion sickness experienced.

A total of 10 volunteers participated in the preliminary tests. Of these 4 were wheelchair basketball athletes of Portuguese Handicap Association of Lisbon (fig. 4). The athletes' feedback was essential to evaluate the realism of the systems' elements and interaction with them. In this first test stage, the participants answered one questionnaire composed of a combination of 22 questions from Witmer and Singer's presence questionnaire [8], and 6 questions regarding motion sickness symptoms from the simulator sickness questionnaire created by Robert S. Kennedy et al. [5].

Figure 4: Athlete playing the game during the user tests

Table 1: Oculomotor (O), disorientation (D), nausea (N) and total severity index (TS) motion sickness scores, computed both globally and for each practice scene

	N	O	D	TS
Global	28.267	19.371	35.573	30.197
Wheelchair	44.52	28.214	51.813	45.296
Full	26.5	20.634	38.667	30.959
Throws	13.78	9.264	16.24	14.337

The preliminary tests' results were positive, although some motion sickness was felt and several users, mainly the athletes, thought the mechanism which controlled movement through the environment was not natural enough. As a result, after these initial tests, the wheelchair maneuvering mechanism was improved. Other changes resulting from this evaluation included adding haptic feedback and attempting to make it possible to dribble the ball.

The second stage of user tests counted with the participation of 18 volunteers. Their ages ranged from 19 to 26 years old, with an average age of 21.667 and the standard deviation of 1.815. Out of the 18 participants, 13 were male and 5 were female, and only 3 of them had experience with VR and 4 had tried it once before. The other 11 had never tried VR previously.

In these final user tests, the participants answered one questionnaire with 24 questions from Witmer and Singer's presence questionnaire [8] (the 22 from the preliminary tests plus 2 questions regarding haptic feedback), and a couple of questions regarding how seamless the integration of elements onto the tracked video seemed and how well the interaction with it felt. They also answered to the entire simulator sickness questionnaire created by Robert S. Kennedy et al. [5], rather then just to the previous 6 symptoms. Each volunteer answered to this questionnaire three times, once for each basketball practice scene available in the game (wheelchair, throws and full practice).

The results of the tests improved relatively to the preliminary ones. The wheelchair maneuvering mechanism seems to have felt more natural to the users, receiving positive results. The added haptic feedback was also well received. The motion sickness feeling also appears to have improved. Although some was still felt, the total severity index (TS) computed (see Table 1), when compared with the ones resulting from Robert S. Kennedy et al.'s experiments with VE devices [4], shows that the pattern of symptomatology obtained is consistent with the one expected from a VR system. The analyses of the results also confirmed the assumption that the maneuvering of the wheelchair is one of the main instigators of motion sickness in the system.

CONCLUSIONS AND FUTURE WORK

The work so far as resulted in the creation of a VR game that simulates wheelchair basketball in which the user plays as one of the athletes. The method developed to allow the user to move through the VE is the maneuvering of a virtual wheelchair. This method mimics the way real athletes move in real life, which helps to confer realism to the game. However, the virtual wheelchair's response to the user's actions should still be improved since its movements could be made more natural. The possibility of dribbling the ball is also in need of further work.

During the user tests most participants mentioned that while playing the game they felt like they truly were an athlete and that they enjoyed playing, but that some form of celebration when they manage to score and more interaction available was still needed. The game's appeal must still be increased, providing goals to the user and rewarding him/her for achievements such as shots scoring.

The NPC's behaviour should also be further developed, and more NPCs added in order to be able to simulate a real basketball game situation.

From the feedback given by the users during the user tests, it can be concluded that the integration techniques applied were successful, helping in the creation of a virtual environment more realistic and immersive. The placement of computer-generated elements onto tracked 360 video seems to be promising and should be better explored in the future.

The system is expected to be extended to include other paralympic sports besides wheelchair basketball, such as boccia, for example. At some point in the future, the possibility of adding some other hardware to the system could also be explored in order to obtain more input, such as the user's body's orientation, and provide additional feedback to the user. A physical wheelchair on a motion platform could be used to allow the user to better interact with the virtual wheelchair, while also providing force feedback. Other hardware capable of, for example, providing haptic feedback to the user's hands would also be helpful. It could be used to allow the user to feel the ball or other objects when these are grabbed, and help determining the force being applied to the ball when throwing it.

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REFERENCES

[1] Larry R. Crichlow, Geoff Fernie, Jennifer Campos, and Peter R. Grant. 2011. A Full Motion Manual Wheelchair Simulator for Rehabilitation Research. In *Proceedings of the 2011 RESNA/ICTA Conference on Advancing Rehabilitation Technologies for an Aging Society. Toronto, Canada, June 2011.*

[2] Iris Gonzalez. 2018. IMG Studio Develops First VR Basketball Game for Paralympic Sports. https://www.startupssanantonio.com/img-studio-develops-first-vr-basketball-game-for-adaptive-paralympic-sports/ Accessed: 16 Aug. 2018.

[3] Victoria Interrante, Brian Ries, and Lee Anderson. 2007. Seven league boots: A new metaphor for augmented locomotion through moderately large scale immersive virtual environments. In *IEEE Symposium on 3D User Interfaces, 2007. 3DUI'07.*

[4] Robert S Kennedy, Julie M Drexler, Daniel E Compton, Kay M Stanney, D Susan Lanham, and Deborah L Harm. 2003. Configural Scoring of Simulator Sickness, Cybersickness and Space Adaptation Syndrome: Similarities and Differences. *Virtual and adaptive environments: Applications, implications, and human performance issues* (2003), 247.

[5] Robert S Kennedy, Norman E Lane, Kevin S Berbaum, and Michael G Lilienthal. 1993. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology* 3, 3 (1993), 203–220.

[6] José Diogo Ribeiro, Brígida Mónica Faria, A Paulo Moreira, and Luis Paulo Reis. 2017. Realistic Boccia Game Simulator Adapted for People with Disabilities or Motor Disorders: Architecture and Preliminary Usability Study. In *World Conference on Information Systems and Technologies*. Springer, 165–176.

[7] Lars Yndal Sørensen and John Paulin Hansen. 2017. A low-cost virtual reality wheelchair simulator. In *Proceedings of the 10th International Conference on PErvasive Technologies Related to Assistive Environments*. ACM, 242–243.

[8] Bob G Witmer, Christian J Jerome, and Michael J Singer. 2005. The factor structure of the presence questionnaire. *Presence: Teleoperators and Virtual Environments* 14, 3 (2005), 298–312.