Integration of Captive Movement Systems in Virtual Environments for Rehabilitation in People with Disabilities

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Abstract: Generally, virtual reality (VR) systems used to improve physical and cognitive skills in people with disabilities generate a limited play area, allowing only a few meters of movement. This work proposes the integration of the Virtuix Omni Pro device, a captive movement system that enables unlimited displacement. This represents an opportunity in VR research for gait training in people with disabilities and adds value in terms of realism and immersion for the practice of activities in which movement is essential, such as shopping in a supermarket or moving freely through an urban environment.

1 Introduction

Virtual Reality (VR) is a technology capable of generating highly realistic virtual environments. Depending on the technology used, a great immersion of the person in these environments can be achieved, causing the sensation of being present in them. Most VR equipment consists of helmets or glasses with stereoscopic vision, controls, and a set of sensors capable of tracking the person's movements. It should be noted that the tracking is limited by the gaming area generated by the device and by the actual space of the room in which it is used.

VR is a motivating, safe, and entertaining means in the process of improving physical and cognitive skills in people with disabilities (Lagos Rodríguez et al., 2022). The existing literature has studied the use of this technology in people with different health situations that limit their autonomy (Chau et al., 2021), (Domínguez-Téllez et al., 2019), (Lee and Jin, 2023). The results point to further research in this line and the development of new VR applications that contribute to improving the daily lives of people with disabilities.

This work is intended to continue this line of research. As mentioned above, VR equipment has a limited play area, which means that the person can only move a few meters. In addition, the actual space itself is also a barrier in this regard. This can be a limitation when working on skills that require complete freedom of movement. Furthermore, being able to move freely through a virtual scenario significantly increases the realism and immersion of the environment. As a solution, a captive movement system has been integrated to allow unlimited movement in virtual environments.

A virtual reality application that simulates a supermarket is also being developed. In it, different daily activities can be carried out that will allow both physical and cognitive work. The fact of working with day-to-day activities can be more enjoyable and motivating for the person compared to other more mechanical or repetitive exercises. In addition, the exercises performed have a direct application in your life.

Therefore, the objective of this work is to integrate a captive movement system in a virtual environment that simulates a supermarket. The final application will consist of three very common activities in a real supermarket and will allow the work of physical and cognitive skills in people with disabilities.

2 Materials and Methods

The project has started with several meetings with organizations in the field of disability. The researchers have presented the VR equipment, as well as the captive movement system, and different tests have been carried out with healthcare professionals and people who need to work on some physical or cognitive ability. These meetings have made it possible to confirm the security of the platform and to define the virtual environment, as well as the tasks to be performed in it.

Subsequently, the development of the tool was started. The first step was the search for a 3D model of a supermarket and its products and equipment. The selection process considered the completeness of the product catalog, the realism of the 3D objects, and their configuration options.

Once the 3D models have been acquired, they have been integrated into a virtual scene. The placement of the objects in each scenario has been done considering the tasks to be programmed in the scenario. The aim is to obtain a realistic, intuitive, and motivating scenario for the user.

After obtaining the first version of the virtual supermarket, the interaction system has been implemented and the captive movement platform has been integrated. It is worth mentioning that the interaction is done through a hand-tracking system, which avoids the use of remotes.

Finally, the programming of the set of activities defined in the meetings held at the beginning of the project was started. Thus, the objective is to develop three activities that allow the work of both physical and cognitive skills.

In addition to the tests carried out by the research team, the organization of test sessions with professionals and users of different entities in the field of disability is proposed. The purpose will be to detect possible errors and implement improvements that will contribute to increasing the usability of the tool.

Below, the hardware and software elements that have been selected for the development of the project are briefly defined:

2.1 Hardware

- **HTC VIVE Pro 2:** It is a virtual reality equipment created by HTC. It consists of a kit made up of glasses, controllers, and position sensors. The glasses have a screen that allows the visualization of 3D virtual environments and a high-quality audio system that increases the immersion capacity (HTC VIVE, n.d.).

- **Leap Motion:** It is an optical hand and finger tracking system. It allows interaction with digital content with the hands, avoiding the use of a keyboard, mouse, or controller. It is possible to integrate it into a virtual reality system, providing greater realism by being able to touch and grasp virtual objects (Leap Motion, n.d.).

- **Virtuix Omni Pro:** It is a captive movement system. It consists of a sliding surface and a harness. It transforms the movement of the feet into movement in the virtual environment (Virtuix Omni Pro, n.d.) (see Fig. 1).

Figure 1: Virtuix Omni Pro

2.2 Software

- **Unity:** It is a real-time 3D content development platform. It allows the creation of interactive environments for a wide variety of devices such as computers, consoles, or VR equipment (Unity, n.d.).

- **OpenXR:** It is a free and open API standard developed by Khronos. It facilitates the development of VR applications compatible with VR devices from different manufacturers (OpenXR, n.d.).

- **Unity Leap Motion Modules:** It is a set of libraries provided by the Leap Motion manufacturer to access the device API and to facilitate the development of functionalities in the VR application (Leap Motion Modules, n.d.).

3 VR Application

The application consists of a virtual supermarket with a high degree of immersion. It has a wide catalog of products, which allows it to carry out a variety of exercises related to cognitive training. Likewise, the environment has the usual equipment of real supermarkets, with cash registers, shelves at different heights, fridges, and freezers with different types of openings, and baskets and trolleys to store the shopping. This is noteworthy because it facilitates the implementation of tasks for physical work while contributing to greater realism in the training process. Also noteworthy is the inclusion of audio and image elements to motivate the person and guide him/her in the completion of each test.

The development of three activities with tasks that allow training of physical and cognitive skills in people with disabilities is proposed. Each of them is described below:

- **Activity 1:** The person must pick up products at different heights and place them in a basket. The objective is to work on the mobility of the upper and lower limbs when reaching each product and placing it inside the basket (see Fig. 2).

Figure 2: Activity 1

- **Activity 2:** The person will have a shopping list and must select only the correct products and place them in a trolley. This task is intended to work on memory and concentration (see Fig. 3).

Figure 3: Activity 2

- **Activity 3:** The person must make the payment for the purchase made. To do this, the person will have bills and coins of different values. Thus, he/she must check the amount on a screen and select the appropriate bills and coins until the correct amount is added up. The objective is to train mental agility (see Fig. 4).

Figure 4: Activity 3

4 Conclusions

The integration of a captive motion system provides a more realistic and natural way of carrying out certain activities that require moving through a virtual environment. In addition, it is an added value in VR research for gait training in people with disabilities.

The programming of tasks based on daily life favors the transfer of the results obtained to the person's life. In addition, it could also imply a better adherence to the prescribed exercises.

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Bibliography

P. H. Chau, Y. Y. J. Kwok, M. K. M. Chan, K. Y. D. Kwan, K. L. Wong, Y. H. Tang, K. L. P. Chau, S. W. M. Lau, Y. Y. Y. Yiu, M. Y. F. Kwong, W. T. T. Lai, and M. K. Leung. Feasibility, acceptability, and efficacy of virtual reality training for older adults and people with disabilities: Single-arm pre-post study. *Journal of Medical Internet Research*, 23(5), 2021.

P. Domínguez-Téllez, J. Moral-Muñoz, E. Casado-Fernández, A. Salazar, and D. Lucena-Antón. Efectos de la realidad virtual sobre el equilibrio y la marcha en el ictus: revisión sistemática y metaanálisis. *Revista de Neurología*, 06(69):223–234, 2019.

HTC VIVE, n.d. URL *https://www.vive.com/eu/product/vive-pro2-full-kit/overview/*. [Online; accessed september 2023].

M. Lagos Rodríguez, A. Gómez García, J. Pereira Loureiro, and T. Pousada García. Personalized virtual reality environments for intervention with people with disability. *Electronics*, 11(10), 2022.

Leap Motion, n.d. URL *https://www.ultraleap.com*. [Online; accessed september 2023].

Leap Motion Modules, n.d. URL *https://developer.leapmotion.com/unity*. [Online; accessed september 2023].

H. K. Lee and J. Jin. The effect of a virtual reality exergame on motor skills and physical activity levels of children with a developmental disability. *Research in Developmental Disabilities*, 132, 2023.

OpenXR, n.d. URL *https://www.khronos.org/openxr*. [Online; accessed september 2023].

Unity, n.d. URL *https://unity.com*. [Online; accessed september 2023].

Virtuix Omni Pro, n.d. URL *https://www.virtuix.com/developer*. [Online; accessed september 2023].