UAV flight simulator to improve elders' quality of life

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Abstract. The quality of life in older people deteriorates faster, depending if these have a sedentary lifestyle. Technology is used as a tool in various fields and there are some applications that have been developed to encourage sports through entertainment, this is the case of the Nintendo Wii. The positive impact of this kind of application has been the base in the development of this research. Our proposal focuses on the easy handling of a drone by sensing arm movements through wearable devices, and providing an immersive experience of being in a different place using virtual reality glasses. The aim is to promote the user's cognitive development, due to the hand-eye coordination required to control the drone. Finally, this research, manages to integrate virtual reality with Bluetooth technologies, establishing real-time communication with wearable devices and human movement.

Keywords: UAV; Sports; Health; VR; Drone; Elders; Wellbeing.

1 Introduction

Improving the people's quality of life is one of the points of interest of medical care. Contributing to the health and well-being of the elderly is an area where technology is providing space for new research. According to Gartner 2016 [1], the virtual reality and its applications are located in the development stage, being a mature technology ready to park in its full productivity stage. This motivation led the present work to use virtual reality as research and technology development, based on a research work done by [2], that propose the combination of virtual reality technology with body area networks, in order to present a simple and fun application for elders. Through virtual reality glasses, they can control an Unnamed Aerial Vehicle (UAV) using the arms' movement. This eyes-hands synchronization improves the psychomotor and cognitive capacities of the user. Additionally, it decreases the sedentary lifestyle thanks to the physical exercise that the elders must realize while using the simulator. The use of these systems avoids the sedentariness and lack of entertainment as well as stimulate their mood.

The present research proposes the development of a simulation system based on virtual reality and wearable devices that works synchronously through Bluetooth LE to improve elders' quality of life. In the proposed solution, simple interaction methods are used to facilitate the use and control of a Drone for a vast number of people in the target group. This is due to the fact that many elders have mobility problems (including difficulty in the movement of their arms) also emphasized with the fact that many cannot stand for long periods of time. All of these initial premises were taken into account to develop a system suitable for the elder. As future work, we intend to increase the interaction methods and add game mechanics to be applied as obstacles within the simulator. This way it will be possible to evaluate the use and improvements of the motor functions necessary to control the Drone in the virtual environment.

This paper is organized and described in five sections: Section 2 describes the relevant characteristics of related work; Section 3 presents the general architecture of the proposed solution, addressing the hardware and software components and also the communication between them; Section 4 covers the interaction methods, the model used to move the Drone, the medium in which the application is made, the landscapes optimized for VR applications and the camera configurations settings; Section 5 presents the latency test with Bluetooth LE technology. Finally, Section 6 present the conclusions and future work.

2 Related Work

Currently, flight simulators are commonly used in academic research, government operations, space exploration, driver training schools, the military sector, computer markets for player distraction and the medical sector.

The human factors and the ease of use of flight-simulators play a very important role in the creation of proposal that satisfies the requirements of the users. Therefore, the development of interfaces in the software-design and hardware-use must meet the requirements of coordination, adaptability, ease of use and cognitive aspects of the adult users to which the present research is focused.

In the work carried out by Bustamante et al. [2], a guide is presented for the development of a virtual reality application using the Cardboard VR Headset. The elderly performs movements with its arms and these movements are reflected in the motion of an UAV, that is in a virtual environment, supporting the improvement of the user's cognitive development (hand-eye coordination).

Another similar application is the work by Ramirez et al. [3] who developed a framework for physical rehabilitation in the upper limbs of the body through virtual reality, where the user feels motivated and is pleasant to interact by presenting a friendly VR interface.

Applications that simulate aerial vehicles include an area of study relevant to scientific technological advancement. Some examples are: Training and capacitation of pilots, militaries, expeditions, testing and management of emergent cases that include a high risk of work in complex environments. According to Sterman [4], flight simulator applications have a high impact as a tool for transmitting knowledge oriented towards constructionism, interactive or action learning.

Virtual reality provides benefits to perform tasks that may present a degree of difficulty or even risk. According to Oberhauser et al. [5], virtual reality glasses are an instrument where the subject can experience a three-dimensional space by using a screen mounted on the head. One of the usefulness of virtual reality glasses is as an instrument to explore ergonomic aspects of aircraft booths [6].

Rivera et al. [7] designed a virtual reality application for people with aerophobia (fear of flying). This application helps overcome the difficulties generated by the phobia,
allowing recreation with interactions in different environments with their fears, while the user is in a safe and protected place, resulting that the virtual reality glasses are effective as the traditional technique, even at a lower cost than using a personal computer to perform simulations.

A study by Griswold et al. [8] comprises determining the reliability and validity of physical rehabilitation exercises, through the use of virtual reality glasses for a group of elderly people. The results show that the reliability in the execution of the exercises increased 5 times. This is supported by the use of virtual reality equipment for the measurement of physical performance tests, consequently to provide a better quality of life for the elderly.

Miller et al. [9], performed a virtual reality application based on a game that allows fun and mobility in older adults, with neurological conditions. The result showed that the retention capacity was greater than 70%. However, the evaluations showed bias, given the non-consecutive attention of users to the sessions, because they presented problems due to their age.

A similar work was done by Zhang et al. [10], who simulated a real environment, in a virtual reality application, to evaluate the cognitive functions of people with brain injury versus voluntary people without brain problems. After conducting evaluations with the two groups, it was determined that the virtual reality environment, generated by the VR glasses, is a reproducible tool. Therefore, it is capable of agile the evaluation of cognitive functions in the users, providing significant help to the evaluators through early answers.

Finally, after realizing an analysis of the realized works, the contribution that offers the present research is the presentation of an application of virtual reality used with virtual glasses as a whole with wearable devices; this interaction will carry out it in a very short time of communication among the devices, to offer a real time interaction to the user.

3 Flight Simulator Architecture

3.1 General Architecture

The architecture is composed by three devices, the smartphone (Server) contains the simulator application and two Raspberry Pi devices (Clients), as remote controllers. The Server and the clients communicate through Bluetooth Low Energy Technology.

The general architecture is represented in Fig. 1.

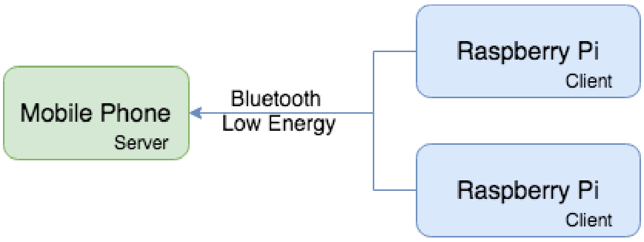

Fig. 1. General Architecture Diagram

Each client scans and connects to the server in order to send information from its sensors. This information is represented by the gravitational force generated by the movements of the user's arms. The server uses this information to determine the actions that the virtual Drone must execute within the simulated environment. Fig. 2. represents these interactions.

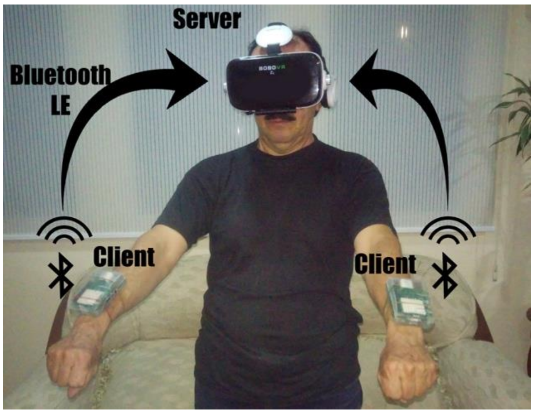

Fig. 2. General Functionality Diagram.

4 User Interactions

In order to plan the system for the elderly, who probably never in their life have used such technology, a special design was considered in which the user only needs to use its eyes and arms to control the system. For this reason, this system is composed of simple interaction methods based on specific movements that are easy to remember. As can be seen in Fig. 6, the services are directly related to the interactions between the m ovements of the user' s hands and the simulator. These methods make that the user only need to remember five movements.

- **Both arms up:** this movement causes the Drone to ascend (Zb+).
- **Both arms in front:** this movement causes the Drone to descend (Zb-).
- **Right palm up:** this rotation movement causes the drone rotate to the right (Zw+).
- **Left palm up:** this rotation movement causes the drone rotate to the left (Zw-).
- **Both arms down:** This movement stops any other movement, is the default idle movement by the Drone (Zb-).

When no action is performed by the user, the drones is in a unique automatic movement characterized by a slow forward motion. In future work this system can contain a more advanced interaction method, where the automatic forward motion will disappear.

Fig. 6. Global (w) and Local (b) Coordinate systems adopted. [12]

The motion of the Drone through the user interactions was defined based on the mathematical model described in [12]. This was a starting point in order to create a simplified model for the movements of the Drone in this project.

The physics used in this system were based on [13] and implemented in the Unity3d Game Engine through the “Rigid Body Component”(shown on Fig. 7).

The flight system of a Drone completely disregards the gravity because it always remains suspended in the air, so the gravity parameter is set to zero and with this, the flight functionality is similar to a helicopter.

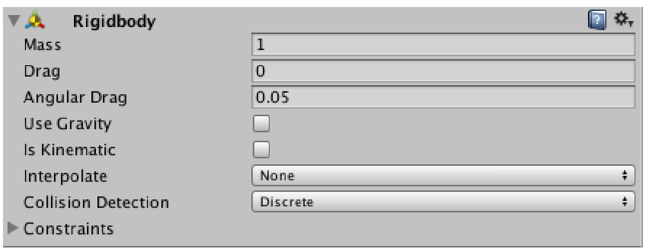

Fig. 7. Unity 3D Rigid Body Component

According to the proposed solution, the simulation of UAV will be displayed in virtual reality; therefore, the simulation will be implemented on android smartphones with any headset glasses (presented in Fig. 8).

Fig. 8. VR Headset Glasses.

The environment created for this simulation must be optimized to run smoothly on smartphones. In addition, internally the system renders the scene two times per frame, this is because the virtual reality system forces the GPU to process all graphic content in each of the two cameras (one camera per eye). This effect, generates an immersive experience, but it is expensive in terms of performance, because each 3D model is composed of several hundreds of polygons, so developing a realistic environment is causes too much computational effort on the GPU. In order to solve this problem the environment was generated through panoramic images. These images are part of a cube model that only have two polygons per face. This method offers a realistic setting with a minimal load on the GPU and the result is a smooth simulation with the ability to support details that maximize the realism with visual effects as falling leaves and shadows. This may have observed in Fig. 9.

Fig. 9. Panoramic Image environment

The parameters of the camera are configured with a field of view of 97.4932 degrees and each camera is located 3.2 cm towards each end of the x-axis. This difference of distance and the same field of view generates a perfect emulation of the human visual system. These parameters are shown in Fig. 10.

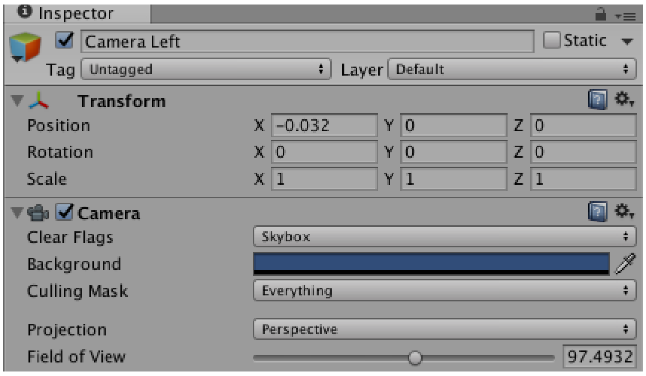

Fig. 10. Camera configuration parameters

Finally, the device responsible for managing the arms movements and interact directly with the smartphone is the Raspberry Pi. This device is a very light computer and incorporates an integrated board sensor, acting as wearable device (see Fig. 11). It runs a python script when is turned on which automatically scans the server and connects with it. After the connection, it starts the management of the sensors service and starts the interaction with the server through the Bluetooth service. This communication is done using Bluetooth LE services, and the sensor service is managed with the support of Sense Hat libraries [14]. The connection between each client and the server is automatic but must be done sequentially. This is because the Bluetooth LE not allow simultaneous connections to a server, it means that a second client must wait until the first one connects completely, since Bluetooth 4.2 will solve this problem.

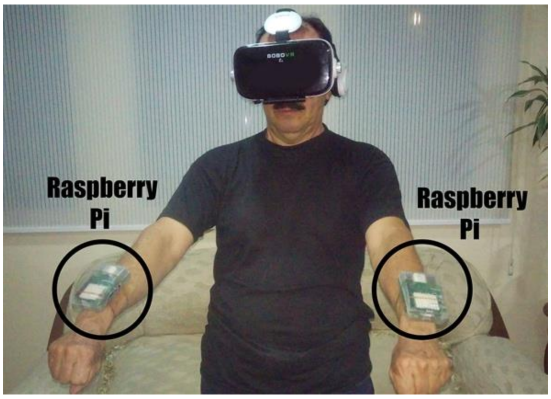

Fig. 11. Raspberry Pi Nodes.

The interactions of each device are given through the flow diagrams of Fig. 12. which clearly show the actions between the two devices under their own processes. As can be seen, both diagrams show the relevant processes where they have the most important interaction between the client and the server.

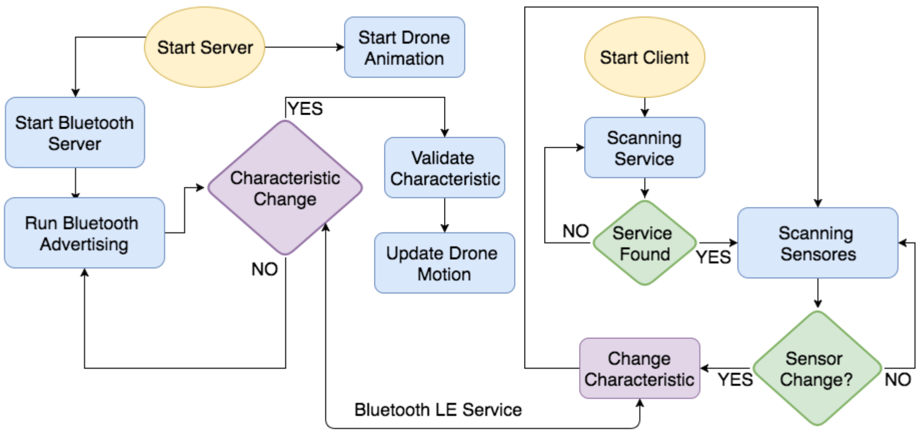

Fig 12. Client-Server Communication Flow Diagram

5 Real Time Communication Tests

In order to determine the performance of the communication in real time, a latency test was performed on the data transmission between the clients and the server at the same time. The test environment is performed locally on each device, while the client writes the current system time in the moment that send data, the server does the same when receiving them, all devices are synchronized with local time Quito-Ecuador so the difference of time corresponds to the latency of transmission with a minimum fraction of error. The distance from the server and the clients is always less than 1 meter for that the Bluetooth signal is very strong and the latency is very low. The following Table 1 represent the values in some interactions with the corresponding latency values in milliseconds.

Table 1: Communication Latency Results

Average Transmission Information	Up (10 times)	Standby (10 times)	Left (10 times)	Right (10 times)	Stop (10 times)	Down (10 times)
Latency in milliseconds	20 ms	18 ms	21 ms	23 ms	21 ms	12 ms

6 Conclusions and Future Work

This research was able to integrate virtual reality and Bluetooth technologies to achieve a real-time communication with the wearable devices that worked as a movement manager of the arms. In addition, this system promotes cognitive development of the person; this is due to hand-eye coordination, which is required to move the drone.

In the future, it is intended to add different levels of difficulty in the simulator interactions. This will allow assessments of use and improvement of motor functions necessary to control the virtual Drone. Then, tests will be carried out in several centers of elderly people in order to validate the solution and conduct further investigation. The advantages of using a Bluetooth low energy is to have the possibility of connecting new clients, so is possible to add functionality to the system, as well as generate another type of approach or different simulation where not only the movement of arms is required, but also other parts of the body.

In future works is intended to use other wearable devices instead of Raspberry Pi and increase the number of nodes (clients) in order to emphasize the movement of the whole body.

For research purposes, the communication technology (Bluetooth LE) could be change for other research to analyze the differences, advantages and disadvantages in a system of this nature.

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