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DEVELOPMENT OF A SERIOUS GAME FOR REHABILITATION OF THE HUMAN GAIT

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Abstract. Stroke is the leading cause of death and disability in adults worldwide. It is estimated that about fifty-seven percent of survivors will need continuous care. One of the consequences of the stroke is the loss, or difficulty, of the ability to walk. Walking consists of several synchronized movements that involve not only the movement of the legs, but also the trunk and upper limbs. The development of the so-called serious games has as its main objective the treatment of people with some type of physical limitation. Thinking about it, the serious game Grove Rehabilitation was developed. This game consists of controlling the avatar that walks through a forest to be able to collect as many fruits as possible and at the same time avoid the existing obstacles. The movements of the avatar are controlled by means of a Microsoft Kinect sensor, in this way the patient will walk on a treadmill for the avatar to walk through the woods. For the avatar to move laterally, the patient must raise the arm in the respective desired direction, in this way it is also possible to work on motor coordination and balance. The serious game was developed using the Unity 3D graphics engine. The Grove Rehabilitation serious game developed proved to be fluid and in the next stages, tests will be carried out with the patients.

Keywords: Gait, Rehabilitation, Kinect, Stroke.

1. INTRODUCTION

Pompeu et al. (2001) refer to the stroke as a severe disease which affects the brain and usually lasts for more than 24 hours. Its sequelae, however, are diverse, and may result in lesions of short duration or that last for the rest of the patient's life (Cancela, 2008). The stroke is the leading cause of death and disability in adults worldwide. It is estimated that about 57% of survivors need continuous care (Kareny et al., 2016). According to the World Report on Disability published by the World Health Organization (WHO), more than 1 billion people worldwide are living with some kind of disability, making it a question not only of rehabilitation, but also of resumption of self-esteem and personal independence (Brasil, 2013). Human gait in people who have lost sensation on one side of the body due to stroke, also known as hemiparetic gait, is characterized by a lack of rhythm and coordination, which generates high physical wear on the patient (Ottoboni et al. 2002), in addition balance is also affected, further impairing locomotion and daily tasks (Pompeu et al., 2001).

Electronic games have characteristic to hold people's attention, regardless of gender and age (Alves et al., 2019). In view of this fact, the so-called serious games emerge, whose main objective is to provide the experience of carrying out activities hitherto considered tedious, for example, training, educational tasks and physical rehabilitation in a playful and often immersive way when using devices such as the Kinect (Clua, 2014).

Therefore, there is a need to develop a serious game, which uses a treadmill and a Kinect sensor that aims to rehabilitate human gait in patients who have suffered a stroke, to provide physiotherapeutic treatment aimed at entertainment of the patient at the same time that patients recovers/improve his movements. The following sections will present this serious game and the main aspects that composes it.

2. GROVE REHABILITATION SERIOUS GAME

The C# programming language, developed by Microsoft and based on the C++ language, was used in all game scripts due to the game engine, Unity 3D, using it natively. There was also the option of using Javascript, however, due to the author's previous experiences, the C# programming language becomes more viable and easier to apply. According to Araújo (2013) some basic characteristics of this language are:

- Powerful as C++ and influenced by the JAVA language;
- Completely object-oriented;

- Strongly typed to avoid handling errors;
- Everything is an object.

The game developed, called Grove Rehabilitation, Figure 1, consists of a straight way where an avatar walks on a dirt track in the middle of a forest full of trees and other objects. Its development followed the model of the sensorimotor theory of gait presented in (Hogan and Sternad, 2012), which takes into account walking in real life with all its variations, such as discrete movements, rhythmic movements and balance.

In this work we used the Microsoft™ Kinect® V2 (Kinect) to develop the serious game, which is a low-cost, real-time, non-marking motion capture system (Lun and Zhao, 2015). Through its depth sensor, Kinect can track 3D motion and estimate the location of 25 human body joints at a rate of 30 Hz (Lun and Zhao, 2015).



Figure 1. Avatar positioned on the trail and some objects in the game.

In order for the reality/interaction of the game to be as large as possible, some important parameters, such as the variation of the avatar speed according to the speed of the treadmill, the reproduction of all the patient's movements in the avatar from the use of the Kinect sensor and the collision with the obstacles that appear randomly along the trail have been taken into account.

In addition, some special objects will appear randomly along the way and will have to be collected by the player. The player must raise his left or right upper limb to move in the desired direction and touch the items and collect the fruits to increase his score. In this way, even though the movement of the treadmill is linear, the avatar moves to the left and right. Thus, it becomes possible to stimulate the upper limbs and at the same time improve the patient's balance, going according to the normal parameters of human gait (Ottononi et al., 2002; Iwabe et al., 2008).

The fundamental focus of the serious game developed is to provide real-time visual feedback to the patient in order to increase their motivation during the human gait therapy sections and to stimulate simultaneous movement of the upper and lower limbs. Thus, the main control script works in order to capture, store, map the user's joints and finally transfer the data to Avatar within the game through a scale, rotation and position transformation function. This data is converted into three-dimensional vectors, which are updated at a rate of approximately 30 frames per second.

In addition to the avatar control algorithms, there are several others to manage the other parameters, such as the speed of movement of the avatar, the position in which obstacles must arise, updating the player's score, sound effects, among others.

2.1 Development

In this paper the Unity 3D engine was used. The choice of this engine is justified by the fact of being a 3D platform, user friendly environment, easy enough for the beginner and having diverse assets to be used (Gutiérrez et al., 2021). An asset is representation of any item that can be used in your project. The asset may come from a file created outside of Unity, like as a 3D model, an audio or image file or any other types of file necessary supported by Unity.

The development of this project followed the steps: selecting one idea, modeling the terrain, searching for free assets in the Unity 3D Asset Store, assembling the game layout, coding the scripts and integrating with the database.

The avatar model was developed by (Filkov, 2016) and adapted to be used in this game. This Unity 3D asset has the avatar and its kinematic model and basic control scripts. From this, other necessary scripts were developed to achieve the objectives of this work. Using image processing from Microsoft Kinect V2, Figure 2, the patient's body will be mapped to enable data acquisition and manipulation.



Figure 2. Microsoft Kinect image processing identifies and maps the joints in the player/patient's body.

2.2 Idea selection

Initially the game would be developed in 2D, with the simulation of a treadmill, Figure 3, in which footprints would appear and the patient should step on them to count points, at the same time that obstacles (red footprints) appear and must be avoided.

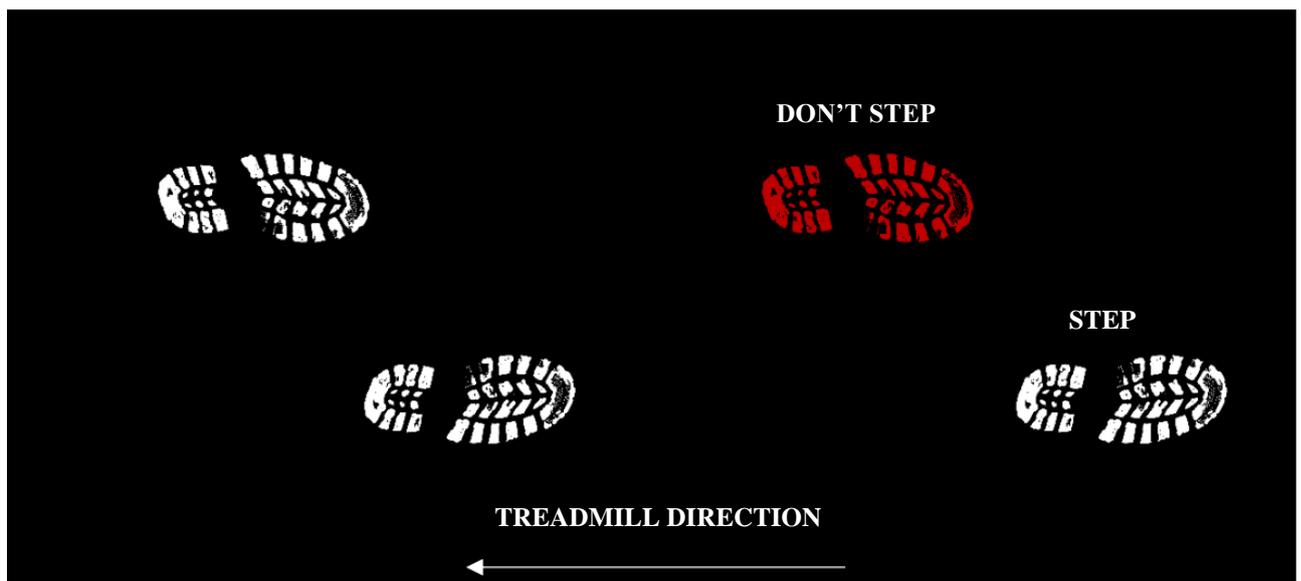


Figure 3. Initial idea for the game.

However, after some tests, it was decided to change the project from 2D to 3D, maintaining the initial essence of the game which was to walk a path while avoiding some obstacles, but adding visual effects with the aim of not only creating greater immersion of the patient as well as making the gameplay more fun.

2.3 Terrain modeling

The terrain modeling was done using the tools available by Unity 3D as shown in Figure 4.

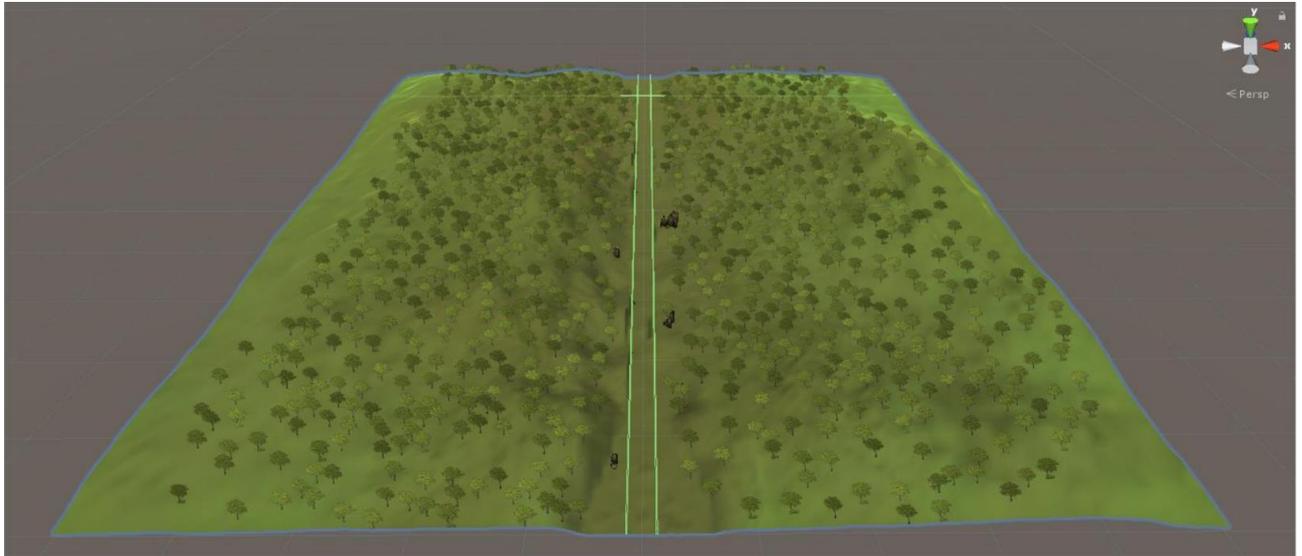


Figure 4. Game map with the hiking trail highlighted.

Initially, the hiking trail where the character would walk was rectangular, Figure 5, so that it is possible to take as many turns as necessary. However, some problems arose in relation to the curves and the map format had to be changed to a system of infinite walking in a straight line, Figure 4.

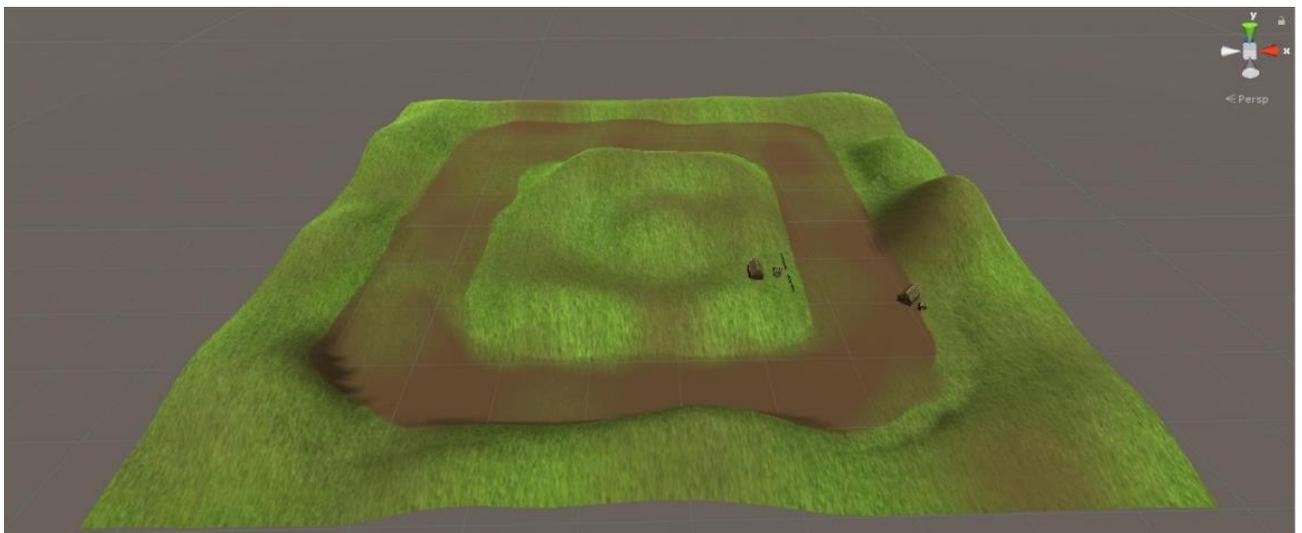


Figure 5. Initial format for the terrain.

2.3.1 Infinity walk

Infinity walk is the mechanism that consists of creating successive terrains so that the avatar will never reach the end of the trail. For this process to work in the best possible way it is necessary to have a trigger before the end of the land where the avatar is, as shown in Figure 6.

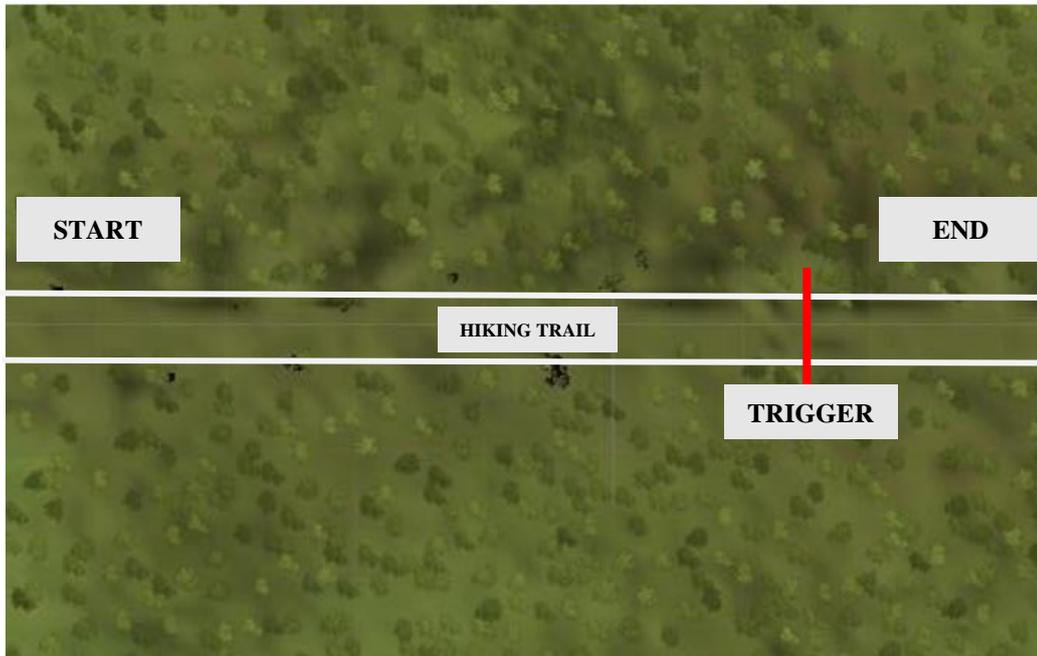


Figure 6. Start and end of the trail and the location of the trigger that creates a new terrain.

Whenever the avatar touches the trigger, a terrain will be created right after which the avatar is currently on and a timer will also be triggered to destroy the terrain that will be left behind. Following this continuous flow, the avatar will always be walking and will never reach the end of any terrain.

2.4 Layout modeling

The layouts of the serious game menus were organized in such a way as to create an environment of easy access for the person responsible for the configuration and insertion of the data of each patient. As an example the Figure 7 shows the initial menu (in Portuguese) for filling in patient data before the first session.



Figure 7. Main menu layout.

During the walk, on the serious game screen, the information was distributed following the pattern of almost all games of this style:

- Score of the number of fruits collected in the upper central part of the screen;
- Player score in the upper right next to the fruit score;

- Pause menu (in Portuguese) in the center of the screen, Figure 8, containing several options that can be accessed by pressing the ESC key.



Figure 8. Pause menu.

All prefabricated elements were inserted from the Asset Store (assetstore.unity.com) free of charge.

2.5 Database integration

The integration was done using the free SQLite software, which according to Bhosale et al. (2015) is indicated for all applications that require portability and that do not require expansion, for example, local single-user applications, mobile applications and games. This software does not have a graphical interface and operates using the Windows command terminal (command prompt). To facilitate development, SQLiteStudio software, also free, was used in conjunction with SQLite. This second software is a graphical interface for SQLite, which allows the visualization and creation of data tables, tests, etc.

The database created was manipulated within Unity through scripts and has the following basic functionalities:

- INSERT: Used to insert new data in the tables, for example, creating new users and saving the progress of each session made by each user;
- UPDATE: We can edit the patient's registration data using the UPDATE command. This option can be found when accessing the data of a specific patient in the search field;
- DELETE: This command is important because it avoids the accumulation of data that will no longer be used, for example, data saved in tests and patients who will no longer have sessions.

2.6. Preliminary results

The fundamental part of the game - moving the avatar in function of treadmill speed, menu, integrating with the database and counting points - was developed allowing a patient to be seen and done use of basic functionalities.

The serious game developed is low-cost and need only a Kinect device to work. The patients need to walk alone in the case that the treadmill don't have a body weight support. The Grove Rehabilitation game permits the gait training with different treadmill speed simultaneous working with the balance in function of the upper limbs movements. The fact of the existence of different fruits can be used to work the cognitive function attributing different scores to each fruit.

The preliminary results can be see at the link:

<https://drive.google.com/file/d/11pJUloyplrmH18yfSTfZ0Ghw0iZBxGtt/view?usp=sharing>

All tests were performed only by the authors and the results were satisfactory, which indicates that it is feasible to continue the development of this game with a clinical trial.

3. CONCLUSIONS

This paper presented the development of a serious game built with the Unity 3D software for the rehabilitation of gait in patients who have suffered a stroke. Through the combination of therapy using a treadmill and the attention-holding power that immersive games provide, it is possible to apply this serious game to healthy people so that it can later be used on patients who are the main objective to be achieved. Aware of this information, this work presented a new serious game with the possibility of jumping random obstacles and allowing the sensation that Avatar is making curves and dodging obstacles from the use of the upper limbs. In this way, in addition to rehabilitating the human gait, it is possible to train balance. In the next stages, the game developed will be tested on healthy volunteers for after being tested on patients.

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