Development of a Responsive System with Immersion in a Virtual Environment Integrated into a Biaxial Force Platform for Balance Training

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Development of a responsive system with immersion in a virtual environment integrated into a biaxial force platform for balance training

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Abstract— **Balance is an essential skill for human motor functioning that causes a sense of security and is indispensable for stability during movement. In this process, the postural orientation provides stimuli responsible for sensations of movement that help in the environmental orientation. The reduction of balance can favor the increase of falls providing some type of injury, which in more serious conditions lead to the need for care with therapies. Currently, one of the strategies for maintaining balance is multisensory training, which consists of series of exercises with sensorized equipment with static and dynamic metrics. One of these equipment is the force platform that measures the fluctuation of the Center of Mass (COM) and Pressure (COP) with load cells. To provide a balance training experience for people who need it, a bipedal force platform with biaxial rotation was used with a virtual environment designed to use the flexibility of chang-ing the inclination of the force platform along with a game element.**

Keywords — **Balance board, Games, Responsive system.**

I. Introduction

Balance is an essential skill for individuals' motor functionality and can be defined as the ability to maintain stable posture despite external disturbances [1]. This skill is essential to provide security and stability during movements [2].

In order for the individual to achieve postural stability, it is necessary to use several sensory systems, which provide information according to the levels of attention [3].

Postural orientation has three main stimuli, exproprioception, which is responsible for the sensation of position and movement of a body part relative to the environment, represented by the vestibular, auditory, somatosensory and visual systems. Proprioception, responsible for the sense of position and movement of a part of the body relative to another, being represented by the somatosensory and visual system. And finally, exteroception, which is responsible for locating an object in the environment in relation to another, represented by the auditory and visual system [4].

Impaired balance can favor an increase in falls, which consequently can increase the risk of injuriy [5], in some cases, loss of balance can contribute to more serious conditions that require intensive care [6].

One of the strategies for maintaining postural balance is multisensory training, which consists of a series of exercises with static and dynamic metrics sensorized equipment, which can be performed in any environment [7].

Among the studies collected in the systematic review of [8], there were no games able to directly control the actions of a dynamic force platform. A game capable of performing this control could make the virtual environment more immersive and interactive. Such a system could stimulate the player to continue training, increasing adherence to the protocol [9].

Therefore, the objective of this study is to develop an immersive balance training game capable of controlling the slopes of a biaxial dynamic force platform.

II. Material and methods

A. Equipment used

To assist the immersion and stimulate the individual's motor training, a bipedal force platform with biaxial rotation was used (Fig. 1). The equipment is composed of eight load cells (Fig. 1A) distributed in two metal plates (Fig. 1B), they are coupled to an axis controlled by four stepper motors (Fig. 1C), which receive command from the microcontrollers by the speed of 74880bps (Fig. 1D), which change the slope of the metal plates of the platform.

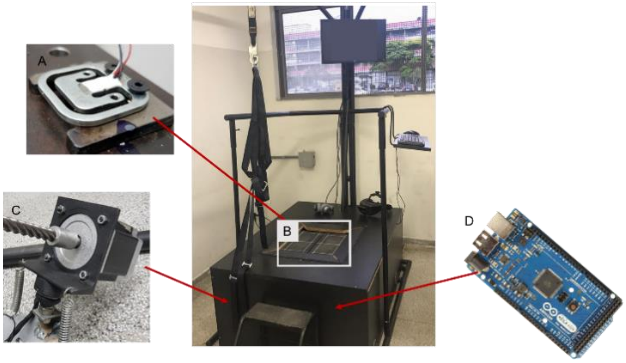

Fig. 1. Force platform with biaxial rotation. A) Load cell, B) Metal plate, C) Stepper motor, D) Microcontroller.

B. Platform/Game interactivity

The interactions between the platform and the game occur via scripts by the Visual Studio coding software, which establishes serial communication with the microcontrollers, responsible for sending and receiving information from the respective hardware (Fig 2).

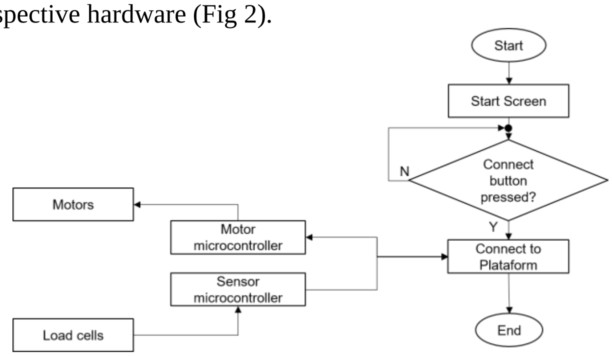

Fig. 2 Platform/Game connection

When passing a checkpoint, the game informs the force platform slope value to the motors microcontroller.

The game moves the avatar based on the value received from the equipment's sensors. The posterior sensors are responsible for the frontal movement at the beginning of the game, the anterior sensors are responsible for the decrease in speed, and the lateral-lateral sensors are responsible for the avatar's medio-lateral movements (Fig 3).

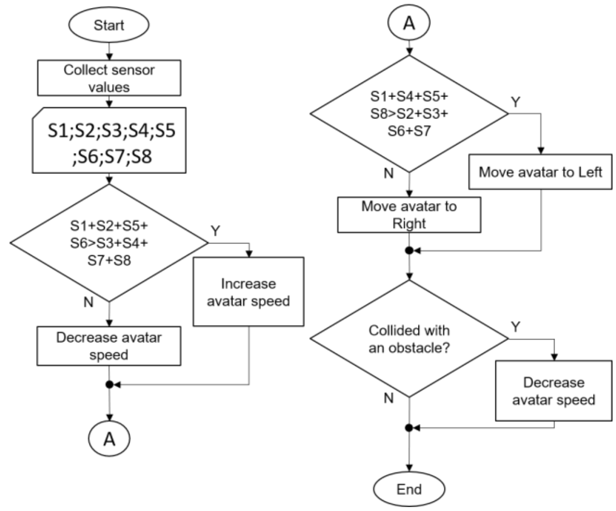

Fig. 3 Player movement

The player's avatar has a RigidBody (responsible for gravity physics in the character), a BoxCollider (responsible for collision interactions and platform tilt changes) and a script (which counts the events during the level). In addition to interpreting the values received by the microcontroller for movement. Movement is limited to a radius of 180º (one hundred and eighty degrees) forward.

C. Game development

The game was developed by the Unity Graphics Engine software, and modeled in 3D by the Blender software.

It consists of a Ski Runner game and aims to go down a snowy mountain with a pair of skis, it also contains several obstacles that, when reached, the descent speed is reduced, thus causing an increase in the completion time of the game. To control the avatar, it is necessary for the volunteer to move his center of pressure (COP) to the right or to the left, thus generating the medio-lateral movement. The faster the volunteer reaches the end game objective, the better his performance.

At the beginning of the game, the user is presented to the initial screen (Fig. 4A), which allows the player to enter his name, connect with the force platform and finally start the game. After pressing the start button, the screen switches to the avatar view, which contains the match time and a representation of the player's current speed. On this screen, the player can start the course through an “Impulse” (Fig. 4B). At the end of the path, the game ends with the non-player characters (NPCs) celebrating the player's arrival. Finally, the final screen is presented, with the total starting time and the number of collisions with obstacles, on this screen there is a button for the game's initial screen (Fig 4C).

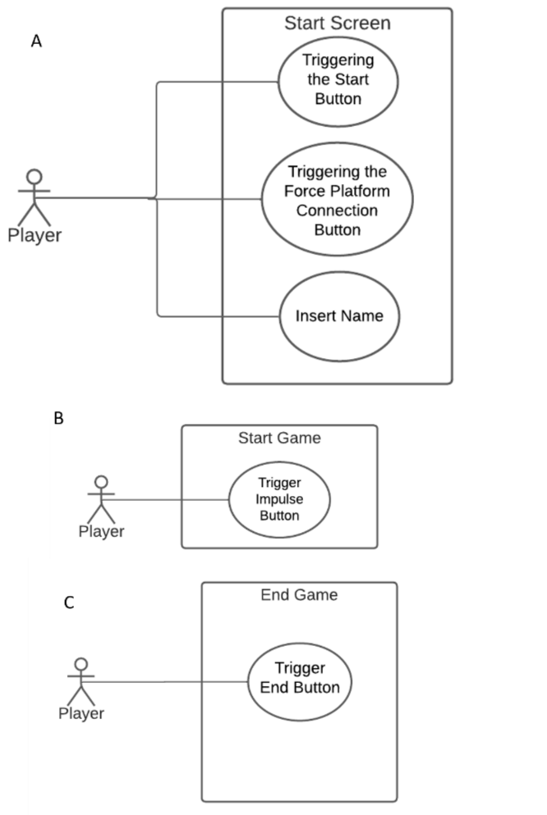

Fig. 4. Use case diagram. A) Start screen use case diagram. B) Use case diagram of the beginning of the game. C) Endgame use case diagram.

The track is composed of a set of random terrain segments (prefabricated objects) that have BoxCollider and RigidBody for interaction with the avatar. There is also a script whose function is to randomly spawn objects in a straight line). Obstacles have BoxCollider to count collisions and a script to slow down the avatar. The side barriers contain RigidBody that prevent the player from leaving the specified route.

At the beginning of the game, the system generates random challenges, different in number of obstacles and inclination from one stage to another.

The game has checkpoints (arcs) containing BoxCollider and script that inform the desired inclination for the motors microcontroller that readjusts the inclination of the platform (Fig. 5). The player must adjust their center of mass (COM) to match the slope faced.

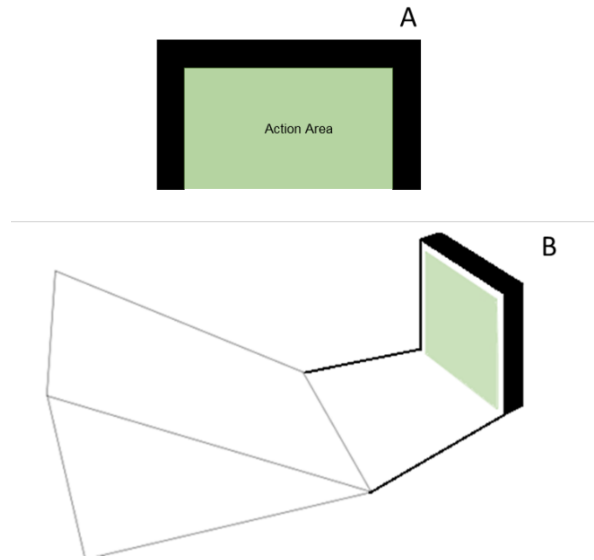

Fig. 5 Checkpoint representation. A) Front Checkpoint; B) Checkpoint in three/fourth view.

During the course, the player must dodge obstacles by shifting his center of pressure accordingly. If the player hits an obstacle, his speed will be reduced, increasing the time needed to complete the course.

After the last screen is displayed, the player has the option of restarting the game with a new clue or exiting the game.

To validate the game's features, a Black Box test was performed, which consists of testing each software function, observing the behavior and analyzing each response received by the command sent.

The actions of the Home Screen Buttons, the “Impulse” function, the controls of medio-lateral movements, actions of increase and decrease of speed, the expected movements of the responsive system and the collisions of obstacles were analyzed.

At the end of each analysis, the answer given by the software is compared with the programmed answer.

III. Results

The game is a Ski Runner and to implement and increase the player's immersion in the game, a realistic scenario was made (Fig. 6), stones (Fig. 7A), trees (Fig. 7B) and logs (Fig. 7C) were implemented.

Fig. 6. Scenery.

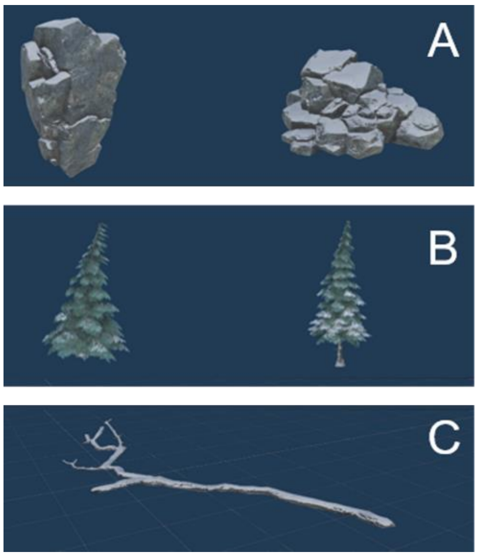

Fig. 7 Scene objects. A) Stones; B) Trees; C) Trunk.

When running the game, the user is directed to the initial screen (Fig. 8), where the type of control is selected, the player's name is entered and the game starts.

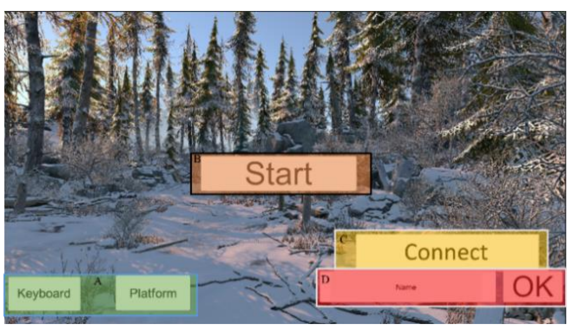

Fig. 8 Game start screen. A) Control selection; B) Start game button; C) Connect to platform; D) Insertion of name.

By pressing the start button the player will be directed to the player view (Fig. 9) where he can start the game with a "Impulse" button.

Fig. 9. Player view. A) Speedometer; B) Stopwatch.

The track is formed by side barriers and some type of obstacle, and at the end of each obstacle sequence a checkpoint area is formed.

The checkpoint change areas (Fig. 10) were made to be visible during the game, thus encouraging the player that from that moment on, the platform inclination and/or speed can be changed.

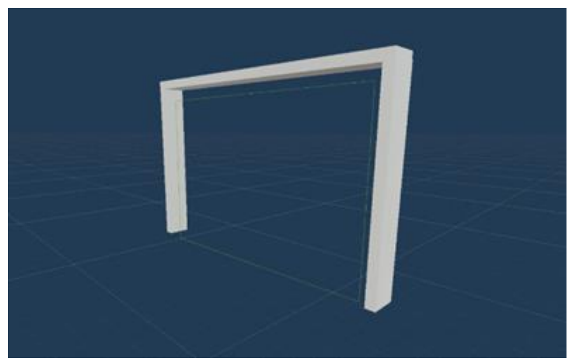

Fig. 10. Checkpoint.

Finally, when reaching the end of the course (Fig. 11) there is a commemoration that symbolizes the end of the game and presents the information about the occurrence of the game (Fig. 12). The game's rewards vary depending on the player's performance during the level. The variables analyzed to determine the feedback are the time and the total of collisions.

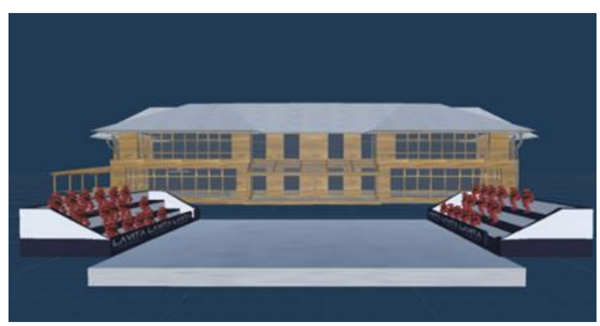

Fig. 11. End of game.

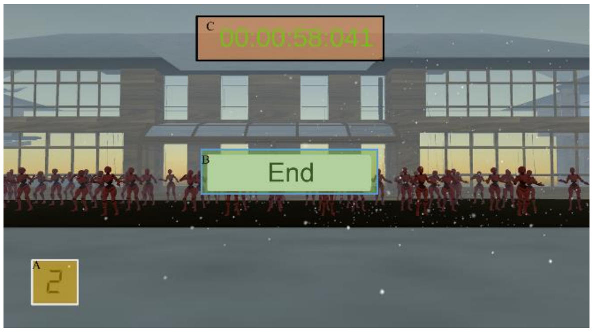

Fig. 12. End of game screen. A) Number of hits occurred; B) Game end/restart button; C) Total travel time.

To validate the functionality of the software, the black box test was performed. This test verifies the functions and performance without looking at the internal functionality of the software [10]. The system is segmented into individual actions (seven actions), where parts of the total functionality were disabled to observe individual behavior, comparing the system response with the expected response.

The results were organized in the board (Fig. 13) to verify if there is any problem in the execution of the codes and functionalities.

Action	1	2	3	4	5	6	7
Pressed Start/End Button	No	Yes	Yes	Yes	Yes	Yes	Yes
Pressed Boost Button	X	No	Yes	Yes	Yes	Yes	Yes
Individual's Center of Mass left/right	X	X	No	X	X	X	X
Individual's Center of Mass backwards	X	X	X	No	X	X	X
Individual's Center of Mass forward	X	X	X	X	No	X	X
Went through the tilt change	X	X	X	X	X	No	X
Collided into an obstacle	X	X	X	X	X	X	No
Expected Output	It wasn't directed to the beginning of the game	Not started the game	Character didn't move sideways	Character hasn't slowdown	Character hasn't speed boost	There was no change of slope on the platform	No character speed reduction

Fig 13 Black Box functionality test.

A. Game timeline

The game starts with the player's impulse, that is, when leaning forward, the platform's front sensors capture the pressure exerted and send it to the game avatar. Upon passing the first checkpoint, the platform tilts and starts the timer.

With the beginning of the game, the user will be able to perform side-to-side movements that will be captured by the sensors to move the avatar. Forward inclusions increase the avatar's speed, conversely, backwards inclusions decrease the avatar's speed.

The player's objective is to reach the end of the track in the shortest possible time, avoiding obstacles. Checkpoints are points that symbolize increase/decrease in the slope of the track and change the slope of the platform.

At the end of the game, the player celebrates with the NPCs the completion of the phase, which finally shows the time and the total number of collisions that occurred during the game.

IV. Conclusions

A virtual environment was produced that can control and interact with a biaxial force platform. The purpose of this game is to provide stimuli in real time through the inter-face and to promote the experimentation of a snow skiing environment, consequently helping in balance training to different audiences (elderly, patients with neurological pa-thologies or in the process of motor rehabilitation due to sports or traumatic injuries).

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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