

HANDS-ON: SUPPORTING HAND REHABILITATION MOVEMENTS IN PLAYTHERAPY VIDEOGAME

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This word is dedicated to the strongest warriors that I know, my mother *Lucy Fernández* and my aunt *Graciela Zambrano* without them none of this will be possible.

"The only person you are destined to become is the person you decide to be."

-Ralph Waldo Emerson

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ABSTRACT

The main objective of this project is to extend the scope of *Playtherapy: Videojuego de apoyo a terapias de recuperación física*, in order to cover the hands movement rehabilitation therapies.

This project arose from the necessity of finding alternatives for conventional therapies, which usually turn out to be monotonous and boring; this factors may cause a demotivation by patients and their later desertion. Thereby, with the purpose of face this weaknesses, *PlayTherapy* project was created, this video game pretends to be a tool for physiotherapists, and try to make physical therapies more interesting and fun in such a way that it increases the motivations of patients.

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ACRONYMS

GDD Game Design Document

MCP Metacarpophalangeal

PIP Proximal Interphalangeal

DIP Distal Interphalangeal

GUI Graphic Game Interface

CRUD Create, Update and Delete

MDLib Movement Detection Library

Part I

HANDS-ON: SUPPORTING HAND REHABILITATION MOVEMENTS IN PLAYTHERAPY VIDEOGAME

INTRODUCTION

1.1 CONTENT DESCRIPTION

This document describes the process of the development of a video game to support physical rehabilitation in *PlayTherapy* video game, which serves as a tool for physiotherapists in physical rehabilitation. This degree project is focused on the rehabilitation of hands which is integrated with *PlayTherapy* platform. First, [Chapter 1](#) describes the problem statement, the proposal justification, the scope of proposal, along with the general objective and the specific objective.

[Chapter 2](#) contains the reference framework which supports the purpose of this work, a literature review about digital games and how it supports physical therapies is presented. Then, a description of digital games development methodology is presented. This methodology is employed in *PlayTherapy*. Finally, this chapter ends with a review of the state of the art, where others project are using video games to physical rehabilitation.

In [Chapter 3](#) a global description of *PlayTherapy* is presented, this chapter describes how the methodology is employed, and how the development team interact with this methodology. At the end of this chapter, the architecture of the technologies used in the global project is shown.

In [Chapter 4](#) the pre-production phase of the project is presented, this phase contains all the previous work required to start with the implementation phase, here the selection of the technology used for hands recognition is described. Additionally, the initial design process of the mini-games is described.

Continuing, [Chapter 5](#) presents everything concerning with the implementation phase, this specifies how the mini-games were developed, and how the Leap Motion was integrated. Moreover, a additional contribution of a web application for *PlayTherapy* is presented in this chapter.

[Chapter 6](#) describes the results of the different tests which were carried out to validate the results of this degree project; also, the disclosure results are presented. Then, [Chapter 7](#) contains the final conclusions of this project, and additionally, some statements of future work.

Finally, [Appendix A](#) presents the game design document for the mini-games developed as part of this work

1.2 PROBLEM STATEMENT

One of the most important issues in people's life is health care, since it might have a significant impact in their quality of life. However, health may be at risk because of an accident or a motor neuron disease, such incidents require patients to perform a

physical therapy. World Confederation for Physical Therapy (2014) defines a physical therapy as a service provided by physical therapists to individuals and populations to develop, maintain and restore maximum movement and functional ability throughout the lifespan. During a physical therapy, patients have to assume responsibility for all their assigned therapies. However, these therapies are long and repetitive, resulting in a loss of motivation payment by patient.

This problems has been addressed before, nevertheless, one of the limitations presented previously were electronic sensors, which were not able to detect several body joints including hand and feed joints. However, recent results of new technological advances have facilitated the study in this field. Consequently, nowadays tools to support physical therapies related to hand rehabilitation are available (Iosa et al., 2015).

Specifically, the *PlayTherapy* project lead by Multimedia and Computer Vision group, supports physical rehabilitation for upper limbs using a series of mini-games. This process is achieved using the Microsoft Kinect 2 sensor which detects the movements performed by patients. Unfortunately, this technology does not detect more specific movements like hand movements. Therefore, a new kind of technology should be included within *PlayTherapy*, in order to support such movements. The main proposal of this work is to extend the scope of *PlayTherapy* project, in order to cover physical therapies related to hands movement recovering.

1.3 PROPOSAL JUSTIFICATION

Patients' motivation is the most important, yet the most difficult, aspect of a physical therapy (O'Gorman, 1975). Improving the motivation of a patient is a very important task; since, in this field, digital games have shown to be a great strategy for this purpose, Lohse, Shirzad, Verster, Hodges, and Van der Loos (2013) argues that the motivating and engaging properties of games can be used to help patients to perform a higher number of movements.

Due to the problems found in conventional therapies, a new kind of therapies have been proposed, which include a different variety of video games called *Serious Games*. A *Serious Game* is a digital game, designed for an additional purpose rather than for pure entertainment Asuncion, Socha, Sung, Berfield, and Gregory (2011). *Serious Games* on physical rehabilitation have been studied before, one of these studies explains that traditional treatment is often considered repetitive and boring, which might be partially solved using digital games. Moreover, the physiotherapy movements can be integrated into a video game in conjunction with rules and mechanics; exercising and challenging players' cognitive and motor skills as well as engaging their attention Rego, Moreira, and Reis (2010).

1.4 SCOPE OF PROPOSAL

This degree project is presented alongside a project of Universidad del Valle, called *Playtherapy: videojuego de apoyo a terapias de recuperación física*. The target audience of this

project is the population of the *Unidad de Medicina Física y Rehabilitación del Hospital Universitario del Valle*. The specific population group and the movements for the joints of the hands were defined along several meetings which occurred during the development of this degree project.

This project is neither a replacement for the physical therapies nor the physiotherapists themselves, on the contrary, it intends to assist the physiotherapists' work. Thus, the purpose of this project is to improve the motivation of patients, while they participate in therapy sessions.

The developed mini-games include a set of simple activities, whose aim is to cover one or more movements that assist the physical rehabilitation of patients. This work does not intend to cover all kinds of motor disability.

1.5 OBJECTIVES

1.5.1 General Objective

Extend the coverage of *PlayTherapy* video game, implementing a module that assists physical therapies for a set of hand joints.

1.5.2 Specific Objective

1. Select a set of technologies to detect hand joints.
2. Design and implement a module to enable the interaction between the hands detection technology and *PlayTherapy* video game.
3. Design and implement a mini-game which will assist hands movements.

REFERENCE FRAMEWORK

2.1 THEORETICAL FRAMEWORK

2.1.1 *Video Games*

The history of digital games started in the 70s, when Will Crowther and Don Woods created the first digital game, which consisted in some text lines (Wolf & Perron, 2003). Nowadays, digital games are used with additional purposes different from the original one, which basically was to entertain. Examples of fields benefited from digital games are education (Griffiths, 2002) and health (Kavalier, 2005). In these fields, digital games include different purposes such as teaching in the educational field and serving as a distraction tool in the medical field. Such games have had positive effects as they capture the attention of players, increasing their motivation and even helping them with pain management (Kavalier, 2005).

This kind of digital games are called *Serious Games*, which are expected to include additional objectives other than entertaining (Susi, Johannesson, & Backlund, 2007). However, this should be achieved without eliminating the fun factor completely, as it would lead digital games to lose their main attribute, which is keeping someone immersed in a world. Furthermore, according to Susi et al. (2007), the term *Serious Game* can be applied to a broad spectrum of application areas such as military, government, educational, corporate and health-care, which run on a personal computer or a game console.

Moreover, with the latest technological advancements, the number of fields that can be treated with digital games have increased significantly, some examples include health and sports Figure 1. Technologies like the Sony Playstation Move or the Microsoft Kinect have made it possible to start developing digital games that can interact directly with the person. Additionally, previous researches have pointed out the possible positive effects that can be achieved with this new kind of therapy, obtaining considerably good results with medical patients (Primack et al., 2012).

2.1.2 *Serious Games on the health*

As it was previously mentioned, games that have as their objective being *more than fun* are called *Serious Games*. According to Zyda (2005) a *Serious Game* is: "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives."

According to Wattanasoontorn, Boada, García, and Sbert (2013), every game, including computer games, can be specified by five components (Figure 2). The first component is

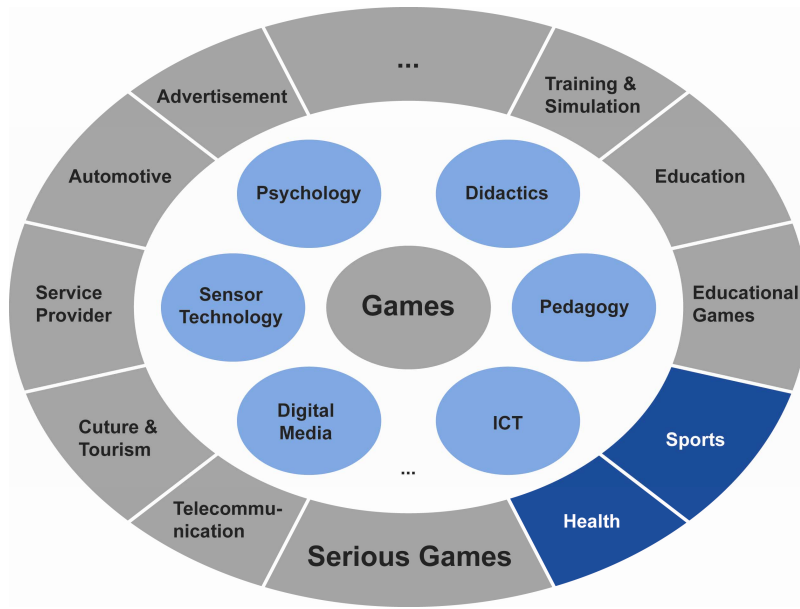


Figure 1: *Serious Games* for Sports and Health (Göbel, Hardy, Wendel, Mehm, & Steinmetz, 2010).

the *rules* that are responsible of creating a defined pattern, which establishes a connection between the game and the player. The second component is the *challenge* that gives an additional value, such as a bonus or a reward for achieving a specific objective, also, this component determines the level of difficulty that can be presented and motivates the player to keep playing and improve their performance. The third component is the *interaction*, which represents the communication with the player and the way that the game interacts with the player. The last component is the *objective*, which contains the action that is required to be achieved and usually requires an additional effort by the player. Inside of this component, two types of objectives can be evidenced: one being explicit and the other being implicit. While the explicit objective is only for entertainment, the implicit might include objectives such as increasing players' skills and abilities. Thus, the difference between a conventional game and a *Serious Game* consists in the existence of an implicit objective (Wattanasoontorn et al., 2013).

2.1.3 Methodology for the Development of Digital Games

The development of a digital game as well as the development of any other software product, requires a process which allows the planning of all the stages and steps that are required to obtain the final result. Said result is a product that is in accordance with what is planned with the developer and what is desired by the user. The methodology proposed by Godoy and Barbosa (2010) called *Game-Scrum*, is an agile methodology based on the lineaments of the agile manifest and was a derivation that appeared as a fusion between the XP(Extreme Programming) and Scrum methodologies.

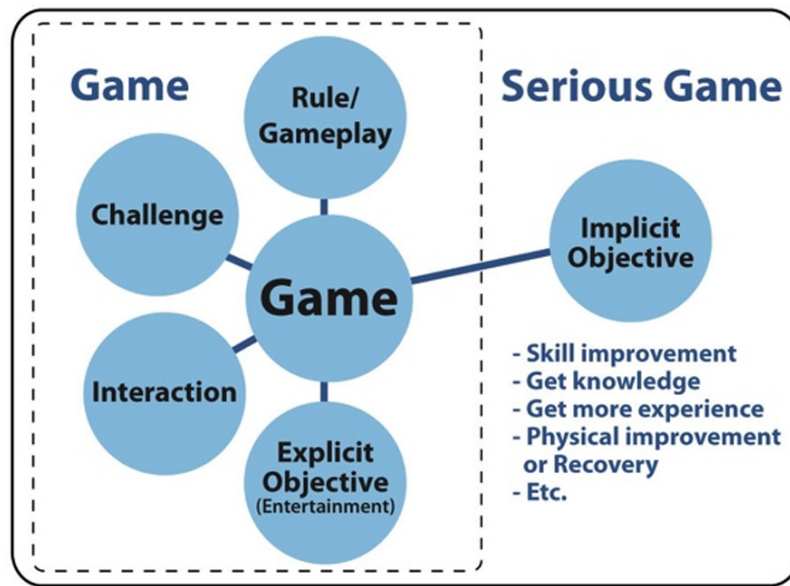


Figure 2: Functions of the Serious Games (Wattanasoontorn, Boada, García, & Sbert, 2013).

2.1.3.1 Stages of Game-Scrum methodology

1. *Pre-Production*: This is the first stage, each part of a previous investigation for the game creation is covered at this stage; furthermore, this stage is where the initial design is planned and how it is going to be the game. Also, it is defined the guidelines to follow by the programmer, like the digital game engine and the programming language for the implementation phase, likewise, an initial sketch of funniest factors on the digital game will be performed in this stage.
 - a) *Game Design Document*: This is a sub-stage of pre-production, in this stage, all the story about the world where the player is engaged is created, this document must therefore be a guide in production phase, also the document should be easy to understand to subsequently be transformed into a product backlog.
2. *Production*: Here all the aims of the project are defined, in this phase the roles of all members of the team should be defined to start with the development of the project, likewise, each task that should be developed on the project must be assigned to a member of the team. One of the features of this development methodology is that it is not necessary to finish all the tasks to start with the next iteration.
3. *Post-Production*: At this moment, the development of the digital game must be mostly finished, leaving the test of the game as a main objective, the tests are performed with the final user to validate the effectiveness of the game.

2.1.4 Leap Motion Sensor

Leap Motion is a sensor of great precision designed for capture the movements of the hands, this sensor has been used in the last years along with the virtual reality viewer Oculus Rift, these technologies are foraying in the virtual realty world, which Leap Motion has shown that have a great precision on hands tracking [Figure 3](#).

A study performed by Weichert, Bachmann, Rudak, and Fisseler (2013) shown the effectiveness of Leap Motion, which indicate that it has a millimeter accuracy reading the data. To develop this study was built a industrial robot, because the human hand present a margin of error, which would be evidenced in the final results. This study reflected that regardless of the plane the Leap Motion obtained a precision of less than 2,5 mm.

Due to this new technology, studies have started to looking for the possibility of design digital games of physical rehabilitation focused on hands. One of the researches in this field, obtained excellent results when was applied this new kind of therapies using the Leap Motion, the final results was an improvement by patient's hands rehabilitation, and they concluded that the use of this technology is feasible for this field in the future (Iosa et al., 2015).

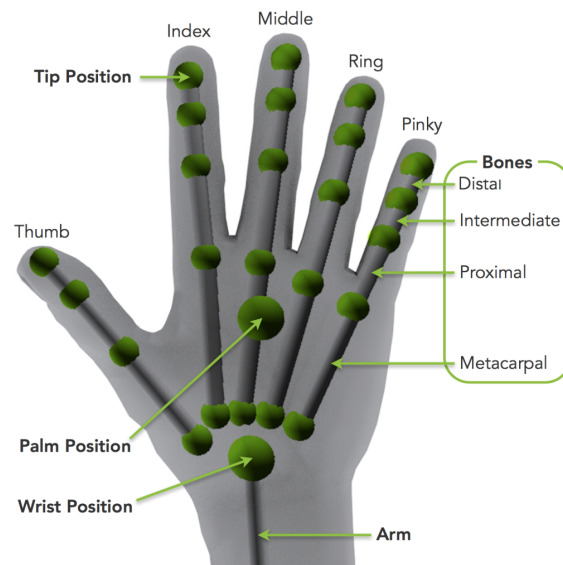


Figure 3: Leap Motion joints of hands recognition (Leap Motion. Inc, 2014).

2.1.5 Microsoft Kinect 2 Sensor

Kinect sensor is a device developed by Microsoft company, which is the interface that capture the movement of a person and send it to a Xbox or a computer. The purpose of this device is allow design digital games in which person can interact directly with the

game. With this new technologies have been possible to perform a new kind of digital games and the benefits that can be obtained with this devices.

Chang, Chen, and Huang (2011) conclude that this technologies are useful on rehabilitation physics process, since improve the motivation of a patient when the rehabilitation process is performed, which is one of the most difficult things of achieve on the rehabilitation process.

One of the principal features of Kinect 2.0, is that it can track the movements of 6 bodies at the same time, and everyone with 25 different nodes that are distributed along of it, the union of this nodes create the skeleton that is used to replicate the human body on the digital game [Figure 4](#).

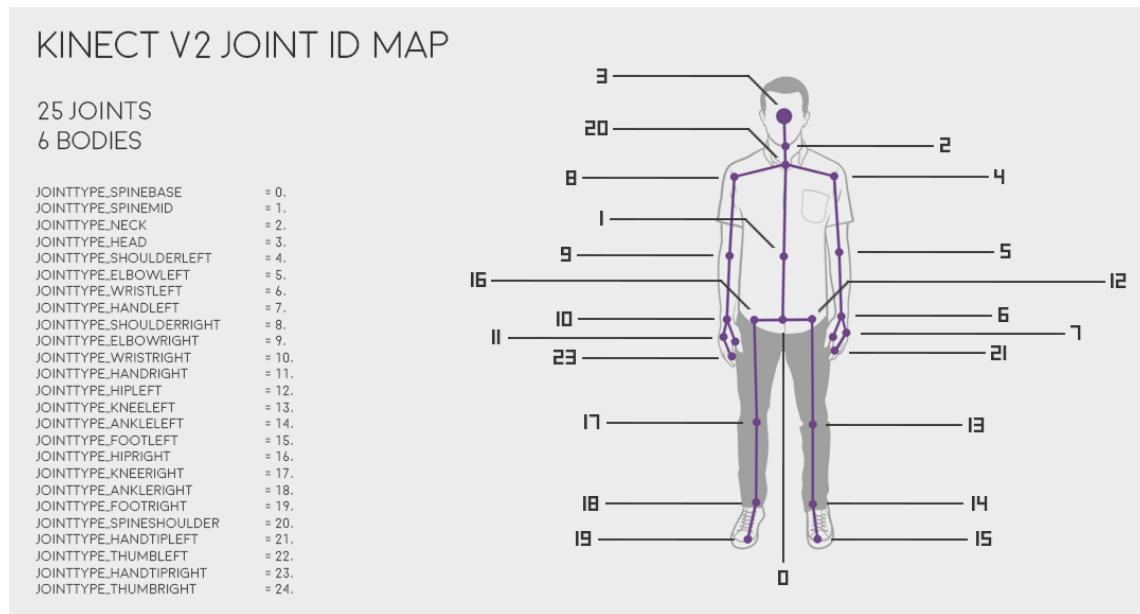


Figure 4: Kinect skeleton (Microsoft, 2013).

2.2 STATE OF THE ART

The emergence of new technologies and the work with physical therapies through digital games, has a recent field of study, due to before the technologies that can track the movements did not exist, however in the last years a new kinds of sensors have been created like Microsoft Kinect, Playstation Move and Leap Motion, and because of that has been possible to study this field. Currently this kind of therapies are only in some countries since it's a new field. The most prominent projects that are working with this new kind of therapies are:

1. *VirtualRehab*: This company is dedicated to physic rehabilitation through the development of digital games, this company is supported by the use of Microsoft

Kinect and Leap Motion, to perform the therapy, currently they are working on Spain, United Kingdom, Mexico and Chile; they give a feedback in every session of therapy.

VirtualRehab is one of the few companies that are working on hands rehabilitation, which is performed through the Leap Motion, this give they a great advantage against the other companies that are working in the same field (Virtualware Group, 2017).



Figure 5: Physic rehabilitation with Virtualrehab

2. *SeeMe*: This is a physic rehabilitation system, which use the technology of Microsoft Kinect, this was designed to support the rehabilitation process and save the report of the progress; it has a management user system, which allow planning the training for each patient, also the system allow to the therapist assign tasks to each patient, this tasks can vary depending of the level of the patient (Brontes Processing, 2011).
3. *ReaKinG*: This project pretend to tackle the physic rehabilitation through digital games, it is focused on older people, his purpose is not just do the physical therapy, but also create a digital game which can help to the older people to keep an exercise routine. To the development of this, they are using Kinect of Microsoft, which is the interface between the user and the digital game (Pedraza-Hueso, Martín-Calzón, Díaz-Pernas, & Martínez-Zarzuela, 2015).

PLAYTHERAPY

3.1 DESCRIPTION

PlayTherapy is a digital game which is part of a research project that has as its main purpose to contribute with the physical rehabilitation process; such digital game looks for fostering a new experience of therapy, where people can feel more comfortable, and at the same time enhancing patients' disposition toward said therapy.

Currently *PlayTherapy* is divided into a set of mini-games; thus, each one of these mini-games are focused on a specific section of the body, and depending on patients, a specific mini-game is used. Originally, *PlayTherapy* was thought to work only with the body parts provided by Kinect skeleton (Figure 4), and now it can work with hands joints (Figure 3).

At this time, *PlayTherapy* has a web application, which is the interface where the therapist can supervise the progress of the patients, said application allows therapists to manage everything concerning with CRUD operations; also, it shows the information of patients' progress, as well as their the functional independence measure (FIM).

3.2 DEVELOPMENT METHODOLOGY

This project was developed using the Game-Scrum development methodology, which was described in Section 2.1.3. This methodology proposes three main development stages: pre-production, production and post-production, which are defined in the next chapters. The roles that are taken into account on *PlayTherapy* project are scrum master, team members, product owner and final users.

3.3 DEVELOPMENT TEAM

This project is comprised by students and professionals on the fields of software development and physiotherapy. Each member has a specific purpose: the physiotherapists (Product owner) are in charge of validating the mini-games, and making decisions about physical rehabilitation issues, so that *PlayTherapy* achieves its goal.

The development team is in charge of designing, programming and functionally testing the mini-games. Additionally, this team leads review and testing meetings involving physiotherapists and final users. Finally, a master's degree engineering student plays the role of scrum master.

3.4 ARCHITECTURE

3.4.1 General Architecture

The general architecture of *PlayTherapy* was defined at the beginning of the project [Figure 6](#), it consist of three layers:

1. *Logic and display layer*: This layer is in charged to show the data collected by the link layer, in this layer, the user can interact directly with the web application of the digital game.
2. *Link layer*: This is an intermediate layer, here es where the programmer works.
3. *Physic layer*: Here is located the hardware components, that is necessary in the project, like the GPU, the processor and the sensors that are needed to interact with the user.

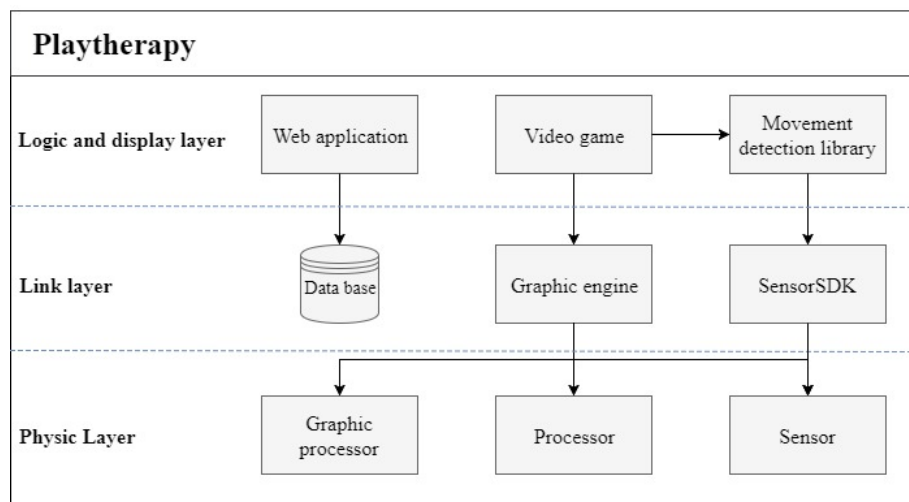


Figure 6: *PlayTherapy* General Architecture

3.4.2 Unity Engine Game Component Interaction

The components used on Unity are used to construct the digital game, this components interact with themselves:

1. *Scenes*: The game is composed by scenes, this scenes are the visual representation of the game objects in the game, and over this components is built the game.
2. *Game Objects*: These are all the assets and object that are use in the scene, the game objects are composed by components that are the features its.

3. *Components*: These are items that can be added to the game object, these items are a specific functionality like position, physics or scripts.
4. *Assets*: This is a representation of the items that can be used in the scene, such representation can be a music file, object model, or an image among others.

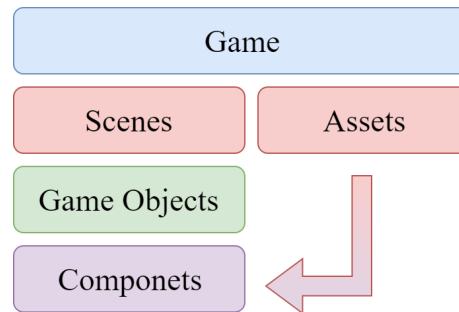


Figure 7: Unity Components Architecture (David Gouveia, 2017).

3.4.3 Web Framework Architecture

The web application is built on Django, which is a framework for web development in python. According to Holovaty and Kaplan-Moss (2009), the Django framework uses a MTV (Model Template View) architecture [Figure 8](#). This architecture has three main components:

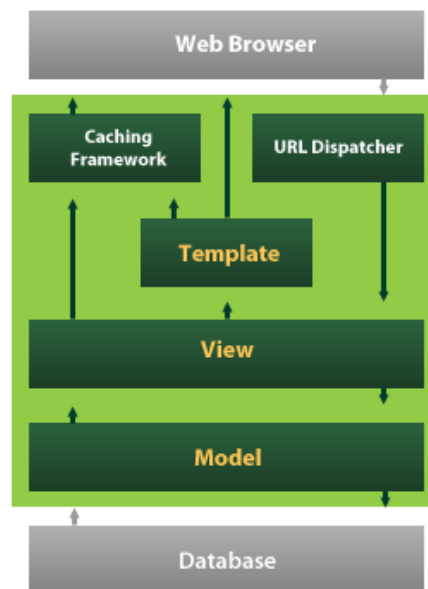


Figure 8: Django MTV architecture (akshay pai, 2017).

1. *Model*: This layer contains everything related to the data of the application, how to access it, how to validate it, which behaviors it has and the relationships between the data.
2. *Template*: This layer is in charge of displaying the information of the application; it is directly connected to the browser.
3. *View*: This is the logic layer of the application, it can access the model and extract the data to be shown on the template; it communicates the model with the template.

PRE-PRODUCTION

This chapter talks about the pre-production phase, this phase has everything about the previous investigation before to start with the development of the project. [Section 4.1](#) talk about the previous work made to the creation of the game, [Section 4.2](#) describe the selection of tracking technologies that are going to be used in this project, in [Section 4.3](#) is everything related with the integration of tracking technology with *PlayTherapy* project. Finally, in [Section 4.4](#) is described the process of design the story of the mini-games in this project.

4.1 PREVIOUS RESEARCH

4.1.1 *Physical Rehabilitation*

At the beginning of the project was necessary perform previous investigations to dock with *PlayTherapy* project, for that was necessary meet with the physiotherapist of the *Hospital Universitario del Valle* to collect the information about hands rehabilitation. This was crucial to the development of this project due to the final users are physiotherapist and patients.

These meetings are conformed by the development team of *PlayTherapy* and the physiotherapist of the hospital, here the functional movements that are involved in this project were defined. The most remarkable problem was the lack of knowledge about physical rehabilitation and the movements that were necessary to carry out this.

4.1.2 *Game Development Aspects*

Game development is conformed by multiple fields [Figure 9](#), each one of these fields have a specific purpose in the project as designing, developing and release the product; as a result of that, a set of difficulties were presented to the development team because none of the team members had a knowledge on art or design aspects, so with the purpose of reinforce these knowledge was necessary perform courses about game development and read documents about it.

All the aspects that are involved with the creation of the story and the objectives of the game are described in [Section 4.4](#). The aspects of art creation were defined with the development team, and most of assets used in this project were provided by Unity Assets Store.

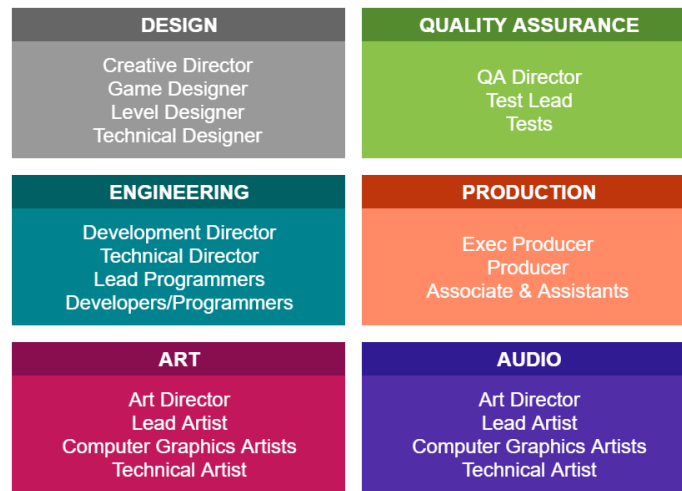


Figure 9: Aspects of Game Development (Brian Winn, 2016)

4.2 SELECTION OF TRACKING TECHNOLOGY FOR HANDS JOINTS

To integrate a game that can be controlled by hands, it was necessary to look for new technology that can track the joints of hands, due to the Kinect can not track this movements; this new interface should be able to connect the computer and *PlayTherapy*, and at the same time it should be suitable with Unity 5.

According with *PlayTherapy* project the technology should be compatible with the main project and its main purpose. The main factors taken into account in the selection of the technology were that the device should track the joints of hands and be compatible with Unity Engine, furthermore this technology can not be invasive, that means that it should not have physical contact with the user.

1. *Microsoft Kinect 2* (Microsoft Corporation, 2014): The latest sensor tracks as many six complete skeletons, and 25 joints per person Figure 4, this sensor has a full HD camera of 1080p and it can give a frame rate of 30 fps (frame per second). This sensor is designed to track the skeleton of an entire person.

This technology has a complete documentation and support multiple languages: C++, C#, Visual Basic, or any other .NET language. One of the main features is that this is focused on game development, thus

2. *Myo Gesture Control Armband* (Thalmic Labs Inc, 2014): This is an armband that can capture the movements of the muscles of the arm, and allows control the phone and computer; it is focused mainly on arm/hands tracking and currently support 5 pre-set gestures but it is possible combine these to create new gestures Figure 10. This armband has a full documentation and API reference which support C and C++ languages, and it can be integrated with Unity project.
3. *Leap Motion* (Alex Colgan, 2014): This sensor is focused on hands tracking, it consists of three infrared LEDs that can track with a wavelength of 850 nanometers, the

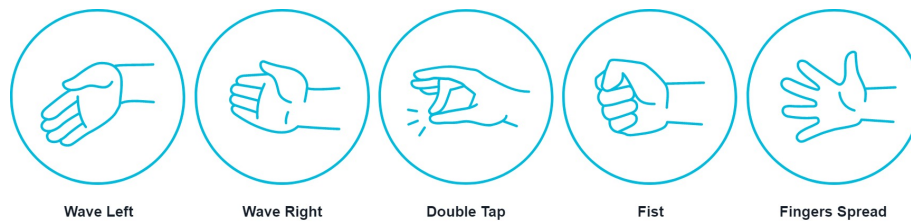


Figure 10: Myo Gestures Recognition (Myo Support, 2014)

last version of this (Orion) allow follow the movements of the hands until 2.6 feet (80 cm) above of the sensor; this device allows to map 24 joints of the hand and additional can map 3 joints of the arm [Figure 3](#).

This technology has a large community and the SDK is designed to work with: JavaScript, Unity, C#, C++, Java, Python, Objective-C and Unreal.

4. *CamBoard Pico* (Pmd Technologies, 2017) is a hands tracking sensor which has a ToF-sensor, this device has a frame rate up to 45 fps and its SDK is built on C, C++ and Matlab. Unfortunately this is a new technology and it does not have a big community, also its API is accessible only to the people who bought the sensor.
5. *Noitom Hi5 VR Glove* (Noitom Ltd, 2017): is a full-hand motion capture, this is one of the first gloves designed to follow the movements of the hand in a virtual reality environment, these gloves are currently in design stage, but the company announced the release date in 2017.

These gloves can offer an orientation output rate of 90 fps, and its SDK support the development on Unity, Unreal Engine 4 and C++; these are focused mainly on games design and virtual reality environments.

In [Table 1](#) is the comparison between the previous technologies described, in this table there are some special features that were taken into account at the moment of choose the device; One of the most important things, it was that the device should be possible of integrate with *PlayTherapy*, and it should be able to track the joint of the hand.

To choose the technology was necessary schedule a previous meeting with physiotherapist and get to an agreement of which of these technologies would be the best; at the end, the Leap Motion sensor was chosen, due to this sensor can follow the most important joints of the hands, and it can be integrated with the global project; One of the main features of Leap Motion is that it has big documentation and it is supported by its community.

4.3 TECHNOLOGY INTEGRATION WITH PLAYTHERAPY

The first version of *PlayTherapy* works with Microsoft Kinect to recognize the movements of the full body, in this version was created MDLib (Prado, Lopez, Gamboa, & Trujillo, 2017) that is a movement detection library, this library has as a purpose get an active measure of the angles which are passed to the digital game.

FEATURES	KINECT 2	MYO	LEAP	CAMBOARD	HI5 GLOVE
Cost (USD)	\$110	\$200	\$70	\$580	\$400
Is it in development?	No	No	No	No	Yes
SDK language	C++, C#, JS, Java/Basic	C, C++	C++, C#, JS, Java, Python	C, C++, Mathlab	C++
Unity integration	Yes	Yes	Yes	No	Yes
Full hands detection	Partial	Partial	Yes	Yes	Yes
Joint Tracking	Yes	No	Yes	Yes	Yes
Tracking method	Infrared	Electromyography	Infrared	Infrared	IMU sensor
Range	0.5m-4.5m	15m	0.8m	0.1m-4m	Unknown
Invasive	No	Yes	No	Yes	Yes

Table 1: Device comparison

4.3.1 Technology Architecture

Leap Motion provides as default two varieties of APIs: a native application interface and a WebSocket interface; for this project the native interface is used, due to its nature. The architecture for this native interface is described in [Figure 11](#), this architecture starts with the service running on the OS and finish with Background application, the components of this architecture are described below (Leap Motion. Inc, 2017).

1. The Leap service is in charged of receiving the data directly from the device, additionally, it collects the data from the leap settings app to charge the default preferences of users. This service is used by leap-enable application to collect the information of the device.
2. The Leap motion application automatically in background, as a service (Windows) or a daemon (Linux & Mac), this service allows to the users set their own preferences.
3. This component use the leap service and collect the information of motion tracking.

4. The background component is used to control the sending of data, the service stop send data to the application if it lose the operating system focus.

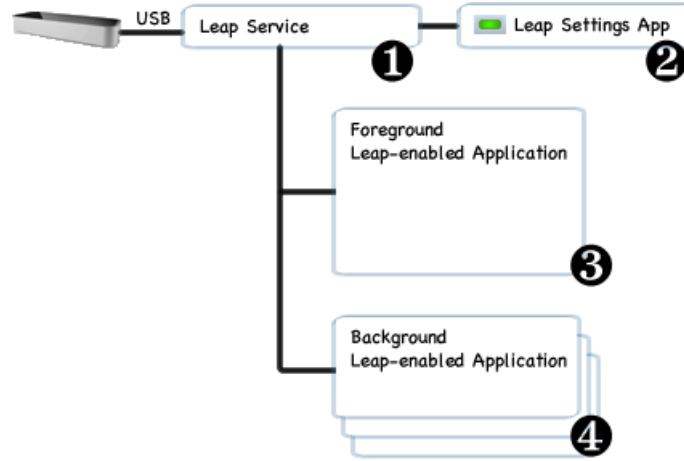


Figure 11: Native Application Interface (Leap Motion. Inc, 2017)

4.3.2 Technology Integration with MDLib

To use the technology of Leap Motion with *PlayTherapy*, an integration with MDLib was necessary, therefore, a restructuring of its architecture was performed. Thus, [Figure 12](#) describes the new architecture for MDLib; The original architecture of MDLib allowed a simple integration with the service of Leap Motion.

The purpose of this library is to provide an active measure of the angles for specific movements, this angles are mapped directly in the digital game, and then they are stored in the data base for a later diagnostic.

4.3.3 Movements Support

The Leap Motion is a great device of tracking, but like all the sensors it has some limitations. The sensor is based in three infrared which have to be positioned under the hands, this infrared create a line of sight which capture the movements of the hand; as a result, when the

The list of movements supported by Leap Motion are described in [Table 2](#), to create this list was necessary hold a meeting with the physiotherapist, and validate the supported movements with them.

4.3.4 Approval with Physiotherapist

Once the list of supported movements was created, it was necessary to schedule a meeting with the physiotherapists to validate the mentioned list. The purpose of said meeting

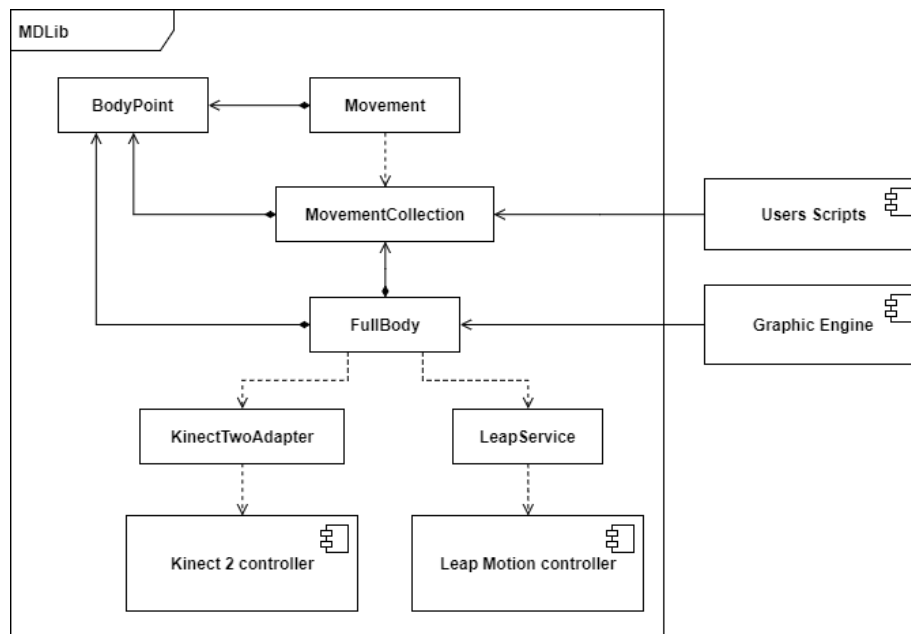


Figure 12: MDLib architecture

was to let the physiotherapists interact with the visualizer mode of Leap Motion, allowing them to determine if a certain movement could be evaluated. Thus, the parameters taken into account to approve these movements were correct realization of the movement captured by Leap Motion with respect to the movement carried out.

4.4 GAME DESIGN

This section describes the process of how the story behind the games was created, as well as its objectives and challenges. Additionally, due to these games having an intrinsic objective, it was also necessary to determine the list of movements the games would include. Thus, this section was performed following the Game-Scrum methodology, which entails the creation of a game design document, presented in [Section 4.4.3](#) (Godoy & Barbosa, 2010).

4.4.1 Brainstorming

Before to start with the design of the game, a meeting with the development team was held, the purpose of this meeting was create a sketch of the mini-games. Thus, said sketch should had a short description of the game, as well as the dynamics of the mini-games. Finally, the sketch was presented to the physiotherapist to their approval.

As a result of the brainstorming, two mini-games were obtained, the first was called *Viajando en el Espacio*, and the second one *Guerra Medieval*; which are focused on recover

JOINT	MOVEMENT	RESULT	PLANE
Wrist	Ulnar deviation	Yes	Coronal
	Radial deviation	Yes	Coronal
	Flexion	Yes	Sagittal
	Extension	Yes	Sagittal
Thumb	P.I.P. Extension	No	-
	P.I.P. Flexion	No	-
	Abduction	Yes	Sagittal
	Adduction	Yes	Sagittal
	M.C.P. Flexion	No	-
	M.C.P. Extension	Yes	Coronal
M.C.P. Fingers 2 - 5	Flexion	Yes	Coronal
	Extension	No	-
P.I.P. Fingers 2 -5	Flexion	No	-
	Extension	No	-
D.I.P. Fingers 2 -5	Flexion	No	-
	Extension	No	-

Table 2: Movements supported by Leap Motion

the functional movement for the joint of hands. Eventually, the content of the sketch was used to create the game design document which is described in [Section 4.4.3](#).

4.4.2 Definition of movements involved

Once the main idea of the mini-games were defined, it was necessary determine which functional movements would be involved in such mini-games. Also, the movements involved in the mini-game should comply with the purpose of a physical rehabilitation. Hence, the definition of such movements were achieve with the assistance of a student of physiotherapy. Finally, this movements were used to create the rules and mechanics of the mini-games.

4.4.3 Game Design Document

This document was built according to the guidelines of Godoy and Barbosa (2010), the standard used to construct this document was defined by the development team. Therefore, this document contain a general description about *PlayTherapy*, and all the mini-games that it contains. In the [Appendix A](#) is presented the full description of mini-games which are involved in this project.

4.4.4 Mini-games description

Initially this degree project comprised the development of one mini-game, but in the end two mini-games were developed. [Table 3](#) and [Table 4](#) present a short description of the mini-games *Viajando en el Espacio* and *Guerra Medieval* respectively.

Viajando en el Espacio mini-game	
Description	This mini-game describes the journey of Daniel and Juan, who embark on a space travel with their spaceship, during the travel they are going to afford a set of obstacles to cross the space.
Objectives	The main objective of this mini-game is to cross the space and get as many points as possible, for this it is necessary collect bonuses and destroy or evade the meteors.
Movements involved	Wrist flexion, wrist extension and grab

Table 3: *Viajando en el Espacio* Description

Guerra medieval mini-game	
Description	In this mini-game, the characters travel to the past and have to confront the wars of the age; therefore, they a capture nearby cannon to defend themselves from the enemy armies.
Objectives	The objective is shot the soldiers and dragon which to obtain a positive score, and also, try to keep the enemies far from the fences.
Movements involved	Wrist flexion, writ extension, radial deviation, ulnar deviation and grab

Table 4: *Guerra Medieval* Description

PRODUCTION

This section describes everything related to the production phase of this project, it contains a description of how it was developed this project. [Section 5.1](#) describes the distribution of the jobs that was needed to carry out this project. Then, [Section 5.2](#) and [Section 5.3](#) present everything related to how was the implementation of this work. Finally, [Section 5.4](#) has a description of the additional contributions to *PlayTherapy* project.

5.1 PRODUCT BACKLOG

At the beginning of the production phase, it was necessary establish the product backlog, as it is described in the Game-Scrum methodology. said backlog was built as of the game design document and the requirements of therapist. Eventually, the product backlog was divided multiple sprints, which are represented in [Table 5](#), [Table 6](#) and [Table 7](#), In these tables are represented the User Stories(US) and Some Unassigned Task(UT).

This product backlog contains a previous sprint to the beginning of this degree project; the sprints 1 to 9 contain an additional contributions to *PlayTherapy* project. Thus, the user stories involved in said sprints contributed to the creation of a web application which is described in [Section 5.4](#). Finally, in the sprints 11 to 20 were executed the work proposed in this project.

5.2 LEAP MOTION MODULE

As it was described in [Section 4.3](#), a module to integrate *PlayTherapy* with Leap Motion was required, said module was made following the architecture proposed in [Figure 12](#). Thus, to carry out this module, it was necessary to perform an additional changes to MDLib, which are described in the next section.

5.2.1 MDLib Implementation

The initial version of MDLib allowed an easy integration with other technologies. Therefore, to achieve this objective a sequence of steps were performed:

1. Adding the joints to BodyPoint class, this class is a representation of the joints which are going to be used to the tracking.
2. Developing the functions to calculate the angle for a specific movement.
3. Connecting the LeapService with FullBody classes to update the position of the joints.

USER STORY	POINTS
Sprint 1 (15 Aug 2016 - 29 Aug 2016)	28
US #2 Patient creation V1	28
UT #18 Compose assigned GDD sections	-
Sprint 2 (29 Aug 2016 - 12 Sep 2016)	-
UT #30 Create the story board for the web manager	-
Sprint 3 (13 Sep 2016 - 27 Sep 2016)	96
US #38 CRUD Therapist V2	48
US #37 CRUD Patients V2	48
Sprint 4 (10 Oct 2016 - 24 Oct 2016)	-
T #65 Look for information about the problem to get ideas	-
Sprint 5 (20 Oct 2016 - 3 Nov 2016)	10
US #129 Therapist management V3	4
US #130 Patient management V3	6
Sprint 6 (3 Nov 2016 - 16 Nov 2016)	-
UT #177 Create a script for populating the database	-
UT #178 Organize the model for showing the table in the admin page	-
UT #178 Populate database	-
Sprint 7 (16 Nov 2016 - 30 Nov 2016)	31
US #157 Create therapy session observations	14
US #192 Webadmin index page should present project relevant information	4
US #178 Webadmin dashboard should present summary of statistics	4
US #209 The test in results screen is blurred	9

Table 5: Sprints 1 - 7 backlog

USER STORY	POINTS
Sprint 9 (13 Feb 2017 - 27 Feb 2017)	30
US #248 Index template update	9
US #192 Add bread crumb to the webadmin	8
US #178 Webadmin dashboard should present summary of statistics	4
US #209 The test in results screen is blurred	9
Sprint 11 (27 Mar 2017 - 10 Apr 2017)	10
US #303 VE: Create game scene	10
Sprint 12 (10 Apr 2017 - 24 Apr 2017)	28
US #306 VE: Ship movement control	8
US #324 VE: Include enemies and bonus elements V1	20
Sprint 13 (24 Apr 2017 - 8 May 2017)	10
US #306 VE: Implement scoring system	10
Sprint 14 (8 May 2017 - 22 May 2017)	24
US #337 VE: Implement feedback system	10
US #334 VE: Implement parameters screen	8
US #336 VE: Save game state in DB	6
Sprint 15 (22 May 2017 - 5 Jun 2017)	3
US #460 VE: Results screen	3
Sprint 16 (5 Jun 2017 - 19 Jun 2017)	20
US #460 VE: Include enemies and bonus elements	14
US #341 VE: Implement game tutorial	6
Sprint 17 (22 Aug 2017 - 6 Sep 2017)	3
US #459 VE: Add final animation	3

Table 6: Sprints 9 - 17 backlog

USER STORY	POINTS
Sprint 18 (6 Sep 2017 - 20 Sep 2017)	44
US #672 Support initial set of hand movements	8
US #707 Support movement detection	12
US #709 GM: Game scene	10
US #710 GM: Interaction elements	14
Sprint 19 (20 Sep 2017 - 4 Oct 2017)	38
US #711 GM: Movement control	16
US #712 GM: Scoring system	6
US #714 GM: Parameters screen	8
US #715 GM: Game persistence	8
Sprint 20 (4 Oct 2017 - 18 Oct 2017)	29
US #713 GM: Feedback system	10
US #716 GM: Game tutorial	6
US #717 GM: Final animation	5
US #718 GM: Results screen	8

Table 7: Sprints 18 - 20 backlog

5.3 GAME IMPLEMENTATION

At this stage the game design document should be finished, this is important because without this the implementation might be delayed and the objective of the game could be lost. This is one of the longer and harder stages since it requires additional knowledge as art design.

The development team and the physiotherapists decided that there are some components that the mini-games should have, said components should help to the rehabilitation of patients as well as the work of physiotherapist. The component that are involved in this project are:

- Game scene
- Control Movements
- Interaction with the Objects
- Point System
- Parameters Configuration GUI

- Mini-Game GUI
- Tutorial GUI
- Final Score GUI
- Database Score System
- Feedback System

At the end of the implementation, each mini-game have to be approved with the physiotherapists to validate that the objectives of the therapy session are fulfilled, then if the physiotherapists have recommendations, these are transformed into a *issue* that would be resolved in the next sprint. Finally, when the mini-game is finished, it is tested with a real patient to get his feedback and annotate a possible *issue* or recommendation.

5.3.1 Game scene

This component is where the ambientation of story take place, this component is very important due to this component help to keep the player immerse into the game. [Figure 13](#) illustrate the scene of the mini-game *Guerra Medieval* here can be evidenced the landscape and the object that represent a fight between two sides. Subsequently, this scene will be the base to continue with the construction of the mini-game.



Figure 13: Guerra Medieval Scene

5.3.2 Control Movements

The control movement is fundamental to the construction of this project, for that purpose MDLib is used in the mini-game; the implementation said library it is achieved creating an instance of FullBody class, once it is created by Unity constructor it is able to be used by other scripts of the mini-game, which can obtain a measure of the angles and transform these values into a visual representation or an internal processing.

5.3.3 Interaction with the Objects

The interaction with the object have to be clear and easy to understand, due to it should reflect the objectives and the rules for the player; to create a specific function to each object of the scene, it is necessary create scripts which manage the behavior of said objects. Figure 14 shows the scripts that interact with the objects of *Guerra Medieval* mini-game, here each one of the objects has its own scripts that later would be connected with the script that manage the entire mini-game.

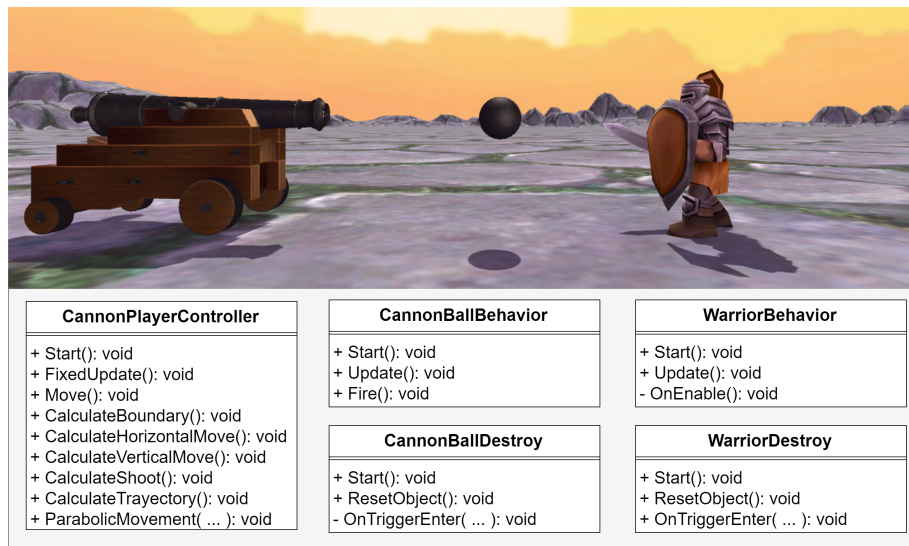


Figure 14: Objects interaction Guerra Medieval

5.3.4 Point System

The point system reflect the good actions performed in the mini-game, this point system should be a guide to the player of how is his performance. Also, this points are used by the program to calculate the global performance of the user, and compare it with his best previous result, Finally, this points are stored into a database for a later analysis.

Each point is achieved when a correct action is done, and if a wrong action is performed then a negative points are summed to the score. In Figure 15 is showed the

score panel that is updating while the mini-game is running. At the end, the final score obtained is displayed in the final score GUI.

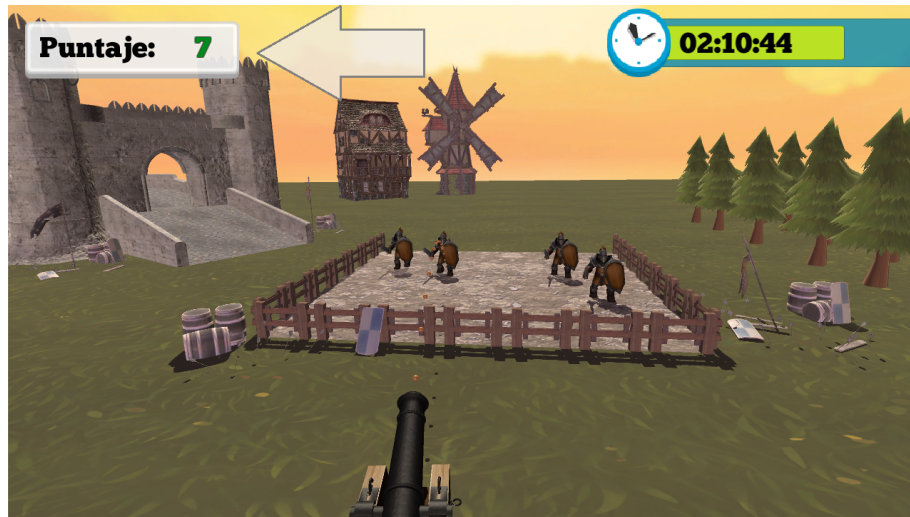


Figure 15: Objects interaction Guerra Medieval

5.3.5 Feedback System

To improve the performance of the patients, a feedback system was implemented, this system should be clear and consistent in order to guide the patient to a good action. The feedback system in *Guerra Medieval* shows when an correct action is performed by text message that contain the number of points achieved. Also, it display an arrow when a enemy is about to disappear [Figure 16](#).



Figure 16: Guerra Medieval Feedback Messages

5.3.6 Parameters Configuration GUI

Parameters GUI allows to physiotherapists modify the behavior of the game, here the physiotherapist can choose the level of difficulty to the patient or the movements involved in the therapy session. Figure 17 represents the parameters GUI of the mini-game *Viajando en el Espacio*; there are some common factors that mini-games should have in this GUI, these factors were proposed by the physiotherapist and correspond to the normal behavior of a therapy session:

- *Type of session*: As a regular therapy session, it can be performed by time or number of repetitions, the selection of said parameter is decision of the physiotherapist. Thus, when the time option is selected, the mini-game ends when the time is over, and if number of repetitions is selected, the mini-game ends when the patient achieve to finish all the movements that they were assigned.
- *Movements involved*: As a requirement of the physiotherapists, the mini-games should be able to adapt to the necessity of the patient, thereby, the physiotherapist should be able to select which movements are going to be used in the mini-game. Also, the angle threshold to recognize the movement should be able to be modified.
- *Additional parameters*: these parameters depend of the functionalities of the mini-game. Thus, the objective these parameters is adjust the difficulty level of said mini-game, such parameters can vary since spawn time of an object until number of objectives per second.

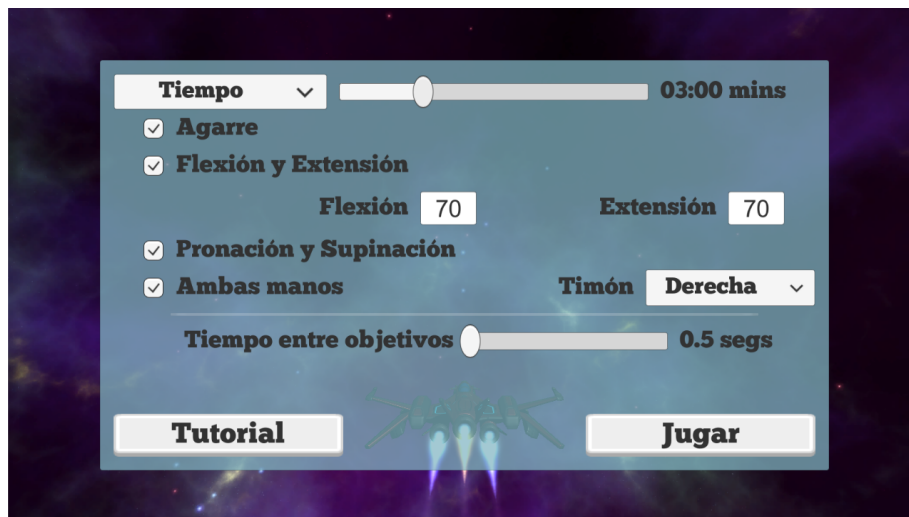


Figure 17: Viajando en el Espacio parameters screen

5.3.7 Tutorial GUI

The purpose of this GUI is to explain the rules, dynamics and objectives of the mini-game, as well as its story; One of the requirements of this GUI is that the information must be easy to understand, due to the final users of this screen are the patient. Additionally, the implementation of said GUI consist of a class called *Tutorial manager*, which manages each one of the pages that the tutorial can contain.



Figure 18: Viajando en el Espacio Tutorial Screen

5.3.8 Final Score GUI

The final score GUI appear once the mini-game is over, it represents the performance of the patient in the mini-game, and compare it with the maximum score obtained previously. Thus, this GUI consist of three stars and a text message (Figure 19), the final score is calculated by the equation $final_score = (score_obtained / total_score) * 100$.



Figure 19: Viajando en el Espacio Final Score Screen

5.3.9 Mini-Game GUI

Here is where the mini-game is performed, this GUI works with the union of the component previously named, the class in charge of connect all the other components is called *Game Manager*, it controls since the mini-game starts until it finishes. This class consists of three main states: *STARTING*, *PLAYING* and *GAMEOVER*.

In this way, [Figure 20](#) show the behavior of the *Game Manager* class. Thereby, said class starts showing the parameters GUI, thus when the game starts the class enter inside of a loop checking if the mini-game is over. Then when it is over the result screen is showed.

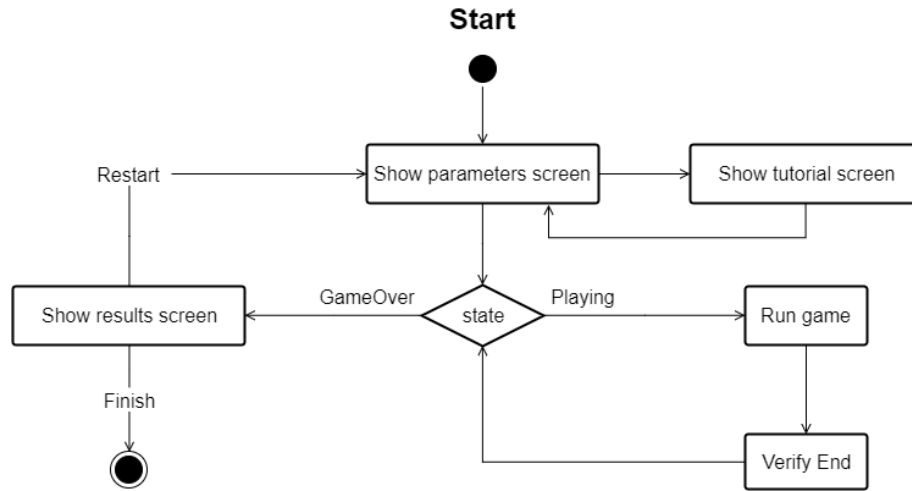


Figure 20: Simplified Activity Flow Diagram of Game Manager

5.4 ADDITIONAL CONTRIBUTIONS

Additional to this project, some complementary contributions were carried out; among which is a web page module, the necessity of create this module arose due to the failure of Unity to create user interfaces for big amounts of data, data that should be accessible to physiotherapists for a later analysis. Hence, a web application was created by the development team of *PlayTherapy*, the modules that are going to be described in the next sections were developed with the assistance of the development team, in this way the contributed modules were:

- Landing module
- Dashboard module
- Patients module
- Physiotherapist module

The technologies used to build this web page module were Django Framework as was said in [Section 3.4.3](#), and PostgreSQL as a database management system.

5.4.1 Landing module

The landing page is the first page that can be found when a physiotherapist open the web application, the purpose of this page is to bring relevance information about the *PlayTherapy* project; also, this page should have a log-in button to provide access to physiotherapist to the dashboard page, In [Figure 21](#) is the landing page, this page was created starting from a free template with a one page design, and adapted to work with Django template.

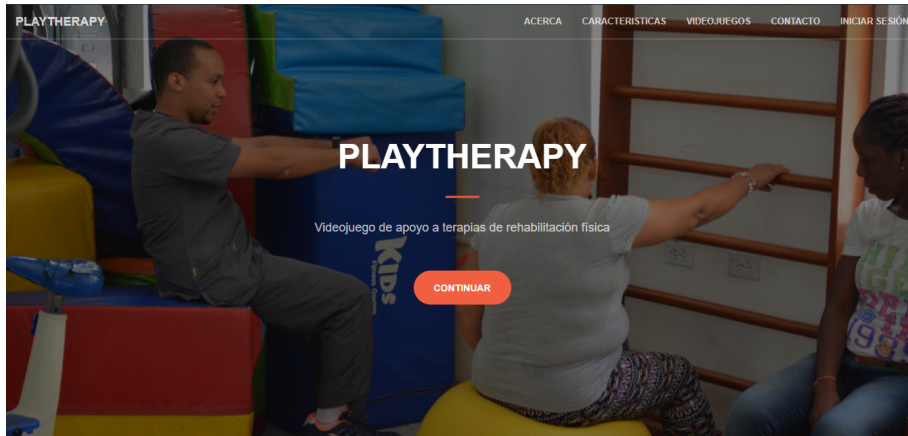
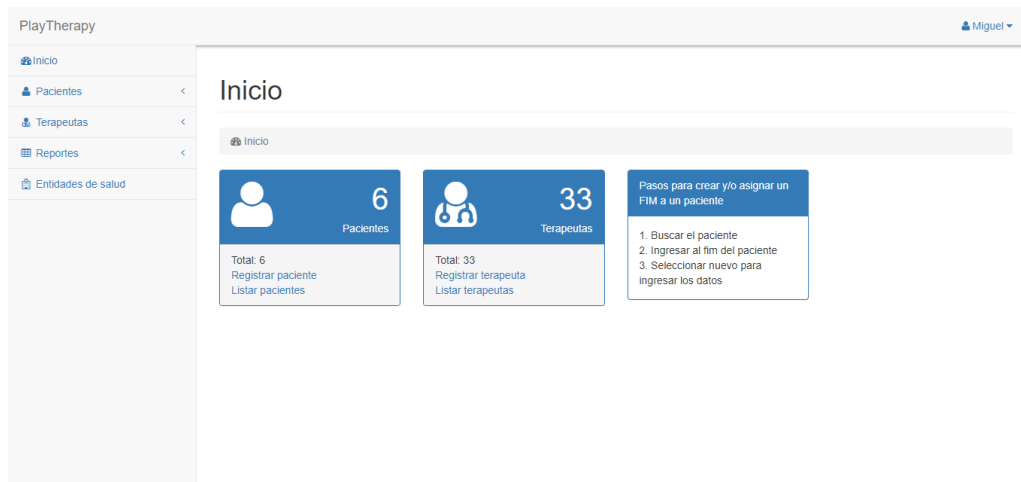


Figure 21: *PlayTherapy* Landing Page

5.4.2 Dashboard module

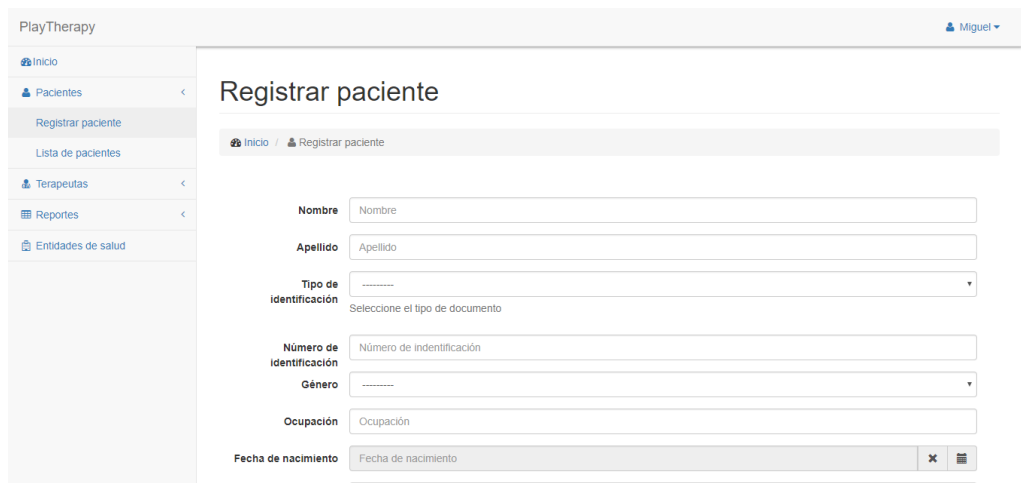
Dashboard([Figure 22](#)) is an administrator page for physiotherapists, here the physiotherapist can manage the information of a patient or a physiotherapist. Thus, this page is designed in order to show the information obtained by a patient in *PlayTherapy*, and get a report with the progress of this; it needs clarify that the module of reports, FIM (Functional Independence Measure) and health entities were developed by others members of the team.

The dashboard page is created from open source template based in bootstrap which is called SB Admin 2, this theme count with a lot of useful features that helped to the process of the web page creation.

Figure 22: *PlayTherapy* Dashboard

5.4.3 Patient module

In the patients module a CRUD implementation was required, due to start with the therapy session is necessary the information of the patient. Also, in a meeting with the physiotherapist they manifested the necessity of a associate the patients with a functional independence measure called FIM, said measure is associated with each therapy session and reflect the progress of patients in the session.

Figure 23: *PlayTherapy* Dashboard

5.4.4 Physiotherapist module

This module is in charge to manage the physiotherapist that are going to use the application (Figure 24). In this application, the physiotherapist has an admin role in the system,

they can create, modify or delete other users. Also they can access to the information generated by *PlayTherapy*, and complete the FIM information of the patients.

PlayTherapy Miguel

Inicio Pacientes Terapeutas Registrar terapeuta Lista de terapeutas Reportes Entidades de salud

Lista de terapeutas

Inicio / Lista de terapeutas

Para editar o desactivar un terapeuta haga click en su identificación.

Mostrar 10 datos Buscar:

Tipo de Documento	No. Documento	Nombres	Apellidos	Genero	Estado
Cédula de ciudadanía	365403140	Edward	Kallenberg	Femenino	Activo
Cédula de ciudadanía	172899544	Jennifer	Curry	Femenino	Activo
Cédula de ciudadanía	406953858	Kelly	Keepers	Masculino	Activo
Cédula de ciudadanía	31856007	Steven	Delo	Femenino	Activo
Cédula de ciudadanía	30988988	Paola	Martinez	Femenino	Activo
Cédula de ciudadanía	453747102	Scott	Haskell Taka	Femenino	Activo
Cédula de ciudadanía	917881717	Blanche	Lewis	Femenino	Activo
Cédula de extranjería	131262063	Kyle	Tavior	Femenino	Activo

Figure 24: *PlayTherapy* Dashboard

POST-PRODUCTION

This chapter discuss everything related whit the tests of the project, and it starts once the production phase is over. First, [Section 6.1](#) describes an accuracy test performed with the Leap Motion, to compare said technology with a traditional technique of angle measurement. Next, the remaining tests were focused on the mini-games, which were performed with the assistance of physiotherapist and patients.

6.1 LEAP MOTION ACCURACY

Leap Motion is a device thought initially to track hand joints, which can be extracted to calculate the angle of a functional movement, and subsequently be used by physiotherapists to observe the progress of patients. For this reason, *PlayTherapy* provides an active measure of the angles, which are saved in the database to generate a report of the progress.

The purpose of this test is to evaluate the accuracy of the positions given by Leap Motion; the results of this test are of high relevance as they make it possible to considerate a new kind of measure to the progress of patients.

This test was carried out performing a set measurements with the Leap Motion and the traditional technique of goniometry, then, it was compared the result of the application with the goniometer to obtain the margin of error. The results of said test are described in [Table 8](#) and [Table 9](#).

DESCRIPTION	GONIOMETER	LEAP MOTION	DIFFERENCE
Wrist Ulnar Deviation - Articular range(Avg): 0° - 45°			
Relaxed position	0°	1°	1°
Half-Way position	22°	12°	10°
Stretched position	40°	25°	15°
Wrist Radial Deviation - Articular range(Avg): 0° - 15°			
Relaxed position	0°	2°	2°
Half-Way position	7°	5°	2°
Stretched position	15°	13°	2°

Table 8: Accuracy Test

DESCRIPTION	GONIOMETER	LEAP MOTION	DIFFERENCE
Wrist Flexion - Articular range(Avg): 0° - 70°			
Relaxed position	0°	2°	2°
Half-Way position	30°	31°	1°
Stretched position	65°	56°	9°
Wrist Extension - Articular range(Avg): 0° - 70°			
Relaxed position	0°	3°	3°
Half-Way position	30°	18°	12°
Stretched position	70°	48°	22°
Thumb Abduction & Adduction - Articular range(Avg): 0° - 90°			
Relaxed position	0°	7°	7°
Half-Way position	45°	33°	12°
Stretched position	90°	50°	40°
M.C.F. Thumb Extension - Articular range(Avg): 0° - 90°			
Relaxed position	0°	15°	15°
Half-Way position	40°	42°	2°
Stretched position	80°	62°	18°
M.C.P. Index Finger Flexion - Articular range(Avg): 0° - 90°			
Relaxed position	0°	11°	11°
Half-Way position	45°	23°	22°
Stretched position	80°	56°	24°

Table 9: Accuracy Test (Cont.)

One of the biggest problems at the moment of performing this test was limited field of view of the Leap Motion, due to the internal software can not capture fully the movements, and it is forced to guess the missing positions. As a result, it is obtained a low precision data set.

Finally, the results of said test were presented to the physiotherapist, and they conclude that this technology is a good approximation to measure the performance of patients, but the margin of error was very high and it can not replace the traditional tech-

niques. However, it can be implemented in the future if a scale to transform the values is designed.

6.2 FUNCTIONAL TESTS

Following the internal quality standards defined by the development team, a set of acceptance test were performed with the mini-games *Viajando en el Espacio* and *Guerra Medieval*, the purpose of this test is validate the correct behavior of the functionalities developed in the mini-games.

Each one of the test was created as of the components described in [Section 5.3](#), to ensure that all the components works appropriately. Thereby, the results of the functional tests¹ are divided in two tables for *Viajando en el Espacio* and *Guerra Medieval* mini-games, said tables are [Table 10](#) and [Table 11](#) respectively. Additionally, the test were carried out with the with the assistance of the development team

NAME	STATUS
<i>Viajando en el Espacio's</i> Scene	Passed
<i>Viajando en el Espacio</i> Control Movement	Passed
Interaction with objects of <i>Viajando en el Espacio</i> mini-game	Passed
Point system of <i>Viajando en el Espacio</i> mini-game	Passed
Parameters interface of <i>Viajando en el Espacio</i> mini-game	Passed
Tutorial interface of <i>Viajando en el Espacio</i> mini-game	Passed
Final score of <i>Viajando en el Espacio</i> mini-game	Passed
The feedback system of <i>Viajando en el Espacio</i> mini-game	Passed

Table 10: Acceptance testing for *Viajando en el Espacio* mini-game

¹ Full test available in: https://drive.google.com/file/d/1qatauMiguPtp7Rj_SbqC3XINbwfNfl89

NAME	STATUS
<i>Guerra Medieval's</i> Scene	Passed
<i>Guerra Medieval's</i> Control Movement	Passed
Interaction with objects of <i>Guerra Medieval</i> mini-game	Passed
Point system of <i>Guerra Medieval</i> mini-game	Passed
Parameters interface of <i>Guerra Medieval</i> mini-game	Passed
Tutorial interface of <i>Guerra Medieval</i> mini-game	Passed
Final score of <i>Guerra Medieval</i> mini-game	Passed
The feedback system of <i>Guerra Medieval</i> mini-game	Passed

Table 11: Acceptance testing for *Guerra Medieval* mini-game

6.3 USER EXPERIENCE TESTS

As was mentioned in previous sections, the objective of a *Serious Game* is obtain a intrinsic purpose without loss of fun, for this reason and with the objective of evaluating the experience of patients, a user experience test was performed. Thus, this test was performed with patients of *Hospital Universitario del Valle* which are the audience target of this degree project.

Additionally, the approach of the test was defined by the development team of *PlayTherapy*, said test is based in two techniques called *Thinking aloud protocol* and *Question Asking protocol* which are described below.

6.3.1 Participants

Taking the audience target of this project as a starting point, the test was carried out with two physiotherapists and two patients, which were attending to a therapy session at *Hospital Universitario del Valle*. One of the difficulties at the moment of perform this test was the limited schedule of physiotherapist and patients.

6.3.2 Testing Techniques

6.3.2.1 Thinking aloud protocol

It is an empirical technique used to get an translation of certain research process, this technique consists in ask a subject to perform a task and express everything that crosses his mind during the task realization (Jääskeläinen, 2010).

6.3.2.2 *Question Asking protocol*

This method consists of bestowing a user with a specific system, without any indication of how it works; then, the users have to interact with the system, and each question or comment of the system is taken into account (Kato, 1986).

6.3.3 *Tests Design*

This test was designed by a member of the development team, which is part of the *PlayTherapy* usability group. Thus, the test was created with the purpose of evaluate the mini-games developed and not the performance of the patient in said test.

6.3.4 *Test for the physiotherapist*

With the objective of obtain a feedback of the physiotherapists was performed this test; for this purpose, the mini-games were configured by a physiotherapist with a custom parameters. Then, a survey was performed to them:

1. Was it easy to set up the mini-game? Why?
2. What do you think about the parameters screen?
3. Do you think that *PlayTherapy* could improve the physical rehabilitation? Why
4. What are the positive aspects of the mini-game?
5. What are the negative aspects of the mini-game?
6. What are the recommendations, comments and suggestions for the mini-game?

6.3.5 *Test for the patients*

The test start with a pre-test survey to obtain the demographic profile of the patient. Then, once the mini-game was configured by the physiotherapist, the patient starts to play the mini-game; after a verbal survey was performed to them.

Population survey:

1. Age
2. Genre
3. How long ago do you play digital games?
4. What other platforms have do you used to play?
5. How often do you play?
6. Have you ever had physical rehabilitation therapies before? Which?

Post-survey:

1. Did you have fun playing?
2. Did you understand the environment?
3. Did you understand the tutorial screen?
4. Did you understand the rules? Were they easy to understand?
5. Did you understand the objectives? Were they easy to understand?
6. Did you understand the actions required
7. Did you understand the actions required in the game?
8. Did you think that you can achieve the objectives of the game?
9. What do you think about the graphic interface of the game?
10. When the game ends, did you wanted to keep playing?
11. What are the positive aspects of the mini-game?
12. What are the negative aspects of the mini-game?

6.3.6 Results

The results of the test are divided according to the principal components of the mini-games. Thus, once the executions of the games ended and the corresponding surveys were performed, the following results were obtained:

- *Parameters Configuration Interface:* The physiotherapists approved this interface expressing that it was easy to use and it follows the general design of the others mini-games from *PlayTherapy*. Additionally, they gave some additional comments of features to add in a future iteration.
- *Mini-game Interface:* The patients agreed the mini-games interface, they expressed that they had fun at the moment of perform the physical rehabilitation throw the mini-games developed in this degree project. Also, a feedback about the scenes of the mini-games were obtained by patients and physiotherapists.
- *Tutorial Interface:* At this point, the patients were discontent with the tutorial despite it contains the rules and the story, the movements involved were not clear. Then, the suggestions of the patients were transformed into a issue which will be resolved in the next sprint.

- *Interaction with the Objects*: When the mini-games were executed, a difficulty to identify the objects was observed; then, at the end of the game, patients and physiotherapists concluded that a visual help to distinguish the depth of the objects was necessary. Additionally, they commented that interactions between the objects was clear.
- *Game Mechanisms*: Finally, when the mini-games ends, the patients were asked for the the mechanism with the mini-game, they express that will be a good idea implement a visual model of hands, with the purpose of watch the full movement on the screen.

Moreover, during the therapy session was observed a full immersion by patients and therapists; furthermore, they conveyed that these kind of therapies makes the therapy session more enjoyable, and also for an moment they forgot their current situation.

Additionally, both physiotherapist and patients conclude that *PlayTherapy* is a good proposal to face the lack of motivation by patients, which is one of the bigger problems for physiotherapists.

Finally, the bigger problem at the moment of perform this test was the hardware limitations, due to the hospital does not have the devices and the adjustments required to perform appropriately this therapies.

6.4 PERFORMANCE TESTS

One of the difficulties in digital game development is the limited capacity of video processing, thereby, the mini-games designed should comply with a standard of performance, due to this mini-game will be implemented in the *Hospital Universitario del Valle*.

The main idea of this test is to measure the frame rate of the mini-games developed in this work; said rate is the frequency each one of those frames refresh the screen per second. Thus, the latest games in industry try to achieve rate of 60 fps(frames per second), but often it is acceptable a rate above of 30 fps. Also, the frame rate is often a measure used to evaluate the performance of digital games with regard to video processing (Unity Technologies, 2017).

The test was carried out with tree different computers to observe the behavior of the mini-games, the selection of the computers consisted in choose three different kinds of video card, which should have low, medium and high specifications. Additionally, the tool used to perform this test was Fraps (Beepa Pty, 2017) which allowed to collect the information of the frames rate for each mini-game. The results of this test can be founded in [Table 12](#).

The results of the test show that even whit the worst video card, the frame rate of the mini-games are above of 30 fps, what qualifies the developed mini-games as acceptable in the worst of cases.

MINI-GAME	TOT. FRAMES	TIME	AVG	MIN	MAX	QUALITY
Video card: Nvidia Geforce 610M, CPU: Intel i5-3210M, Resolution 1366 x 768						
Guerra Medieval	7206	62406ms	115.470	104	118	Fastest
Guerra Medieval	2674	63094ms	42.381	40	44	Fantastic
Viajando en el Espacio	35787	67563ms	529.683	280	673	Fastest
Viajando en el Espacio	7754	68312ms	113.509	85	127	Fantastic
Video card: Intel HD Graphic 530, CPU: Intel i7-6700, Resolution 1366 x 768						
Guerra Medieval	11172	61250ms	182.400	167	188	Fastest
Guerra Medieval	3902	60375ms	64.629	61	67	Fantastic
Viajando en el Espacio	26670	68234ms	390.861	334	456	Fastest
Viajando en el Espacio	11600	68453ms	169.459	152	181	Fantastic
Video card: Nvidia Geforce 970M, CPU: Intel i7-6700HQ, Resolution 1366 x 768						
Guerra Medieval	27585	61688ms	447.170	429	478	Fastest
Guerra Medieval	15257	61485ms	248.142	229	262	Fantastic
Viajando en el Espacio	70760	70453ms	1004.358	950	1036	Fastest
Viajando en el Espacio	46081	67844ms	679.220	634	717	Fantastic

Table 12: Performance Test

6.5 DISCLOSURE RESULTS

This project was presented along with *PlayTherapy* project in two different events:

1. *Colombian Conference on Computing*: Presentation at Universidad Autonoma de Occidente, on September 22th, with the objective of present the short paper called: *MDLib: A Movement Detection Library for Motion Sensors and its Use on Physical Therapies*

2. *IV Jornada de Investigadores y Semilleros de Investigación en Fisioterapia*: Presentation at Universidad Mariana, on October 13th -14th, with the objective of present the poster titled *Playtherapy: Videojuego de apoyo a terapias de recuperación física*, which was selected as best poster of work in progress.

CONCLUSIONS, FINAL REMARKS AND FUTURE WORK

7.1 CONCLUSIONS AND FINAL REMARKS

At the end of this project two mini-games were obtained, which are focused on improving the process of hands rehabilitation. These mini-games are going to assist the physical rehabilitation therapist from the *Unidad de Medicina Física y Rehabilitación del Hospital Universitario del Valle*.

A literature review and feature comparison of several hand tracking technologies was performed, concluding that Leap Motion is a good alternative for integrating hand therapies with digital games, as it provides the most hand joints and it is compatible with the Unity graphics engine.

Additionally, although Leap Motion is a good technology to develop rehabilitation digital games, it is not suitable to get an appropriate angle measure, due to its internal settings being designed to give a high availability of joints rather than a high accuracy of these. Furthermore, others alternatives for hand tracking were analyzed, some of which such as the *Hi5 VR Glove* could improve the active angle measurement when available in the future.

The integration of Leap Motion with *PlayTherapy* was performed successfully, it was possible due to the large quantity of technologies that can be used with *PlayTherapy* and thanks to *MDLib* which provides an easy way of integrating Leap Motion with *PlayTherapy*.

The meeting with the physiotherapists allowed the acquirement of new concepts about physical rehabilitation, which contributed to the creation of mini-games according to the necessities of the physiotherapist and the patients.

The development methodology used in this project was ideal, as it allowed the unification of the interaction of every actor of the project and the adaptation to the many different changes that appeared from the feedback provided by the physiotherapists and patients. Moreover, the iterations and meetings proposed by the methodology allowed the obtaining of the necessary requirements for the construction of the project.

Furthermore, the final results of this degree project sustain to *PlayTherapy* to the leading edge of the other companies that foray this field, which in the most of cases works only with the Kinect sensor and the interaction with hands is not supported.

Finally, the development of this project allowed the author of this project to interact with the reality of the *Hospital Universitario del Valle* and its patients.

7.2 FUTURE WORK

Due to this project having shown to be a great strategy to perform the process of hand rehabilitation, it is expected that in the future the number of mini-games assisting this set of joints increases inside the *PlayTherapy* project.

Additionally, due to the current limitations of the Leap Motion, in the future the integration of new technologies that solve the shortcomings of the current technology is expected, and together with the Leap Motion they can provide a full accompaniment for physiotherapists in therapy sessions.

Moreover, in the future a Virtual Reality system could be integrated with *PlayTherapy*, which might increase the immersion of the player, being able to achieve an increment in patients' motivation during therapy sessions.

Finally, considering that the development of a digital game should be conformed by a multidisciplinary team, professionals from areas such as graphic design and narrative creators are expected to join the *PlayTherapy* team in the future.

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Part II

ANNEXES

GAME DESIGN DOCUMENT

A.1 GENERAL GAME DESCRIPTION

A.1.1 ¿What is PlayTherapy?

PlayTherapy is a digital game designed to assist the work of physiotherapist in the physical therapies. Thus, to achieve this objective, it has a set of interactive mini-games, which can track the movement of the people. As a result, this game expected increasing the motivation of the player while it performs their physical therapy.

A.1.2 ¿Why is this game created?

The main reason to create this game, is due to some researches has shown that through a digital game is possible to increase the motivations of the patients, this is in order to the patient finish his physical rehabilitation and recover his functional movements in the expected time.

A.2 MAIN STORY

This game is based on two stories, the first is about a teenager and an old man, who are interested in explore the entire world and draw on of this.

A.2.1 Main characters

1. *Daniel*: is a 14 years old teenager, he is an fearless adventurer who wants to travel around the world, thanks to his friendly personality he has obtained a lot of friends around the world, which will help him to face all the challenges that he is going to face.
2. *Juan*: is a 55 years old man, he is tired of his bored and monotonous life, he is going to begin a new travel together with his nephew to turn his boring life; they are going to be in an innumerable challenges that will make them remember their childhood.

A.3 GAMEPLAY

This game has a series of mini games in which the player should complete a set of activities to obtain points. The player should use his body as a control, due to the game has two sensors to detect the movements.

A.3.1 Mini-Game 1 - *Viajando en el espacio*

A.3.1.1 Description of the gameplay

In this game Daniel and his grandfather decide that they want to explore new worlds; to that end, they start with a new interstellar travel in their spaceship, this will lead to a new set of challenges, to overcome this, it is necessary drive the ship and try to keep safe until their destination planet.

While the spaceships is moving in the space, the player is going to find asteroids and meteors, that he must dodge or make it explode, at the same time he can collect bonuses that can improve the ship, this bonuses can be munitions, shields or starts, which will help to cross the space.

A.3.1.2 Controls

This game will be controlled by hands movements; the movements involved in this game will be flexion and extension of the wrist to drive the ship, when the player clench his fist the ship shoot the cannons

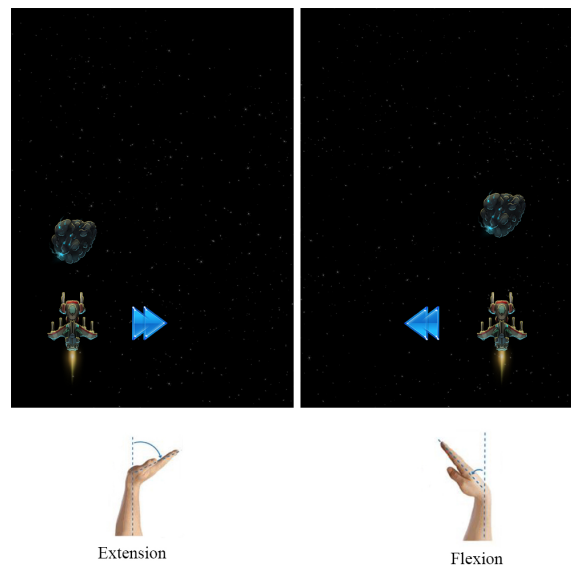


Figure 25: Movements of hands to control the ship.

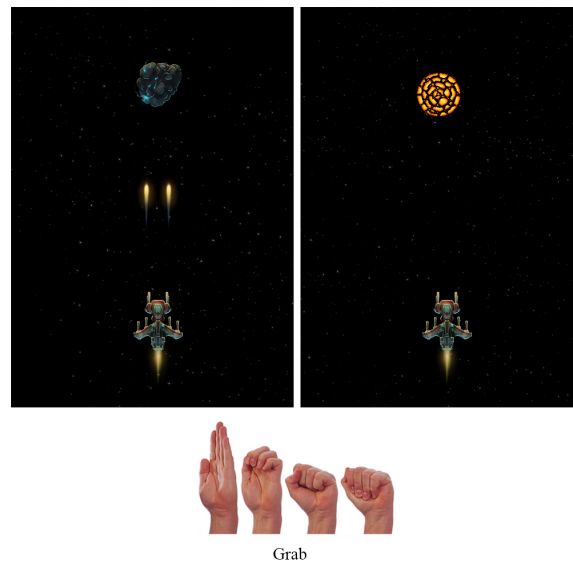


Figure 26: Movements of hands to make the ship shoot.

- Flexion and extension of wrist to drive the ship [Figure 25](#).
- Clench fist to make the ship shoot [Figure 26](#).

A.3.1.3 Graphical User Interfaces

The mini-game has four GUI:

- Parameters settings GUI, this allow modify the level and options of the mini-game like the time, difficulty, velocity and repetitions.
- The second GUI is a tutorial screen, which explain the controls and the dynamics of the game.
- The third GUI is where the mini-game is performed, this is developed in the outer space, which will be crossed by a spaceship.
- The last GUI will show the final score obtained by the player, the best score so far, and tree stars that means the performance on the mini-game.

A.3.1.4 Rules

- Each meteor that crash with the ship will generate a negative score, and so on avoid this will generate a positive score.
- Catch bonus objects will reflect improvements for the ship.
- Each meteor destroyed will have a special bonus in the score.

A.3.1.5 *World*

The game will be located in the outer space, which is full of planets, asteroids and enemy ships; in this stage the player can find items that can improve the spaceship.

A.3.1.6 *Conditions to win*

Catch the most number of items, avoid or explode the meteor and destroy the enemies to obtain a high score.

A.3.2 *Mini-Game 2 - Guerra Medieval*

A.3.2.1 *Description of the game-play*

The adventure of Daniel and Juan continue when they find a machine time, which will return them to the medieval era, an age that is full of wars and dragons.

In this game the player will be immerse in the medieval age which is constantly in wars, in this the player should act as a shooter of an army, for that he must destroy all the enemies with a cannon.

A.3.2.2 *Controls*

This game will be controlled by hands, which will serve as command to aim with the cannon, change the munitions and shoot the cannon. The movements involved in this game will be flexion and extension of wrist, radial and ulnar deviation, and grab.

A.3.2.3 *Graphical User Interface*

This mini-game has four GUI:

- Parameters settings GUI, this will serve to modify the time, velocity, and the number of repetitions, also is possible the movements range that the player can realize.
- The second GUI is the tutorial screen, which explain the controls and the dynamics of the game.
- The third is where the mini-game is performed, this is developed in the medieval era where cannon is located.
- The last GUI will show the final score obtained by the player, the best score so far, and tree stars that means the performance on the mini-game.

A.3.2.4 *Rules*

- Each objective destroyed will generate a positive score.
- Each objective destroyed in a consecutive streak will generate an additional bonus.
- Special enemies will generate higher scores.

A.3.2.5 *World*

The game will be performed in a medieval atmosphere, where is possible observe the cannon which will be responsible of shoot the projectiles to the enemies.

A.3.2.6 *Conditions to win*

Try of destroy and avoid the most number of enemies to obtain a high score.