frail safe

Project Title:	**Sensing and predictive treatment of frailty and associated co-morbidities using advanced personalized models and advanced interventions**
Contract No:	690140
Instrument:	Collaborative Project
Call identifier:	H2020-PHC-2014-2015
Topic:	PHC-21-2015: Advancing active and healthy ageing with ICT: Early risk detection and intervention
Start of project:	1 January 2016
Duration:	36 months

Deliverable No: D5.2

Beta version of the Synthesized AR game system

Due date of deliverable:	April 30th 2017
Actual submission date:	May 3rd 2017
Version:	1.4
Lead Author:	Enric Montesa (BRAINSTORM)
Lead partners:	Javier Montesa (BRA) Luisa Pérez Devesa (BRA) Andreas Vasilakis (CERTH) Victor Kyriazakos(CERTH)

Horizon 2020
European Union funding
for Research & Innovation

Change History

Ver.	Date	Status	Author (Beneficiary)	Description
1.0	18/04/2017	Draft	Luisa Pérez Devesa (BRAINSTORM)	First draft
1.1	30/04/2017	Pre-final	Victor Kyriazakos (CERTH)	CERTH Contribution
1..2	30/04/2017	Pre-final	Enric Montesa (BRAINSTORM)	BRA Contribution
1.3	03/05/2017	Final	Enric Montesa (BRAINSTORM)	Corrections and final changes includes
1.4	03/05/2017	Final	Enric Montesa (BRAINSTORM)	Further typos corrections and modifications in the abstract for dissemination
1.5	03/05/2017	Final	Javier Montesa (BRAINSTORM)	Red Wings Dynamic difficulty adjustment (DDA) connected with Frailty Indicators
1.6	04/05/2017	Final	Enric Montesa (BRAINSTORM)	Dynamic adaptability for AR (suggestions added by Konstantinos Moustakas)

EXECUTIVE SUMMARY

This deliverable is a demonstrator of the system, including all the modules and systems but the database connection. It will also contain a beta version of two of the proposed games that will make use of the described hardware and software modules.

DOCUMENT INFORMATION

Contract Number:	H2020-PHC–690140	**Acronym:**	**FRAILSAFE**
Full title	Sensing and predictive treatment of frailty and associated co-morbidities using advanced personalized models and advanced interventions		
Project URL	http://frailsafe-project.eu/		
EU Project officer	Mr. Jan Komarek		

Deliverable number:	5.2	**Title:**	Beta version of the Synthesized AR game system
Work package number:	5	**Title:**	Dynamic Intervention Services

Date of delivery	**Contractual**	**30/04/2017 (M16)**	**Actual**	**30/04/2017**
Status	Draft ☐		Final ☒	
Nature	Report ☐	Demonstrator ☒ Other ☐		
Dissemination Level	Public☐	Consortium ☒		
Abstract **(for dissemination)**	This is a confidential document and exposes the result of the serious games developed so far. In this deliverable two games are presented: 1) Red Wings, and 2) Gravity Ball, developed by Brainstorm and CERTH respectively			
Keywords	Periodic progress report, periodic technical report, periodic financial report			

Contributing authors (beneficiaries)	○ Luisa Pérez Devesa (Brainstorm) ○ Javier Montesa (Brainstorm) ○ Enric Montesa (Brainstorm) ○ Andreas Vasilakis (Certh) ○ Victor Kyriazakos (Certh)			
Responsible author(s)	Javier Montesa		**Email**	jmontesa@brainstorm3d.com
	Beneficiary	Brainstorm	**Phone**	+34 660 522 594

Table of Contents

1 Introduction

The ***FrailSafe*** platform will provide a set of serious games created for the study and intervention of older people who may have the frailty syndrome or associated co-morbidities.

The exercises and activities proposed in the games are conceived to train and improve specific motor and cognitive capabilities of the users of ***FrailSafe*** platform. The games are designed to be played on a daily basis and do not require high skills with video games.

Each game integrated in the synthesized AR game component will be able to track the player's performance along the game. When the database connection is available, the recorded performance data will be sent to the FrailSafe cloud for post-processing and feeding of the Virtual Patient Model (VPM).

The current document describes two of those games: ***Red Wings*** and ***Gravity Ball***.

Red Wings is a game developed by Brainstorm Multimedia. The main character is a plane that needs to be controlled using a dynamometer device provided by ***FrailSafe*** project.

Gravity Ball is an AR game designed and developed by CERTH. The player observes a virtual sphere, governed by real-world dynamics, moving freely in terrains of varying complexity, and tries to guide it into the level's whole, denoting the completion of the level.

2 Games

2.1 Red Wings

2.1.1 Objectives

The aim of the ***Red Wings*** game is to control the flight altitude of a plane, which is flying along a series of landscapes, so to get as far as possible from a starting position.

The users have to avoid some obstacles appearing on the way, either on the ground, e.g. trees, or floating in the air, e.g. clouds. To do that, the user will have to make the plane fly above (by gaining altitude) or underneath (by losing altitude) the obstacles, going through different levels of difficulty.

2.1.2 Game dynamics and exercises

The main character of the game is a red plane, which has the ability to fly in the right direction and is controlled using a hand dynamometer.

There is only one scenario with several stages. The layout of the game is a hilly landscape with background forestland and meadows. The game goes through several stages of day and night to entertain the player, provide a pleasant feeling of dynamism and give feedback on the progression level. Some other items of the game, e.g. the soil layers, also change throughout the game.

At the start of the game the plane is resting on the ground and will take off as soon as the hand dynamometer is peered with the tablet device and the user applies pressure on the dynamometer with either hand. To peer the dynamometer, it has to be started by pressing the Reset (red) button. The game is configured to automatically recognize and connect to active dynamometer devices. To keep the reached altitude the user will have to apply a constant pressure (exactly the same as the gravity force) on the dynamometer. If the pressure is below the value of the gravity force, the plane will fall. On the other hand, if the pressure is greater than gravity, the plane will go up.

Figure 1. RedWings' starting point

At the beginning of the game the user is granted 3 lives, which are displayed on the top-right corner of the screen. Lives are lost when the plane hits the obstacles. The ground and the ceiling of the screen are not considered obstacles, i.e. reaching the ground or the ceiling will not take any life.

The obstacles will be the objects on the front. The red plane will not collide with trees and clouds belonging to the background. Possible kinds of obstacles are: Trees and bushes (ground objects), clouds, hot air balloons and blue planes (aerial objects).

Figure 2. Red plane approaching an obstacle.

The first stage (less than hundred meters) will not include any obstacle, so to let the user learn the right degree of pressure required to control the flight level of the plane.

When the red plane hits an obstacle, one life is taken, and the user is granted some seconds to recover from this and get back on track, i.e. to control the flight altitude and speed. During this recovery period, the red plane flickers and no lives are taken if the plane hits other obstacle again. As soon as the flicker is over, the flight mode is back to normal and the user is at risk of losing another life if the plane meets other object.

The game will start with fewer obstacles and will seamlessly increase the number of obstacles and/or speed of the red plane to increase the level of difficulty.

As the objective is to reach the furthest distance, this parameter (the covered distance in meters) is showed at the top-left corner of the screen, so that the user gets feedback on his own performance.

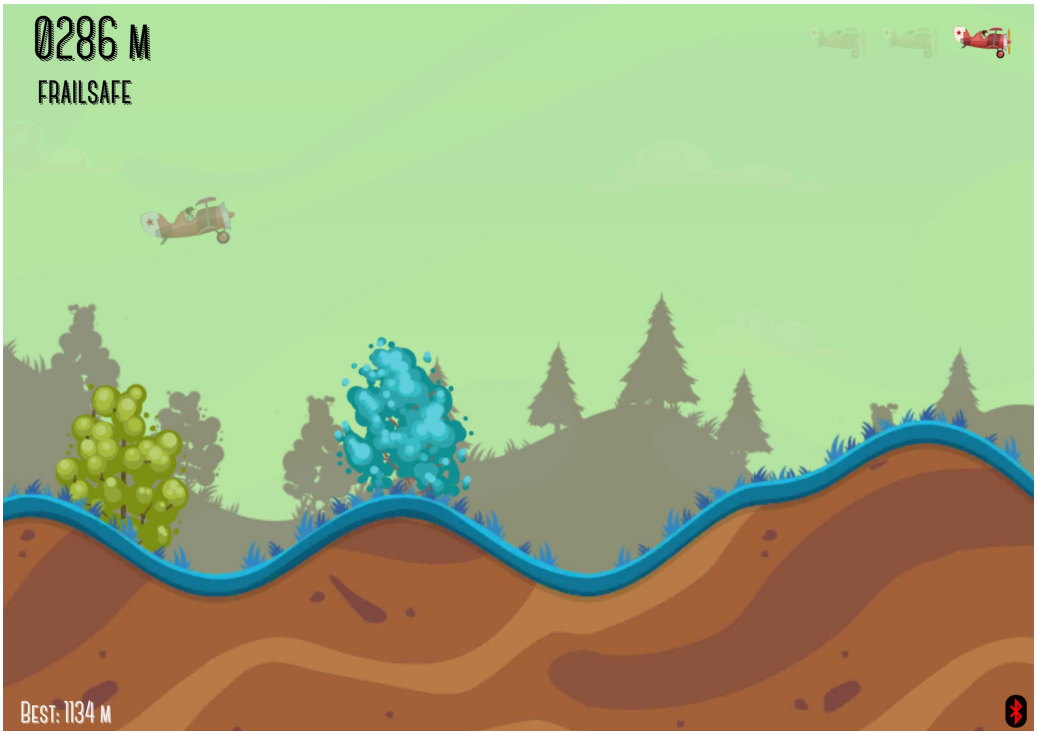

Figure 3. Flickering red plane recovering from a collision with an obstacle.

2.1.3 Outcome

The ***Red Wings*** game is developed to measure, record and train the hand grip strength and train the coordination and reflex abilities of the user.

The game receives a continuous flow of values from the dynamometer, which represent the hand grip strength applied by the user. The received values are used to determine the current altitude and distance of the plane based on the current status of the plane (retrieved from previous frame), e.g. altitude, distance and recovery mode, and layout of next frame, e.g. other objects on the way of the plane. The game generates the new frame and registers the hand grip strength and other relevant parameters in a log file.

The full lists of parameters recorded in the log are:

1. At the start of the session:
    - Timestamp
    - Device ID
    - User name

2. For each frame
    - Frame number
    - Hand grip strength
    - Distance
    - Number of remaining lives
    - Vertical component of the speed

2.1.4 Detailed developments

Red Wings is an endless one-button game developed for the tablet device Pixel C and peered with the hand dynamometer device ***Hoggan MicroFet Hand Grip***.

The ***Red Wings*** game and game framework has been developed with the game engine Unity selected in Deliverable *"D5.1 Analysis of hardware devices and software tools. Game hardware and software design".* It also uses the "Dynamometer Java Library" component developed by CERTH to facilitate the connection with the device.

Figure 4 Hand dynamometer device Hoggan MicroFet Hand Grip.

The framework provides some functionality required to:

- *Communicate with external devices*, i.e. Unity plugin to integrate the games with peered Bluetooth devices, e.g. the dynamometer device. See diagram in below. The status of the Bluetooth connection is displayed on the bottom right corner of the screen. There is a Bluetooth icon that turns from red to white when the dynamometer device is peered with the tablet.

- *Provide a log system* that records all the relevant data of the user performance. See section 2.1.3.

- *Access to the database* (it is a dummy version, as the database connection is not in the scope of the current deliverable)

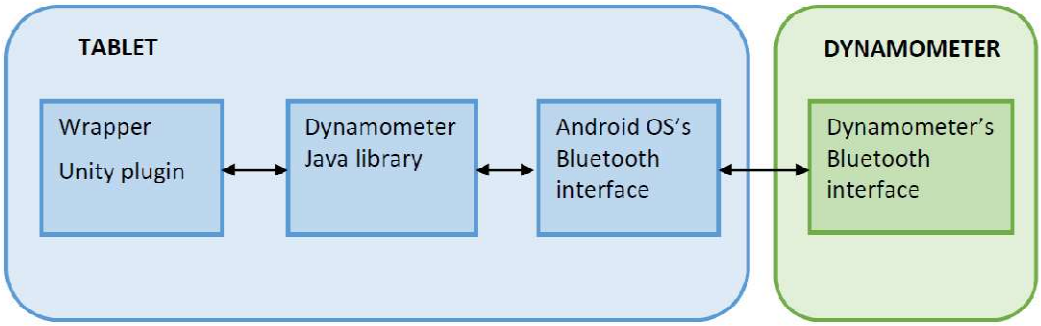

Figure 5. Bluetooth integration

The game has a customized menu and opens by holding one finger at the bottom of the screen for 2 seconds. The game menu developed for Red Wings provides following options:

- *Re-play feature*: this option allows the user to re-play all the played sessions for the current game.

- *Set user name*: the user can specify the user name that will be displayed on the screen and recorded in the log files.

- *Testing mode*: This play mode avoids losing lives when the main character hits obstacles so that developers can test the features of the game.

- *Bluetooth connection manager*: this option opens a configuration window to choose the Bluetooth device you want to connect to.

- *Restart*: this option stops the current session and begin a new one from the starting point.

- *Reset best score*: this option resets the recorded best score achieved in this device.

2.1.5 Dynamically adaptable

Red Wings will implement elements to make more enjoyable and interesting the experience.

Brainstorm developers are working in order to make them dynamic adaptable in the next versions. This demonstrator beta version hasn't implemented the solution yet.

Red Wings adaptability will be based upon a set of Key Performance Indicators:

1. ***Cognitive KPI***: maximum distance reached by the player will used to be evaluated the cognitive patient situation and will affect at the number of obstacles
2. ***Physical indicators*** (strength and endurance) indicators. The data will be collected by the dynamometer inputs and will be evaluated based on the maximum strength done by the player and his historical evolution.

Those indicators will affect at the maximum strength needed to be applied by the player, the speed of the game, and the gravity factor

2.2 Gravity Ball

Gravity Ball is a marker-based Augmented Reality game, targeted for tablets and/or Smartphone. As can be seen in 5, the user holds the marker and controls its orientation, which in turn controls the orientation of the terrain and therefore the gravity vector guiding the virtual sphere. Each level contains a hole, and the user tries to guide the virtual sphere into the hole to complete each level. The

game aims to measure hand motor skills and eye-hand coordination of the user, extracting various metrics, detailed below.

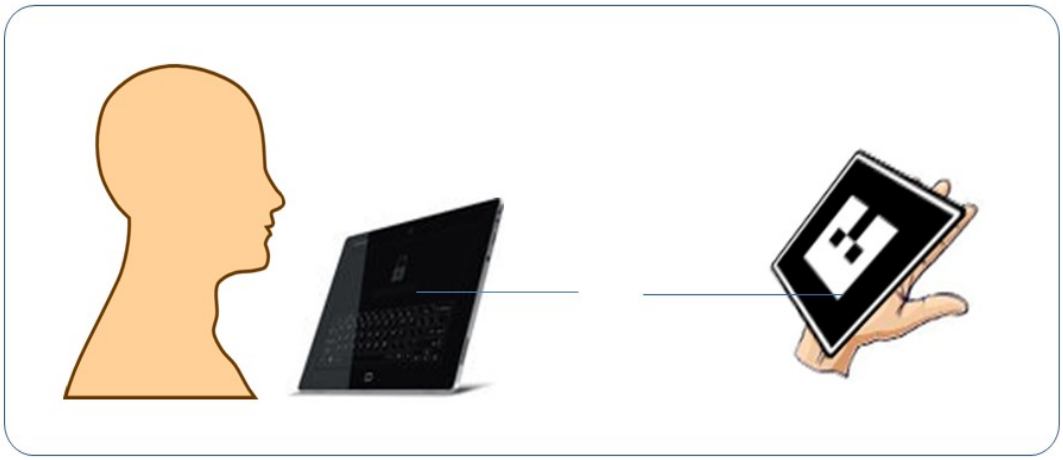

Figure 6. The user hold the marker with his hand, and observes the game augmented upon it through the tablet.

2.2.1 Objectives

The aim of the ***Gravity Ball*** game is to guide the virtual sphere into the level's hole, the finishing point, as fast and as steadily as possible.

In order to do that, the user has to tilt the handheld marker accordingly, so that the sphere bypasses the level's "valleys" and "mountains" and guide it through the routes that successfully result in the finishing hole.

2.2.2 Game dynamics and exercises

The active component of the game is a virtual sphere, which has the ability to roll inside the game's terrain influenced solely by real-world dynamics and gravity. The user can control the orientation of the terrain by controlling the orientation of the physical marker on which the augmentation of the game is happening.

There is only one scenario with various levels. The layout of the game is box-like terrain with "valleys and mountains", and a hole denoting the finishing point. The game contains several stages of different complexity, designed with realistic and colorful textures, to appeal to the player.

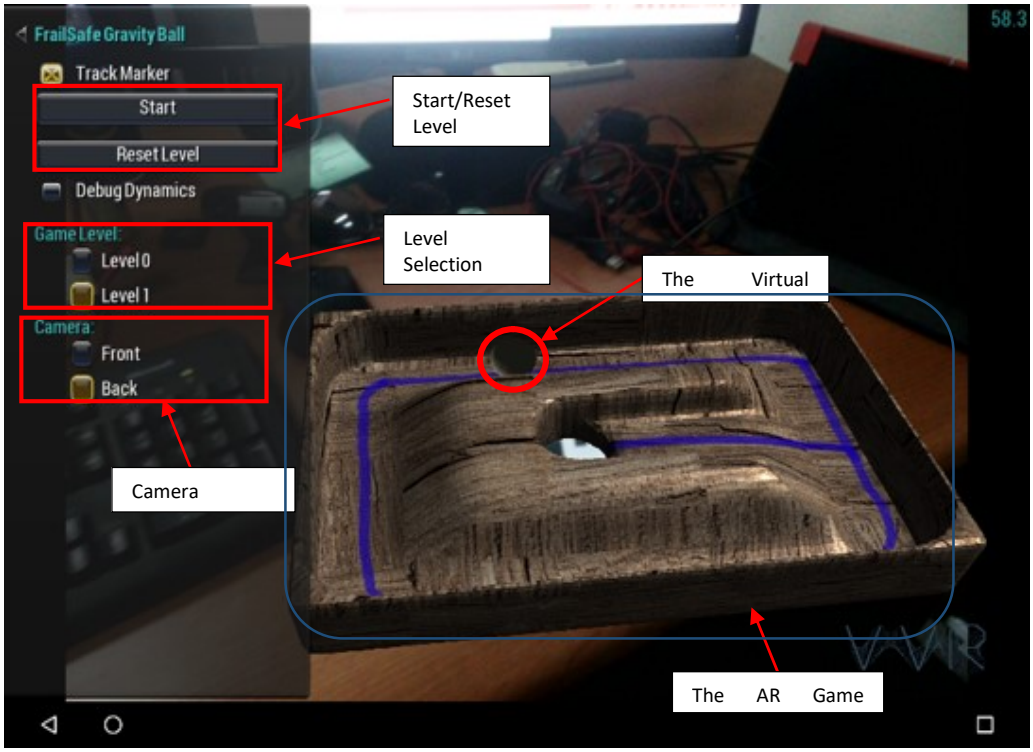

Figure 7. The Game's UI and Graphics Components.

As the user opens the app, he must point the camera to the physical marker and open the menu in order to choose and begin the level (6). At the start of the game, the virtual sphere is statically floating above the level, until the user taps the **Start** button, which enables the sphere dynamics and starts the logging components for the session. When the user successfully places the sphere into the hole, or hit the **Restart Level** button, the level resets and necessary information is stored in the session log.

The game currently offers two (2) levels as a beta version (7), a simple box-like terrain that serves as a tutorial for the player, and a more complex level, showing the challenges that the user may experience in the game. CERTH plans to develop more levels for the final version, aiming to assess specific aspects of motor skill and eye-hand coordination.

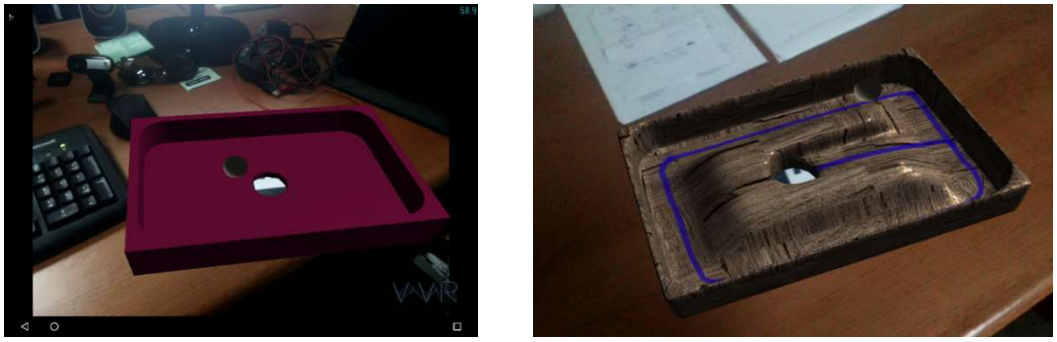

*Figure 8. The current levels of the beta version of the **Gravity Ball** game.*

2.2.3 Outcome

The ***Gravity Ball*** game is designed to measure, record and train the hand stability of the user, as well as his eye-hand coordination skills. The game records a continuous stream of data including the current gravity vector, marker orientation, virtual sphere position, time elapsed from the beginning of the level, and distance from the finishing hole, which are used to estimate the performance of the user and extract clinical metrics. Specifically, a variety of signal processing algorithms are currently explored, like the standard deviation of the gravity vector after passing through a cut-off high pass frequency filter, which is closely correlated to the hand stability of the user, since the virtual gravity vector that guides the sphere is calculated from the marker orientation, that the user controls.

The full list of parameters recorded in the log is:

1. At the start of the session:

    - Timestamp
    - Device ID
    - Session ID

2. For each frame:

    - Current level
    - No. of tries on current level
    - Frame number
    - Frame timestamp
    - Marker orientation
    - Gravity vector orientation
    - Distance from finishing hole

2.2.4 Detailed developments

Gravity Ball is developed using a dedicated graphics framework developed by CERTH for FrailSafe to support the easy development of AR games for mobile devices and consists of the following main modules (Figure):

- *FrailSafe AR Renderer*: The FrailSafe AR Renderer module facilitates the development of graphics applications that are based on a camera video feed, needed for AR games, and a marker for calculating the scene pose.

- *Dynamic Simulation Engine*: This module is based on the open dynamics library "Bullet" and extends it to enable easier AR real-world dynamics for the FrailSafe games.

- *Marker Tracker*: This component is responsible for pre-processing the camera feed in order to efficiently detect markers and calculate their orientation.

- *Sensor Manager*: This component extends the OS's sensor manager module in a cross-platform way, in order to provide necessary sensor information (gyroscope, magnetometer, gravity etc.) to the developed application.

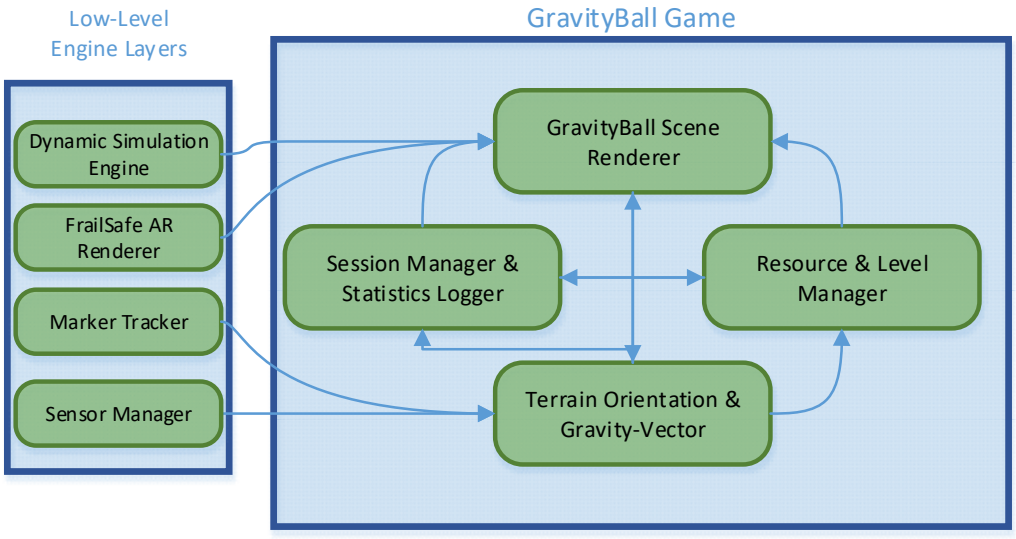

*Figure 9. Architectural diagram of the **Gravity Ball** game.*

Moreover, the following modules where developed specifically for the ***Gravity Ball*** game, to implement its basic functionalities:

- ***Gravity Ball*** *Scene Renderer*: This module controls the AR Renderer and receives information from all the modules necessary to compute the update step of the application, in order to decide the current state of the AR world.

- *Session Manager*: This module controls all the recorded quantities during a session and auto-logs them in .csv and .xml formats.

- *Resource & Level Manager*: This component is responsible for finding all supported levels, and plans to be extended to support dynamic levels for personalized gaming, i.e. alter the current level to make it more difficult/easy, depending on the performance of the user

- *Terrain Orientation & Gravity Vector*: This module takes as input all the sensorial information from the Sensor Manager, as well as the current Marker Orientation, and extracts the virtual gravity vector that guides the sphere. It also provides some filtering option for the raw marker orientation to prevent tracking-induced jittering.

3 Dinamically Adaptative games

Users are varied. They came in all sorts of knowledge, skills and age, motives, needs, interests and lifestyles. This is why games have developed an approach known as dynamic difficulty adjustment (DDA) or dynamic game balancing (DGB).

Serious games are challenged by the same problem and ***FrailSafe*** games should implement a “dynamically adaptable” approach.

The goal of dynamic difficulty balancing is to keep the user interested from the beginning to the end, providing a good level of challenge.

Game difficulty increases steadily along the course of the game (either in a smooth linear fashion, or through steps represented by levels). The parameters of this increase (rate, frequency, starting levels) can only be modulated at the beginning of the experience by selecting a difficulty level. But Dynamic difficulty balancing provides a tailor-made experience for each gamer.

Additionally and whenever possible, the developed games will be context aware in terms of the user's environment. This will be mainly the case in the AR games where the system is able to sense the environment through the camera. Wherever, clinically meaningful and technically possible, the AR games will be able to sense the environment and adapt accordingly.

4 Conclusions

As mentioned above, this document describes the serious games created by ***FrailSafe*** partners Brainstorm Multimedia and CERTH as part of WP5. The first game, ***Red Wings***, was developed by Brainstorm Multimedia, and the second game, ***AR Gravity Ball***, by CERTH.

The current document explains the objectives, game dynamics, exercises, outcomes and detailed developments for each game.

The games have been successfully tested with the participants of current clinical study by the clinical partners located in Greece (University of Patras), Cyprus (Materia Group) and France (Inserm) and the reported results are quite positive.

The clinicians have gathered the users' experience with the games and have forwarded the comments of the users to the developers, so that the current beta version of the games can be improved and a final version can be released.

The main issues of the games, as reported by the clinicians, are:

1) The *user's acceptability*, e.g. enjoyment and difficulty.

2) *Adequacy to measure* the main clinical topics: strength, endurance and balance control.

3) The *Bluetooth connectivity* among used devices, especially the dynamometer.

Besides that, developers have analyzed how well the users were performing in the game, in order to identify which parts of the game shall be improved.

Generally speaking, the game goals are achieved and the current beta version is seems to be a solid foundation for future developments.