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1.0	30/05/2016	Draft	Javier Montesa (BRA)	First draft version with BRA contribution.
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1.2	28/06/16	Final	Javier Montesa (BRA)	Corrections and final changes included.

EXECUTIVE SUMMARY

In order to define the FrailSafe architecture both in the terms of hardware devices and software requirements implementation, the aim of this deliverable is to review the state - of-the-art in hardware devices and software tools that are needed for the FrailSafe game hardware and software design process. Thus, a first detailed analysis is needed in order to analyze the available devices that are found in the market as well as the different operating systems and software libraries that will define the development of the applications and the games in the project. So, this document presents the analyzed solutions in order to determine the most preferable options and the reasons why. Thus, the deliverable will provide the basis for the development of the FrailSafe implementations. In this context, the following comparative analysis was achieved during the project:

- A Mobile Devices analysis which was led to the selection of Google Pixel C and Nexus 5X as the base devices for the FrailSafe developments and tests,
- A comparison of the latest AR glasses devices that meet the project requirements,
- Different graphics and game engines oriented to the development for portable devices have been taken into account and the detailed results are also presented in form of comparative tables where pros and cons are studied and highlighted.

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Dissemination Level	Public ☒	Consortium ☐		
Abstract (for dissemination)	This document presents the analyzed devices and libraries to use in FrailSafe and determines which options have been selected and the reasons why.			
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LIST OF ABBREVIATIONS AND ACRONYMS (*IN ALPHABETIC ORDER*)

AMOLED	Active Matrix Organic Light Emitter Diodes
ARM	Advanced Reduced Instruction Set Computer Machine
ADT	Android Development Tools
API	Application Programming Interface
BASIC	Beginner's All-purpose Symbolic Instruction Code
C2DM	Android Cloud to Device Messaging
CPU	Central Processing Unit
CDMA	Code Division Multiple Access
DDMS	Dalvik Debug Monitor Server
EDGE	Enhanced Data rates for GSM Evolution
FOV	Field of View
GPS	Global Positioning System
GSM	Global System for Mobile communications
GCM	Google Cloud Messaging
HD	High definition
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Parallel Adder
HSUPA	High Speed Uplink Packet Access
HDMI	High-Definition Multimedia Interface
HTML	HyperText Markup Language
IMU	Inertial Measurement Unit
ISM	Industrial, Scientific and Medical
IPS	In-plane switching
IDE	Integrated Development Environment
ISP	Internet Service Provider
LED	Light Emitting Diode
LCD	Liquid Crystal Display
LAN	Local Area Network
LTE	Long-Term Evolution
LTPS	Low-temperature polycrystalline silicon
Mbps	Mega bits per second
MP	Megapixel
microSD	micro Secure Digital
mAh	milli Amperes per Hour
mm	Millimeter
MMS	Multimedia Message Service
MIMO	multiple-input and multiple-output
NFC	Near Field Communication
GLU	OpenGL Utility Library

GLUT	OpenGL Utility Library Toolkit
OS	Operating system
OLED	Organic Light Emitting Diode
PDA	Personal Digital Assistant
ppi	pixels per inch
QML	Qt Meta Language
RAM	Read Access Memory
RTSP	Real Time Streaming Protocol
RTP	Real-Time Transport Protocol
RGB	Red Green Blue
SATA	Serial Advanced Technology Attachment
SMS	Short Message Service
SDK	Software Development Kit
SQL	Structured Query Language
SIM	Subscriber Identity Module
SHF	Super High Frequency
SoC	System on a Chip
TV	Television
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
UWP	Universal Windows Platform
Whr	Watt Hour
WLAN	Wide Local Area Network
WQHD	Wide Quad High Definition
WCDMA	Wideband Code Division Multiple Access
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
XAML	eXtensible Application Markup Language

1. INTRODUCTION

Within the present document, an evaluation of the most remarkable software and hardware solutions for game development to be used in the FrailSafe project has been undertaken. A comparative analysis of different concepts has been done, taking into consideration the different operating systems already existing for mobile platforms and the most relevant graphics engines for gaming. In addition a concrete study has also been conducted with regard to the hardware requirements that are needed in the project as well as a comparative analysis of the most important available devices.

The rest of this deliverable is organized as follows.

Section 2 states the minimum software requirements that will make possible the expected developments for FrailSafe.

Section 3 specifies the minimum hardware requirements that FrailSafe devices should comply with, in order to enable the different physical interactions and visual capabilities that the project games will use.

Section 4 contains a review of the current mobile platforms and operating systems available. For each examined platform, the most important game-related or general features are listed, along with the development tools available. Furthermore, notes regarding the future evolution of each platform are provided, discussing whether each platform is promising for future development.

Section 5 discusses the currently available game engines compatible with smart devices. Different features and parameters as level of market acceptance, price and terms of use, characteristics and capabilities, are analyzed and compared among the most preeminent engines in the market today.

Section 6 displays a comparison of the most powerful smart devices in the market today, covering both smartphones and tablets. This comparison is based on the previous selected devices capabilities with the objective to determine the smart phone and tablet of choose for FrailSafe.

Section 7 Describes and compares the most versatile Augmented Reality devices available in the market, with the objective to select the most suitable to be used in FrailSafe.

Finally, Section 8 concludes the deliverable, summarizing and discussing the selected software and hardware for game development within the context of FrailSafe.

2. SOFTWARE REQUIREMENTS

This section describes the software requirements of the games that will be developed within FrailSafe. On one side, graphics acceleration, and particularly OpenGL ES, is needed as the base architecture for any of the presented game engines for the visualization of 3D models and scenes.

Geolocalization may or may not be required in games, depending on their design, but would be of great utility in other to sense the user activity.

2.1 OpenGL

OpenGL for Embedded Systems (OpenGL ES) is a subset of the OpenGL computer graphics rendering application programming interface for rendering 2D and 3D computer graphics such as those used by video games, typically hardware-accelerated using a graphics processing unit. It is designed for embedded systems like smartphones, computer tablets, video game consoles and PDAs. The API is cross-language and multi-platform but the libraries GLUT and GLU, devoted to the creation of user interfaces, are not available for OpenGL ES.

OpenGL ES is managed by the non-profit technology consortium Khronos Group. Vulkan, a next-generation API from Khronos, is made for simpler high performance drivers for mobile and desktop devices. OpenGL ES is the most widely deployed 3D graphics API.

2.2 Geolocation

Geolocation is the identification of the real-world geographic location of an object, such as a radar source, mobile phone or Internet-connected computer terminal. Geolocation may refer to the practice of assessing the location, or to the actual assessed location. Geolocation is closely related to the use of positioning systems but may be distinguished from it by a greater emphasis on determining a meaningful location rather than just a set of geographic coordinates.

For either geolocation or positioning, the locating engine often uses radio frequency location methods, for example Time Difference Of Arrival for precision. Those systems often utilize mapping displays or other geographic information systems. When a GPS signal is unavailable, geolocation applications can use information from cell towers to triangulate the approximate position, a method that is not as accurate as GPS but has greatly improved in recent years. This is in contrast to earlier radiolocation technologies, for example Direction Finding where a line of bearing to a transmitter is achieved as part of the process.

3. HARDWARE REQUIREMENTS

This section contains the main hardware requirements of the games that will be used within FrailSafe and the devices selected for the project must have.

3.1 3D Acceleration

When developing the mobile application, in addition to software constraints, the hardware part of the different devices will also have an impact on the development of the project and its final result.

To carry out this task is necessary that the above- mentioned mobile devices have certain advanced graphic features that enable such integration. In terms of software, it is essential to have as minimum OpenGL ES 2.0.

As for the hardware capacity, most of the assessed devices have an Adreno GPU (Graphic Processing Unit) in its different versions, or a modification of it, although we also find devices with PowerVR GPU's or Mali.

After a performance analysis regarding the painted triangles and pixels per second, the different GPU's integrated in the devices were evaluated within the project in order to meet the required expectations for this initiative.

3.2 Connectivity

- **Third generation of mobile telecommunication networks (3G),** support services that provide an information transfer rate of at least 200 kbit/s. Later 3G releases often denoted 3.5G and 3.75G, also provide mobile broadband access of several Mbit/s to smartphones and mobile modems in laptop computers. This ensures it can be applied to wireless voice telephony, mobile Internet access, fixed wireless Internet access, video calls and mobile TV technologies.
- The **Global Positioning System (GPS)** is a space-based navigation system that provides location and time information in all weather conditions, anywhere on or near Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil, and commercial users around the world. The United States government, which created the system, maintains it, and makes it freely accessible to anyone with a GPS receiver.
- **IMU Sensors** In some cases and depending on their design, some of the games may make use of accelerometers and even compass as part of their interaction paradigm. Nowadays almost every smart device counts with these systems.
- **Wi-Fi** is a technology that allows electronic devices to connect to a wireless LAN (WLAN) network, mainly using the 2.4 gigahertz UHF and 5 gigahertz SHF ISM radio bands.

  Devices which can use Wi-Fi technology include personal computers, video-game consoles, smartphones, digital cameras, tablet computers and digital audio players. Wi-Fi compatible devices can connect to the Internet via a WLAN network and a wireless access point. Such an access point (or hotspot) has a range of about 20 meters (66 feet) indoors and a greater range outdoors. Hotspot coverage can be as small as a single room with walls that block radio waves, or as large as many square kilometers achieved by using multiple overlapping access points.
- **Bluetooth** is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices, and building personal area networks. Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization.

3.3 Screen

- Types
  - AMOLED (active-matrix organic light-emitting diode) is a display technology used in smartwatches, mobile devices, laptops, and televisions. OLED describes a specific type of thin-film-display

technology in which organic compounds form the electroluminescent material, and active matrix refers to the technology behind the addressing of pixels.

- IPS (In-plane switching) is a screen technology for liquid crystal displays (LCDs). It was designed to solve the main limitations of the twisted nematic field effect matrix LCDs in the late 1980s. These limitations included strong viewing angle dependence and low-quality colour reproduction. In-plane switching involves arranging and switching the orientation of the molecules of the liquid crystal layer between the glass substrates. This is done, essentially, parallel to these glass plates.

- The **resolution** in which a human eye is finally unable to see the pixels of the screen is around 320 pixels per inch for a screen located about 40 cm away; therefore this is the minimum density of pixels that terminals to be used should have.
- A **touch screen** is an input device normally layered on the top of an electronic visual display of an information processing system. A user can give input or control the information processing system through simple or multi-touch gestures by touching the screen with a special stylus and/or one or more fingers. The touch screen enables the user to interact directly with what is displayed and to control how it is displayed; for example, zooming to increase the text size.

4. MOBILE PLATFORMS

A mobile operating system (Mobile OS) is an operating system that controls a mobile device like PCs using Windows or Linux. Likewise, mobile devices have their operating systems such as Android and iOS among others. However, mobile operating systems are much simpler than those for PC and are more oriented to wireless connectivity, mobile multimedia formats and different ways to enter information in them, especially by touch screens.

4.1 Firefox OS

Firefox OS is an operating system for mobiles, mainly developed by Mozilla Corporation, which is based on HTML5 with a Linux kernel designed in such a way that enables HTML5 applications to directly communicate to the hardware using JavaScript and Open Web APIs.

FIGURE 1 - Firefox OS logo

4.1.1 Features

- SQLite, a server-less database management system based on SQL.
- Web applications without navigator
- Adaptive searching.
- Adaptable interface design.
- The initial development work involves three major software layers:
  - Gonk: Platform denomination for a combination of the Linux kernel and the hardware abstraction layer from Android
  - Gecko: the web browser engine and application run-time services layer
  - Gaia: An HTML5 layer and user-interface system

4.1.2 Development Tools

Firefox OS applications are just Open Web apps. These are basically HTML5 applications, which are installed on a device running Firefox OS.

Web applications are built using web standard technologies working on any modern web browser and can be developed using a wide variety of tools, such as Dreamweaver or Eclipse.

4.1.3 Evolution and future

The development of Firefox OS has been discontinued due to the poor reception among the business sector and thus, the marketplace is intended to only accept applications until 2017. From that moment on, no developments or updates on the devices will be officially made containing this operating system.

In addition, current devices using this operating system are scarce and all belong to the range of low-end devices (see FIGURE 2).

FIGURE 2 - Alcatel One Touch Fire E running Firefox OS

4.2 Ubuntu Touch

Ubuntu Touch is an operating system for mobile phones based on Linux and developed by Canonical. Ubuntu Touch is in general a new Ubuntu distribution with a different UI that is adapted specifically for mobile devices with a touch screen like phones and tablets (see FIGURE 3).

4.2.1 Features

- Qt 5, a user interface library for application development in computers using C++ language.
- Lock screen
- Scopes
- Side Stage
- Convergence desktop mode
- It doesn´t count on some widespread applications such as WhatsApp

4.2.2 Development Tools

- HTML5
- Qt/QML (Native applications)
- Targeting APIs: Ubuntu applications and scopes are packaged, distributed and deployed using a format called click packaging. When packaged, all apps and scopes must declare which API framework they are intending to use on the device.
- Security and app isolation: All Ubuntu apps and scopes are confined, meaning they only have access to their own resources and are isolated from other apps and parts of the system. The developer must declare which policy groups are

needed for the app or scope to function properly within the confinement rules providing security and privacy.

- The build environment: A build environment, or click target, will be required to develop and test an app or scope. This environment will make it possible to build the software for a different architecture if cross-compilation is required (e.g. an app that uses C++) and to run it on different devices (the desktop, a phone/tablet or the emulator). Whenever a target is required the Integrated Development Environment (IDE) will help to configure it based on the framework and target architecture (e.g. i386 or armhf). The architecture will correspond to the test environment the developer is using and ultimately what the products are built with.
- Testing applications on devices: As far as testing environments, the developer can choose an Ubuntu emulator, which can be x86 or armhf, or real hardware with a reference device, such as the Nexus 4 or Nexus 7. While it is possible that simple apps may work in the local desktop environment, it is only in these supported testing environments that the entire set of framework APIs are available. It is generally recommended that an app or scope be packaged as a click and installed to the device or emulator in order to properly test it. Again the IDE will assist with creating, validating, deploying and installing the package.

4.2.3 Evolution and future

Mark Shuttleworth, the founder of the company Canonical Ltd., believes that Ubuntu for phones will first find a niche in countries where Ubuntu is well known; more specifically, developing markets such as India and China where computers have Ubuntu pre-installed. However, the success of Ubuntu Phone in these markets is difficult to predict.

FIGURE 3- Two different devices running Ubuntu Touch

4.3 Windows 10 Mobile

Windows 10 Mobile is an edition of the Windows 10 operating system developed by Microsoft. This edition of Windows 10 is a mobile operating system that follows Windows Phone 8.1 and is designed for smartphones and tablets less than 8 inches of screen size, it runs on ARM as well in processor architectures IA-32 and 32 bits (see FIGURE 4).

FIGURE 4 - Windows 10 Mobile logo

4.3.1 Features

A major aspect of Windows 10 Mobile is a focus on harmonizing user experiences and functionality between different classes of devices specifically, devices running the PC-oriented version of Windows 10. Under the **Universal Windows Platform** concept, Windows Runtime apps for Windows 10 on PC can be ported to other platforms in the Windows 10 family with nearly the same codebase, but with adaptations for specific device classes. Windows 10 Mobile also shares user interface elements with its PC counterpart, such as the updated Action Center and settings menu. Although marketed as a converged platform, and as with Windows Phone 8, using a Windows NT-based kernel, Windows 10 Mobile still cannot run Win32 desktop applications, but is compatible with software designed for Windows Phone 8.

Notifications can be synced between devices; dismissing a notification on, for example, a laptop will also dismiss it from a phone. Certain types of notifications now allow inline replies. The start screen now has the option to display wallpapers as a background of the screen behind translucent tiles, rather than within the tiles. The messaging app adds support for internet-based Skype messaging alongside SMS, similarly to Apple´s iMessage, and can synchronize these conversations with other devices. The new Photos app aggregates content from local storage and OneDrive performing automatic enhancements to photos. The on-screen keyboard now contains a virtual pointing stick for manipulating the text editing cursor, a dedicated voice input button, and can be shifted towards the left or right of the screen to improve one-handed usability on larger devices (see FIGURE 5).

Windows 10 Mobile supports "**Continuum**", a feature that allows supported devices to connect to an external display, and scale its user interface and apps into a "PC-like" desktop interface with support for mouse and keyboard input over USB or Bluetooth. Devices can connect directly to external displays wirelessly using Miracast, via USB Type-C, or via docking station accessories with USB ports, as well as HDMI and DisplayPort outputs.

4.3.2 Development Tools

Universal Windows Platform (UWP) is a platform-homogeneous application architecture created by Microsoft and first introduced in Windows 10. The purpose of this software platform is to help develop Metro-style apps that run on both Windows 10 and Windows 10 Mobile without the need to be re-written for each. It supports Windows

application development using C++, C#, VB.NET, or XAML. The API is implemented in C++, and supported in C++, VB.NET, C#, and JavaScript. Designed as an extension to the Windows Runtime platform first introduced in Windows Server 2012 and Windows 8, the UWP allows developers to create applications that will potentially run on multiple types of devices.

4.3.3 Evolution and future

Developers may be less interested in developing for Windows Phone because of lower ad revenue when compared to competing platforms. The main criticism of Windows Phone is still the lack of applications when compared to iOS and Android. Developers are backing out of the platform and retiring apps because of the low market share.

FIGURE 5- Lumia phone running Windows 10 Mobile

4.4 Android

Android is an operating system for mobile devices such as smartphones and tablet computers. It is developed by the Open Handset Alliance led by Google. It's is built on a Linux foundation. Google purchased the initial developer of the software, Android Inc., in 2005. The unveiling of the Android distribution on November 5, 2007 was announced with the founding of the Open Handset Alliance, a consortium of 84 hardware, software, and telecommunication companies devoted to advancing open standards for mobile devices.

This alliance shares a common goal of fostering innovation on mobile devices and giving consumers a far better user experience than much of what is available on today's mobile platforms. By providing developers a new level of openness that enables them to work more collaboratively, Android will accelerate the pace at which new and compelling mobile services are made available to consumers. Android is often symbolized by a green robot (see FIGURE 6).

FIGURE 6 - Android logo

4.4.1 Features

- **Messaging**: SMS and MMS are the available forms of messaging, including threaded text messaging and Android Cloud to Device Messaging (C2DM). The now enhanced version of C2DM. Android Google Cloud Messaging (GCM) is also a part of Android Push Messaging services.
- **Web browser**: The web browser available in Android is based on the open-source Blink (previously WebKit) layout engine, coupled with Chrome's V8 JavaScript engine. The WebKit-using Android Browser scored 100/100 on the Acid3 test on Android 4.0 ICS; the Blink-based browser currently has better standards support. The browser is variably known as 'Android Browser', 'AOSP browser', 'stock browser', 'native browser', and 'default browser'. Starting with Android 4.4 KitKat, Google has mandated that the default browser for Android proper be Google Chrome. Since Android 5.0 Lollipop, the WebView browser that apps can use to display web content without leaving the app has been separated from the rest of the Android firmware in order to facilitate separate security updates by Google.
- **Voice-based features**: Google search through voice has been available since the initial release. Voice actions for calling, texting, navigation, etc. are supported on Android 2.2 onwards. As of Android 4.1, Google has expanded Voice Actions with the ability to talk back and read answers from Google's Knowledge Graph when queried with specific commands. The ability to control hardware has not yet been implemented.
- **Multi-touch**: Android has native support for multi-touch which was initially made available in handsets such as the HTC Hero. The feature was originally disabled at the kernel level (possibly to avoid infringing Apple's patents on touch-screen technology at the time). Google has since released an update for the Nexus One and the Motorola Droid which enables multi-touch natively.
- **Multitasking**: Multitasking of applications, with unique handling of memory allocation, is available.
- **Screen capture**: Android supports capturing a screenshot by pressing the power and home-screen buttons at the same time. Prior to Android 4.0, the only methods of capturing a screenshot were through manufacturer and third-party customizations (apps), or otherwise by using a PC connection (DDMS developer's tool). These alternative methods are still available with the latest Android.
- **Video calling**: Android does not support native video calling, but some handsets have a customized version of the operating system that supports it, either via the UMTS network (like the Samsung Galaxy S) or over IP. Video calling through 3rd party apps is available.
- **Multiple language support**: Android supports multiple languages.
- **Accessibility**: Built-in text-to-speech is provided by TalkBack for people with low or no vision. Enhancements for people with hearing difficulties are available, as are other aids.
- **Connectivity**: Android supports connectivity technologies including GSM/EDGE, Bluetooth, LTE, CDMA, EV-DO, UMTS, NFC, IDEN and WiMAX.

- **Bluetooth**: Supports voice dialing and sending contacts between phones, playing music, sending files or accessing the phone book. Keyboard, mouse and joystick support is available in Android 3.1+, and in earlier versions through manufacturer customizations and third-party applications.
- **Tethering**: Android supports tethering, which allows a phone to be used as a wireless/wired Wi-Fi hotspot. Before Android 2.2 this was supported by third-party applications or manufacturer customizations.
- **Streaming media support**: RTP/RTSP streaming (3GPP PSS, ISMA) and HTML progressive download (HTML5 <video> tag) are supported. Adobe Flash Streaming (RTMP) and HTTP Dynamic streaming are supported by the Flash plugin. Apple HTTP Live Streaming is supported by RealPlayer for Android, and by the operating system since Android 3.0 (Honeycomb).
- **Media support**: Android supports the most common and newest audio/video media formats
- **External storage**: Most Android devices include microSD card slots and can read microSD cards formatted with the FAT32, Ext3 or Ext4 file systems. To allow use of external storage media such as USB flash drives and USB HDDs, some Android devices are packaged with USB-OTG cables. Storage formatted with FAT32 is handled by the Linux Kernel vFAT driver, while 3rd party solutions are required to handle some other file systems such as NTFS, HFS Plus and exFAT.
- **Hardware support**: Android devices can include still/video cameras, touch screens, GPS, accelerometers, gyroscopes, barometers, magnetometers, dedicated gaming controls, proximity and pressure sensors, thermometers, accelerated 2D bit blits (with hardware orientation, scaling, pixel format conversion) and accelerated 3D graphics.
- **Java support**: While most Android applications are written in Java, there is no Java Virtual Machine in the platform and Java byte code is not executed. Java classes are compiled into Dalvik executables and run on using Android Runtime or in Dalvik in older versions, a specialized virtual machine designed specifically for Android and optimized for battery-powered mobile devices with limited memory and CPU. J2ME support can be provided via third-party applications.
- **Handset layouts**: The platform works for various screen sizes from smartphone sizes and to tablet size, and can potentially connect to an external screen, e.g. through HDMI, or wirelessly with Miracast. Portrait and landscape orientations are supported and usually switching between them is performed by turning the device. A 2D graphics library and a 3D graphics library based on OpenGL ES 2.0 specifications are used.
- **Storage**: SQLite, a lightweight relational database, is used for data storage purposes.
- **Native Apps**: Android apps are also written in HTML.

4.4.2 Development Tools

Android software development is the process by which new applications are created for the Android operating system. Applications are usually developed in the Java programming language using the Android software development kit (SDK), but other development environments are also available.

The Android software development kit (SDK) includes a comprehensive set of development tools. These include a debugger, libraries, a handset emulator based on QEMU, documentation, sample code, and tutorials. Currently supported development platforms include computers running Linux (any modern desktop Linux distribution), Mac OS X 10.5.8 or later, and Windows XP or later. As of March 2015, the SDK is not available on Android itself, but the software development is possible by using specialized Android applications.

Until around the end of 2014, the officially supported integrated development environment (IDE) was Eclipse using the Android Development Tools (ADT) Plugin, though IntelliJ IDEA IDE (all editions) fully supports Android development out of the box, and NetBeans IDE also supports Android development via a plugin. As of 2015, Android Studio, made by Google and powered by IntelliJ, is the official IDE; however, developers are free to use others. Additionally, developers may use any text editor to edit Java and XML files, then use command line tools (Java Development Kit and Apache Ant are required) to create, build and debug Android applications as well as control attached Android devices (e.g., triggering a reboot, installing software package(s) remotely).

Enhancements to Android's SDK go hand in hand with the overall Android platform development. The SDK also supports older versions of the Android platform in case developers wish to target their applications at older devices. Development tools are downloadable components, so after one has downloaded the latest version and platform, older platforms and tools can also be downloaded for compatibility testing.

4.4.3 Evolution and future

At the moment, Android is the indisputable leader of the mobile market: its devices sell more than iOS, Windows and BlackBerry together. As of July 2013, the Google Play Store had over 1 million Android apps published, and over 50 billion apps downloaded. Around 71% of mobile developers develop for Android, and Android’s open nature has encouraged lots of developers to use the open-source code as a foundation for community-driven projects, which add new features for advanced users or bring Android to devices which were officially released running other operating systems.

Developers’ priority is clearly Android (37%), followed by the always more elitist iOS (32%). Most of Android developers don’t want to monetize their apps, and that’s why revenues are much bigger for iOS. On the contrary, Android apps are much popular and loved by users. And developers seem to focus in the quantity of users more than in the revenues, so they will probably prioritize developing for Android in the future, although iOS could provide them bigger revenues.

FIGURE 7 - Nexus 6P running Android 6.0 Marshmallow

4.5 iOS

iOS (originally iPhone OS) is a mobile operating system created and developed by Apple Inc. and distributed exclusively for Apple hardware (see FIGURE 8). It is the operating system that presently powers many of the company's mobile devices, including the iPhone, iPad, and iPod touch. It is the second most popular mobile operating system in the world by sales, after Android. iPad tablets are also the second most popular, by sales, against Android since 2013.

The iOS user interface is based on the concept of direct manipulation, using multi-touch gestures. Interface control elements consist of sliders, switches, and buttons. Interaction with the OS includes gestures such as swipe, tap, pinch, and reverse pinch, all of which have specific definitions within the context of the iOS operating system and its multi-touch interface. Internal accelerometers are used by some applications to respond to shaking the device (one common result is the undo command) or rotating it in three dimensions (one common result is switching from portrait to landscape mode).

FIGURE 8 - iOS logo

4.5.1 Features

- **Home screen** displays application icons and a dock at the bottom of the screen where users can pin their most frequently used apps. The home screen appears whenever the user unlocks the device or presses the "Home" button (a physical button on the device) whilst in another app. Before iOS 4 on the iPhone 3GS and newer, the screen's background could be customized with other customizations available through jailbreaking, but can now be changed out-of-the-box. The screen has a status bar across the top to display data, such as time, battery level, and signal strength. The rest of the screen is devoted to the current application. When a passcode is set and a user switches on the device,

the passcode must be entered at the Lock Screen before access to the Home Screen is granted.

- **Accessibility** allows the user to customize various aspects of iOS to assist the user if assistance is needed in the area of seeing or hearing, and allows the addition of accessibility shortcuts.
- **Multitasking** for iOS was first released in June 2010 along with the release of iOS 4.0. Only certain devices—iPhone 4, iPhone 3GS, and iPod Touch 3rd generation—were able to use multitasking. The iPad did not get multitasking until the release of iOS 4.2.1 in November 2010. Currently, multitasking is supported on iPhone 3GS or newer, iPod Touch 3rd generation or newer, and all iPad models.
- **Siri** is a personal assistant and knowledge navigator which works as an application on supported devices. The service, directed by the user's spoken commands, can do a variety of different tasks, such as call or text someone, open an app, search the web, lookup sports information, find directions or locations, and answer general knowledge questions. Siri was updated in iOS 7 with a new interface, faster answers, Wikipedia, Twitter, and Bing support and the voice was changed to sound more human.
- **Game center** is an online multiplayer social gaming network released by Apple. It allows users to invite friends to play a game, start a multiplayer game through matchmaking, track their achievements, and compare their high scores on a leaderboard.

4.5.2 Development Tools

On 2007, Steve Jobs announced that a software development kit (SDK) would be made available to third-party developers. The SDK was released on March 6, 2008, and allows developers to make applications for the iPhone and iPod Touch, as well as test them in an iPhone simulator. However, loading an application onto the devices is only possible after paying an iPhone Developer Program fee.

The fees to join the respective developer programs for iOS and OS X were each set at 99€ per year. As of July 20, 2011, Apple released Xcode on its Mac App Store free to download for all OS X Lion users, instead of as a standalone download. Users can create and develop iOS and OS X applications using a free copy of Xcode; however, they cannot test their applications on a physical iOS device, or publish them to the App store, without first paying the yearly $99.00 iPhone Developer or Mac Developer Program fee.

Since the release of Xcode 3.1, Xcode is the development environment for the iOS SDK.

Developers are able to set any price above a set minimum for their applications to be distributed through the App Store, keeping 70% for the developer, and leaving 30% for Apple. Alternatively, they may opt to release the application for free and need not pay any costs to release or distribute the application except for the membership fee.

4.5.3 Evolution and future

Apple products have less and less weight in the technology market. This fact which could be unthinkable for most of the people, it becomes already a reality after knowing the data offered by the American company about their sales in 2015.

iPhone´s sales, Apple's flagship product, have been rated at 74.4 million units sold during the last quarter. On this occasion, the mobile sales have only increased by 1% over the last three months of 2014 showing the product stagnation, while the company is expecting a decrease in sales for the coming quarters, something that had never happened since its launch in 2007.

Still, the company continues its development plans foreseeing the launch of new devices and the evolution of its operating system in the future.

4.6 Comparison table

After the carried analysis on the most frequent available operative systems these are the features that allow comparing all of them:

	Firefox OS	Ubuntu Touch	Windows 10 Mobile	Android	iOS
Last version	2.2.0	14.04	10.0	6.0.1	9.3.2
Last version release	April 2015	April 2016	April 2016	October 2015	May 2016
OS Family	Linux	Linux	Windows NT 8+	Linux	Darwin
Open source	Yes	Yes	No	Yes	No
Open API/SDK	Yes	Yes	Yes	Yes	Yes
License	Free and open-source	Free and open-source	Microsoft EULA	Apache	Proprietary
Company	Mozilla Foundation	Canonical Ltd.	Microsoft	Open Handset Alliance	Apple Inc.
Application store	Firefox Marketplace	Windows Phone Store	Ubuntu Store	Google Play	App Store
Architecture	ARM, ARM64, x86	ARM, x86, x86-64	ARM, ARM64, x86, x86-64	ARM, ARM64, x86, x86-64, MIPS	ARM, ARM64
SDK platforms	Windows, Mac OS X and Linux	Ubuntu	Windows	Windows, Mac OS X and Linux	Mac OS X
Market share	< 1%	<1%	< 1%	**> 80%**	± 15%
Market place openness	More opened	More opened	More closed	More opened	More closed

TABLE 1 - Mobile OS comparative analysis

4.7 Conclusions

Android and iOS are considered the most suitable operative systems for the project for several reasons; both have reached a mature development state and both are a greatly accepted on the market. Android has an extra value due to the fact that many smart devices firms have adopted it as their standard while iOS is only supported on Apple devices.

Other factors pointing to an Android device selection are the market share (> 80%) and the easiness to develop and upload apps to its corresponding market place.

5. GAME ENGINES FOR MOBILE PLATFORMS

A game engine is a term that refers to a series of programming routines that enable the design, creation and representation of a video game. Similarly, there are game engines operating in both game consoles and operating systems, or as in our case, mobile devices. The basic functionality of an engine is to provide the video game with a rendering engine for 2D and 3D graphics, physics engine or collision detection, sound, scripting, animation, artificial intelligence, memory management, and a graphic environment.

Next, the most outstanding graphics engines for gaming are listed:

5.1 Unity 3D

FIGURE 9 - Screenshot of the Unity 3D interface

Unity[1] is a cross-platform game engine developed by Unity Technologies and used to develop video games for PC, consoles, mobile devices and websites. First announced only for OS X, at Apple's Worldwide Developers Conference in 2005, it has since been extended to target twenty one platforms. It is the default software development kit (SDK) for the Wii U.

5.1.1 Features

- Real-time Global Illumination by Enlighten
- Physics based shading
- Curve and gradient managed particle system
- Facial animation
- Intuitive UI Tools (see FIGURE 9).
- Multithreading capabilities
- Box2D physics and NVIDIA PhysX 3.3
- C# and Java scripting
- Native integration with Visual Studio

5.2 Unreal engine 4

The Unreal Engine[2] is a game engine developed by Epic Games, first showcased in the 1998 first-person shooter game Unreal. Although primarily developed for first-person shooters, it has been successfully used in a variety of other genres, including stealth, MMORPGs, and other RPGs. With its code written in C++, the Unreal Engine features a high degree of portability and is a tool used by many game developers today.

The current release is Unreal Engine 4, designed for Microsoft's DirectX 11 and 12 (for Microsoft Windows, Xbox One, Windows RT); OpenGL (for OS X, Linux, PlayStation 4, iOS, Android, Ouya and Windows XP); Vulkan (for Android); Metal (for iOS) ;and JavaScript/WebGL (for HTML5 Web browsers).

5.2.1 Features

- Multi-platform
- Scripts with Unreal Scripting

[1] unity3d.com

[2] www.unrealengine.com

- Artificial intelligence
- Full source code access
- Terrain & foliage generation
- Character animation
- Instant game preview & hot reload function
- Cinematic toolset
- Physics by NVIDIA PhysX

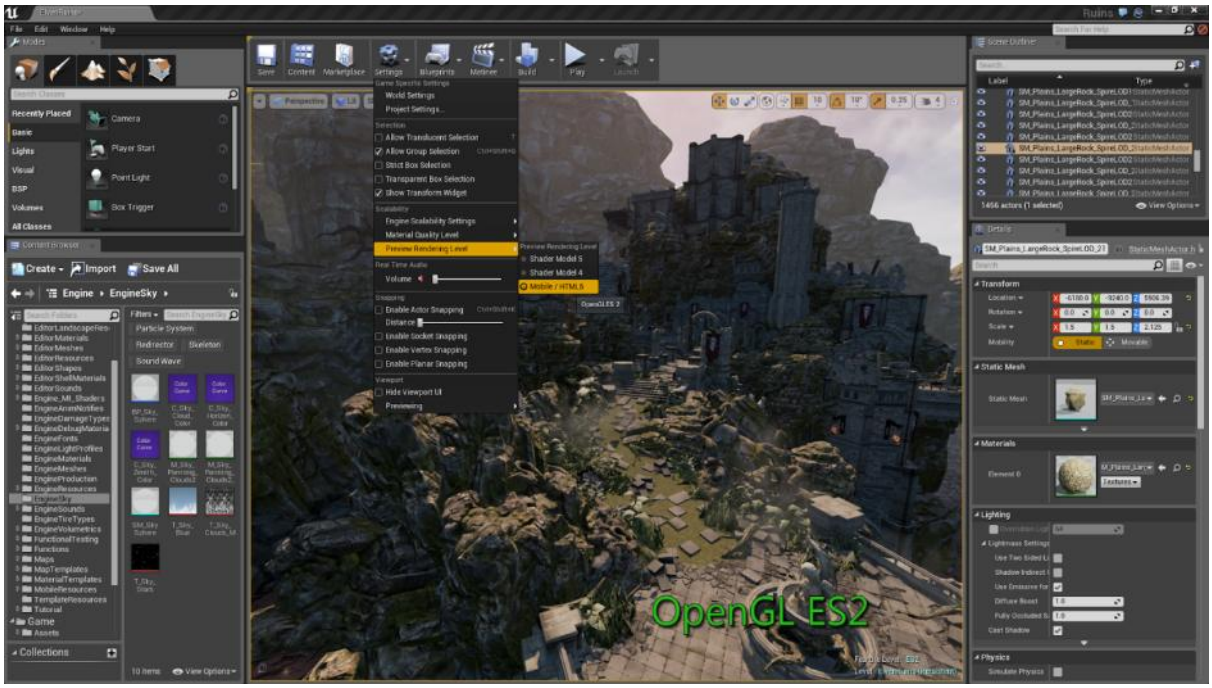

FIGURE 10 - Screenshot of the Unreal engine 4 interface

5.3 CryEngine

CryEngine[3] is a game engine designed by the German game developer Crytek. It has been used in all of their titles with the initial version being used in Far Cry, and continues to be updated to support new consoles and hardware for their games. It has also been used for many third-party games under Crytek's licensing scheme, including Sniper: Ghost Warrior 2 and SNOW. Cloud Imperium Games use a modified version of the engine for the games Star Citizen and Squadron 42. Ubisoft maintains an in-house, heavily modified version of CryEngine from the original Far Cry called the Dunia Engine, which is used in their later iterations of the Far Cry series.

5.3.1 Features

- Multi-platform

[3] www.cryengine.com

- Scripting with Lua
- Material editor
- Vehicle creator
- Performance Analysis Tool
- Integrated vegetation & terrain cover generation system
- Real time dynamic global illumination
- Natural lighting & dynamic soft shadows with penumbra
- Integrated multi-threaded physics engine
- Volumetric, layer & view distance fogging

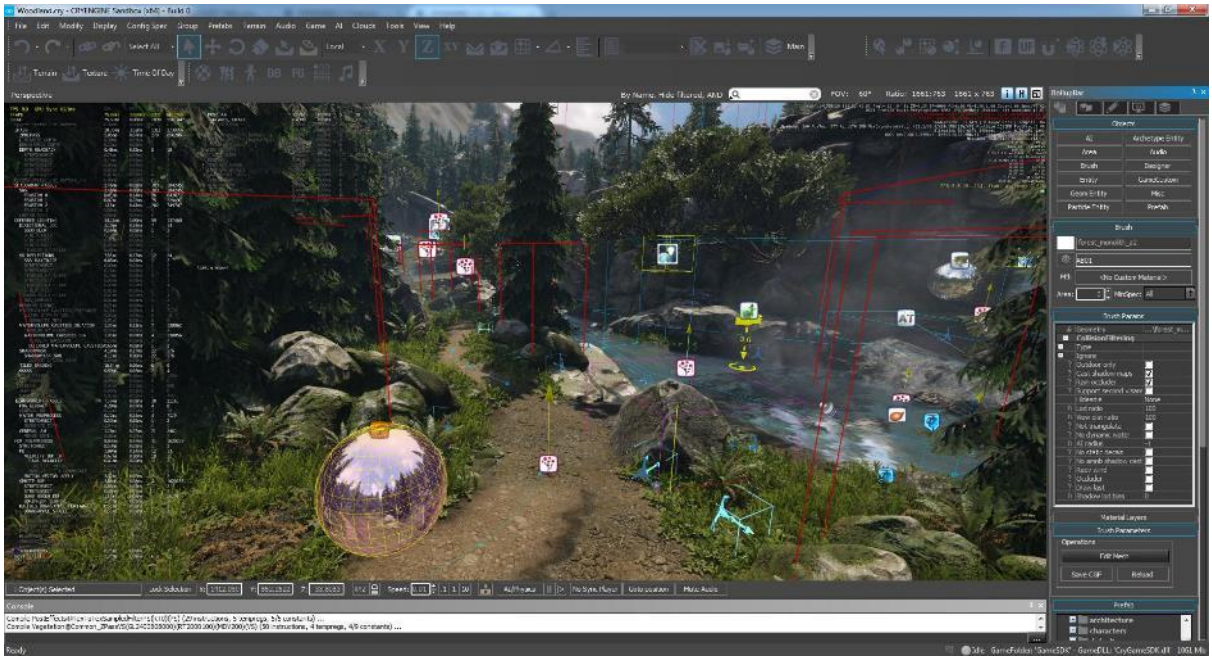

FIGURE 11 - Screenshot of the CryEngine interface

5.4 GameMaker Studio

GameMaker Studio[4] is a tool for rapid application development (RAD), property of YoYoGames, which is based on an interpreted programming language and a software development kit (SDK) to develop video games, created by Professor Mark Overmars in the Delphi programming language, which is mainly oriented to inexperienced users or ones knowing basic notions of programming. The program is free, although there is an extended commercial version with additional features.

The program is designed to allow its users to easily develop games without having to learn a programming language such as C ++ or Java. For advanced users, Game

[4] www.yoyogames.com/gamemaker

Maker contains a scripting programming language so called Game Maker Language (GML), which enables users to further customize their games and expand their features. Video games can be distributed under any license subject to the terms of the EULA of Game Maker in non-editable executable files ".exe" Android packages ".apk" and sets HTML5 script as source code with extension .gmx. Users of Game Maker are allowed to distribute and even sell their creations as long as they comply with the EULA terms of Game Maker, which bans a number of illegal programs such as those involving unauthorized use of copyrighted material.

FIGURE 12 - Screenshot of the GameMaker interface

5.4.1 Features

- Multi-Platform
- Drag and drop interface (see FIGURE 12)
- C programming language
- *Box2d* physics and *LiquidFun* particle physics engine
- Spine 2D animation from Esoteric Software
- Shaders capability
- Resources marketplace
- Own scripts language (GML)

5.5 ShiVa3D

ShiVa3D[5] is a 3D game engine with a graphical editor designed to create applications and video games for desktop PCs, the web, game consoles and mobile devices (see FIGURE 13). Games made with ShiVa can be exported to over 20 target platforms, with new export targets being added regularly.

Many applications have been created using ShiVa, including the Prince of Persia 2 remake for Mobiles and Babel Rising published by Ubisoft.

FIGURE 13 - Screenshot of the ShiVa3D interface

5.5.1 Features

- Multi-Platform
- Geometry up to 15M triangles per frame
- Shaders
- Lights and shadows
- Particles and trails
- C++ plugin support
- Lua scripting
- ODE based physics
- 2D HUD system for on-screen information displays

[5] www.shivaengine.com

5.6 AppGameKit

App Game Kit[6] is an easy, instant game development engine, ideal for beginners and indie developers. One can easily and quickly code and build apps for multiple platforms using AppGameKit's BASIC scripting system. Using a few commands, one can have demos/games running on mobile devices.

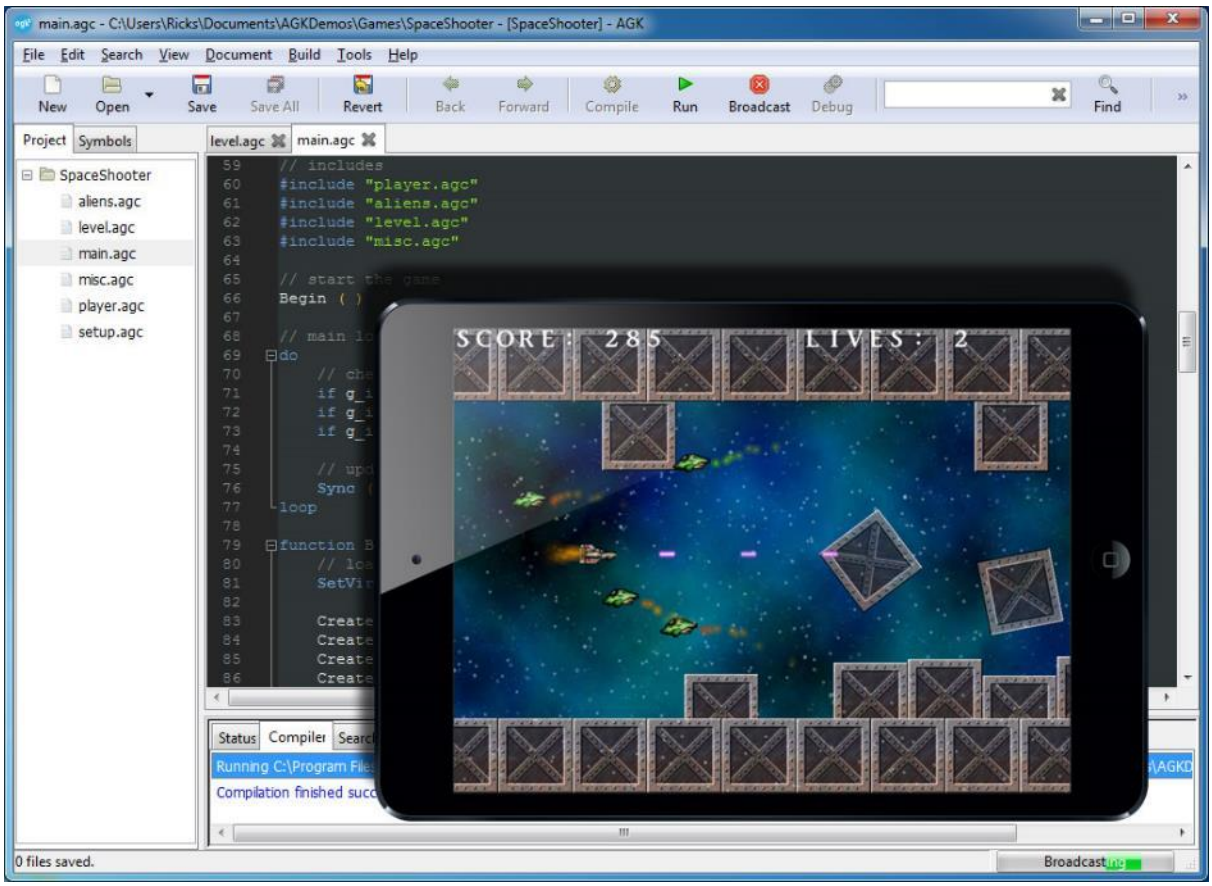

FIGURE 14 - Screenshot of the AppGameKit interface

5.6.1 Features

- Multi-Platform
- IntelliSense
- Code folding
- Colour schemes
- Multiple projects editing
- Fast Compiler

[6] www.appgamekit.com

- Full debugger
- Broadcast direct to device
- Export to exe, app, ipa, apk

5.7 Marmalade SDK

Marmalade SDK[7] is a cross-platform software development kit and game engine from Marmalade Technologies Limited that contains library files, samples, documentation and tools required to develop, test and deploy applications for mobile devices (see FIGURE 15).

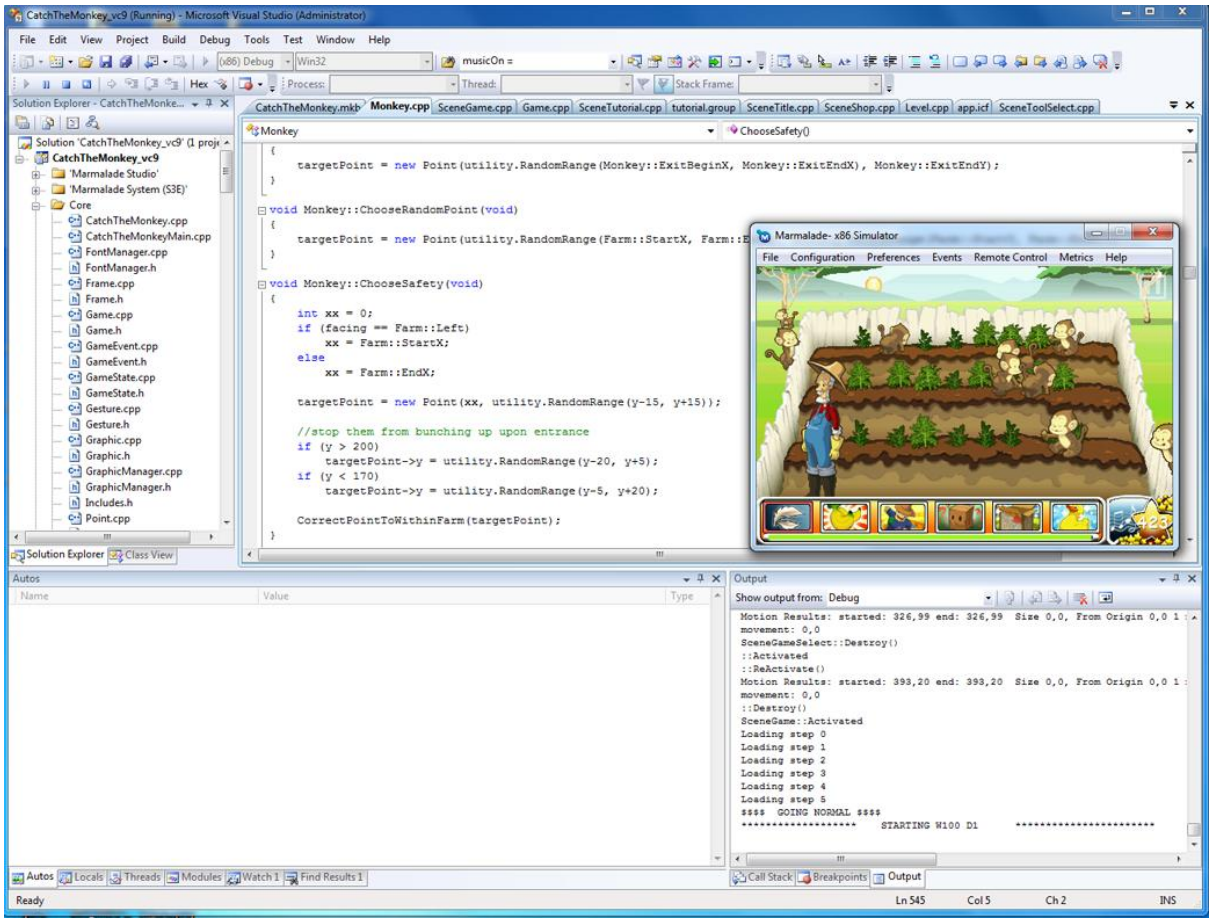

FIGURE 15 - Screenshot of the Visual interface with Marmalade debug window

5.7.1 Features

- Multi-Platform

[7] www.madewithmarmalade.com

- Divided in two layers: Marmalade system (abstraction layer) and Marmalade Studio (high level).

5.8 GameSalad

GameSalad Creator[8] is an authoring tool developed by GameSalad, Inc. aimed primarily at non-programmers for composing games in a drag-and-drop fashion; using visual editors and a behavior-based logic system (see FIGURE 16). It is used by consumers and creative professionals such as graphic designers, animators, and game developers for rapidly prototyping, building and self-publishing cross-platform games and interactive media.

The application runs on Mac OS X for producing games for iPhone. It also runs on Windows which is optimized for producing games on Android devices although games developed on Windows have to be converted to Mac OS files to be published to the App Store, web browser-based content in HTML 5, and Android applications.

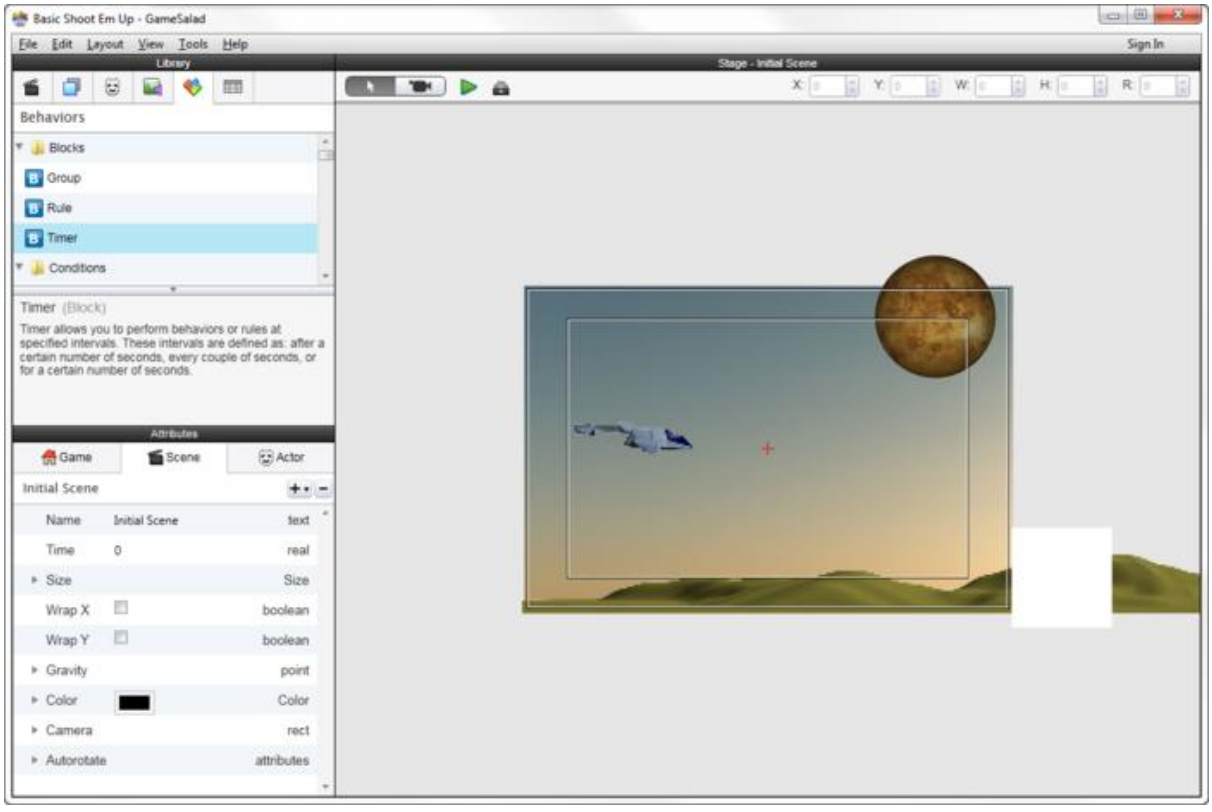

FIGURE 16 - Screenshot of the GameSalad interface

[8] gamesalad.com

5.8.1 Features

- Mobile devices multi-platform publishing
- Tables/arrays for data management
- Real-time editing
- Game preview
- Scene editor
- Integrated physics
- Mathematical expressions and math functions library
- GameSalad market website to buy and sell sprites, graphics, and other content.

5.9 Comparison

The following table contains a collective comparison of the above examined game engines, with respect to the most important features.

Game engines comparison								
	Unity 3D	**Unreal Engine 4**	**Cry Engine**	**Game Maker**	**ShiVa3D**	**App Game Kit**	**Marmalade SDK**	**Game Salad**
Platform	All	All	All	All	All	All	All	Mobile
Own interface	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
2D/3D	2D & 3D	2D & 3D	2D & 3D	2D	3D	2D & 3D	2D & 3D	2D
Physics	PhysX	PhysX	Cry Physics	Box2D	ODE	Bullet physics	Box2D	Yes
Scripting	C# and Unity Script	Blueprints Visual Scripting	Lua	C based	Lua	Basic	Lua	No
Notable games	> 200	> 200	> 100	> 25	> 25	> 10	> 10	>25
Free edition	Yes	Yes	Yes	Windows only	Trial	Trial	With advertisements	Education only
Pro edition	75 € /month	-	-	75€ - 500€	200€ - 1000€	> 70€	500€ - 3.500€	29€ / month

Royalties	No	5%	No	No	No	No	No	No
Resources market	Yes	Yes	Yes	Yes	No	No	Yes	Yes

TABLE 2 - Game engines comparative analysis

5.10 Conclusions

After having analyzed the existing graphic engines and their supported functionalities, the FrailSafe consortium has agreed to use the Unity game engine in order to develop the different games that will be integrated into the FrailSafe platform.

The Unity engine has been selected because of its wide possibilities of development, even included in the free version, and due to its technical superiority over other game engines as analyzed above (see TABLE 1). Moreover, the fact that it is one of the most well-known and used engines, makes it possible to find a large community of users sharing problems and solutions.

6. DEVICES

6.1 Smartphones

A smartphone is a type of mobile phone built on a mobile computing platform, with greater capacity to store data and activities, similar to a minicomputer, and with greater connectivity than a conventional mobile phone. The name, which is used for commercial purposes, refers to the ability to be used as a pocket PC, even being able to replace a personal computer at the user level.

Among the common features we can find the touch screen, email management, installation of additional and third-party applications and third-party, multitasking, access to the Internet via Wi-Fi or 4G, 3G or 2G networks, multimedia function (camera and video player / mp3), calendar programs, contact management, accelerometers, GPS and other sensors and some navigation programs, and occasionally the ability to read documents in a variety of formats.

A comparative analysis of the most significant models on the market at this moment is presented thereafter.

6.1.1 HTC 10

The HTC 10 smartphone is the latest in the company´s portfolio. It is a next-generation device with a Wide Quad HD (2.560x1.440) 5.2-inch screen.

The terminal has a physical start button and capacitive buttons for navigation and options. The phone also incorporates a rear and front cameras of 12 and 5 megapixels respectively.

The processor is a 4 core Snapdragon 820, with 4 GB of RAM, and the option of 32 or 64 GB for internal storage. It also has a microSD slot for expanding the storage capacity.

The device also has a fast charge system (QuickCharge 3.0) that allows for half the battery power 3,000 mAh in 30 minutes.

This terminal has GPS sensors, ambient light sensors, proximity sensors, accelerometer, compass, gyroscope, and HUB fingerprint sensor.

FIGURE 17 – View of the HTC 10 smartphone

6.1.2 Google Nexus 5X

Nexus 5X is a next-generation mobile phone manufactured by LG at the Google´s request, on the occasion of the new version of the Android operating system launch. Google also provides these devices with the advantage of being the first to receive the operating system and applications software updates. It has a 5.2 inch screen with a FullHD resolution (see FIGURE 18 - View of the Google Nexus 5X smartphone

The processor is a 6-core Snapdragon 808 and has 2GB of RAM. There are available versions of 16 or 32 GB of internal storage, but it has no expandability. The battery capacity is 2700 mAh.

It has a 12.3-megapixel main camera and a secondary with 5 megapixels. Start buttons and options are implemented by software and are integrated into the screen.

This phone is the most economical by far among all the evaluated Android devices, being ranked at the head in comparison with other options studied.

The sensors this device comprises are the following: the fingerprint sensor, Hub sensor, accelerometer, gyroscope, barometer, ambient light, proximity and Hall sensor.

FIGURE 18 - View of the Google Nexus 5X smartphone

6.1.3 Samsung Galaxy S7

This is the latest smartphone from Samsung, launched in February 2016; it has a Snapdragon 820 quad-core processor and 4 GB of RAM, having installed the Android 6.0 operating system.

There are versions of 32 or 64 GB for internal storage, but both of them have microSD expansion slot for up to 200GB.

The device has a 5.1 inch WQHD screen, a physical start button and capacitive navigation buttons and options. The main camera has a resolution of 12 megapixels and the front one has 5 megapixels.

This smartphone battery has a capacity of 3000 mAh and sensors included in the terminal are accelerometer, barometer, fingerprint, gyroscope, compass, Hall sensor, proximity sensor and RGB light.

FIGURE 19 - View of the Samsung Galaxy S7 smartphone

6.1.4 iPhone 6s

iPhone 6s is Apple´s smartphone, and therefore integrates the operating system iOS 9 of the same company.

The phone has a 4.7-inch screen with a resolution of 1.334x750 pixels (see FIGURE 20), implying that is one of the phones with the lowest resolution within this study.

Apple integrates a dual-core A9 processor and 2GB of RAM. There are models available with storage capacity of 16, 64 and 128 GB, albeit none of them include the possibility of extension. Its 1715 mAh battery, despite working with an operating system of lower consumption, does not reach the level of other models in comparison to.

The phone cameras have a resolution of 12 and 5 megapixels respectively.

The sensors included in this phone are GPS, digital compass, fingerprint, barometer, gyroscope, accelerometer, proximity sensor and ambient light sensor.

FIGURE 20 - View of the iPhone 6S smartphone

6.1.5 Lumia 950

The phone model Lumia 950 belongs to Microsoft, which comprises the Windows 10 operating system; it has also integrated a six-core processor Snapdragon 808 and 3GB of RAM. It has a 5.2 inch screen with a resolution of 2.560x1.440 pixels (FIGURE 21).

The storage capacity is 32 GB expandable to 200 GB via a microSD card. The main and front cameras have a resolution of 20 and 5MP respectively.

The smartphone has ambient light sensors, GPS, accelerometer, proximity sensor, barometer, gyroscope and magnetometer.

FIGURE 21 - View of the Lumia 950 smartphone

6.1.6 Comparison table

After the analysis of the different devices, these are the more important characteristics found on them:

	HTC 10	Google Nexus 5X	Samsung Galaxy S7	iPhone 6s	Lumia 950
Width	71.9 mm	72.6 mm	69.5 mm	67.1 mm	73.2 mm
Height	145.9 mm	147.0 mm	142.5 mm	138.3 mm	145.0 mm
Depth	9.0 mm	7.9 mm	8.7 mm	7.1 mm	8.2 mm
Weight	161 gr.	136 gr.	152 gr.	143 gr.	150 gr.
Screen Size	5.2”	5.2”	5.1”	4.7”	5.2“
Resolution	1440 x 2560	1080 x 1920	1440 x 2560	750 x 1334	1440 x 2560
Pixels per inch	565 ppi	424 ppi	577 ppi	326 ppi	565 ppi
Screen type	Super LCD IPS	LCD IPS	Super Amoled	LCD IPS	Amoled
CPU	Snapdragon 820 (2 x 2.15	Snapdragon 808 (4 x 1.44	Exynos 8 8890 (4 x 2.3	Apple A9 (2 x 1.84	Snapdragon 808 (4 x 1.44

	GHz + 2 x 1.6 GHz)	GHz + 2 x 1.82 GHz)	GHz + 4 x 1.6 GHz)	GHz)	GHz + 2 x 1.82 GHz)
GPU	Adreno 530 (624 MHz)	Adreno 418	Mali-T880 Mp 12 (650 MHz)	PowerVR GT7600	Adreno 418
RAM	4 GB	2 GB	4 GB	2 GB	3 GB
Storage	32 GB	16 GB	32 GB	16 GB	32 GB
SD Slot	Yes	No	Yes	No	Yes
Camera resolution	12.2 Mpx	12.0 Mpx	12.0 Mpx	12.2 Mpx	20.1 Mpx
Camera aperture	f/ 1.8	f/ 2.0	f/ 1.7	f/ 2.2	f/ 1.9
Camera sensor	Sony IMX377 Exmor RS	Sony IMX377 Exmor RS	Sony IMX260 Exmor RS	Apple iSight Camera	PureView
Slowmotion	120.0 fps	120.0 fps	120.0 fps	120.0 fps	No
Fingerprint recognition	Yes	Yes	Yes	Yes	No
Wi-Fi	802.11 a/b/g/n/ac	802.11 a/b/g/n/ac	802.11 a/b/g/n/ac	802.11 a/b/g/n/ac	802.11 a/b/g/n/ac
Bluetooth	4.2	4.2	4.1	4.2	4.1
NFC	Yes	Yes	Yes	Yes	Yes
Navigation	A-GPS, Beidou, GLONASS, GPS	A-GPS, GLONASS, GPS	A-GPS, Beidou, GLONASS, GPS	A-GPS, GLONASS, GPS	A-GPS, Beidou, GLONASS, GPS
Charge cable	USB Type-C	USB Type-C	Micro USB 2	Lighting	USB Type-C
Battery	3000 mAh	2700 mAh	3000 mAh	1715 mAh	3000 mAh
OS	Android 6.0	Android 6.0	Android 6.0	iOS 9	Windows 10

					Mobile
Cost	749 €	429 €	720 €	749 €	585 €

TABLE 3 – Smartphones comparative analysis

6.1.7 Conclusions

The selected phone for the project has been the Google Nexus 5X because it presents enough features according to the project's needs and meets all the technical requirements mentioned, while having a low cost compared to other Android operating system alternatives.

6.2 Tablets

A tablet can be described as a laptop larger than a smartphone or a PDA, integrated into a touch screen with which the user has to interact primarily making use of the finger or a stylus, with no need of physical keyboard or mouse. These peripherals have been replaced by a virtual keyboard and, in certain models, a mini trackball integrated into one of the edges of the screen.

The term can be applied to a range of formats that differ in the screen size or position with respect to a keyboard. The standard format is called *blackboard*, usually 7 to 12 inches dimension, without integrated keyboard but it can be generally connected to via an external one.

The common uses attributed to the tablets are:

- Reading e-books or comics.
- Documents consultation and editing.
- Web browsing.
- GPS navigation.
- Playing videos, movies and music.
- Photographic camera and HD video.
- Videoconference.
- Video game.

6.2.1 Pixel C

Google Pixel C is a tablet designed and manufactured by Google unlike the Nexus range devices that are designed by Google but manufactured by other companies.

The outer finishing is completely made of aluminum, a material that has an exceptional touch. At the rear of the device, an elongated LED stands out which is common in the Pixel range of products which serves as a battery level indicator.

The sound is heard from two stereo speakers in what is perhaps one of the best sounds that may be found on an Android device. The device is completed also with 4 microphones designed primarily for speech recognition.

Despite being sold separately, the **keyboard** is an important part of the tablet (see FIGURE 22). Its price amounts to 169 €. It has a 5.5 mm magnetic system to allow adjusting the inclination angle. The connection with the tablet is via Bluetooth. It also acts as a protective cover when the device is not used. Besides, the device includes a 0.5Whr battery that can be recharged through the tablet wirelessly.

The **screen** made using LTPS technology (Low-temperature polycrystalline silicon) shows an exceptional result. The resolution of 2560 x 1800 pixels gives a density of 308 ppi. The brightness reaches 500 nits and contrast is 1500:1.

The **performance** is outstanding, one of the best in the market. This is thanks to the Tegra X1 processor with 4 cores at 1.9GHz and the GPU Maxwell both manufactured by NVIDIA. As for RAM capacity, the device counts on a 3GB RAM available.

FIGURE 22 - Tablet Pixel C and keyboard

6.2.2 Google Nexus 9

After Nexus 7 and Nexus 10, Google decided to renew its range of tablets with Nexus 9. This time the chosen manufacturer for the task was HTC.

The **screen** size is 8.9 inches in 4:3 format (see FIGURE 23). The side edges of the screen are narrow whereas the upper and lower are wider. This last feature is due to the fact that two front speakers are located in that place with **HTC BoomSound** system offering a good level of volume and dynamic range. The side is formed by a metal frame, in concrete made of aluminum. And the back is made of plastic with a matte finishing. All in all, it turns out to be a fairly compact design although there are other thinner devices.

The **performance** of this tablet is quite good. It has a CPU NVIDIA Tegra K1 dual-core 2.5 GHz and 64-bit architecture. It is important to bear in mind that this device was the first to take advantage of 64-bit thanks to Android 5.0 Lollipop. It also comes with a 192-core Kepler GPU and 2GB of RAM.

Autonomy does not disappoint, it can last between 8 and 10 hours of moderate and continued use. However the battery charge is ratherslow because the charger is 1.5 A. Consequently, the process might last up to 5 hours.

FIGURE 23 - Google Nexus 9

6.2.3 Samsung Galaxy Tab S2

The Samsung Galaxy Tab S2 is an evolution of the previous model, Galaxy Tab S, which evolves from a format screen 16:9 to a 4:3 being launched in two different screen sizes: 9.7 and 8 inches.

Having reduced the tablet dimensions in comparison with to the previous version, it is especially notable for its thickness of only 5.6 mm and weight of 389 grams. Values that make this device very suitable if one is looking for portability and ease of transport.

The construction is very good, glass is the main material in the front and the back is made of plastic with a slightly rough texture.

The **performance** of this tablet is remarkable, though not excellent. It includes a processor that is not top-end, the same that integrates Galaxy Note 4 Exynos 5433 (4 x 1.9 GHz + 4 x 1.3 GHz). To all this, it is also added 3GB of **RAM** and a choice of 32 or 64 GB of **storage**. The possibility to expand storage with microSD cards is also a very interesting feature.

The **fingerprint reader** is a component that is becoming quite relevant in the latest models of smartphones recently released to the market. This is not the case with tablets, where their presence is still insignificant. This device includes this element, which differentiates this tablet from its competitors.

The **screen** here is excellent, both due to the Super AMOLED technology that provides striking colours and brightness, and the resolution of 2048 x 1536 pixels. This offers a total of 264 ppi density, which is more than acceptable for a nearly 10-inch screen value (see FIGURE 24).

The **battery**, of 5870 mAh, can last for up to 6 hours. Although it may be sufficient for many users, some of them would have preferred a slight increase in the thickness of the tablet, in expense for a larger battery.

FIGURE 24 - Samsung Galaxy Tab S2

6.2.4 BQ Aquaris M10 Ubuntu Edition

This BQ company´s device is the first to provide tablets with the Ubuntu Touch operating system. It is based on another model BQ itself, the Aquaris M10 with which it shares hardware, but not the OS. The specifications are mid-range but the price is quite affordable starting from € 219.90.

Regarding the **screen,** one can choose between two different configurations, one with HD resolution of 1280x800 pixels and a FullHD with 1920x1200 pixels with a density of 240 ppi (see FIGURE 26).

As for the **processor,** it includes a SoC (System on a Chip) Mediatek MT8163A to 64 bits Cortex A53 cores and four 1.5GHz, accompanied by 2GB of RAM. These components are sufficient enough to run easily other operating systems, but in this case, with Ubuntu Touch the device has constant stoppages and slowness typical in computers from several years ago. This behavior is even more evident on the **desktop mode**, which is automatically activated when connecting a keyboard and a mouse. The operating system shows that it is not yet up to its competitors, Android and iOS.

The **battery**, which has 7280 mAh, does not provide more autonomy than half day intensive use. This added to the fact that the device is not properly inserted in idle mode, makes the device to have to be constantly charged.

The structure quality is not the strongest point, since the plastic is the principal material and it is prone to get dirty because of fingerprints, both at the rear part and on screen.

As positive aspects, it can be outlined that there is a video output **microHDMI**, enabling the user to connect directly to the TV. Besides, the phone also has two speakers which generate **stereo audio** thanks to Dolby Atmos technology but the competitive **price** for the FullHD screen version amounts at € 269.90

FIGURE 25 - BQ Aquaris M10 Ubuntu Edition

6.2.5 Comparison table

After the analysis of the different devices, these are the more important characteristics found on them:

	Pixel C	Google Nexus 9	Samsung Galaxy Tab S2	BQ Aquaris M10 Ubuntu Edition
Width	242 mm	226.1 mm	237.3 mm	246 mm
Height	179 mm	153.7 mm	169 mm	171 mm
Depth	7 mm	7.9 mm	5.6 mm	8.2 mm
Weight	517 gr.	425 gr.	389 gr.	470 gr.
Screen Size	10.2”	8.9”	9.7”	10.1”
Resolution	2560 x 1800	2048 x 1536	2048 x 1536	1920 x 1200
Pixels per inch	308 ppi	281 ppi	264 ppi	224 ppi
Screen Type	LTPS LCD	LCD IPS	Super Amoled	LCD IPS
CPU	NVIDIA Tegra X1 (4 x 1.9 GHz)	NVIDIA Tegra K1 (2 x 2.3 GHz)	Exynos 5433 4 x 1.9 GHz + 4 x	MediaTek MT8163A (4 x 1,5 GHz)
GPU	256-core Maxwell GPU	192-core GPU Kepler	Mali-T760 MP16	Mali-T720 MP2

RAM	3 GB	2 GB	3 GB	2 GB
Storage	32 GB	16 GB	16	16
Bluetooth	4.1	4.1	4.1	4.0
Charge cable	USB Type C	Micro USB 2.0	Micro USB 2.0	Micro USB 2.0
Battery	34.2 WHr (9000 mAh approx.)	6700 mAh	5870 mAh	7280 mAh
OS	Android 6.0	Android 5.0	Android 5.0	Ubuntu 15.04
Cost	499 €	389 €	469 €	269.9 €

TABLE 4 - Tablets comparative analysis

6.2.6 Conclusions

Finally, the selected tablet for the project is Pixel C, since the different games of the project will be developed to be used in tablets. Consequently, the technical team has chosen a model offering better screen features and resolution in order to facilitate user´s usability.

It also has a large battery capacity and is the one with the largest storage capacity. Although not being a determining aspect, this tablet also comes with the latest version of Android operating system what enables using the latest programming tools provided with that operating system.

6.3 PC

The selected personal computer has been Skylake, which is based on the Intel platform. The motherboard includes the Z170 chipset that replaces the previous Z97. Thanks to this component, now user can get support for DDR4 memory type, which is faster and more efficient than DDR3. In this case, apparently, 16 GB of RAM seems to be more than enough for a period of time of 3 years. On the other side, the selected CPU, based on Skylake, includes the socket 1151 that is the Intel Core i5-6500 to 3.2GHz, quad-core processor which is in fact quite powerful.

The graphics card is an NVIDIA GeForce GTX 970 with a power in line with the processor. As storage, it has been selected a mechanical hard drive Seagate Barracuda 7200.14 1TB capacity. For the time being, it has not been considered advisable, but if it comes, there could be also the option of including a hard disk SSD to improve the speed at loading files.

To be able to operate all components, it has finally been selected the power supply Tacens Radix AG VII 700W, which will be powerful enough to feed the graphics card, which is the component with the highest consumption.

The technical specifications of the computer to be used are:

- CPU: Intel Core i5-6500 3.2 GHz
- Motherboard: MSI Z170A PC Mate
- Fan: Cooler Master Hyper 212X
- RAM: G.kill Ripjaws V Red DDR4 2400 PC4-19200 16GB 2x8 CL15
- Hard Drive: Seagate Barracuda 7200.14 1 TB SATA3
- Power supply unit: Tacens Radix VII AG 700W 80 Plus Silver
- Case: NOX Coolbay SX USB 3.0
- MSI GeForce GTX 970 Gaming 4GB GDDR5

6.4 Wireless Mobile Broadband Modem

A mobile broadband modem, also known as a connect card or data card, is a type of modem that allows a laptop, a personal computer or a router to receive Internet access via a mobile broadband connection instead of using telephone or cable television lines.

A mobile Internet user can connect using a wireless modem to a wireless Internet Service Provider (ISP) to get Internet access.

6.4.1 Huawei E303

- Network band: 3G HSPA / HSUPA / HSDPA / HSPA / UMTS(WCDMA)-2100MHz
- 2G GSM/GPRS/EDGE-850/900/1800/1900MHz
- Data Speed Downlink Speed: 7.2Mbps
- Uplink Speed: 5.76Mbps
- Micro SD Memory Card Slot

FIGURE 26 - Huawei E303

6.4.2 TP-LINK M5250

The TP-LINK M5250 is a 3G pocket router with an integrated modem in order to be able to be connected to the Internet with all our devices from anywhere.

The main features of the TP-LINK M5250 are, among others, the incorporation of a 3G modem, so that one has just to insert inside a SIM card of choice in order to start using the mobile broadband. It supports HSPA + 21.6Mbps that speeds up to 5.76Mbps download and upload. It supports WCDMA 2100MHz and 900MHz bands, and also GSM 850, 900, 1800 and 1900MHz.

It has Wi-Fi N connectivity with speeds up to 150Mbps and allows connecting up to 10 users simultaneously.

Another important feature is that it has a slot for microSD cards up to 32GB capacity. Thanks to this internal storage, one can share files among those different Wi-Fi clients who will be connected to the device.

To increase mobility, it incorporates a battery with a capacity of 2000mAh to last a full day of intensive use.

It incorporates an LED screen devoted to display the battery level, connectivity to the Internet via 3G and the status of the Wi-Fi network.

FIGURE 27 - TP-Link M5250

6.4.3 ASUS 4G-N12

The main feature of this router is that it is provided with two aerials to supply Internet connection via 3G and 4G LTE networks through the main operators, with high speed and low latency connection.

This router is compatible with all major frequency bands used by operators both HSPA+ and 4G LTE. In addition, it also offers support for the 800MHz band that has greater penetration within homes; however this router has shown that using also higher bands can achieve a high speed of up to real 27Mbps inside the home. This router is Category 3, which means that it achieves a maximum speed of 100Mbps download and 50Mbps upload on 4G LTE technology. The ASUS 4G-N12 has a slot size MiniSim to directly enter the card provided by the operator.

Other features of this equipment are that it has Wi-Fi N; it achieves a speed of up to 300Mbps in the 2.4GHz band with its two internal aerials in MIMO 2T2R configuration and uses a 40MHz channel width. It also incorporates a Fast-Ethernet (10/100 Mbps) port that can work as WAN / LAN and three Fast Ethernet (10/100 Mbps) ports for LAN only.

Regarding the firmware ASUSWRT, this is one of the most complete as it is now fully operational with a large number of ISP, and it also has a large number of options and services.

FIGURE 28 - Asus 4G-N12

6.4.4 Conclusions

The option of the use of a 3G router for communicating mobile terminals to servers has been dismissed, since mobile phones themselves have the ability to connect using this technology and they can share an Internet connection wirelessly with those devices that are closer.

7. AUGMENTED REALITY DISPLAYS

7.1 Display Types

Augmented reality displays are generally the display devices that show the augmented world to the user. They can be separated into three categories: a) Head-mounted displays (HMDs), b) projection-based displays and c) handheld displays.

7.1.1 Head-Mounted Displays

Head-mounted displays are mostly employed in latest AR developments as they allow the user to see the real world with virtual objects superimposed on it by optical or video technologies. This distinction lets us further divide this type of displays into two subcategories: 1) Video see-through (VST) and 2) Optical see-through (OST) HMDs.

Video see-through displays are those that actively feed-forward the video of the real-world, captured by a forward-facing camera, with graphics superimposed on it. The advantages of VST devices include the availability of image-processing techniques like color and intensity correction and blending control, that allow easier handling of occlusion problems, and a larger field of view (FoV) compared to OST HMDs as they generally follow the concept of a VR HMD (e.g. Oculus Rift) with front-facing external cameras. The greatest disadvantage of VST devices is the susceptibility to common perceptual issues arising from presenting a stereoscopic image to the user.

As explained further in Section 7.2, within the context of FrailSafe, it is of significant importance to tackle and alleviate, if possible, perceptual issues such as depth-perception, latency etc. that can induce motion sickness and fatigue, because of the possible intolerance of the elderly to such side-effects.

Optical see-through displays are those devices that allow the user to see the real world with their natural eyes and which overlay graphics onto the user view by using a holographic optical element, translucent glass or similar technology. Their main advantage is that they offer a superior view of the real world including a natural, instantaneous view of the real scene and seamlessness between the augmented and periphery view. As elaborated later, these devices are the optimal type for the needs of FrailSafe. The disadvantages of OST HMDs include small field of view (approx. 40°), low contrast and inconsistency between the real and synthetic view.

7.1.2 Projection-based Displays

Projection-based displays are typically room-level setups that track the users in a room and actively project graphics directly on real objects. A projection-based display is a good option for applications that do not require several users to wear anything, providing minimal intrusiveness. However, since it requires a special setup and installation process for every target room, it is usually employed in applications where the users go to specific venues for their AR sessions (e.g. an AR rehabilitation center). It thus opposes the personalized home-based philosophy of the FrailSafe AR Serious Games concept and will not be detailed further in this section.

7.1.3 Handheld Displays

Handheld displays are a good alternative to HMD systems for AR applications, particularly because they are minimally intrusive, socially acceptable and highly mobile. Although initial developments mainly included tablet PCs and tethered LCD monitors, the latest advancements in mobile technology, as well as latest trends in AR, have directly associated the concept of handheld display to modern smartphones and tablets, making them the ideal candidate for handheld AR.

Since mobile devices are thoroughly detailed in the preceding sections, the following sections will focus on the comparison of HMDs, specifically optical see-through devices, based on the necessary requirements.

7.2 Hardware Requirements

The hardware requirements of the HMDs are defined by considering the following: a) minimum requirements in order for the device to be able to adequately function in the scenarios of the AR Games developed within FrailSafe (e.g. minimum autonomy) and b) to minimize common perceptual issues resulting from certain device characteristics and/or non-sufficient hardware specifications (e.g. low resolution leading to inaccurate depth perception).

7.2.1 Device Autonomy

Device autonomy refers to both the device's capability to be untethered, i.e. not need to be connected to a laptop or a desktop PC, either by having a wireless link to the processing unit or by having the processing unit built-in, as well as the autonomy specified by its battery capacity. Within FrailSafe, it is required that the user can move freely around in a room for their sessions. Also, a typical AR Serious Game session is estimated to be close to **60 minutes**, making that the minimum requirement for **battery autonomy**.

7.2.2 Binocular/Monocular Display

Various researches have concluded that using a monocular display HMD for AR applications more sophisticated than a simple informative Heads-Up Display (HUD) often results in highly inaccurate depth perception, which is a crucial perceptual problem in task-based AR applications. However, binocular displays demand more processing power and accurate stereoscopy, as one study found that binocular displays, where both eyes see the same image, cause significantly more discomfort, both in eyestrain and fatigue, than monocular. Latest advances in HMD graphics units, however, satisfy the computational power demand of stereoscopy, and latest calibration and registration techniques result in very accurate stereoscopic imaging. Considering this, **binocular displays** are chosen for the purposes of the project in order to provide a more natural and immersive AR experience.

7.2.3 Screen Resolution & Contrast

Photorealistic graphics are directly dependent on pixel density and screen contrast. Photorealism cannot be achieved if the pixel density isn't large enough so that the human eye cannot distinguish independent pixels. Complementing this, several AR studies have shown that low resolution and dim displays cause objects to appear further away than they really are, causing inaccurate depth perception. This problem is amplified in HMDs, where the screen is 5cm close to the eyes, demanding for even greater pixel density. A vertical **resolution of 720 pixels** is shown to be the minimum for the human eye in order to achieve seamlessness in displayed graphics.

7.2.4 Video/Optical see-through

As described before in Section 7.1.1, AR see-through HMDs are fundamentally divided in Optical see-through (OST) and Video see-through (VST) displays. The lack of the real-world view in VST displays has shown to negatively impact AR-task performance and depth perception. Also, adaptation of the user's eyes to the HMD's displays result in fatigue and eye-strain, followed by a large overshoot in depth-pointing tasks after the removal of the device, as well as mild disorientation. These reasons render VST devices unsuitable for long-term AR use, making **OST devices** a core requirement for the selected device.

7.2.5 Latency

Delay causes more registration errors than all other perceptual factors combined. For close range tasks, a simple rule of thumb is that one millisecond of delay causes one millimeter of error. More importantly, delay can reduce task performance. This creates a requirement for both the highest possible CPU and graphics power available, but also the need to dismiss devices that are wirelessly tethered to a host device responsible for all computation. In order to maintain low latency, the device must have **built-in processing** and be able to achieve a constant rendering rate of 60 frames per second (FPS).

7.2.6 Connectivity

The AR HMDs must be able to achieve the same level of local connectivity as smartphones and tablets within FrailSafe. This results in the requirement for both **Wi-Fi** and **Bluetooth**, which are thoroughly described in Section 3.2

7.3 Devices

Based on the hardware requirements defined in Section 7.2a comparative analysis of the most significant models and prototypes on the market is presented.

7.3.1 Atheer AiR

The latest model from Atheer after Atheer One, is considered to be one of the most competitive AR HMDs currently on the market. The AiR Smart Glasses, powered by the Android-based AiR OS, is an award winning platform with considerably high-end specifications.

The devices feature see-through 3D displays with large field of view, dual RGB 4MP cameras in combination with a 3D Time-of-Flight (ToF) range camera and the NVIDIA Tegra K1 processor. The device also offers broad mobile connectivity of Wi-Fi, Bluetooth, and optional 4G LTE built-in

FIGURE 29 – View of the Atheer AiR HMD

The main features of Atheer AiR are the following:

- Optical see-through display
- Binocular display
- 1028x768 pixels resolution
- NVIDIA Tegra K1 processor
- Wi-Fi, Bluetooth and 4G
- Android-based OS
- Dual 4MP RGB cameras
- ToF Depth camera
- 9-axis IMU
- 3100 mAh battery
- 50° Field of view
- 2GB RAM
- 128 GB Storage (up to)

7.3.2 ChipSip SiME Smart Glasses

SiME Smart Glasses are a monocular optical see-through device made by Chipsip integrating competitive features in a stand-alone Android OS headset, mainly targeted for remote work-support and activities such as exhibition viewing, goods purchase and tasks implementation.

FIGURE 30 - View of the SiME Smart Glasses.

They feature a Newton32 SiP, Dual cortex-A9 processor along with a standard connectivity bundle (Wi-FI, Bluetooth 4.0 BLE, GPS), a 9-axis IMU and a single 5MP RGB Camera. Its biggest disadvantage is the small 610mAh Li-ion battery which allows for less than 1 hour autonomy.

The main features of ChipSip SiME Smart Glasses are the following:

- Optical see-through

- Monocular display
- 800x480 resolution
- Android 4.4.2 OS
- Newton32 SiP, Dual cortex-A9 processor
- Wi-Fi, Bluetooth 4.0 BLE, GPS
- 1GB DDR3 RAM
- 5MP RGB Camera
- Image and voice recognition
- 9-axis IMU & Light Sensor

7.3.3 Daqri Smart Helmet

Although mainly work-oriented, the Daqri Smart Helmet consists a very competitive optical see-through binocular device, as it is employed with a high-end sensor package, along with a proprietary computer vision and navigational technology, a large field of view (80°) and a powerful Intel Core M7 processor.

FIGURE 31 - View of the Daqri Smart Helmet

Although many technical specifications are yet unknown, the device features unique capabilities such as electroencephalography sensors that allow complex interactions, a dedicated low-power camera used for tracking the device's position, two RealSense R200 IR depth-cameras (front and rear facing), a FLIR thermal camera and a 13MP high-definition color RGB camera. Moreover, it integrates standard Bluetooth connectivity, an Android-based OS, 2 hours of estimated autonomy and high luminosity displays.

The main features of the Daqri Smart Helmet are the following:

- Optical see-through display
- Binocular display
- Intel Core M7 processor
- 2 hours autonomy
- 2 independent front and rear-facing RealSense R200 IR depth-cameras
- 80° field of view
- Android OS
- High luminosity display
- Electroencephalography sensor
- 13MP RGB Color camera
- FLIR thermal camera
- Viz nav low power camera for position tracking
- Industrial grade 9-axis IMU

7.3.4 Epson Moverio Pro BT-2000

The Moverio Pro BT-2000 Glasses are an industrial-grade optical see-through binocular device that has been developed after the previous BT-100 and BT-200 products by Epson. It has a TI OMAP 4460 processor, 1GB of RAM and 8GB of internal memory.

FIGURE 32 - View of the Epson Moverio Pro BT-2000 Glasses.

The device features Wi-Fi and Bluetooth connectivity, 4 hours of battery autonomy with removable 1230 mAh capacity and a complete sensor package. Its biggest advantage is the dedicated 640x480 depth camera, which rests in the headband over the glasses along with a 5MP RGB Color camera. Its biggest disadvantage is the relatively low field of view (approx. 23°) and its low GPU capabilities.

The main features of Epson Moverio Pro BT-2000 are the following:

- Optical see-through display
- Binocular display
- 960x640 pixel screen resolution
- TI OMAP 4460 @ 1.2Ghz Dual Core processor
- 1240 mAh exchangeable battery (4 hours autonomy)
- Wi-Fi, Bluetooth 4.0 BLE
- 25° field of view
- Android 4.0.4 OS
- 5MP RGB Color camera
- 640x480 depth-camera
- 9-axis IMU
- Ambient Light, Geomagnetic, GPS sensors

7.3.5 Space Meta 2

Meta 2 is the newest development kit from Meta vision. Although specific technical details are not known, the optical see-through headset features top-grade specifications including a high field of view (90°) and high 2560x1440 pixels display resolution, as well as a front-facing 720p RGB camera and a sensor array for hand interactions and positional tracking.

FIGURE 33 - View of the Meta 2 Glasses.

The devices biggest disadvantage is the fact that it relies on a tethered connection with a desktop PC on a 3-meter cable, making it unsuitable for room-scale applications.

The main features of Space Meta 2 are the following:

- 90° field of view
- 2560x1440 pixels display
- 720p front-facing RGB camera
- Hand interactions
- Positional tracking
- 6-axis IMU
- Tethered connection to PC

7.3.6 Microsoft Hololens

Hololens is a high-end optical see-through device by Microsoft, is considered to be the most powerful AR Headset currently developed. Featuring a comfortable and adjustable headband-based design, and powered by a high-end processing unit, with a separate novel Holographic Processing Unit (HPU) to handle AR-related calculations, the headset is expected to provide a seamless high-quality AR experience.

FIGURE 34 - View of the Microsoft Hololens headset.

Although exact specifications of the commercial model are unknown, the device will feature at least a 720p Binocular display, powered by the latest Intel Atom processor, and will run Windows 10 Mobile or Windows Holographic, a platform built on top of Windows 10 that aims to easily integrate the device's capabilities in the OS.

The device features a variety of integrated sensors, including a high-quality Time-of-Flight (ToF) depth-camera, based on Microsoft Kinect 2, a 1080p RGB color camera, and at least 2 more dedicated cameras, for positional and orientation tracking. Also, the makers allege a 5.5 hour of autonomy on standard use, exceeding competition standards. Its biggest disadvantage to time is the small field of view (approx. 35°).

The main features of Microsoft Hololens are the following:

- Optical see-through display
- Binocular display
- 720p+ display resolution
- Intel Atom processor
- Window 10 mobile (Windows Holographic)
- Holographic Processing Unit (HPU)
- 35° field of view
- Wi-Fi, Bluetooth connectivity
- Kinect 2-based ToF depth-camera
- 3GB RAM
- 9-axis IMU, gyroscopes, magnetometer
- 2 dedicated cameras for positional tracking
- 2-5.5 hours of autonomy

7.3.7 Osterhout R-7

The R-7 Glasses are the second AR Glasses product from Osterhout, featuring powerful specifications, making them one of the most competitive AR Headsets currently on the market. They have optical see-through binocular displays, powered by the Snapdragon 805 quad-core processor, 3GB of RAM, 64GB storage and a 1300mAh Li-ion battery, competing current high-end tablets in processing power.

FIGURE 35 - View of the Osterhout R-7 Glasses.

The device runs on Android 4.4.4 and has two 720p 80Hz displays with alleged 80% transparency and 35° FoV, as well as front-facing 1080p @ 60Hz RGB camera. It has a standard connectivity package including Wi-Fi, Bluetooth and GPS, and an array of multiple 9-axis IMUs, altitude, humidity and ambient light sensors, used for positional and environmental tracking.

The main features of Osterhout R-7 are the following:

- Optical see-through display
- Binocular 720p @ 60Hz displays
- 1080p RGB front-facing camera
- Qualcomm Snapdragon 805 2.7GHz quad-core processor
- 1300mAh Battery (
- Android 4.4.4 OS
- Array of 9-axis IMUs
- Ambient light, humidity, altitude sensors
- Wi-Fi, Bluetooth, GPS

7.4 Comparison

	Atheer AiR	Daqri Smart Helmet	Epson Moverio BT-2000	Space Meta 2	Microsoft Hololens	Osterhout R-7
Availability	Available	Prototype	Pre-order	Pre-order	Development kit (US Only)	Available
Type of vision	Optical see-through	Optical see-through	Optical see-through	Optical see-through	Optical see-through	Optical see-through
Field of View	50°	80°	25°	90°	35°	35°
Weight	n/a	1000g	290g	n/a	579g	160g
Screen Resolution	1028x768	n/a	960x540	2560x1440	1280x720	1280x720
Monocular/ Binocular	Binocular	Binocular	Binocular	Binocular	Binocular	Binocular
Battery (autonomy)	3100mAh (n/a hours)	n/a (2 hours)	1240mAh (4 hours)	-	n/a (5.5 hours)	1300mAh (3 hours)
Operating System	AiR OS (Android-based)	4D OS (Android-based)	Android 4.0.4	-	Microsoft Windows 10	RecticleOS (Android-based)
Processing	Built-in	Built-in	Built-in	Tethered	Built-in	Built-in
CPU	NVIDIA Tegra K1	Intel Core M7	TI OMAP 4460	-	Intel Cortex	Snapdragon 805
RAM	2GB	n/a	1GB	-	3GB	3GB
Storage	128GB	n/a	8GB	-	64GB	64GB
Connectivity	Wi-Fi, Bluetooth 4.1, GPS, 4G LTE	Wi-Fi, Blueetooth	Wi-Fi, Bluetooth 3.0 & BLE	Wired	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth 4.1

Cameras	3D Depth-camera, Dual 4MP RGB cameras	13MP RGB camera, dual IR-depth cameras, FLIR thermal camera, Viz Nav low power camera	640x480 depth camera, 5MP RGB color camera	720p front-facing RGB camera	Kinect-based depth camera, Array of auxiliary color cameras	1080p @ 60fps front-facing RGB camera
Sensors	9-axis IMU	Industrial-grade 9-axis IMU	9-axis IMU	6-axis IMU	Array of 9-axis IMUs	Array of 9-axis IMUs, altitude, humidity
Other	-	Electroencephalography sensor	-	Hand tracking/ Positional tracking	Holographic Processing Unit (HPU)	-
Link	http://atheerair.com/	http://hardware.daqri.com/home/product/daqri-smart-helmet/	https://www.epson.com/cgi-bin/Store/jsp/Landing/moverio-bt-2000-smart-headset.do?UseCookie=yes	https://www.metavision.com/	https://www.microsoft.com/microsoft-hololens/en-us/hardware	http://www.osterhoutgroup.com/products-r7-glasses
Cost ($)	3,950	Approx.15,000	2,999	949	3,000	2,750

Table 5 - AR HMDs comparison table.

7.5 Conclusions

After taking into consideration all the technical requirements and involved human factors and perceptual issues, the choice of binocular optical see-through displays was found to be optimal for the purpose of FrailSafe developments and testing. Amongst the devices that satisfy these requirements, the current best options, commercial and prototypes, where chosen for comparison and feature analysis.

While many of these devices, such as Atheer AiR, Microsoft Hololens and Osterhout R-7, exhibit the same level of high-end computing power and display technologies, they also feature various different characteristics (e.g. different sensor components, cameras, field of view etc.) and semi-defined features as many of them are still in a development stage. Based on the analysis above, the appropriate device will be chosen at a later stage, depending on how well each device matches the derived project requirements, how well it satisfies elderly-related ergonomics issues and market availability at the current time.

8. CONCLUSIONS

This document has analyzed all the hardware devices and software tools that may be used in FrailSafe, from smart devices to augmented reality glasses and from mobile operative systems to game engines. After this analysis, a reasoned selection has been made on each section. These are the chosen devices and tools:

Device / Tool	Selection
Operative system	Android
Game engine	Unity
Smartphone	Google Nexus 5X
Tablet	Google Pixel C
Augmented Reality Glasses	Postponed decision

TABLE 6 - Final selected hardware and tools