



Universidade de Brasília – UnB
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Engenharia de Software

UnB Games: A collaborative project

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Monograph submitted to the Software Engineering department from *Universidade de Brasília*, as a partial requisite to obtain the title of Software Engineer.

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“It is our choices, Harry, that show what we truly are, far more than our abilities.”
(Harry Potter and the Chamber of Secrets)

Resumo

Jogos desenvolvidos nas universidades não têm muito reconhecimento ou suporte, e usuários geralmente não têm a oportunidade de jogá-los ou dar algum *feedback* aos desenvolvedores. Todo o trabalho desenvolvido numa universidade, especialmente pública, deve ser acessível a toda a sociedade, desde a concepção até a implementação, mas a maioria das pessoas nem sabe que jogos são criados nas salas de aula e que esses jogos são públicos e gratuitos. Este projeto tem como objetivo fazer uma plataforma *online* que permita às pessoas baixar e jogar o que for desenvolvido nas turmas de jogos da UnB. Para ajudar os desenvolvedores, o projeto também visa criar um modelo para facilitar a distribuição dos jogos, facilitando a geração de instaladores para múltiplas plataformas. Este documento explica como esta meta foi alcançada, ao se fazer um trabalho colaborativo entre várias pessoas da Universidade de Brasília. Ele também detalha o funcionamento do modelo e da plataforma desenvolvidos, apresentando suas funcionalidades e arquivos. Conclusões são tiradas a partir dos resultados obtidos e o documento termina com algumas ideias para trabalhos futuros.

Palavras-chaves: jogos. desenvolvimento. plataforma. empacotamento.

Abstract

Games developed in the University don't have much recognition or support, and, usually, users are not able to play or give feedback about any version of any of them. Everything created in the university, especially a public one, should be accessible to the society, from conception to implementation, but most people don't even know that games are created in classes and that these games are free and public. One of the objectives of this project is to make these games available to people via an online platform where they can be downloaded and play offline. To help the game developers, the project also aims to create a template to facilitate game distribution, by making it easier to generate installers for multiple platforms. This document outlines how this task was accomplished, by doing a collaborative project between various people of the *Universidade de Brasília*. It also explains how the template and the platform works, by detailing their features and corresponding files. Conclusions are taken from what has been done and the document finishes by providing some ideas for future work.

Key-words: games. development. platform. packaging.

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List of abbreviations and acronyms

SDL	Simple DirectMedia Layer version 1
SDL2	Simple DirectMedia Layer version 2
API	Application Program Interface
GUI	Graphical User Interface
VM	Virtual Machine
OS	Operating System
dpkg	Debian Package Management System
rpm	RPM Package Manager
pacman	Pacman Package Manager
RUP	Rational Unified Process
XP	eXtreming Programming
FHS	Filesystem Hierarchy Standard
FGA	<i>Faculdade UnB Gama</i>
MDS	<i>Métodos de Desenvolvimento de Software</i>
GPP	<i>Gestão de Portfolios e Projetos</i>
PMBok	Project Management Body of Knowledge
LAN	Local Area Network
indie	Independent
GPL	GNU General Public License
VS	Visual Studio

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Introduction

Games are known to provide several benefits to the players. It may be enjoying a good story, developing new abilities and skills, bonding with friends or just relaxing after a big rushed day (SANDFORD; WILLIAMSON, 2005). Independent game developers find it harder to make their games any of these goals because it's so much harder for people to see their games.

There are some courses taught in the *Universidade de Brasília* (like *Introdução ao Desenvolvimento de Jogos* at the campus *Darcy Ribeiro*, and *Introdução aos Jogos Eletrônicos* at the campus Gama) that have the goal to teach students to develop games. Students that enroll in these classes have the opportunity to learn how to create a game from scratch. Several of these students wish to continue working on game development after their graduation.

The games developed in those courses are complete, with story and gameplay but they are never seen outside class because developers have little to no experience on publishing games and there is no public place to show them. This project was created to give visibility to these games and developers and to show the work that has and will be done in this University concerning game development.

Goals

The main goals of this project are to create an online platform to host the games developed in the courses of this University and a template that will allow game developers to quickly distribute their games. The secondary goals are the following:

- allow users to download, run and distribute these games in major operating systems, like Windows, macOS, Debian and Red Hat;
- let the students of these courses easily create the respective installers and make the packages available to the public;
- build packages to some selected games that don't have one.

Work Structure

This document is divided into chapters. Chapter 1 explains some basic concepts for the reader. Chapter 2 gives an overview of how the goals were achieved. Chapter 3

shows the results of the project and the difficulties to achieve those results. Chapter 4 concludes the project and gives directions for future work.

1 Basic Concepts

This chapter gives an overview of some basic concepts needed by the reader to understand this work. It speaks briefly of games and their development using the Simple DirectMedia Layer (SDL) library and repositories to store the code on sections 1.1, 1.2 and 1.3. Sections 1.4 and 1.5 give some explanation on the folder structure of both GNU/Linux and Windows systems, while sections 1.6 and 1.7 describe how packaging works on both of these systems. At last, section 1.8 shows what has been done and how these works inspired this project.

1.1 Games

Games have been a part of human development since their early childhood and have been part of history in its most basic ways (BETHKE, 2003). Providing a fun time, bonding with friends and learning new skills are some common goals of games. They consist of interacting with other people (or computer) or just with the game structure itself, following the rules to achieve a goal.

They can take several formats, like board and card games, for example. Each form has unique strategies to win. To illustrate that, take the two cited cases: board games usually divide the user space into sectors, and everything is related to which sectors you are in and how you control them; card games, however, rely on the symbols and possible combinations of them (CRAWFORD, 1984). To win the former type, a player has to understand the cost to acquire/leave sectors and plan accordingly, while on the latter, one needs to watch their symbols and try to get the best combination out of them.

Since computers were invented, they completely changed the gaming world. New kinds of games, like *first person shooter*, and *tower defense*, were created and made accessible, while it became possible to play virtually the ones that required a physical board or a lot of people. With the Internet, it grew even more comfortable to own and play different games. It's also possible to play any game with anyone in the world.

Because computer games are software with audio, art, and gameplay, they should follow a software development method, anyone chosen by the team. It is something that most game developers avoid because they see their work as pure art (BETHKE, 2003). Although that is probably true, a game has everything a “normal software” has and more, therefore requiring a known development process or method. Using software engineering techniques (adapted to their needs, naturally) will result in a better game and better interaction with the final user (PRESSMAN, 2010).

1.2 SDL

Digital games have many things happening at once. There is sound playing; inputs are coming from the player, often from multiple sources; there is the rendering of scenarios and scenes; statistics are displayed. To simplify that, developers use several libraries in their source codes, one of the most popular being SDL.

SDL is a library that helps developers by creating cross-platform APIs to make easier handling video, input, audio, threads. It's used in several games available in big platforms like *Steam* and *Humble Bundle* (SDL, 2017). To be fully integrated with the developer's code, it requires a few files during compilation: the headers, that contains definitions of functions and structures; and the library itself, that contains the binaries that will run with the main code and may be static or shared (MITCHELL, 2013).

A shared library is one that can be used in multiple programs. It provides common code that is reusable and can be linked to the developer's code at the running time. On GNU/Linux systems they have the `.so` file extension, while on Windows they have `.dll` (CAMPBELL, 2009). In this case, the library code is not merged to the main code, resulting in a smaller binary for the developer. It's required to have the library installed on both the developer's and the player's system, though.

The static library is compiled against the main source code, and it's merged with it. Instead of being a dependency on the user's system, it's now a part of the distributed version of the software, resulting in a more prominent binary. The new license on SDL2, *zlib*¹, allows users to use SDL as a static library; however, they are not encouraged to, because that wouldn't provide several things the user might need. For example, security updates that come on the new patches, wouldn't be available to a game that has SDL built into it (GORDON, 2017).

1.3 Repository and Version control

Game development, as has been said, demands special care with the source code. Like any software, when a bug is accidentally inserted, there should be an easy way to return to a previous state, where that didn't happen. The solution to this problem is using a repository with versioning for the source code.

According to the Merriam-Webster Dictionary (2017), a repository is "a place, room or container where something is deposited." A software repository is a computer, directory or server that stores all the source code for that software project. This is usually available on the Internet, but it can also be local to the developers.

¹ The text of this license can be found at <https://www.zlib.net/zlib_license.html>

Repositories are also related to the version control of the source code being produced. The definition of version control is “a system that records changes to a file or set of files over time so that you can recall specific versions later” (LOELIGER; MCCULLOUGH, 2012). This allows the user to compare versions, to check updates, see who introduced (or removed) an issue and to rollback to previous versions of the system (CHACON; STRAUB, 2014). The goal is to make it easy to return to states that were working, even after changes are made after a long time.

Modern version control systems allow developers to work on a distributed basis and to parallelize their tasks, with the ability of *branching* the repository. Those *branches* are separated lines of development, that won't mess with the main one until they are merged (WESTBY, 2015). This feature lets developers create and test new changes before submitting them to the project's stable line of work, without affecting the final product.

1.4 Linux Filesystem Hierarchy Standard

When installing a game, it must go somewhere in the filesystem of the user. For games developed to run in the GNU/Linux environments, they should follow the patterns found in FHS. The Filesystem Hierarchy Standard (FHS) was proposed on February 14, 1994, as an effort to rebuild the file and directory structure of Linux and, later, all Unix-like systems. It helps developers and users to predict the location of existing and new files on the system, by proposing minimum files, directories and guiding principles (BANDEL; NAPIER, 2001).

The Hierarchy starts defining types of files that can exist in a system. Whenever records differ in this classification, they should be located in different parts of the system: *shareable* files are the ones that can be accessed from a remote host, while *unshareable* are files that have to be on the same machine to be obtained. *Static* files are the ones that aren't supposed to be changed without administrator privileges, whereas *variable* ones can be altered by regular users (BANDEL; NAPIER, 2001)

The root filesystem is defined then: this should be as small as possible, and it should contain all the required files to boot, reset or repair the system. It must have the directories specified in Table 1 and installed software should never create new directories on this filesystem (ALLBERY et al., 2015).

From the directories in Table 1, “/usr, /opt and /var are designed such that they may be located on other partitions or filesystems.” (ALLBERY et al., 2015). The /usr hierarchy should include shareable data, that means that every information host-specific should be placed in other directories. About the /var hierarchy, FHS specifies that “everything that once went into /usr that is written to during system operation (as opposed to installation and software maintenance) must be in /var.” (ALLBERY et al.,

Table 1 – Directories on the Hierarchy ([ALLBERY et al., 2015](#))

Directory	Description
<code>bin</code>	Essential command binaries
<code>boot</code>	Static files of the boot loader
<code>dev</code>	Device files
<code>etc</code>	Host-specific system configuration
<code>lib</code>	Essential shared libraries and kernel modules
<code>media</code>	Mount point for removable media
<code>mnt</code>	Mount point for mounting a filesystem temporarily
<code>opt</code>	Add-on application software packages
<code>run</code>	Data relevant to running processes
<code>sbin</code>	Essential system binaries
<code>srv</code>	Data for services provided by this system
<code>tmp</code>	Temporary files
<code>usr</code>	Secondary hierarchy
<code>var</code>	Variable data

[2015](#)).

The Hierarchy has some optionally defined places to put the binaries of the installed games, like `/usr/games`, or `/usr/local/games`. The difference between the two is that the former is where the package manager installs, while the other is where packages compiled locally are usually installed ([TEAM, 2017](#)). Variable data, as usual, should be inserted into the the `/var` filesystem, under `/var/games`.

1.5 Windows Registry

According to Wikipedia ([2017a](#)), “without a file system, information placed in a storage medium would be one large body of data with no way to tell where one piece of information stops and the next begins”. Just like every Operating System, Windows has a Filesystem that handles how the archives are stored in this platform and also gives a naming convention for those files. On top of that, there is the Windows Registry, that is a system-defined database ([MICROSOFT, 2017b](#)) that provides configuration data for applications, user preferences, system configurations, among other data ([FISHER, 2017](#)).

The Registry was created on early versions of Microsoft Windows to replace most of the `ini` files that contained system information and editing entries that don’t relate to the developer’s application may lead to a malfunctioning system ([MICROSOFT, 2017d](#)). It has a tree structure, with nodes called keys. Each subnode is a subkey, and the data entries are called values, and one key (or subkey) can have as many values as it needs ([MICROSOFT, 2017c](#)). Using the Registry is not mandatory for Windows apps because they might use XML files or be totally portable ([FISHER, 2017](#)).

1.6 Linux Packages

In computer science, a package can mean multiple things, depending on the context being used. A GNU/Linux package means a bundle of files containing the required data to run an application, such as binaries and information about the package. Game packages behave precisely the same as any other software.

To facilitate installing software, GNU/Linux has package managers, and most distributions have their own. Each expects and handle different types of files, but all of them have the common goal of making the installation easier. They download the package, resolve dependencies, copy the needed binaries and execute any post- or pre-configuration required by the system to install a package (LINODE, 2017). For example, Debian has *dpkg*, Red Hat has *rpm* and Arch Linux has *pacman* as default package managers.

Another method to install software is compiling from scratch. That may be very handy if the user has more experience with Linux packages, or the package is not in the package manager's repository. However, in this case, the user will have to manually handle dependencies, download, compile and do everything else the manager does.

1.7 Wix Toolset

The Wix Toolset was developed by Microsoft to build installation packages for Windows. Developers may integrate the tools to their build process, in Visual Studio, SharpDevelop, or Makefiles (FIREGIANT, 2017). It works by reading a `.wix` XML file, that contains all the data of the installer, like target folder, images, sounds, shortcuts, and links (WIKIPEDIA, 2017d).

One of the Wix tools, `candle`, reads and parses the `wxs` file to create an object file. `Light`, another Wix tool, will read the `wxsobj`, that was generated on the previous step, and bundle everything described in the XML into an `.msi` installer. When the user runs the installer, it will copy all files to their respective locations and create the necessary shortcuts and folders, while registers everything in the Windows Registry, that will manage the installation and removal of the package.

1.8 Related Work

There are several platforms to share and distribute games online. Amongst the most popular ones, there are Steam², GOG³, and Humble Bundle⁴. They have thousands of games, including indie, with the vast support of the gaming community. There is

² <https://steam.com>

³ <https://gog.com>

⁴ <https://humblebundle.com>

another platform that focuses on indie titles called Splitplay⁵. Some of these platforms are described here as an inspiration for this work.

Steam was announced in 2002 and released in 2003. Valve saw the need that many games required to run on up to date environment and decided to create a system that would target that issue (WIKIPEDIA, 2017c). The website has the purpose to be the store for the platform, while the system is installed on the player's machine and needed to play the games made available by them. Today, they have a vast community, cross-platform (Linux, Mac, mobile devices, and consoles) system with many games and extra content for them (STEAM, 2017).

GOG started out with the name *Good Old Games* trying to provide DRM free games to people. It was released in 2008 and has been active ever since (with a brief down period in September 2010). Since March 2012, it was rebranded, and independent games were added to their library (WIKIPEDIA, 2017b). They also have a system, like Steam, but this one is not required to run the games. It was built though to provide easy sharing and buying of games, among other things (GOG, 2017).

Humble Bundle is a platform that provides a bundle of games (books, software and other things) to the public at meager prices. Part of their profit proceeds to charity (the buyer can also choose where their money goes), and they have already raised more than 98 million dollars for that purpose (BUNDLE, 2017). They also provide a store with games at regular and, sometimes, discounted prices.

Splitplay is a Brazilian platform specialized in indie games. They realized that several indie developers couldn't bring forth their games and decided to create a place where those would be published them in their platform. Splitplay allows developers to send their games complete or incomplete (as a project), they can be free or paid. The site creators personally overview the submissions and don't charge developers (SPLITPLAY, 2017). The main difference between Splitplay and this project is the games each focuses. While Splitplay aims to publish indie games in general, this project targets games developed only in *Universidade de Brasília*.

⁵ <http://www.splitplay.com.br>

2 Methodology

This chapter explains how things were done within the duration of the whole project. Section 2.1 gives an overview of the whole project and its goals. Section 2.2 explains how the work was divided between all parties involved in the development of this project. Section 2.3 shows how and which games were selected for both parts of this work. Section 2.4 clarifies how the packaging template was created and its main parts. Section 2.5 illustrates how the platform was developed. Section 2.6 references the tools that were used to create and test everything the project has aimed to create.

2.1 Project Overview

The first primary goal of the project is to create a platform for all the games developed in this University. The second one is to make a project template to make it easier to distribute these games in Windows, Debian, Red Hat and macOS systems.

To achieve this goal, the games developed in this *campus* of the University were cataloged and cloned into a main GitHub organization¹(whenever possible), and a template system was created to package the files for each one of the contemplated operating systems. The platform itself was developed while all the other activities took place, during the first semester of 2017. The template was designed in the first semester but changed in the second. Some games were chosen to test it, but its real use will be during the new development cycle inside the game courses.

2.2 Task Division

This project was collaborative depending and relying on different classes and courses. Because of that, during the first half of it, the work was divided among students and teachers, as illustrated in Figure 1.

Professor Edson and Mr. Faria were responsible for first cataloging the existing games. They remained as helpers in the packaging system and as primary stakeholders for the team that developed the website.

The team *Plataforma de Jogos UnB* from the courses *Métodos de Desenvolvimento de Software* (Software Development Methods) and *Gestão de Portfólios e Projetos* (Management of Portfolios and Projects) was in charge of creating the first version of the actual website with some of the features. The names of all the members are in the Appendix A.

¹ <https://github.com/unbgames/>

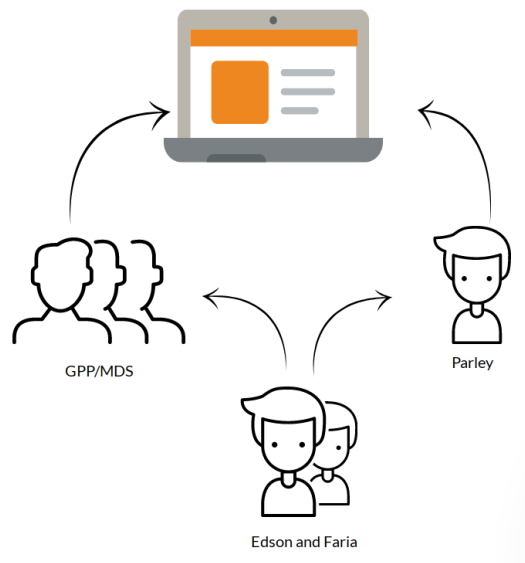


Figure 1 – Task Division

Before the second half of the project, professor Edson developed the packaging template. During this term, my responsibility was to test this template in a few selected games and to evolve and maintain it, as well as to add some features to the platform developed in the previous semester. Professor Edson and Mr. Faria were code reviewers and helpers in the system.

2.3 Game Gathering

Introdução aos Jogos Eletrônicos (Introduction to Electronic Games) is one of the courses that teach game development in the University. It was created in the first semester of 2012, with Professor Ricardo Jacobi as the instructor. Professor Edson taught the class in the subsequent semesters until 2016, and at the beginning of this year (2017) Mr. Matheus Faria assumed it. The games selected to test the template were developed in this course. They were chosen mostly because they compiled and ran on Linux distributions. Another reason for this choice is the proximity with the students who created those games.

Professor Edson and Mr. Faria first contacted the students and asked them to post their codes to GitHub. They cloned them into the `fgagamedev`² GitHub organization. After that, I was responsible for checking the status of the games, gathering information such as which of them compiled, which SDL version they used, which ones had licenses. Table 2 shows these initial results.

Out of 20 games created in *Introdução aos Jogos Eletrônicos* while Professor Edson taught it, four didn't have a known repository and eight didn't have a license that allowed

² <https://github.com/fgagamedev/>

Table 2 – Initial status of the selected games

Name	Source?	License?	SDL	Compiles?	Year
Deadly Wish	y	n	2	n	2016
Strife of Mythology	y	n	2	y	2016
Travelling Will	y	n	2	y	2016
7 Keys	y	MIT	2	n	2015
Babel	y	GPL 2	2	y	2015
Terracota	y	MIT	2	n	2015
Dauphine	y	n	2	n	2014
Imagina na Copa	y	n	2	y	2014
Kays Against the World	y	n	2	y	2014
Ankhnnowledge	y	GPL 2	1	y	2013
The Last World War	n	-	-	-	2013
Post War	y	n	1	y	2013
War of the nets	y	GPL 2	2	y	2013
Jack the Janitor	y	GPL 3	1	y	2013
Drawing Attack	n	-	-	-	2012
Earth Attacks	n	-	-	-	2012
Emperor vs Aliens	y	n	1	y	2012
Ninja Siege	y	GPL 2	1	y	2012
Space monkeys	y	GPL 2	1	n	2012
Tacape	n	-	-	-	2012

modificate them at that time. Next task was finding games that didn't have a known repository and getting the missing licenses. As result of this task, *The Last World War* was added and five other had licenses acquired as shown in Table 3.

In the second semester, to test the new packaging template, four games were selected. two of these previously chosen, developed with SDL, and two new ones developed in the first semester of 2017, made with SDL2: *Ankhnnowledge*, *Ninja-Siege*, *Wenova*, and *Mindscape*, respectively. These games were chosen because they already worked correctly without any need to change their source code.

Another decision was to separate the games in a different GitHub organization, to hold all the ones developed at the University, instead of just those from FGA. Mr. Faria created the `unbgames`³ organization for this purpose and `fgagamedev` remained as an FGA specific organization, where the packaging template is maintained, for example.

2.4 Packaging

The template for packaging was created by professor Edson. It is based on two fundamental directives, modularisation and platform independence. The first one is related

³ <https://github.com/unbgames>

Table 3 – Game status after contacting developers

	License	SDL	Compiles
Deadly Wish	GPL 3	2	n
Strife of Mythology	GPL 2	2	y
Travelling Will	MIT	2	y
7 Keys	MIT	2	n
Babel	GPL 2	2	y
Terracota	MIT	2	n
Dauphine	MIT	2	n
Imagina na Copa	MIT	2	y
Kays Against the World	n	2	y
Ankknowledge	GPL 2	1	y
The Last World War	n	1	y
Post War	MIT	1	y
War of the nets	GPL 2	2	y
Jack the Janitor	GPL 3	1	y
Emperor vs Aliens	n	1	y
Ninja Siege	GPL 2	1	y
Space monkeys	GPL 2	1	n

to dividing the directories by topic, meaning that each folder will be responsible for one thing and all the files inside of them should be specifically related to that. The second directive, platform independence, is to make the development of multiple platforms easy. Each directory will have a division for each of the platforms.

To achieve the template modularisation, professor Edson decided to use a folder structure that would be easy to understand to anyone familiar with GNU/Linux FHS, with a few additions. Apart from the original directories in the repository, he added the folders `bin`, `dist`, `lib` and `scripts`. This structure is represented in Figure 2

- `bin` has all needed libraries and the game executable.
- `lib` All the third-party libraries should live here. The scripts to build the code are already set to look for libs inside this directory, being each subdirectory a dependency;
- `dist` This contains the files needed to generate the packages for each platform;
- `scripts` this is where the scripts to build, package and distribute the binaries for all the platforms will live. It also has a subdirectory called `utils` that holds some specific platform scripts, like generating each installer, or gather information about the host OS;

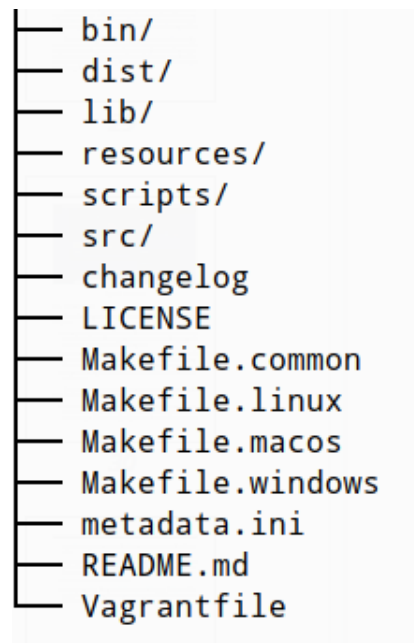


Figure 2 – Folder tree

The second directive was met by dividing some of the directories into platform-limited directories, making the code that lives there accessible only when running on that individual platform. Any file outside the platform directory is considered generic and can be used for any Operating System. For example, when running on Windows, the compiler would only access generic files and Windows specific ones, like `dlls`. The same thing happens for macOS and GNU/Linux systems. This division is represented inside the `lib` directory in Figure 3.

As also seen in Figure 3, inside each platform folder (only for libraries) there is yet another division to make sure the template can generate different versions of the program for `debug` and `release`. The binaries that live on `release` are stripped of all debug symbols, resulting in smaller versions of those dependencies. Library headers go inside `include` and a compressed file with the source goes inside `src`.

The scripts stored in the `scripts` directory are the backbone of the template. Through them, it's possible to compile (creating a new executable with all the dependencies locally available), run and package a game. As long as the other files are placed correctly, the scripts work correctly. There are four main and seven auxiliary scripts to accomplish these tasks that are listed in Figure 4 and described below.

- `build.sh` builds the executable, being possible to choose which is the desired version, `debug` and `release`. Calls the appropriate `Makefile`, depending on the version and platform;
- `cleanup.sh` clears the repository, removing files generated during build and pack-

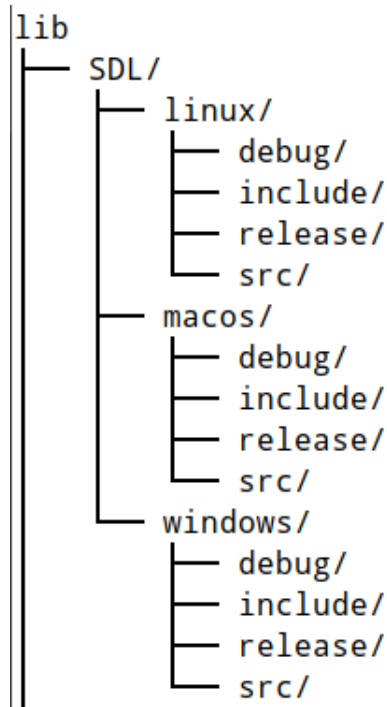


Figure 3 – Library division

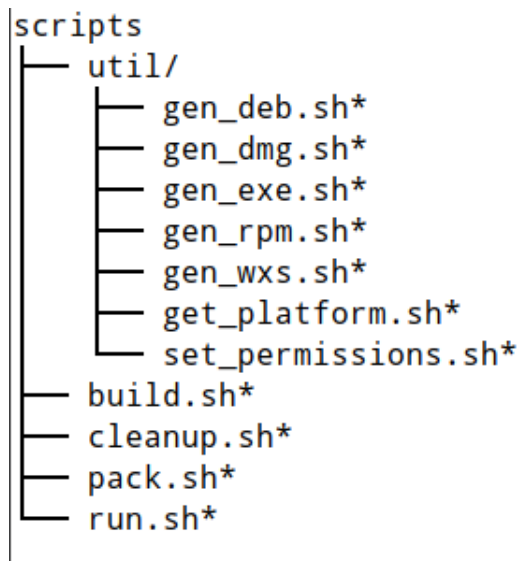


Figure 4 – Scripts

aging, like object files and installers;

- `pack.sh` builds the release version of the program (by calling `build.sh`) and generates the installer for the specific platform it's running on. It's important to notice that it's not possible to generate a package for a different platform from the same host system. This means that, for example, to generate Windows packages, this script must be called from within Windows and not from a Linux machine;
- `run.sh` runs the generated executable, setting the correct environment variables and

pointing to where the local libs are. Attempting to run the program without this script may lead to errors;

- `util/get_platform.sh` checks and returns the current platform;
- `util/set_permissions.sh` sets files to 644⁴ permission and folders to 755⁵ inside a given directory;
- `util/gen_deb.sh` generates a `.deb` file to be installed in Debian-based systems;
- `util/gen_rpm.sh` generates an `.rpm` file to be installed in Red Hat based systems;
- `util/gen_exe.sh` generates the `.exe` and `.msi` to be installed on Windows systems;
- `util/gen_wxs.sh` This is called from `gen_exe` to create a `.wxs` file, that will be used to create the Windows intaller.
- `util/gen_dmg.sh` creates the `.dmg` file for macOS.

All the scripts described in this section must be executed from the root folder of the repository. All paths inside the scripts are relative to that directory and running them anyplace else may cause unwanted errors.

The template doesn't relate (or connects) directly to the platform. It is instead something that will allow the platform to be entirely used. The template proposes to create the installers the user needs, while the platform will be used to share these executables so people can download and play them.

2.5 Platform Development

The first version of the platform was developed using mixed development methods. During the first half of the semester, the Rational Unified Process and the PMBOK were used. For the next part, Scrum and XP were chosen. This choice of development framework is because of how the courses are divided and because of their syllabi.

Throughout the RUP part of the development, the team created several documents to aid the development cycle, such as vision, architecture document, class diagram, use case diagram, use case specification, test case specification. These documents helped the team to understand the system requirements and how they should be implemented as seen in Figure 5. The most experienced members also helped the others to learn the technologies to develop the website.

⁴ 644 - File owner has read and write permissions, while group and all users have only read access.

⁵ 755 - File owner has read (r), write(w) and execute (x) permissions, while group and all users have only two permissions, rx.

2.6 Tools

GNU Make and bash were chosen as building and packaging software. Make is supposed to help developers managing their applications and they can run on several platforms, like Linux, Mac, and Windows. Bash is a popular script tool to manipulate files and folders from the terminal. They are distributed under GNU General Public License version 3 and the minimum required version is 4.0 (for both of them).

The chosen compilers were `gcc`, for Linux, distributed under GPL3, with at least version 5.0; `Visual Studio Compiler`, for Windows, shared with a Microsoft community License, version 2017; and `clang`, for macOS, distributed under BSD License.

For the website development, Django was selected because of the previous knowledge the group had with it. To make the front end of the application, Facebook's React was chosen for the flexibility it gives to the user interface. They are both very scalable, have significant support in the community and are released under the BSD 3-clause license. The versions being used are the last ones at the beginning of the project, namely, 1.11.1, for Django, and 15.5.4, for React.

To develop and test the template, virtual machines running Debian Jessie and CentOS 7 were used. The VMs were powered by VirtualBox 5.2, released under GPL2, which allows flexible environment virtualization. It also enables a developer to test in several operating systems, which is required for the nature of this project. The computer hosting the virtual machines and used to has an Intel Core i5-6200U 2.3 GHz processor, 8 GB of RAM and an NVIDIA GeForce 940M graphic processor.

To package on Debian based systems, `lintian` version 2.5. For Red-Hat systems, `rpmlintian` version 1.9 was chosen. Both of them are distributed under GPL 2. For Windows, both Wix toolset, version 3.11, distributed under Microsoft Reciprocal License; and Gywin shell, 2.9.0 and GPL, were used.

3 Results

This chapter explains the results obtained with the project development. Section 3.1 gives an explanation of how the game project template works, how it is divided and what files it contains. The chapter also explains what each file is responsible for and if the user should edit it or not. Section 3.2 describes what is ready from the platform and what should have been done. Section 3.3 shows some of the problems that came through the development/maintenance of the template and how they were overcome.

3.1 Template

One of the goals of this work was to generate a game project template that allowed the game developers from the courses of this University to develop their games and quickly create packages to install in major operating systems, namely, Windows, macOS, Debian-based and Red Hat based distributions of GNU/Linux. Professor Edson wrote this template, and I had the responsibility of testing it in a few games, evolving and maintaining it throughout all the platforms.

The template consists of a series of Bash scripts, Makefiles, libraries and a directory structure that is supposed to be followed by anyone who wants to use it. It is intended to be used as a template for new games developed in the courses taught at this University, and it contains the most common libraries in game development, like `SDL`, `SDL_image`, and `SDL_mixer`.

3.1.1 Root directory

Currently, there are seven required files on the root directory, specifically, `LICENSE`, `Makefile.common`, `Makefile.macos`, `Makefile.windows`, `Makefile.linux`, `Vagrantfile`, `changelog`, and `metadata.ini`. These files assure compilation is possible in any platform and also give some information about the project. An explanation of what each of them does and what information each may or may not have is given on Table 4. Some extra optional files are also explained.

Table 4 – Files on the root directory

File	Mode	Description
LICENSE	<i>Editable</i>	This should be the text of the license or a reference to a file that has the full text. Debian packages warn if this file is the actual license text for common licenses, therefore it may be a better option to only refer to a file inside the system (usually <code>/usr/share/common-licenses/<LICENSE></code>).
Makefile.macos Makefile.windows Makefile.linux	<i>Uneditable</i>	Each of these files sets variables with specific for each system, like <code>CC</code> and <code>DEBUG_FLAGS</code> . If a variable isn't needed it will remain blank and won't change the effect of the compilation. The template is supposed to work with values as they are and users shouldn't change them unless they <i>actually</i> want a different behavior.
Makefile.common	<i>Partially editable</i>	Sets some other variables, common to all OSs, like <code>LDFLAGS</code> , based on each platform Makefile. The template has set default SDL libs (<code>SDL</code> , <code>SDL_image</code> , <code>SDL_mixer</code> , <code>SDL_ttf</code>), but other external libs may be wanted. When this happens, the user should add the libs wanted to the variable <code>EXTERNAL_LIBS</code> without quotes and separated by simple space. Each of these libs must be a directory inside the <code>lib</code> folder. The rest of the file should not be changed since it may lead to major errors when using the template unless the user is sure of how it works.
Vagrantfile	<i>Optional</i>	This file creates two Virtual Machines running Debian and CentOS. If the user wishes to give support for them both (generating both <code>.deb</code> and <code>.rpm</code> packages), they could either use the VMs or run the template natively on each system. The virtualization provides an easier way to do that, but it is up to the user deciding this detail of the development cycle.
changelog	<i>Editable</i>	When creating the Debian package, it needs a changelog, that registers what was changed from the previous versions, much like a commit message. There are ways of generating this file automatically because its syntax is very particular, but the template doesn't contemplate it yet.

Table 4 – Files on the root directory

File	Mode	Description
<code>metadata.ini</code>	<i>Editable</i>	As the extension suggests, <i>ini</i> stands for <i>initialization</i> . It is a configuration file that follows the <code>ini</code> syntax. It defines some project properties that will be used in several steps, like building and packaging, making it a critical file to use the template correctly. The user should change this file with the appropriate information as soon as cloning the repository and throughout the development.

3.1.2 Sources Directory (`src`)

The directory that holds all source code, including headers, is called `src` and is divided in two subfolders, `engine` and `game`, as shown in Figure 6. The reason for this division is to keep separate engine-specific elements (like movements, rendering windows, capturing input from the player) from the actual game. Separating these elements is a good practice because engines can be reused in several projects, providing a basic API to create new games. Both of these directories have the same structure, that is explained in Table 5, along with the files outside them.

Table 5 – Files in the sources directory

File	Mode	Description
<code>main.cpp</code>	<i>Partially Editable</i>	It is where the function <code>main</code> should live. This file must not be renamed or moved to inside any of the subdirectories. Users should add their logic to it, with all the relative includes. Because of compatibility issues with Windows, there is a function called <code>WinMain</code> , that only calls the main function and should not be touched.
<code>Makefile</code>	<i>Uneditable</i>	This makefile is called during the build process, from inside <code>Makefile.common</code> . It builds the final executable, linking <code>main</code> with the game library, engine library, and the libraries inside <code>lib</code> .

Table 5 – Files in the sources directory

File	Mode	Description
<code>{game,engine}/include/*</code>	<i>Editable</i>	These are the header files for the engine and the game. The template already has one header in the engine, that should not be removed, but may be renamed if the correct references are made after that. This header defines the function <code>resources_dir_path</code> , that is very important to keep the template ability to run on multiple platforms.
<code>{game,engine}/src</code>	<i>Editable</i>	The implementation of all header functions should go inside this directory. Under this three other directories are supposed to hold platform-specific implementation, namely, <code>linux</code> , <code>windows</code> , and <code>macos</code> . Any code outside them is considered to be generic and can be used in any of these platforms. Every piece of code specific to one of these systems should be placed in the corresponding folder. The template already has the specific implementation to find the <code>resources</code> folder that may be renamed or reimplemented. It is not advised to change the <code>macos</code> implementation though, except for the directory name.
<code>{game,engine}/Makefile</code>	<i>Uneditable</i>	Called from the <code>Makefile</code> in the <code>src</code> directory. Responsible for building each of these two libraries. If the folder structure was followed correctly, there is no need to change the contents of this file.

3.1.3 Distribution folder (`dist`)

Each platform has particularities concerning package generation. Debian, for example, requires a changelog inside the package, while Windows needs to have the package registered (with all of its contents). The `dist` folder contains some specific files that are needed for each package. Figure 7 shows the files needed for each system, while Table 6 explains what is of them is supposed to do.

```

src
├── engine/
│   ├── include/
│   │   └── engine.h
│   ├── src/
│   │   ├── linux/
│   │   │   └── resources_dir.cpp
│   │   ├── macos/
│   │   │   └── resources_dir.cpp
│   │   ├── windows/
│   │   │   └── resources_dir.cpp
│   │   └── engine.cpp
│   └── Makefile
├── game/
│   ├── include/
│   │   └── game.h
│   ├── src/
│   │   ├── linux/
│   │   │   └── game.cpp
│   │   ├── macos/
│   │   │   └── game.cpp
│   │   └── windows/
│   │       └── game.cpp
│   └── Makefile
├── main.cpp
└── Makefile

```

Figure 6 – src directory

```

dist
├── linux/
│   ├── debian/
│   │   ├── control
│   │   └── template-test.6
│   └── redhat/
│       └── template-test.spec
├── macos/
│   └── Info.plist
└── windows/
    └── templateTest.wxs

```

Figure 7 – dist directory

Table 6 – Files on the dist directory

File	Mode	Description
windows/templateTest.wxs	<i>Uneditable</i>	This file is required to generate the installer for windows. It is an XML that lists all directories, files and libraries inside the installer. Each one of them has a unique UUID, because this

Table 6 – Files on the `dist` directory

File	Mode	Description
		is how Windows controls what is installed or removed. This file is generated when <code>pack.sh</code> is first called in Windows. If the user has updated the resources and other files, they should delete this and rerun <code>pack.sh</code> , but never edit it themselves, because it is a very particular large file.
<code>macos/Info.plist</code>	<i>Uneditable</i>	Because macOS packages are self-contained, this file is pretty simple. It is an XML that contains keys and values related to the package installed, like its name, version, and developer. This file has its information updated when <code>pack.sh</code> is called on a macOS system.
<code>linux/redhat/template-test.spec</code>	<i>Uneditable</i>	Every <code>rpm</code> package must have a file containing the instructions of what to and how to install that package. This file is replaced with the specifics of each game, mostly the information in <code>metadata.ini</code> , when <code>pack.sh</code> is called on a Red Hat machine.
<code>linux/debian/control</code>	<i>Uneditable</i>	Inside a debian package there is a control section that contains some metadata for the package being installed. It is a required file on every <code>.deb</code> package. This file has this data, acquired from <code>metadata.ini</code> .

Table 6 – Files on the `dist` directory

File	Mode	Description
<code>linux/debian/template-test.6</code>	<i>Uneditable</i>	Even though this file is inside <code>debian</code> , it is used for both linux distributions. It is a <code>man</code> file, that contains the package usage description.

3.1.4 Scripts folder (`scripts`)

The core of the template is the ability to build, run and package the game. This ability happens because several scripts allow users to quickly do this process, by running them from the root directory of the repository. None of these files should be modified by the user.

The scripts inside this folder are not complex or complicated since the hard work is mostly done inside the `util` directory. The build script is fairly simple, requiring one argument that is the mode the script will run, `debug` or `release`. If none is provided, it will use `debug` as default. It simply checks the platform and run the command `make` with the appropriate Makefile and mode; `run.sh` sets some variables and change the directory to where all the libs are to then call the executable; `cleanup.sh` remove objects, libraries and other files generated during compilation; and `pack.sh` calls one of the scripts inside `util` to generate the corresponding package.

Generating a `.deb` package consists in a few steps as shown in Listing 1. It first sets some variables and loads info from `metadata.ini`, in lines 7-11. When the function `gen_deb()` is called, it creates a temporary directory and its structure, in lines 15 through 24. From line 26 through 43, the executable, the required libs, and the resources are copied to their respective location inside this structure. The `control` file is copied from `dist` folder and the information is replaced with what is in `metadata.ini` in lines 46-59. Lines 62-75 create some other directories, copy license, changelog and man pages to a documentation folder, and compress some of the files. Lines 77-88 set the correct permissions, strip the executable, builds and checks the package for errors.

Listing 1 – `gen_deb.sh`

```

1 #!/bin/bash
2 #
3 # Generates .deb package for Linux
4 #
5
6 # Include project metadata

```

```
7 . metadata.ini
8
9 PACKAGE_NAME=$EXECUTABLE_NAME
10 PACKAGE_VERSION=$VERSION_MAJOR.$VERSION_MINOR-$VERSION_RELEASE
11 OUTPUT_FILE=$PACKAGE_NAME\_ $PACKAGE_VERSION.deb
12
13 function gen_deb()
14 {
15     # Build dir
16     tmp_dir=/tmp/$PACKAGE_NAME\_ $PACKAGE_VERSION
17     rm -rf $tmp_dir
18     mkdir -p $tmp_dir
19
20     # Data dir: resources, scripts and executable
21     var_dir=$tmp_dir/var
22     data_dir=$var_dir/games
23     install_dir=$data_dir/$PACKAGE_NAME
24     mkdir -p $install_dir
25
26     cp src/$EXECUTABLE_NAME\_release $install_dir/$EXECUTABLE_NAME
27
28     lib_dir=$install_dir/lib
29     mkdir -p $lib_dir
30
31     for extlib in `ls lib`;
32     do
33         cp -P lib/$extlib/linux/release/* $lib_dir;
34     done
35
36     # Removing embedded libraries
37     rm $lib_dir/libjpeg*
38     rm $lib_dir/libpng*
39
40     resources_dir=$install_dir/resources
41     mkdir -p $resources_dir
42
43     cp -r resources/* $resources_dir/
44
45     # Launcher script dir
46     usr_dir=$tmp_dir/usr
47     exec_dir=$usr_dir/games
48     mkdir -p $exec_dir
49
50     printf "#!/bin/bash\nexport LD_LIBRARY_PATH=/var/games/$PACKAGE_NAME
51     /lib && cd /var/games/$PACKAGE_NAME/ && ./ $EXECUTABLE_NAME" >
52     $exec_dir/$EXECUTABLE_NAME
```

```
52 # Debian package info dir
53 mkdir -p $tmp_dir/DEBIAN
54 cp dist/linux/debian/control $tmp_dir/DEBIAN/
55 sed -i -- 's/%%PACKAGE_NAME%%/' "$PACKAGE_NAME" '/' $tmp_dir/DEBIAN/
control
56 sed -i -- 's/%%PACKAGE_VERSION%%/' "$PACKAGE_VERSION" '/' $tmp_dir/
DEBIAN/control
57 sed -i -- 's/%%MAINTAINER_NAME%%/' "$MAINTAINER_NAME" '/' $tmp_dir/
DEBIAN/control
58 sed -i -- 's/%%MAINTAINER_CONTACT%%/' "$MAINTAINER_CONTACT" '/'
$tmp_dir/DEBIAN/control
59 sed -i -- 's/%%GAME_DESCRIPTION%%/' "$GAME_DESCRIPTION" '/' $tmp_dir/
DEBIAN/control
60
61 # Documentation
62 share_dir=$tmp_dir/usr/share
63 doc_dir=$tmp_dir/usr/share/doc/$PACKAGE_NAME
64 mkdir -p $doc_dir
65
66 cp changelog $doc_dir/changelog.Debian
67 cp LICENSE $doc_dir/copyright
68 gzip -n9 $doc_dir/changelog.Debian
69
70 man_dir=$share_dir/man
71 section_dir=$man_dir/man6
72 mkdir -p $section_dir
73
74 cp dist/linux/debian/template-test.6 $section_dir/$PACKAGE_NAME.6
75 gzip -n9 $section_dir/$PACKAGE_NAME.6
76
77 # Set the permissions
78 scripts/util/set_permissions.sh $tmp_dir
79 chmod 755 $exec_dir/$EXECUTABLE_NAME
80 chmod 755 $install_dir/$EXECUTABLE_NAME
81
82 # Strip executable debug symbols
83 strip $install_dir/$EXECUTABLE_NAME
84
85 # Build and check the package
86 fakeroot dpkg-deb --build $tmp_dir
87 mv /tmp/$OUTPUT_FILE .
88 lintian $OUTPUT_FILE
89 }
90
91 echo "Generating "$OUTPUT_FILE "..."
92 gen_deb
93 echo "Done"
```


Making an `.rpm` package is somewhat simpler than generating a Debian package. As seen in Listing 2, `gen_rpm.sh` starts on lines 7-11 also loading `metadata.ini` and defining some variables. When `gen_rpm()` is called, it first calls the `rpm` tool that creates a folder structure for the package, on line 18. After that, on lines 21 - 29, it copies the spec file to its place on that structure and replaces the information read from `metadata.ini`. Line 32 puts the text script that will be executed in the folder structure. Lines 35-39 remove any traces of previous executions of this script and create a `tar` package based on the structure the `rpm` builder created. Lines 42-44 build the `rpm` package and calls the `lint` to check it. Unlike Debian, everything the builder needs to know is inside the `spec` file; the script only copies things to where they are supposed to be.

Listing 2 – `gen_rpm.sh`

```
1 #!/bin/bash
2 #
3 # Generates .deb package for Linux
4 #
5
6 # Include project metadata
7 . metadata.ini
8
9 PACKAGE_NAME=$EXECUTABLE_NAME
10 PACKAGE_VERSION=$VERSION_MAJOR.$VERSION_MINOR-$VERSION_RELEASE
11 OUTPUT_FILE=$PACKAGE_NAME\_ $PACKAGE_VERSION.rpm
12
13 function gen_rpm()
14 {
15     work_dir='pwd'
16
17     # RPM build dir setup
18     rpmdev-setuptree
19
20     # Preparing the spec file
21     spec_file=$PACKAGE_NAME.spec
22     cp dist/linux/redhat/template-test.spec ~/rpmbuild/SPECS/$spec_file
23     cp dist/linux/debian/template-test.6 dist/linux/debian/$PACKAGE_NAME
24     .6
25
26     sed -i -- 's/%%PACKAGE_NAME%%/' $PACKAGE_NAME '/g' ~/rpmbuild/SPECS/
27     $spec_file
28     sed -i -- 's/%%VERSION_MAJOR%%/' $VERSION_MAJOR '/g' ~/rpmbuild/SPECS/
29     $spec_file
30     sed -i -- 's/%%VERSION_MINOR%%/' $VERSION_MINOR '/g' ~/rpmbuild/SPECS/
31     $spec_file
32     sed -i -- 's/%%VERSION_RELEASE%%/' $VERSION_RELEASE '/g' ~/rpmbuild/
33     SPECS/$spec_file
34     sed -i -- 's/%%GAME_DESCRIPTION%%/' "$GAME_DESCRIPTION" '/g' ~/
```

```

rpmbuild/SPECS/$spec_file
30
31 # Launcher script dir
32 printf "#!/bin/bash\nexport LD_LIBRARY_PATH=/var/games/$PACKAGE_NAME
/lib && cd /var/games/$PACKAGE_NAME/ && ./$EXECUTABLE_NAME\n" > dist/
linux/redhat/$EXECUTABLE_NAME
33
34 # Preparing the source package
35 rm -rf /tmp/$PACKAGE_NAME-$VERSION_MAJOR.$VERSION_MINOR
36 mkdir -p /tmp/$PACKAGE_NAME-$VERSION_MAJOR.$VERSION_MINOR
37 cp -r * /tmp/$PACKAGE_NAME-$VERSION_MAJOR.$VERSION_MINOR/
38 cd /tmp && tar -czpf ${PACKAGE_NAME}.tar.gz $PACKAGE_NAME-
$VERSION_MAJOR.$VERSION_MINOR/
39 cp /tmp/${PACKAGE_NAME}.tar.gz ~/rpmbuild/SOURCES/
40
41 # Build and check the package
42 cd ~/rpmbuild/SPECS && rpmbuild -ba $spec_file
43 cp ~/rpmbuild/RPMS/x86_64/* $work_dir
44 cd $work_dir && rpmlint $PACKAGE_NAME-$VERSION_MAJOR.*
45 }
46
47 echo "Generating "$OUTPUT_FILE "..."
48 gen_rpm
49 echo "Done"

```

To generate the Windows installer, the script `gen_exe.sh` as shown in Listing 3 is called. It starts, in lines 7-11, loading and setting variables just like the other scripts. When `gen_exe()` is called, it makes the folder where all the libs and resources will live, in lines 14-15. Lines 17-20 copy the release libs to the folder created in the previous step. Lines 22-25 create a new `wxs` file, only if one doesn't exist. This decision was made because generating this file is a very time-consuming task. If the user wants to recreate it, they just have to delete it from the `dist` folder. Lines 27-36, copy all the libs, resources, executable and `wxs` to a temporary directory. Lines 38-41 do the actual package building, calling `candle.exe` and `light.exe` that are Wix tools that compile the `.wxs` file into `.wxsobj` and create the `.msi`, respectively.

Listing 3 – `gen_exe.sh`

```

1 #!/bin/bash
2 #
3 # Generates .exe installer for Windows
4 #
5
6 # Include project metadata
7 . metadata.ini
8

```

```
9 WXS_PATH="dist/windows/$PACKAGE_NAME.wxs"
10 OUTPUT_FILE=$EXECUTABLE_NAME.exe
11 PACKAGE_VERSION=$VERSION_MAJOR.$VERSION_MINOR.$VERSION_RELEASE
12
13 function gen_exe() {
14     rm -rf bin/windows
15     mkdir -p bin/windows
16
17     for DIR in $(ls -D lib);
18     do
19         cp -P lib/$DIR/windows/release/* bin/windows
20     done;
21
22     if ! [ -e $WXS_PATH ];
23     then
24         scripts/util/gen_wxs.sh
25     fi
26
27     mkdir -p .tmp
28     cp -u src/$EXECUTABLE_NAME\_release .tmp/$OUTPUT_FILE
29
30     cp -u bin/windows/* .tmp/
31     cp -f $WXS_PATH .tmp/$PACKAGE_NAME.wxs
32
33     # cp -u dist/windows/Manual.pdf .tmp/
34     cp -ur resources .tmp/
35
36     cd .tmp
37
38     candle.exe $PACKAGE_NAME.wxs
39     light.exe -sice:ICE60 -ext WixUIExtension $PACKAGE_NAME.wixobj
40     cp $PACKAGE_NAME.msi ..
41     cd ..
42 }
43
44 echo "Generating "$OUTPUT_FILE "..."
45 gen_exe
46 echo "Done"
```

3.2 Platform

The platform developed in the first half of the project was made with Django and React, both very well established on their own. Putting them together, however, is another matter, where the team had a real hard time to make everything work right. They used React as the primary user interface and the Django Admin package to create

the administrator part of the site.

The admin page is shown in Figure 8. It allows an administrator to upload a game and manually add all its information like supported platform, related media, installers, etc. On the home page, the user can see a slide with some images of highlighted and most downloaded games. After choosing one, it's possible to see its data and download one of the installers available. The platform also lets the user interact with the system by leaving a Facebook comment on the game and an evaluation in the format of liking or disliking as seen in Figure 9. The user can also categorize the games, apply some filters to them, and search for a specific game by its name or description.

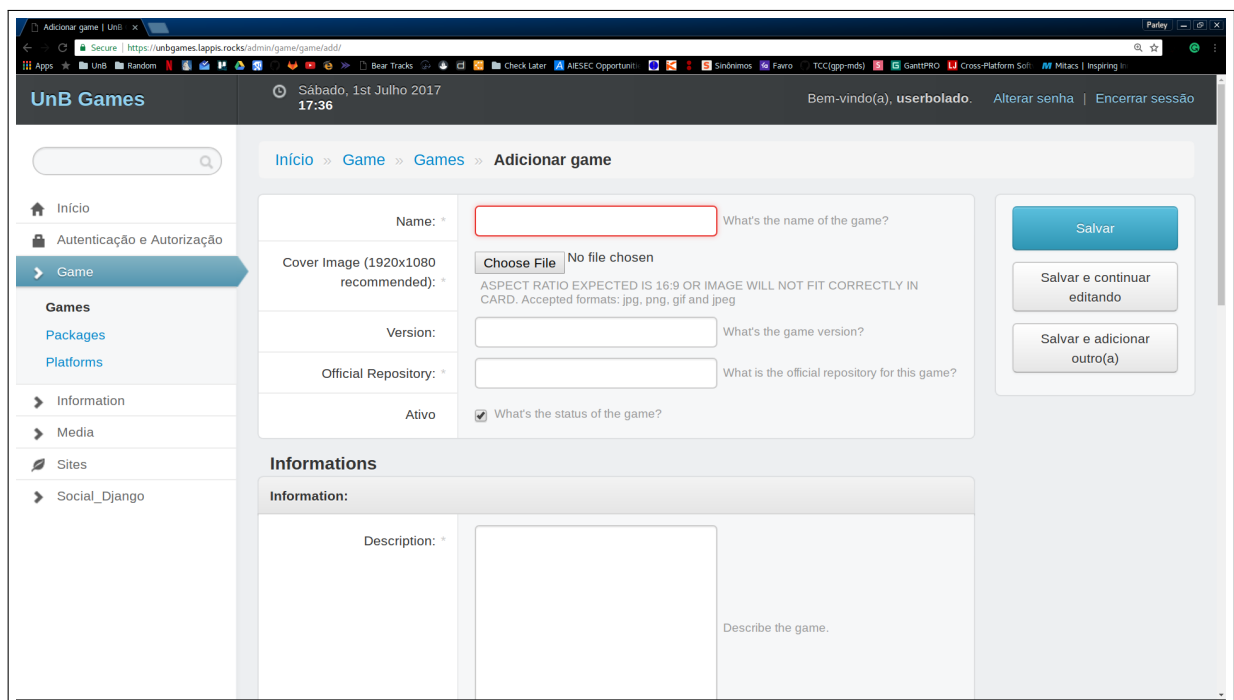


Figure 8 – Include new game

The team reported they had some problems in their organization during the first semester, while they developed the system. They were 13 people that had to learn and use different software development methods and also create the platform. Above all that, they informed that they were too naive to choose React and Django for the development of the platform. This integration is not something very trivial for experienced programmers in both frameworks; it was even harder for developers that didn't have any experience with any of them. They said it was hard to manage everything that had to be done, learn the new technologies and still merge them.

During this second semester, the plan was to maintain and evolve the platform while evolving the template. The template took a very prolonged amount of time, especially on Windows, leaving the platform on hold. When there was some time to finally

change something there, the lack of documentation and the complexity of the system made very hard to do anything on the platform in such a short time.

It's important to notice that *there is* extensive Software Engineering documentation, like Vision Document and Use Cases description. These documents are useful during inception and early development stages, but not so helpful to maintain and evolve a complete system. The documentation that would have helped in this case is what can be called "Open Source documentation". Some of them are: comments in the code, clear instruction of how to run the application, a list of the dependencies, and other things for anyone who wants to contribute to it.

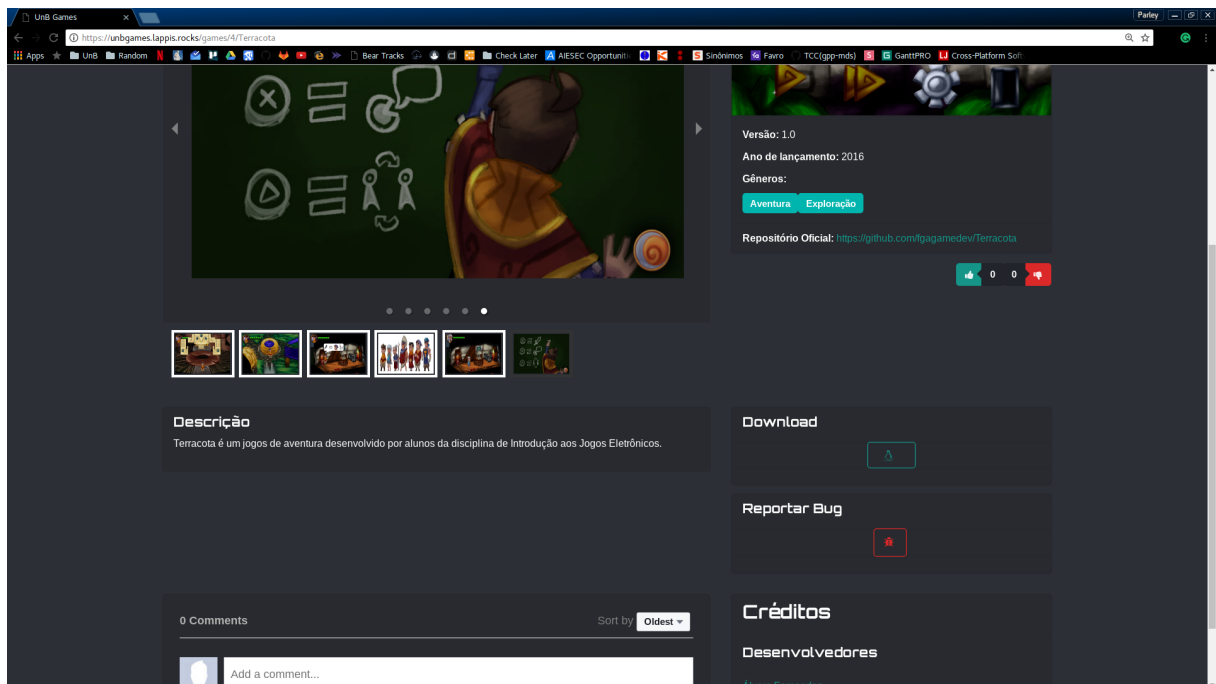


Figure 9 – Game detail

3.3 Difficulties

Creating the installer for Windows has proved to be the hardest part of the template because Windows has an entirely different folder structure from GNU/Linux systems, and they also don't have the same tools available (like Bash). Compiling for Windows has also turned out to be more challenging than Professor Edson first anticipated, because the template wouldn't run correctly, even after installing all required dependencies.

The template for Windows was supposed to use Visual Studio compiler, which is a tool made specifically for that platform, however when calling the compiler, it would not find any of the .cpp files. To try to revert that situation the parameters passed to the

compiler inside `Makefiles` were checked and the compiling commands were run individually inside each folder that had the source code. Even after that thorough examination, the compiler would refuse to find the files. All tools were uninstalled and reinstalled, and the problem remained. It was decided to change the compiler to `gcc` to solve this issue, just like the GNU/Linux systems.

Changing the compiler was partially easy because it was needed only to replicate the Linux `Makefile` on Windows (with a few commands replaced). It required the installation of one more dependency to the project though. The new compiler caused another complication, because, for some reason, during the final part of the compilation, it didn't recognize the `main` function. It became apparent that the compiler needed a different entry point instead of the default `main`. According to Visual Studio documentation, when creating a GUI application, it requires a function called `WinMain` (MICROSOFT, 2017a) and even with `mingw` it complained about not having it. This function was added, and it simply called `main`.

After compiling, the issue was to generate the installer. Initially, the script didn't provide any means to create the required `wxs` with the data from the repository, demanding the user to create that file manually. It wasn't an easy task, since this is a very particular large file, with specific tags, keywords, and syntax. For example, every independent set of data must be wrapped around a component, and each of the resources inside the package must be listed.

To aid in that process, the script `gen_wxs` was created and the `wxs` generation was divided into three parts (header, directory, and feature), just to make it easier to generate the whole file. The main problem in this part of the template development was finding and listing the resources because there could be any number of subdirectories. Recursion was the first idea to solve this issue, as seen lines 189-207 of Listing 4, but it proved to be hard to use in Bash because it defines variables only once. The recursive variable had to be updated, to solve that issue, before returning to the previous call. The command in line 206 of Listing 4 removes everything in the name of the file until the last `/`, assuring that `$FILE_PATH` has the correct value on the next recursive call. By doing that, it was possible to list all resources and their folders in the `wxs` file.

Listing 4 – Part of `gen_wxs.sh`

```
189 function check_directory_for_file() {
190     BASE_DIR=$1
191
192     for FILE in $(ls $BASE_DIR);
193     do
194         FILE_PATH="$BASE_DIR/$FILE"
195         if [ -d $FILE_PATH ];
196         then
```

```
197     append_directory_tag $FILE_PATH
198     check_directory_for_file $FILE_PATH
199     close_tag "Directory"
200 else
201     append_component_tag $FILE_PATH
202     append_file_tag $FILE_PATH
203     close_tag "Component"
204 fi
205 done
206 BASE_DIR=${BASE_DIR%/*}
207 }
```

Another challenge in testing the template was the migration to SDL2. Even though it was intended to be used with SDL2 since the beginning, Professor Edson chose to start with SDL and then add support to the newer version. The games initially selected for this part were *Traveling Will* and *Deadly Wish*, from the beginning of 2015. Even though they work fine when the libs are installed, there was a problem using them to test the template, because they needed the external engine created for the course a few years ago. This engine was built to be used as a shared library, which is fine and encouraged, but it expected a different folder structure than the template offered. Even after a few minor changes in it, the game still didn't adequately run when packaged. These errors might be happening from the version of the engine being used because the games didn't specify which they needed. Since the goal of this work was to test the template and not to fix/maintain the engine or the games, *Traveling* and *Deadly* were dropped. The new games selected were *Wenova* and *Mindscape*, both developed on the first semester of 2017.

Changing the template to support SDL2 was a little tricky. Different than the previous SDL version, the libraries didn't work on both Linux distros out of the box, requiring specific binaries for Debian based systems and Red-Hat based systems. Still on Linux, playing `.mp3` files proved to be slightly more complicated in SDL2. To read that extension `SDL_mixer` needs to be compiled with the `speeg` library, that will be loaded as a shared lib with the program. Even with the library installed, `SDL_mixer` would refuse to open `.mp3` songs, showing the error: Unrecognized format. The solution came after carefully observing the output of the `configure` script, that checks which dependencies and third party libs are installed in the computer building SDL. It was disclosed that `SDL2_mixer` required version 2 of `speeg`, but that wasn't discriminated anywhere in their documentation. `SDL_mixer 1`, used version 0.4.5 of `speeg`, the one that comes in the distro repositories, and worked fine because of that.

On Windows, the problem was loading the images of *Wenova*. Since `mingw` is being used as compiler for Windows, the `mingw` binaries were downloaded. It turns out that, for some reason, `SDL_image` would not load `.png` files, due to `libpng` having some reference

to some function that wasn't defined in any part of it or its dependencies. The error on the console wasn't of any help, and the internet searches would only result in adding `zlib1` to the dependencies, which was already done. In an attempt to correct the error, just to try something, I unzipped the Visual Studio binaries, which in theory wouldn't run on `mingw` and tried recompiling the game. For some unknown reason, probably all the dependencies were correctly put inside this version of `libpng`, the game ran successfully this time.

Mindscape was probably the hardest game to compile in both platforms, because of a foolish mistake the developers made, that was masked in the source code. For some reason, they had defined two headers called `game.hpp`, one in the engine, the other in the game. To prevent users from importing the same header accidentally and, consequently, redefining it, it is a good practice to guard it against multiple imports using a `#ifndef` macro (DISCH, 2009). The team that made *Mindscape* naturally used this strategy, but they hard referenced all of their imports, therefore always importing the engine `game.hpp`, which had all the definitions they needed. The template works differently, passing the path of the headers to the compiler. The hardcoded address in the source code made it impossible to find the right import. Because of that, when removing the full path in the `.cpp` files, the compiler would find the first defined `game.hpp`, which was in the game folder. This file had no definitions other than the constructor and the destructor, causing a lot of `Undefined reference` errors during compilation. After a long time investigating the logs, the existence of these two files was discovered, one empty and the other with all the functions correctly defined. Once this was solved, the game compiled and ran successfully.

4 Conclusion

Creating games is something supposed to be challenging and fun. But just like other types of software, it requires a lot of effort to distribute them to the player, mainly if a developer targets multiple platforms and operating systems. Each machine has a different configuration, different libraries, and architecture and most of the development inside the University doesn't take that into account, which may cause the final software to have unexpected errors.

This work has shown just how difficult it is to support multiple OSs, seeking to create a unique solution to easier this task. Even with the care of separating the specifics for each operating system and package the binaries within each, this project hasn't worked the way it was expected to. It wasn't possible to test the macOS distribution, due to lack of time, and Windows just gave a lot of other problems, like issues with the local environment, executables that worked partially, runtime errors (that didn't happen on Linux, for example).

With all these problems, the project served best as a learning experience, from which everyone involved should take a few lessons. The first lesson is that creating the template the way it was made wasn't the correct approach because all of the parties tried to replicate the macOS "way of packaging" on *all* the platforms, instead of focusing on how to follow each platform "rules." Using a self-contained package might have seemed a good idea, but that's not how Windows or Linux work.

Another lesson is that we should take advantage of the natural environment in each platform, by creating files to work with Visual Studio and XCode instead of 'forcing' the way around with Bash and Make. On Windows, even with the initial idea of using Visual Studio compiler, we still had Bash scripts, and when VS didn't work, we used another Linux solution, which may be the cause of all the errors and issues that happened on that OS.

This previous experience has to be taken to just some extent of the project. The template tried to avoid replication by creating scripts that would adapt to each environment. Just creating three separate templates would've been a bad idea, multiplying the problems by three. The project's got that idea right, except for the amount of it. There must be a standard part of the template, but it just wasn't all we proposed.

The third lesson is concerning the libraries used in the project. To make all the libs available for the player it was decided to use binaries and not the source files in the template (even though the source is in it too, but just to use in extreme cases). Every binary carries some information of how it was built, and that may cause problems if the

computer running them doesn't have all the dependencies that were there at compiling time. In the future, the source probably will be used.

On top of that, there is also the development and maintaining of the *UnB Games* website. Maintaining a free software project demands time and volunteers that want to work with that software, but it also needs a well-written documentation, to aid people that will contribute to it, and guidelines to prevent the mess of everyone coding the way they want to. The website is still at a very early stage on that matter, with poor documentation and without guidelines for someone who wants to help, but this will change soon.

The full project has shown that game developing in this University is much better than previous years, but it still has a long way to go. The template must be improved to facilitate the distribution of these games to society, and the platform has to mature to receive contributions from other people.

Future Work

A few decisions were made about the template and the platform, to improve the game development environment in the University, The template will be rewritten in Python, that is native to Unix platforms and easier to install in Windows. The new goal is to generate the files needed to support the development cycle on each platform. Instead of creating the binaries with just some scripts, the idea is to create the files that XCodes or Visual Studio can read so *they* can do the heavy lifting of compiling and linking binaries of the project.

The platform will also change. From experience, during this semester it was decided that the best option is to create a simpler version of the website, more comfortable to maintain and support, especially for new people in the project. It will probably still be developed in Django, but without React, that only adds another complexity layer to its evolution. The relationship between classes and objects will also be simplified, with fewer classes representing the same thing. On top of that documentation, called here "Open Source documentation" will be focused on, so anyone (in the University or not) can quickly contribute to the growth of the platform.

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Appendix

APPENDIX A – Members of GPP/MDS team

The following students were the direct responsible for developing the first version of the platform. They are students of the courses *Métodos de Desenvolvimento de Software* and *Gestão de Portfolios e Projetos* ministered by Professor Carla Silva Rocha Aguiar.

- Arthur Temporim
- Artur Bersan
- Eduardo Nunes
- Ícaro Pires de Souza Aragão
- João Robson
- Letícia de Souza
- Marcelo Ferreira
- Matheus Miranda
- Rafael Bragança
- Thiago Ribeiro Pereira
- Varley Santana Silva
- Victor Leite
- Vinicius Ferreira Bernardo de Lima

APPENDIX B – Selected games

This appendix shows the authors, year of publication, quantity of players, genre and description, whenever possible, of each selected game for this first part of the project.

B.1 Jack the Janitor

Authors: Athos Ribeiro, Alexandre Barbosa, Mateus Furquim, Átilla Gallio

Year: 1/2013

Genre: Puzzle, platform

Players: Single player

Repository: <<https://github.com/fgagamedev/Jack-the-Janitor>>

Description¹: Jack, The Janitor is a puzzle game where the player controls Jack, a school's janitor who must organize the school's warehouse. Jack can push boxes to the left or to the right and jump boxes.

When Jack fills an entire row with boxes, they disappear from the screen and go to a small window on the right side of the screen called the closet.

The closet shows how Jack organized the rows of boxes. When similar boxes are combined in the closet, Jack gets extra points and some power ups (to be implemented).

The game ends if a falling box hits Jack or if the closet gets full.

B.2 Emperor vs Aliens

Authors: Leonn Ferreira, Luis Gustavo

Year: 2/2012

Genre: Tower defense

Players: Single player

Repository: <<https://github.com/fgagamedev/Emperor-vs-Aliens>>

¹ Available on the repository README.md

B.3 Ninja Siege

Authors: Tiago Gomes Pereira, Matheus Fonseca, Charles Oliveira, Pedro Zanini

Year: 2/2012

Genre: Tower defense

Players: Single player

Repository: <<https://github.com/fgagamedev/Ninja-Siege>>

Description: The ninja academy is being raided and you have to defend it.

B.4 Space Monkeys

Authors: Victor Cotrim

Year: 2/2012

Genre: Tower defense

Players: Single player

Repository: <<https://github.com/fgagamedev/Space-Monkeys>>

Description: Monkeys are attacking your home planet. They come in waves and you have to get rid of them all.

Remarks: It's interesting to notice that, by this time, the students of *Introdução aos Jogos Eletrônicos* didn't have designers with them in the team. Figure 10 shows that, given the complexity of developing a game, sometimes the artwork was not a priority. This is also one of the games that didn't run properly after the compilation.

B.5 War of the Nets

Authors: Matheus Faira, Lucas Kanashiro, Luciano Prestes, Lucas Moura

Year: 2/2013

Genre: Turn Based Strategy

Players: Multiplayer on LAN

Repository: <<https://github.com/fgagamedev/War-of-the-Nets>>

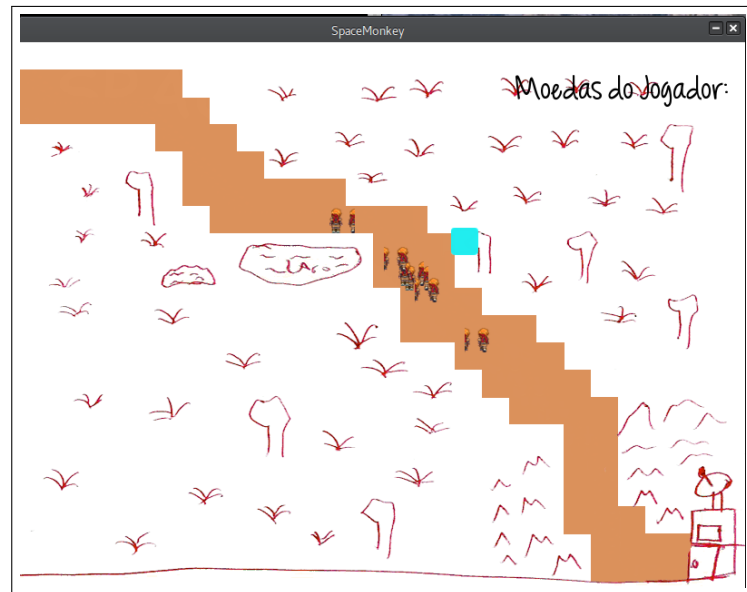


Figure 10 – Space Monkey

Description: It is a turn based strategy (TBS), where the objective is to construct a network from the base to a right point, faster than your enemy. You also can destroy his network with bombs, or infiltrate it with spies.

B.6 Post War

Authors: Bruno de Andrade, Jonathan Rufino, Yago Regis

Year: 2/2013

Genre: Turn Based Strategy

Players: Multiplayer on LAN

Repository: <<https://github.com/fgagamedev/Post-War>>

B.7 Anknowledge

Authors: Arthur del Esposte, Alex Campelo, Atilla Gallio

Year: 2/2013

Genre: Turn Based Strategy

Players: Multiplayer on LAN

Repository: <<https://github.com/fgagamedev/Anknowledge>>

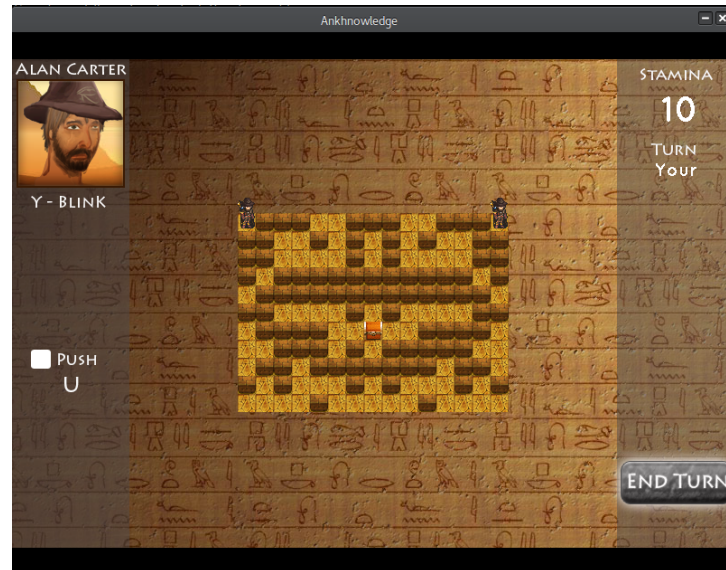


Figure 11 – Ankhnowledge

Remarks: From the games developed before the time the course was taught in conjunction with the students from *Darcy Ribeiro*, this is one of the prettiest and most pleasant games to play. Because one of the students is a software developer and designer, the user interface was very well drawn as seen in Figure 11.

B.8 Last World War

Authors: Gabriela Navarro

Year: 2/2013

Genre: Turn Based Strategy

Players: Multiplayer on LAN

Repository: <<https://github.com/fgagamedev/LastWorldWar>>

B.9 Kays against the World

Authors: Carlos Coelho, Bruno de Amorim Campos, Bruno Carbonell, Guilherme Fenterseifer, Fernando Tollendal, Lucas Sanginez, Victor Bednarczuk

Year: 1/2014

Genre: Platform

Players:

Repository: <<https://github.com/fgagamedev/Kays-Against-the-World>>

B.10 Imagina na Copa

Authors: Iago Mendes Leite, Jonathan Henrique Maia de Moraes, Luciano Henrique Nunes de Almeida, Inara Régia Cardoso, Renata Rinaldi, Lucian Lorens Ramos

Year: 1/2014

Genre: Platform

Players: Single player

Repository: <<https://github.com/fgagamedev/Imagina-na-Copa>>

B.11 Dauphine

Authors: Caio Nardelli, Simiao Carvalho

Year: 1/2014

Genre: Platform

Players: Single player

Description: A platforming/stealth game in a medieval fantasy setting, developed with SDL2.

Repository: <<https://github.com/fgagamedev/Dauphine>>

B.12 Terracota

Authors: Álvaro Fernando, Macartur Sousa, Carlos Oliveira, André Coelho, Pedro Braga, Wendy Abreu, José de Abreu

Year: 1/2015

Genre: Adventure

Players: Single player

Repository: <<https://github.com/fgagamedev/Terracota>>

B.13 7 Keys

Authors: Paulo Marques, Bruno Contessotto Bragança Pinheiro, Lucas Rufino, Luis André Leal de Holanda Cavalcanti, Maria Cristina Monteiro de Oliveira, Guilherme Henrique Nunes Lopes

Year: 1/2015

Genre: Adventure

Players: Single player

Repository: <<https://github.com/fgagamedev/7-Keys>>

B.14 Babel

Authors: Álex Silva Mesquita, Jefferson Nunes de Sousa Xavier, Rodrigo Gonçalves, Vinícius Corrêa de Almeida, Heitor Campos, Max Von Behr, Aleph Telles de Andrade Casara, Washington Rayk

Year: 1/2015

Genre: Adventure

Players: Single player

Repository: <<https://github.com/fgagamedev/Babel>>

Description: The mankind wanders the universe looking for a new habitable planet. They found an unknown planet with a big and strange tower.

The challenge is explore the tower and the planet and expand your resources, but be careful with the mysteries of this new planet.

B.15 Strife of Mithology

Authors: Jônntas Lennon Lima Costa, Marcelo Martins de Oliveira, Victor Henrique Magalhães Fernandes, Dylan Jefferson M. Guimarães Guedes

Year: 1/2016

Genre: Tower Defense

Players: Single player

Repository: <<https://github.com/fgagamedev/Strife-of-Mithology>>

Description: A 2d-isometric Tower Defense based on mythology.

B.16 Traveling Will

Authors: João Araújo, Vitor Araujo, Igor Ribeiro Duarte, João Paulo Busche da Cruz

Year: 1/2016

Genre: Platform, Runner

Players: Single player

Repository: <<https://github.com/fgagamedev/Traveling-Will>>

Description: This game tells the story of Will, personification of the Will, trying to restore

Remarks: This game has one of the most attractive user interfaces from the games packaged so far. The team that developed it was able to create a very good game, technically speaking, with engaging scenarios and soundtrack, because they had design and music students. A screen of the game running after compiling it with the building script is shown in Figure 12.

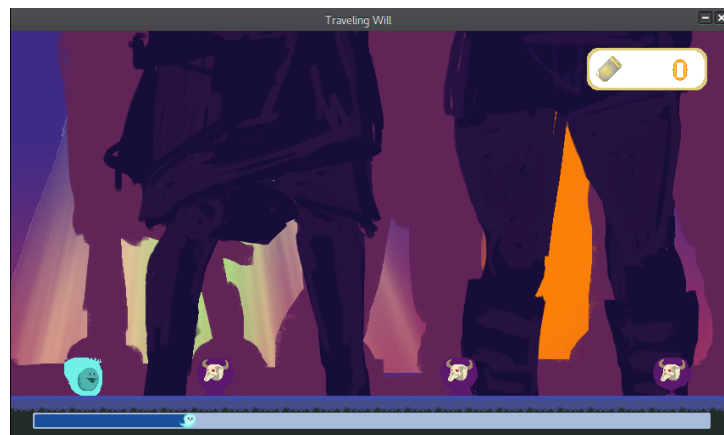


Figure 12 – Traveling Will

B.17 Deadly Wish

Authors: Lucas Mattioli, Victor Arnaud, Vitor Nere, Iago Rodrigues

Year: 1/2016

Genre: Battle Arena

Players: Single player

Repository: <<https://github.com/fgagamedev/Deadly-Wish>>