

UNIVERSITY OF ST ANDREWS

CS4099: MAJOR SOFTWARE PROJECT



A Tactical RPG Engine

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Abstract

A Tactical RPG are games that are comprised of a series of battles, which take place in various environments intertwined with an over-arching story. Battle are similar to the game of chess but include RPG elements. These including attributes such as *Hit Point* which represents how much damage a piece can receive before being defeated. The aim of this project is to develop an engine that affords the user a high degree of customisability. This is in addition to a isometric view of the battles and an editor which allows the user to visually specify the aspects of the engine. This reports discusses the process of creating the system, starting from the objectives of the project, following on with the design and implementation. To conclude a critical evaluation of the project in regards of the objectives and related works will be detailed. The use of user testing and an example game's will be used to demonstrate the the project's capabilities.

Declaration

I declare that the material submitted for assessment is my own work except where credit is explicitly given to others by citation or acknowledgement. This work was performed during the current academic year except where otherwise stated.

The main text of this project report is words 14,011 long, including project specification and plan.

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1 Introduction

An RPG (Role Playing Game) is a game where a player assumes the role of a character. An RPG is usually story driven and the character usually has a quest to complete. In the course of the game the player will go to different environments such as town and dungeons. In these environments the player will have to fight opponents in battles. Combat in RPGs is normally a simple turn based system where players and their opponents take turns to attack each other using various skills¹.

A Tactical RPG is a sub-genre of an RPG that focuses on the combat side of the genre. A Tactical RPG is a series of battles, which take place in various environments intertwined with an over-arching story.

Each battle is grid based (like chess) where each player has a number of units(pieces). The players take turns to move their units. Each unit has attributes associated with it, such as



Figure 1: **Tactics Ogre**^[1] a classic Tactical RPG

strength, and hit points that affect all the actions in the game. Like chess, there are different kinds of units which have different abilities which affects how the unit moves and what actions they can perform. A unit can attack another player's units. The goal of the battle is usually to defeat all the opponent's units although other goals are possible.

The aim of this project is to create an engine which will take resources such as graphics, sounds and rules of the game to create a runnable Tactical RPG. A detailed description of the scope and goals of the project is in section 3

1.1 Project Baseline

No previous work was used for this project. All of the project was created during the course of the academic year.

¹Although there are some common variants that will be discussed later on.

1.2 Project Success

Having completed all the primary and secondary objectives as well as nearly all the tertiary objectives, I would say that the project was successful. Notable features that were accomplished include a very customisable engine which allows the user to specify most aspects of their created game and an editor which allows the user to make a complex game without any programming(although programming can be used to further enhance their game).

The ability to export the user's created game as a standalone application without any external dependencies is a significant feature of the project. Since Java was used, the created game is cross-platform and can run on any system with a complete Java runtime environment².

Results from the usability studies were very positive, with most users saying they enjoyed using the system and found it usable.

²i.e The GUI and Editor won't run on Android since it does not have the Swing toolkit.

2 Context Survey

2.1 Evolution of Tactical RPGs

Classic Tactical RPGs(TRPGs) were heavily influenced by traditional Strategy games, in particular chess. The earliest game that shares the concepts of a TRPG is “Bokosuka Wars”(1983) which had many of the features now common in TRPGs including grid based combat with a number of units^[2]³.

Although there were many western games that had similar gameplay at the time, like “Ultima III: Exodus”(1985), which is a traditional RPG with TRPG like battles, they quickly diverged and soon featured real time combat, or reverted to a simple combat system like traditional RPG such as “Final Fantasy”. This trend led to most TRPG being made in Japan since, until recently, western publishers thought TRPGs were too niche to be profitable ^[3].

I will briefly describe the games that made a significant contribution to the genre, these will be used in evaluating the capabilities of the created engine.

- *Fire Emblem*(1990) popularised the genre. The game introduced RPG elements such as weapons and skills that became standard in later games. It also was one of the first TRPG to have a non-trivial plot.
- *Tactics Ogre*(1994) was the game which started the trend to have the tactics in its name which gave rise to the Tactical RPG name³^[4]. A unique feature for its time included isometric maps, an overworld map⁴ and a branching storyline. It also popularised dynamic unit ordering that is determined by the character’s attributes rather than each player moving all their units when it’s their turn.
- *Final Fantasy Tactics*(1997) was probably the most prolific TRPG in America/Europe. It featured a 3D viewpoint that imitated the 2D isometric view of previous games. It allows the user to rotate the map which allowed less restricted maps⁵.
- *Disgaea: Hour of Darkness*(2003): The first in a series of games that had the unique feature allowing the player to play randomly generated maps to improve replayability. The latest in the series (“Disgaea 4”) is one of the few TRPGs that contains a map editor, which allow the player some limited customisability.
- *Valkyria Chronicles*(2008) started the trend of blurring TRPG with other genres. The game played like a typical TRPG *except* when attacking an opponent, where it acts like a first person shooter.

2.2 Tactical RPG Game Engines

Unlike other genres such as interactive fiction^[5] or even traditional RPGs⁶, there are hardly any engines specific to Tactical RPG, developers preferring to use their own engines or a general

³Tactical RPG are also called Simulation Strategy RPG(SRPG), most commonly in Japan.

⁴A overworld map has a series of user selectable locations, where the battle can take place.

⁵Older TRPGs’ maps could not be rotated hence they were designed such that tiles with greater height were at the far ends of the map. This was done to make sure that nothing was obscured.

⁶RPG have many engines available such as RPG Maker ^[6]

purpose engine such as Unity⁷

One of the only complete⁸ and successful TRPG creator is “Simulation RPG Maker 95”⁹. As apparent from it’s name, it is extremely old but it does allow the creation of fairly complex TRPG, utilising a top down view. Notable features of the application is that it allowed visual map making and it allowed a high degree of customisation to the units.

The project’s editor will be evaluated against the described applications in terms of features and ease of use.

⁷Used to produce many independent games such Mysterious Castle and Grotesque Tactics: Evil Heroes

⁸There are many half finished engine, which have been abandoned, mainly due to difficulty or lack of interest.

⁹Simulation RPG being another name for a TRPG.

3 Requirements Specification

3.1 Project Scope

The aim of the project is to enable the user to create a highly customisable Tactical RPG. There are three main parts to the project: the *engine*, the *GUI* and the *editor*.

The engine will contain all the logic of the game including handling the game progression as well as the battle system. The GUI will be an isometric view of the game (see Section 6.5.2).

The editor will allow the user to specify the input to the engine. This includes visual map making as well as specifying all the attributes of the units and weapons in addition to the winning conditions. The editor will also allow the user to export the game as a standalone application.

3.2 Requirements Overview

A complete listing of requirements is in section 3.4. The main requirements are to create an engine which allows a high degree of customisability, an isometric view and the ability to export the game as a standalone application.

3.3 Overview Description

3.3.1 Product Perspective

3.3.2 Product functions

3.3.3 User characteristics

The system is for anyone that would like to create a TRPG. They need not have any experience in creating TRPG before, or even played one before since the game can be created without any programming.

For more advanced users, they can further customise the created game using their own code. This allows the user to completely change most aspects of the game. This could be used for example to make unique abilities or battle systems.

3.3.4 Constraints, assumptions and dependencies

The system should be portable i.e it should work on most operating systems. To achieve this I chose to use Java since it would work on any system that has the Java runtime environment installed on it.

3.4 Objectives

In the following sections ✓ means that the objective is fully completed, ✗ means incompleteness and - signifies partial completion.

3.4.1 Primary

The main goal of the primary objectives is to allow the user to create a complex Tactical RPG, with limited customisability.

- ✓ To develop an engine that takes:
 - ✓ The definition of character attributes and a combat system.
 - ✓ The definition of a world broken up into the smaller environments.
 - ✓ The rules of the game.
 - ✓ The kinds of enemies.
 - ✓ The definition of a simple story as a wrapper for the whole game, from the start to the conclusion of the game
 - ✓ Which is told between the movement between different environments.

and create a playable tactical RPG.

- ✓ To include in the engine support for the following:
 - ✓ `units` with a fixed set of associated attributes such as:
 - ✓ Hit-points (which represent the health of the unit).
 - ✓ Strength.
 - ✓ Defence.
 - ✓ Move (The number of tiles the unit can move each turn).
 - ✓ `battles` which take place on grid and include:
 - ✓ A set number of `units` for each player.
 - ✓ A Winning condition, which is to defeat all of the other player's units.
 - ✓ Battles are `turn based` meaning only one unit performs at any one time.
 - ✓ A combat system.
 - ✓ A combat system that includes
 - ✓ `combat` between adjacent units.
 - ✓ When the unit hit-points are reduced to zero they are defeated and are removed from the map
 - ✓ A set of rules that govern the combat.
 - ✓ A predefined set of behaviours for how the non-player characters should behave.
 - ✓ Including pathfinding.
 - ✓ An isometric graphical representation of the game.
 - ✓ Which shows the grid with all the units.
 - ✓ Allows the user to move their units and see the opponents moves.
 - ✓ Allows the user to attack the opponent's units.
 - ✓ Which allows the user to see a unit status (e.g current hit points).
 - ✓ Text will be used to describe the more complex actions such magic.

3.4.2 Secondary

The main goal of the secondary objectives is to allow the user more customisability.

- ✓ Tiles have `height`, where units can only move to tiles of a similar height.
- ✓ Tiles that are not passable such as sea, lava, etc ¹⁰.
- ✓ Tiles have different movement costs associated with them.
- ✓ A combat system that includes
 - ✓ combat between non-adjacent units,
- ✓ Players have items such as weapons that affect the result of combat between units.
 - ✓ Including long distance weapons for the player and AI.
- ✓ Direction and height of the character's tile affects the unit's actions. ¹¹
- ✓ Sound effects.
- ✓ Music.
- ✓ Saving and loading games.
- ✓ Allow the user to specify some of behaviour of non-player characters
 - ✓ An example: always attack a certain kind of unit or always attack the unit with the least Hit Points.
- ✓ A graphical view to allow the user to specify input to the engine.

3.4.3 Tertiary

The goal of the Tertiary objectives are to provide the user with more customisability and to provide a GUI for customising aspects of the engine.

- ✓ A combat system that includes
 - ✓ Support for `skills` which can effect multiple units.
 - ✓ Including weapons that can attack multiple units at the same time.
- ✓ Animations for units and movement.
- ✓ A graphical editor for creating and specifying the input to the engine which allows:
 - ✓ Creating and editing maps.
 - ✓ which also allows placement of enemy units.

¹⁰The engine as well as the GUI full supports impassable tiles. The editor has partial support only allowing 'empty' tiles

¹¹At the moment only the height affects the attack, while the direction is displayed in the GUI and changes based on the unit's movement, it not used in the model.

- ✓ specifying the order of the maps.
- ✓ making animations.
- ✓ making items such as weapons.
- ✓ making skills.
- ✓ making units.
- ✓ specifying the story, at the start and end of a battle.
- ✓ specifying the music and sound effects played on each map.
- ✓ specifying the condition to win a map such as:
 - ✓ Defeating all the opponent's units.
 - ✓ Defeating a specific unit.
- ✓ specifying some of the behaviour of the enemy units.
- ✓ Allows exporting the game as a self contained application.

✗ Custom events

- Attached to units or titles, could be used for:
 - Making the player win if some enemies unit has less then 50% Hit Points¹².
 - Damaging a character if it steps on a specified tile¹³.
 - Showing some part of the story when a player's character reaches a specified tile.¹⁴

3.5 Specific Requirements

The system should allow the user to export the created game with no additional dependencies apart from the Java runtime environment.

3.5.1 Security Requirements

Although there are no security requirements in the objectives, they could nevertheless be considered in the future. Xml is used as the data format for the created games. This aids maintainability since xml is human readable and there are many tools to manipulate the files. The disadvantage of this is that the end users of the created game can also access the data, hence they could edit it or steal the resources of the game. A solution to this problem would be to encrypt the data files so they are not editable by the end users.

3.5.2 User Interface Requirements

The GUI should provide a isometric view of the game as shown in 1. The GUI should visually display to the user which action the opponent performs. The GUI should give visual feedback for any actions the user makes.

¹²The user could specify this using a custom win condition.

¹³The engine supports performing an action when it moves to a tile, but this is not yet exposed to the editor

¹⁴The engine and GUI support displaying dialog at any time, but the editor only supports creation of dialog for the start and end of a battle.

4 Software Engineering Process

4.1 Methodologies Used

I chose to use an iterative spiral development model for the project. This allowed me to focus on specific parts of the system before moving on to the next component. Prototypes were extensively used, especially in the GUI when choosing how to render the map.

4.1.1 Test Driven Development

Test-driven development (TDD) was utilised in the project. This also helped with verification of requirements as tests assess whether the code matched the minimum requirements. The JUnit library¹⁵ was used to write the unit tests.

The main stages in TDD are[7],[8]:

1. Before the code is written, unit tests to test the functionality are created. These will initially fail.
2. Code is written to pass the test and no more.
3. If more functionality is required, first the test is written and then the code to pass it.
4. Changes to the previously written code must pass all previously created tests.
5. The code is refracted.

The major benefits of TDD are that the system will be well tested. An additional benefit is that it prevents new features from introducing bugs. Combined with version control, as discussed in the next section, it makes it very easy to find bugs since the unit tests can be used to find out *when* the code stopped working as well as find out *which* piece of code was the root cause.

This method of development was perfectly suited to implementing the algorithms in the engine (such as unit movement) because the expected output was known beforehand. Since all components of the model are programmed to an interface, it allows the use of mock objects^{4.2}.

However TDD has few drawbacks such as the difficulty of realising all possible test scenarios, which becomes apparent when testing the GUI and the editor. To test these aspects of the system, I played multiple created games from start to finish with the goal of finding any lingering bugs. In addition, I carried out user surveys as well as usability studies to find any unexpected defects in the user interface. (results in)

4.2 Mock Objects

Mock objects are used predominantly in very large software development projects to aid testing. The aim is to create mock objects which simulate only the essential behaviour of the object required for testing. Mock objects abstract the detailed functionality of the implementation away and focus only on what is required for the test.

¹⁵JUnit 4.8.2, see www.junit.org/ for details

4.3 Version Control

Version control keeps track of all changes to a project. It keeps the history of changes and helps to detect when a bug was first introduced, hence the cause of the bug. In particular I chose to use `git`, which is a distributed version control system. It differs from traditional client server systems such as Subversion in that each user has a complete copy of the repository.

Distributed version control system have the advantage of allowing changes to be committed locally, even without an internet connection. This was particularly useful for this project since it allowed experimenting with various features before choosing the features to integrate into the system.

5 Ethical Considerations

Although participants were asked to complete a survey to gain feedback on usability as well as testing, no personal information was stored. Following the ethics requirements of the School of Computer Science I submitted a 'Preliminary Ethics Self Assessment Form'. The result of the assessment was that there were no ethical issues raised by this project.

6 Design

6.1 Methodologies

The Model View Controller (MVC) design paradigm was chosen to be used to structure the project. The MVC design pattern has many benefits, as discussed below.

6.2 Engine

The main considerations for the engine was to make it as configurable as possible. To achieve this everything was designed in terms of interfaces, which allowed the particular implementation to be changed. The objects themselves were loaded from their serialised form on disk.

6.2.1 Data Format

XML was chosen as the data format for this project. The main reason is that it is human readable, this allowed me to create and test the data format before the editor was created.

The data was designed to be extendable, as well as provide implementations of the various assets. An advanced user can specify their own custom classes.

Listing 1: Example of Custom weapon

```
<weapon class="custom.customWeapon" uuid="0f0dee33">
  <name>Longicollis</name>
</weapon>
```

Listing 1 shows how a custom weapon can be used. The `class` attribute is the fully qualified name of the class. The only thing the user has to do is to add a `jar` with their classes in it to the `classpath` of the game.

6.2.2 XML schema

XML schema is a way of validating an xml document. A schema was produced for each serialised object¹⁶. The main use of this was for testing the hand written xml I used before the editor was created. It also helped ensure that the xml produced by the editor was correct.

6.3 Game Progression

Figure 2 shows the overview of how the created game progresses. Each game has a number of maps where a battle takes place. After the map is loaded, any relevant dialogue is displayed, along with the winning conditions. The player's units are then placed on the map, and the battle starts¹⁷. If the player loses the battle, a gameover screen is shown and the game ends. In contrast if the player wins, he/she advances to the next map, if there is one.

¹⁶in the `schemas` directory

¹⁷While the engine allows the user to choose where their units are placed, the GUI does not due to time constraints. The editor supports specifying the starting location for the player's units.

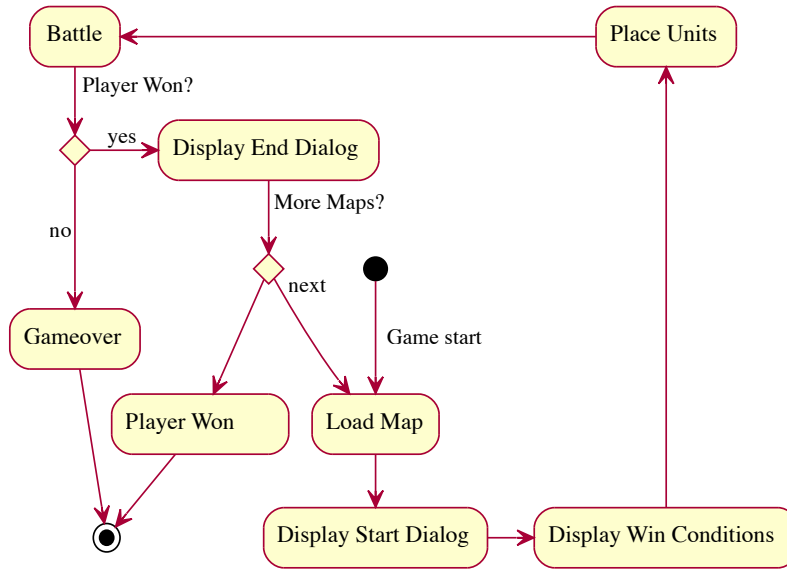


Figure 2: Activity diagram which a high level of overview of the engine

6.4 Game Mechanics

As apparent from the name of the project, a TRPG is turn-based. There were two main choices for turns works; the first is where the players take turns to move all the units, the other method is where the next unit to move is based on some statistic such as the unit's agility. Both methods are widely used, the first more often in games that focus on micro-management such as Civilization but there are exceptions to this such as Disgaea.

The second method has the advantage of allowing more dynamic unit ordering. An example of how this is commonly used: A unit can get their turn quicker if they did not perform any action on their last turn. It also has the advantage of making the game flow much quicker, since the player does not have to wait too long to move their next unit.

I chose to use the second method because it allows the user more customisability since they can choose how unit ordering works. The other reason is based on my own experience, where I think it works better.

6.5 Map Rendering

6.5.1 Introduction

An isometric viewpoint is a way of display 3d objects in 2d while giving the impression that it s 3d. Two different variations are shown in figure 3.

The main benefit of an isometric map compared to a topdown view is that height can be easily displayed.

6.5.2 Tilemap

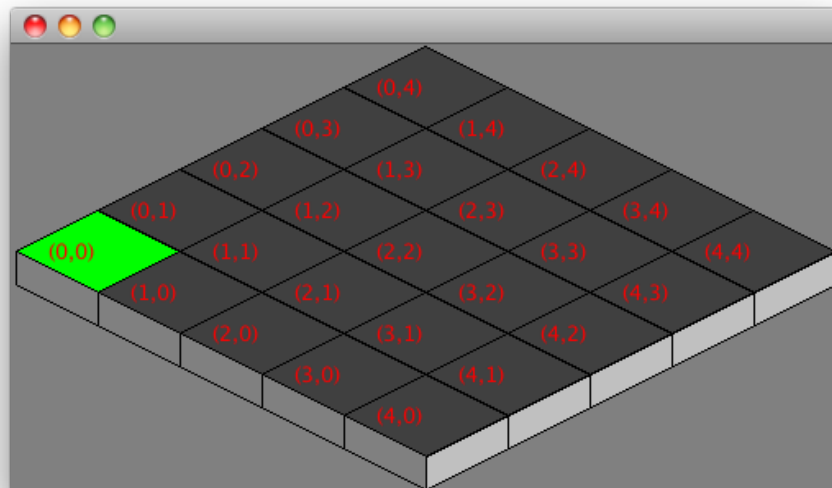
There were two main choices for the isometric tilemap, a "Diamond" map or a "Staggered" map [9], examples of both are shown below in figure 3. Prototypes of each map type were created and the following was found.

The “Staggered” was the first to be considered and it had the following advantages:

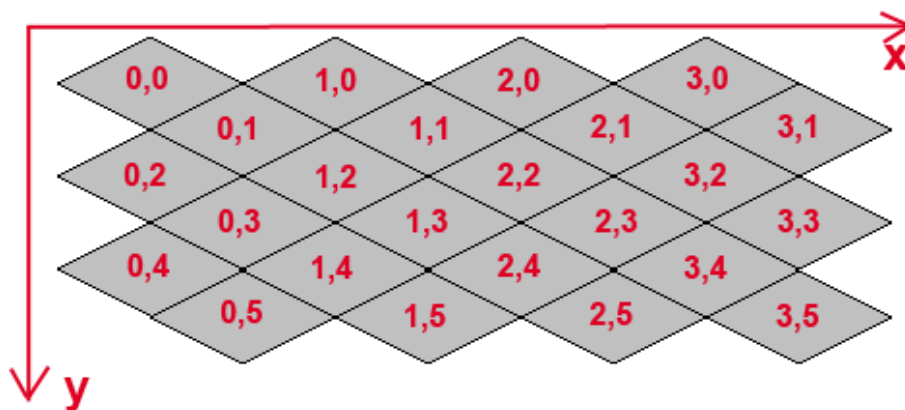
- The map filled up the screen with very little wasted space, so the user can see more of what is happening on the map.

The “Diamond” map was chosen for the following reasons:

- “Diamond” map look more aesthetically pleasing than “Staggered” maps because it has no ragged edges.
- If the map is large enough, it will fill the whole screen negating the “Staggered” map advantage.
- Simpler to think about, since a “Diamond” map is just a rectangular map rotated.



(a) Diamond Map



(b) Staggered Map

Figure 3: The two main types of isometric tilemaps

6.6 Units

I designed the actions a unit can take as a finite state machine as show in figure 4. The main actions the unit can take are:

Move This allows the unit to move to any tile in it's movement range.

Attack Attack any opponent in their weapons range.

Skill Use one of their skills

Wait Finish their turn without taking any action.

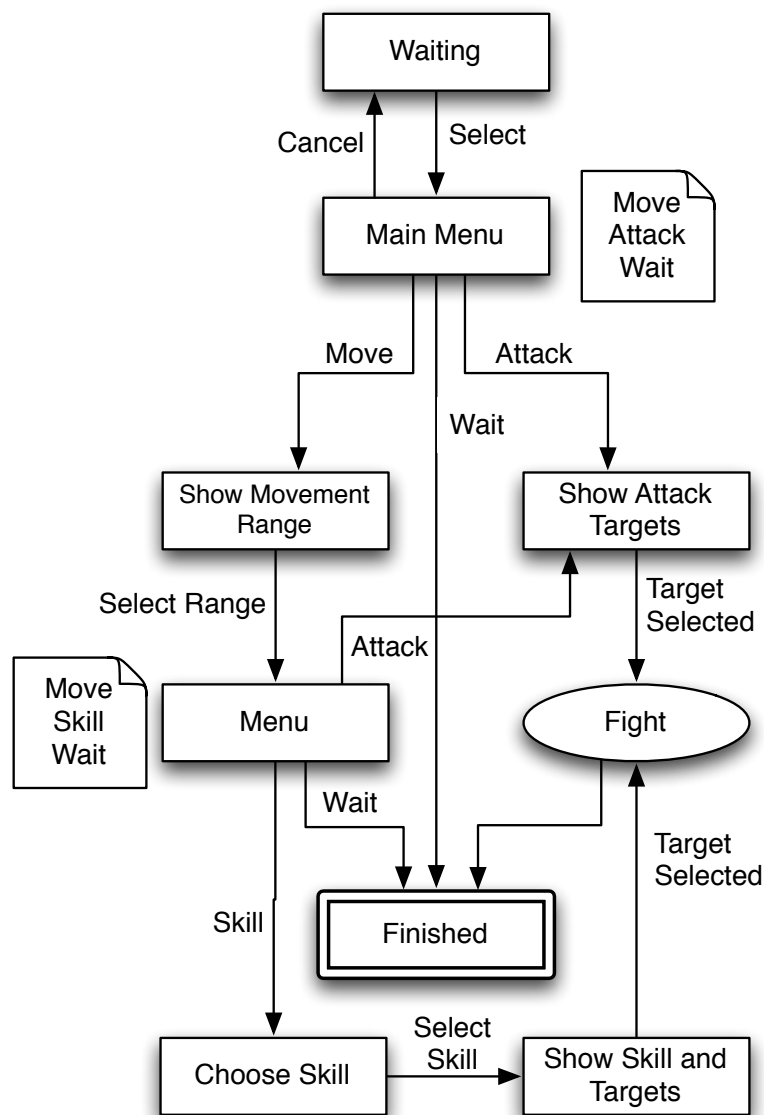


Figure 4: The State diagram of a single turn of a player's unit

6.7 Weapons & Skills

As is common in TRPG, I included weapons as well as skills in the design. A Weapon has a certain strength, a specified range and it may have unique effects. As discussed in section 6.2.1, the weapons and skills are completely configurable, but to enable the user to create common weapons, I designed the following weapons to be included as standard in the engine.

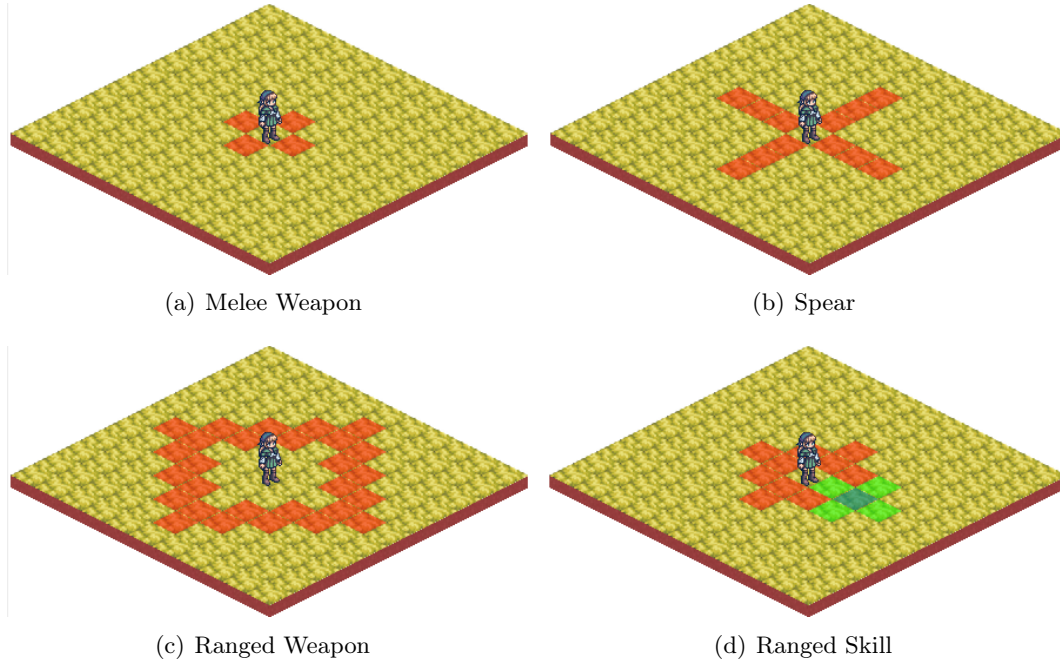


Figure 5: The above figure shows the attack range of various weapons and skill

Melee Weapon this is the simplest kind of weapon, where the unit can only attack adjacent enemies.

Spear A spear can attack enemies in its range, in a single direction. The unique feature is that it damages all enemies in that direction at the same time.

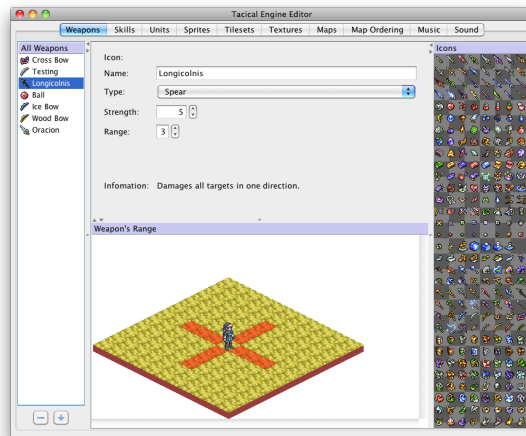
Ranged Weapon A ranged weapon attacks a single faraway target. It has the limitation of not been able to attack enemies which are too close (as shown in the diagram).

Ranged Skill A skill can attack enemies in its range. The main difference from a weapon is that the skill has an attack area (shown in green) which are the units affected. Unlike most weapons, skills affect *all* units in the attack area.

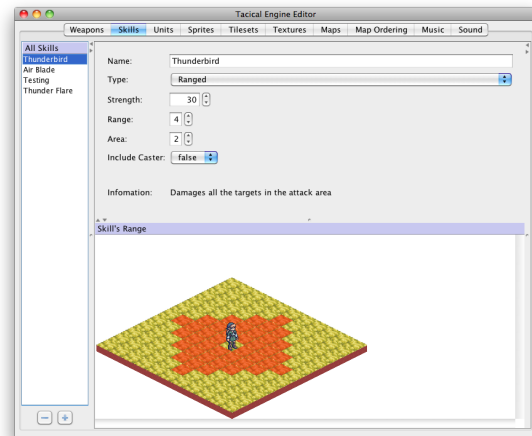
6.8 Editor

The editor was designed to be easy to use. I designed a tabbed interface which allows the user to choose which parts to edit. One of the main features of the editor is the updating of related panels. For example, if the user creates a new weapon, it will automatically be added to the list of available weapons. The main components of the editor are shown below.

Weapons & Skills the editor is designed to allow the user to visually see how changing the stats affect it. This includes showing the user the attack range of the weapon/skill.



(a) Weapons Panel



(b) Skill Panel

Units All the attributes of the units are user editable. This includes their weapon, skill as well as the unit's sprites.

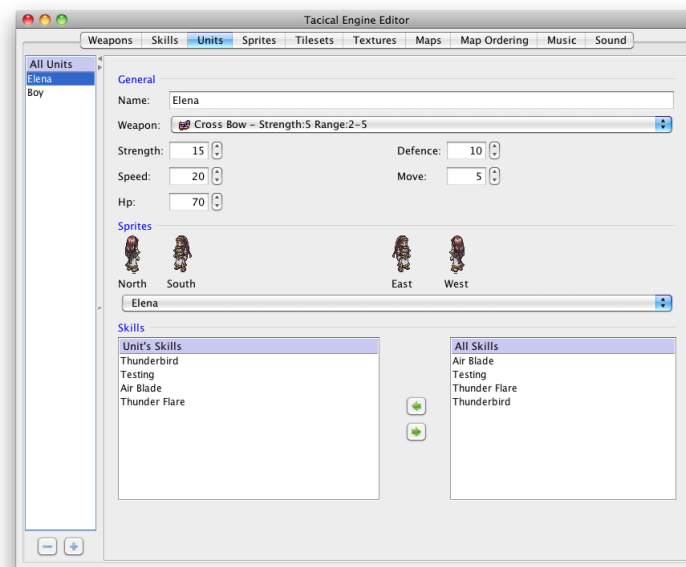


Figure 6: Unit panel

6.8.1 Visual Map Editing

The editor supports visual map editing as shown in figure 7. This allows the user to design their map without writing lots of xml. One of the notable features is that the user can specify the enemy's locations, which gives the user more freedom, compared with older TRPG where the enemies always start on the same corner on every map.

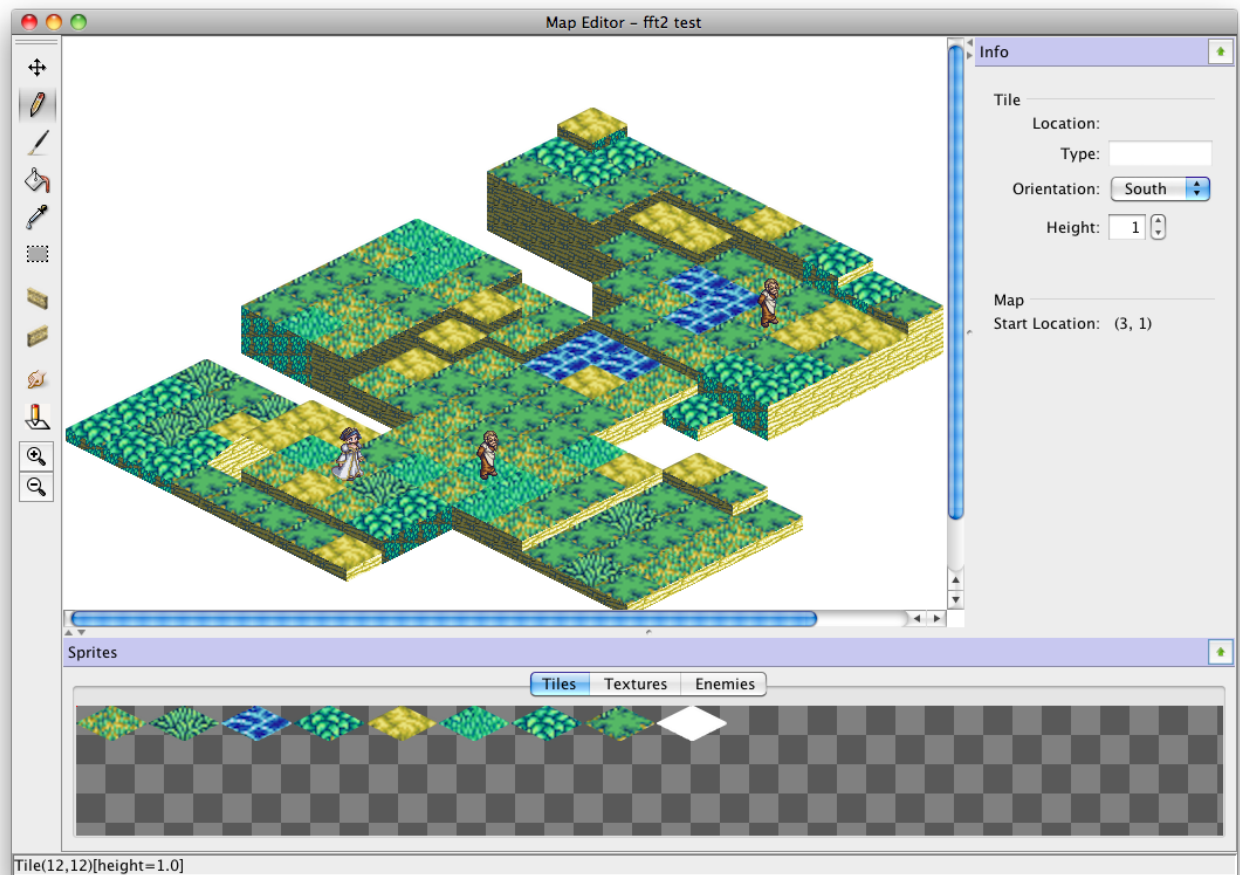


Figure 7: Visual Map Editor

Each tile has many attributes associated with it, these include

- The main image.
- The left and right wall images.
- A specified height.
- An *orientation*, which affects which way the slanted tiles are drawn.

The tools are based on their equivalents in a painting program and include a pencil for drawing the currently selected tile image onto the selected tile. Other tools include enemy unit placement using an icon of a pointing finger.

7 Implementation

7.1 Overview

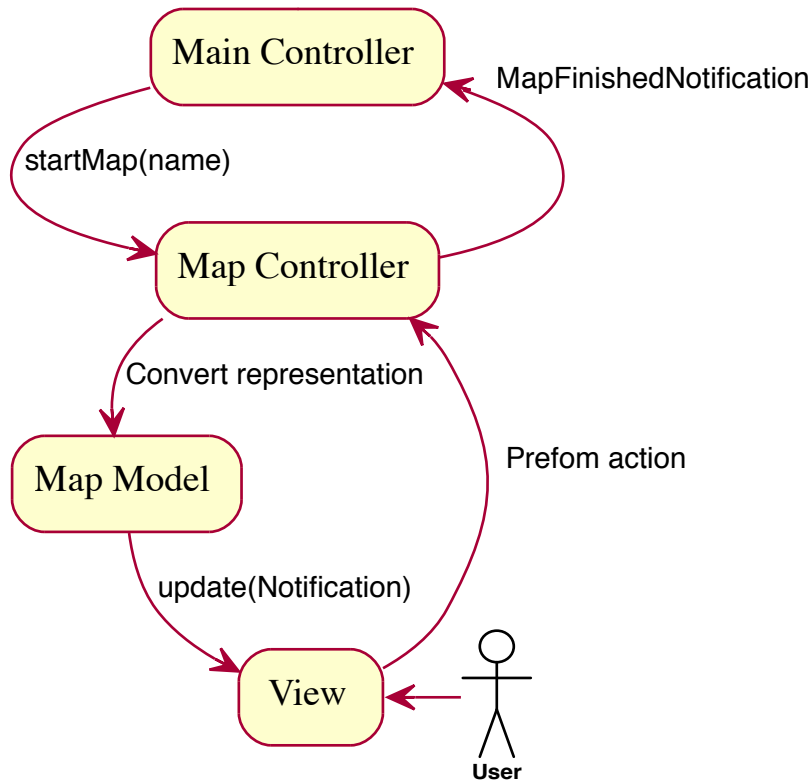


Figure 8: Overview of the implementation.

The system is structured using MVC for the overall architecture as well as using the Observer Pattern, as shown above.

The `MainController` handles the overall logic, including the game progression. Although the objectives only require an isometric map view, the implementation was designed to be more general, hence a *separate* controller for each stage of the game is used. When the stage is finished (e.g. when a map has been completed) the controller notifies the `MainController`, which decides what to do next.

The observable components (i.e. the view and the map controller) communicate using notification objects which encapsulate any relevant information. For example, the model sends a `UnitMovedNotification` when the computer controlled opponent moves one of their units. This notification includes a reference to the unit moved as well as the path it took to get there. The information is used by the GUI to display an animation of the unit moving to the user.

7.2 Data Format

The schema for the data format was only slightly changed for the reason stated in section 7.5. To parse and serialise the xml the Xstream Java library was used.

XStream is an open source library used to serialise Java objects to and from XML. One of its major benefits is that it abstracts over the parsing and serialisation and allows the user to focus on what the data should be used for.

XStream achieves this through the use of Java annotations¹⁸, as shown in the below example¹⁹.

Listing 2: Example of class that is serialisable with XStream

```
@XStreamAlias("tile")
public class SavedTile {
    protected final String type;
    protected final int height;
    protected int startingHeight;

    @XStreamAsAttribute
    protected final int x;
    @XStreamAsAttribute
    protected final int y;

    protected Orientation orientation;
    protected String leftWall, rightWall;

    private Object readResolve() {
        if (orientation == null)
            orientation = Orientation.TO_EAST;
        if (startingHeight == 0 && height != 0) startingHeight
            = height;
        return this;
    }
}
```

As shown above, no extra logic apart from the annotations is needed for serialisation. Another benefit of XStream is that it allows setting default values for the fields. This allows the user to omit redundant tags, as shown in the xml where most of the tags have been omitted.

Listing 3: Serialised form of the above class.

```
<tile x="0" y="0">
    <type>grass</type>
    <height>1</height>
</tile>
```

¹⁸A special form of syntactic metadata that can be added to the source of a Java file, with the notable feature of being retained in the compiled class files.

¹⁹Getter, Setters and trivial constructor omitted.

7.2.1 Resources

All resources that are loaded are `Identifiable`, that is they have a unique id. There are two main advantages to using this scheme. The first is that it allows cacheing of resources which means that there is only a single instance for each resource (such as weapons and images). This is especially important for the images to reduce the memory requirements as well as the load times.

The other advantage is that I could use the same framework for loading and saving all the resources, hence saving development time as well as reducing code duplication.

A detail description of the structure and required resource of a project is in the appendix [E](#).

7.2.2 Sprite Sheets

A sprite sheet is a collection of images combined together. The advantage of this is that a single image is loaded, which reduces loading times. It also makes it easier to cache images, since a *subimage* can be efficiently created²⁰. A subimage shares the same image data as the original so it is an ideal way for each tile to have access to it's images^[10].

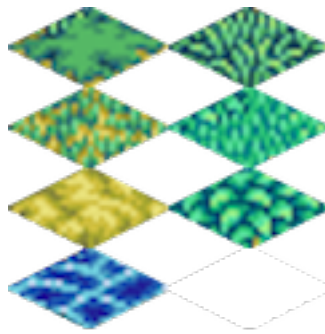


Figure 9: A 128×128 sprite sheet containing a tileset for a map

Sprite sheets make maps more reusable, since the tileset can be changed without any consequences²¹.

I created a sprite sheet editor to allow the user to easily edit the tilesets. Using sprite sheets allows abstracting over the file system, hence increasing the usability of the system. The editor was reused for editing other images such as the character images and it can even be used independently.

²⁰using the Java method `BufferedImage.getSubimage`

²¹As long as the new tileset has the same number of images or the tilemapping has extra entries for missing images.

7.3 Engine Development

7.3.1 Map

The Map class handles the overall logic and game flow. The main components are:

- The tiles for the maps. Each tile includes height information as well as the tile's location, as shown in listing 2.
- The enemy units.
- The `TileMapping` which specify what images to use in addition to *how* the tile is drawn.
- The conditions of the maps. These include winning conditions (such as “Defeat All Enemy Units”, the placement of player's units and a `turnComparator` which decides how the turn ordering works.
- The events. These include the dialog which displays parts of the story at the start and end of each battle.

The other major responsibly of the map is to send notifications to the view.

7.3.2 Units

A `Unit` has a set of attributes whose values can be specified by the user. A unit is the abstract representation and is used for serialisation. A `MapUnit` extends the unit's sets of attributes with extra information such as the location and the current hit points.

A unit has a specified weapon (as discussed in section 6.7). A weapon has an *attack range* which specified how the unit attacks. As an example, consider a spear which attacks all units in a specified direction and a bow which attack a single faraway target. A unit with the same attributes would play very differently with either of these examples since a spear can only be used in melee combat, whereas a bow can only be used from a distance.

A unit has a set of skills (as descried in section 6.7). The main difference, apart from the possibility of having *multiple* skills, is the concept of an *attack area*. The *attack area* is the tiles that are affected by the skill, which includes *both* friendly and enemy units. A skill can either include the caster in the area or explicitly exclude the caster, which gives the user more flexibility.

While default implementation of skills and weapons are provided, the advance user can create their user using the extension mechanism of the data format (see section E.7).

Units can “level up” which means the attributes of the unit increase. Levelling up can also affect how quickly the unit can get their next turn. levelling up is defined in the battle system as discussed in section 7.3.6.

7.3.3 Movement and Path Finding

To find the movement range of a unit, Dijkstra's algorithm was used. Dijkstra's algorithm finds the shortest path from a tile to every other tile. This is expensive of course as the maps can be large, so as an improvement I only searched *locally*. Since a unit can move at most n squares

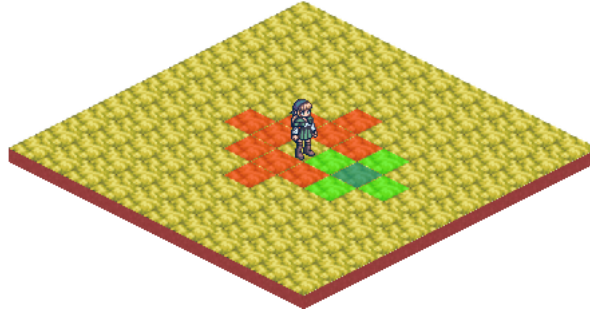


Figure 10: An example of a Skill. The red squares are the *attack range*, the green the *attack area*

in any direction, (n being the number of tiles the unit is allowed to move) there is no point checking any tile which is more than n tiles away. Searching *locally* means not finding the paths to any tile which is more than n squares away.

The path is then used to display *animated* unit movement to the user. This required keeping track of the *direction* in the movement algorithms.

Other algorithms such as A* (which is generally an improvement on Dijkstra) was considered for finding the shortest path between two tiles. A* was rejected since it does not provide much improvement since the paths to *every* tile in range are needed. Since the paths were cached, the difference would be negligible and hence it was not worth the time implementing and testing it.

7.3.4 AI Behaviour

Each AI unit has a *Behaviour* which specifies how the unit acts and which of the opposing player's units to target. The engine provides a default implementation which tries to get as close as possible to the target while attacking any of the player's units that happen to be in range on the way. The targets the engine provides by default include attacking the player's unit that has the lowest hit points and attacking the unit with the highest strength. Like other parts of the engine, a user can provide their own behaviour to further customise the game by linking their classes.

7.3.5 Turn Ordering

The engine provides dynamic unit ordering. This allows the ordering to change based on a unit's attributes or actions. The default implementation allows the unit with the highest speed to move first. To make the ordering more interesting, it also takes account of the unit's action when deciding which is the next unit to move. For example, if the unit does not move (i.e. uses `wait`) they get their next turn quicker. As with other parts of the engine the user can use their own classes to further customise the unit ordering.

7.3.6 Battle System

The battle system controls how units interact with each other. It specifies how damage is calculated as well as any other effects resulting from an action. The engine provides a default implementation where

- The damage dealt by a weapon is calculated by adding the weapon's power to the unit's strength and subtracting the opponent's defence. The least damage a weapon can do is zero, i.e. negative damage is not allowed.
- The damage created by a skill is independent of the unit's attributes.

The damage caused by a weapon is also affected by the difference in height of the attacker's tile and the target's tile. Attacking from a higher height gives a bonus whereas attacking from below reduces the attack.

The battle system also defines how units "level up". The default implementation "levels up" a unit when they gain 100 experience points. The unit gains experience points by performing actions. Each action gives a different amount of experience points ranging from none from using wait to 60 (before any modifiers are applied).

The amount of experience gained is dependent on the levels of the attacker and the target. Attacking a higher level unit gives a bonus whereas attacking a lower level unit reduces the amount of experience points gained.

7.3.7 Conditions

A map has a win condition which can be specified by the user. The engine provides two default implementations, defeat all enemy units and defeat a specific unit. The user can, of course, provide their own conditions which can be basically anything e.g. move to a specific tile.

7.3.8 Dialog

The engine supports displaying dialog to the user at the start and end of a battle.

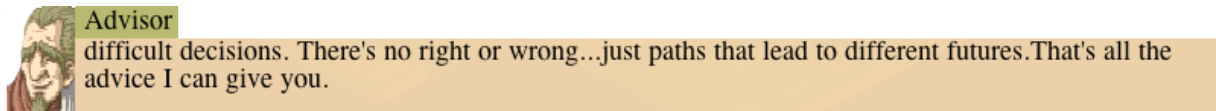


Figure 11: A example of a dialog

One of the major features is that the engine handles line wrapping and pagination of the text, which is in contrast to many earlier games. This allows the user to focus on writing the plot of the game rather than on fitting the text into the dialog box.

Optionally, a speaker can be specified for the dialog, this can be used to have a conversation between characters on a map to make the dialog more interactive.

The editor, as discussed in section 7.9.8, supports editing of the dialog. It has the notable features of allowing the user to visually reorder parts of the dialog. It also supports importing and exporting the dialog as a text file. This allows the user to write the script of the game independently in whatever application they prefer.

7.4 Saving and Loading

The engine supports Saving and Loading at any point during the game. The only possible downside for the user is that when the saved data is loaded, the game continues from the

beginning of the map which was lasted played.

The reason for this limitation is to keep the save format small and easy to load. Using this method means the only details that need to be saved are the maps left to be played and the unit's attributes (which can change since units can "level up").

The other limitation is that there is only one save file. This is not a big limitation since the save file is stored in the user's home directory, meaning each user would have their own save file.

7.5 Inter-compatibility

As discussed previously the maps use xml as their data format, one of the advantages of this is that it required very little change to the data format to have incompatibility with Oleksandr Stasyk's Terrain Generator's output format. The Terrain generator uses various algorithms to produce a sensible looking map. Users can use these maps as a starting point for their own creation, hence this lowers the time and effort to design a map.

The terrain generator is called by the editor on behalf of the user with appropriate settings²² saving the user from having to configure the many options available in the terrain generator (since the terrain generator is a command line application).

7.6 Map Rendering

The GUI uses isometric viewpoint to display the map.



Figure 12: An isometric map which shows the features of the renderers including height, empty tiles, wall textures and unit placement

The map is composed of isometric tiles which have the following features:

- The height is *exactly* half the tile's width.
- To create the tile, a square tile is rotated by 45° then the height is halved.

²²In the form of a YAML configuration file `bundle/config.yaml`

One the major features of the map render is how the height is specified. Instead of using a bunch of careful constructed tiles to simulate height, each tile has a specified height which the renderer uses to draw the tile with appropriate height.

7.6.1 Drawing Algorithm

The algorithm for drawing tiles is firstly the top of the tile is drawn, then the walls are drawn. It is quite general since it supports tiles which can slant in any direction, as shown in figure 13(b) where the tile is slanting to the north, as well as zooming and arbitrary height ²³.

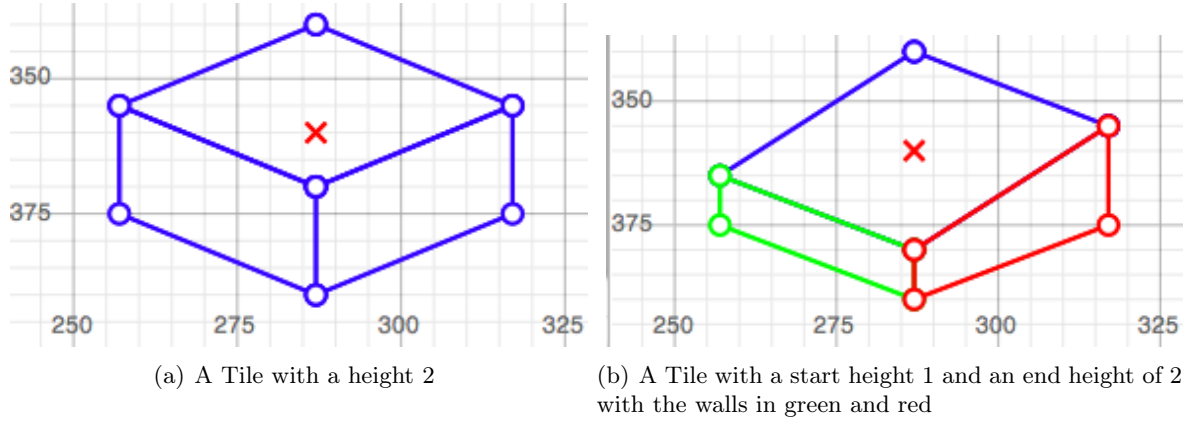


Figure 13: The above figure shows normal and slanted tiles, The red X is the start point for drawing

Mathematically the set of points used to draw tile are as follows:

$$\begin{bmatrix} x \\ y \end{bmatrix} = \left\{ \begin{bmatrix} tx \\ ty - h2 \end{bmatrix}, \begin{bmatrix} tx + \frac{hoz}{2} \\ ty - h2 + \frac{vet}{2} \end{bmatrix}, \begin{bmatrix} tx \\ ty - h1 + vet \end{bmatrix}, \begin{bmatrix} tx - \frac{hoz}{2} \\ ty - h1 + \frac{vet}{2} \end{bmatrix} \right\} \quad (1)$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \left\{ \begin{bmatrix} tx \\ ty - h2 \end{bmatrix}, \begin{bmatrix} tx + \frac{hoz}{2} \\ ty - h2 + \frac{vet}{2} \end{bmatrix}, \begin{bmatrix} tx \\ ty - h1 + vet \end{bmatrix}, \begin{bmatrix} tx - \frac{hoz}{2} \\ ty - h1 + \frac{vet}{2} \end{bmatrix} \right\} \quad (2)$$

$$\begin{bmatrix} x \\ y \end{bmatrix} = \left\{ \begin{bmatrix} tx \\ ty - h1 + vet \end{bmatrix}, \begin{bmatrix} tx - \frac{hoz}{2} \\ ty - h1 + \frac{vet}{2} \end{bmatrix}, \begin{bmatrix} tx - \frac{hoz}{2} \\ ty + \frac{vet}{2} \end{bmatrix}, \begin{bmatrix} tx \\ ty + vet \end{bmatrix} \right\} \quad (3)$$

tx, ty is the starting point (shows an red X in the above figure)

vet, hoz is the height and width of the tile adjusted for the zoom and pitch

$h1, h2$ are the differences in the start height and end height and vice verse

where equation 1 is for the top of the tile, equation 2 for the right wall and equation 3 for the right wall.

²³A simulation of the equations was made first and is in `IsomerticRendering.gcx` (Mac Only).

The equation converted to Java easily since the `Graphic` class has the methods `drawPolygon` which draw a polygon using set of points conveniently in the same form as the equations.

7.6.2 Images and Texture Mapping

The top of tile can be texture mapped or be drawn directly from an image. Texture mapping repeats a small image across the tile. This is the simpler method for the user since they only have to provide a small texture image, but they lose control over where exactly the image is drawn. Texture mapping is also required for slanted tiles since there are too many variations to provide images for.

The user also has the option of using an image which is drawn directly. To do this they would have to provide their own isometric tile²⁴. This method allows more control on what is drawn.

Walls like slanted tiles are always texture mapped since there are too many variations to provide images for.

7.6.3 Units

Each image has at minimum *four* images associated with it, one for each direction (east, west, north, south). These are used to show which way the unit is facing. The unit can also have an animation associated with each direction, to make unit movement more interactive. The unit can optionally have a portrait which, if available, would be used for their dialog

7.6.4 Reusability

Since the map renderer is not dependant on the main GUI, it could be reused in many different places in the editor.

7.7 Map Rotation

The map renderer supports four different rotations which the user can choose from. This is implemented *not* by actually rotating the map (since this would be expensive) but by changing the draw order. By default (0,0) is on the top left of the map. Rotation merely changes the location of (0,0). This means that none of the tile have changed so all the cached calculations can be kept.

Rotating the map can be used by the user to see units that are hidden or obstructed by tiles.

²⁴There are scripts to help the user though

7.8 User Interface

7.8.1 Controls

The main control scheme for the GUI is the keyboard, but the user can perform nearly every action using the mouse. All the elements were designed to work equally well with the mouse and keyboard. This means for example that the tiles are clickable, (which result in the tile being selected when clicked).

7.8.2 Menus

The GUI uses a menu system to handle the unit's actions. The menu is quite general since it will resize to the longest item in the menu. It also supports nested menus which are used when the user chooses to use a skill. The menu is controllable using the keyboard arrows keys, but the user can also click an item directly to select it.

7.8.3 Other Features

The GUI supports other features to improve the user experience these include:

- Zoom in/out which lets the user see more detail.
- Changing the `pitch` of the map (increasing the pitch flattens the map which allows the user to easily see obstructed units).
- A `log` which can be used to see which actions have taken place. This is useful to find out what the enemy has done if the user misses it the first time.
- The key mapping is displayed to the user on startup.
- The GUI automatically scrolls to the enemy unit's location if they are out of range when it is their turn.
- The unit information shows the unit's attributes including the current hit points. They are displayed in a different colour for opposing units to easily distinguish them.

7.9 Editor Development

7.9.1 Overview

The editor allows the user to customise nearly all aspects of the engine. Notable features include visual map making as well as exporting the created game as a completely self contained application with *no* external dependencies apart from a recent version of Java²⁵.

The editor uses a tabbed interface, the benefit is that it shows the users what's available in the editor. Each tab shares the same overall structure for two reasons, namely to keep all aspects of the editor consistent, hence making it easier to use. The second reason is that most of the code can be reused for each tab, saving development time.

²⁵specify Java 6+

In each tab the current resources created are listed on the left as shown in figure 14. The user can click on any of the resources to customise them. At the bottom of the list are two buttons: the left button (−) removes the selected resource, whereas the right button (+) adds a new resource. Since it is likely the user would create simpler resources (e.g a weapon of the same type differing only in Strength), any newly created resource takes on the characteristics of the last selected item.

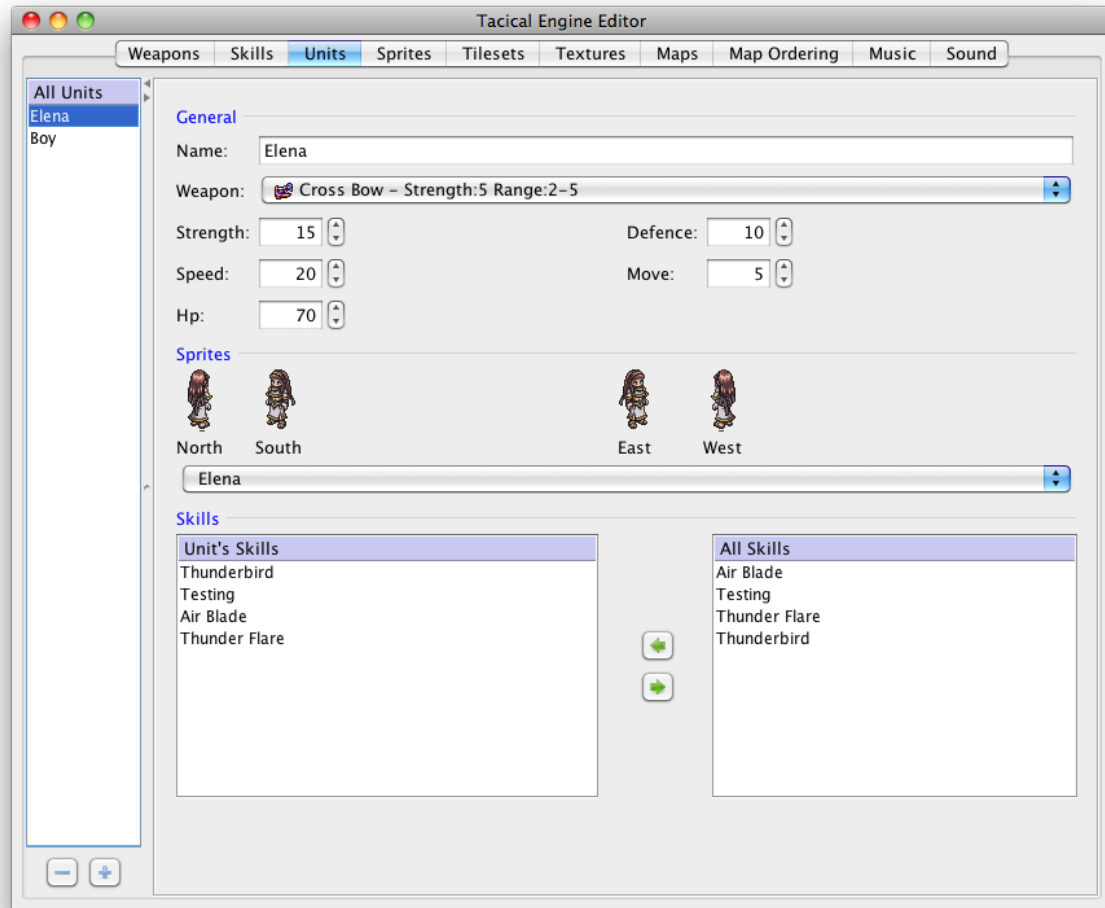


Figure 14: Unit Editor

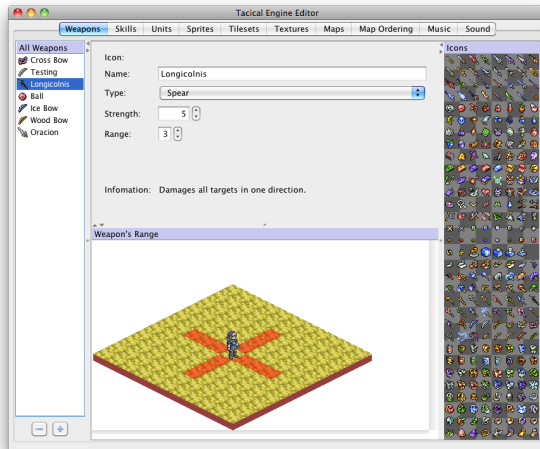
To prevent error and increase usability, `JSpinner` was used whenever numeric input was needed. `JSpinner` also allows a minimum and maximum range to be specified, the component will then reject any input which is not in range.

Each of the tabs can only edit their own data but they can *read* data from other tabs, as shown above where the weapons and skills are received. One of the advantages is the data is always consistent. This was made a lot simpler since the user can only edit one set of resources at a time.

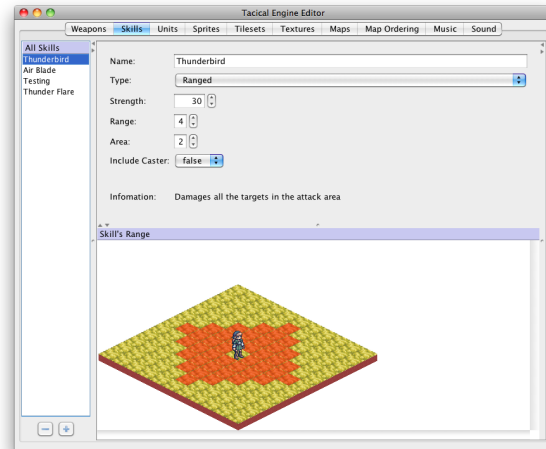
Since the tabs only expose their resources (instead of handle I/O as well), this means that the tabs can be reused e.g. (Sprite, Tilesets and textures share nearly all their code).

7.9.2 Weapons & Skills

The editor supports customising of the weapons and skills as shown.



(a) Weapons Panel



(b) Skill Panel

The editor shows visually what the attack range looks like. This is updated whenever the user makes any change to the resource. This required very little extra code since the map renderer was general enough to be easily embedded.

7.9.3 Unit Editor

The unit allows the user to edit all of the attributes of the units. These include the skills and weapon as well as the images of unit, as shown in figure 14.

7.9.4 Sprite Sheet Editor

A sprite sheet editor is used for many of the tabs including the unit's images, textures and tileset.

7.9.5 Music Editor

The music editor supports choosing which music is available to use in the game. When a track is selected in the editor, the metadata (include the 'artist' and 'album') of the track is displayed. As a further enhancement, the track can be previewed, this is especially useful when used in combination with the sound effect editor (which has exactly the same interface) to see what the combination of sounds and music sound like.

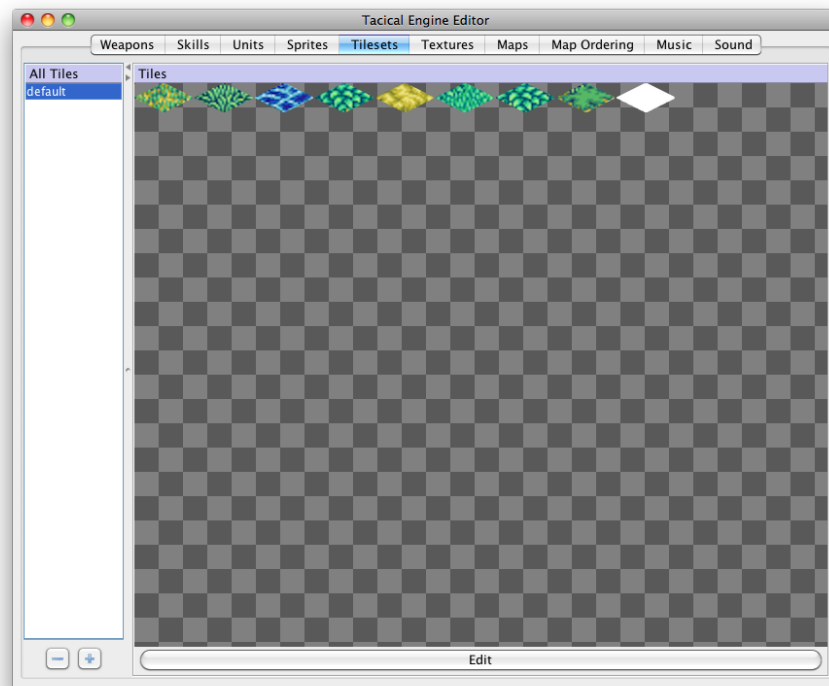


Figure 15: A sprite sheet editor for the tiles

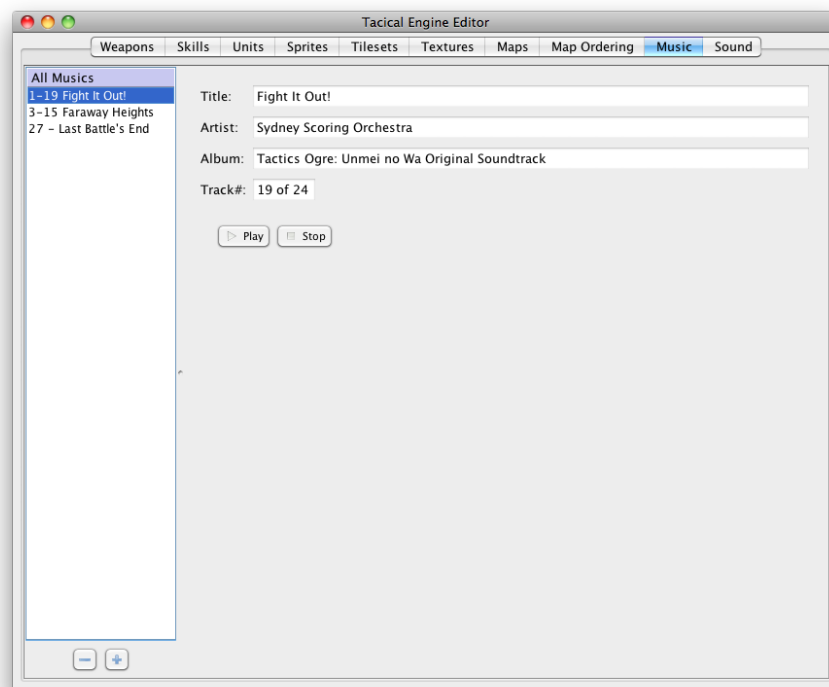


Figure 16: The Music Editor

7.9.6 Map Editor

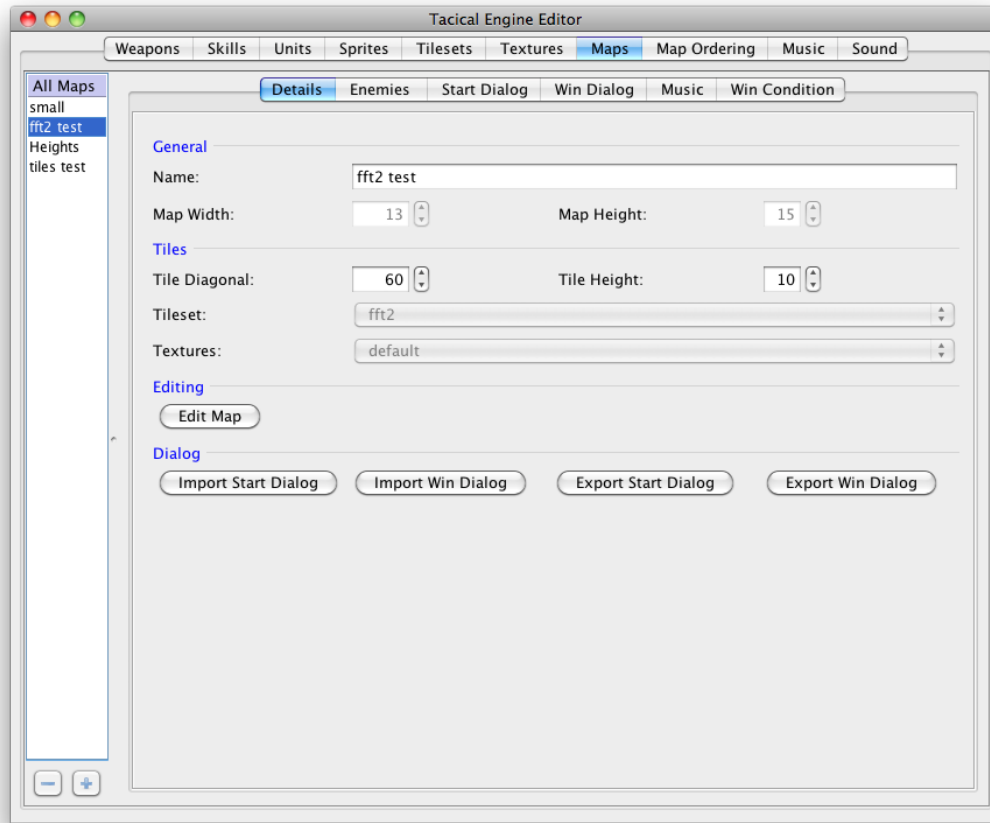


Figure 17: The Map Editor

The map allows the user to customise all of the aspects of a created map. The editor is composed using a series of tabs so that the user does not get overwhelmed with all the options available. More importantly it allowed reuse of the unit editor(section 7.9.3) for enemy units (with the addition of extra fields to allow customisation of the enemy behaviour).

Usually all the resources of an editor are loaded when the tab is selected and then cached. While this did work for the maps, it caused unacceptable startup time hence I found an alternative method.

Lazy Loading only loads a resource when it is actually used instead of just been referenced. In the case of the map editor a map is only loaded if the user tries to *edit* the map. This significantly reduces loading time of the editor, especially if the user has created a large number of maps.

Details Tab

The details tabs allows the user to change a map's name, as well as the size of the tiles. The size of the map cannot be changed after creation to keep the implementation of the simple²⁶. Another reason for not allowing the user to change the map size is that some of data, such as

²⁶Although the engine does support changing the map size.

the enemy unit placement, may become invalid, which goes against the goal of always keeping the data consistent.

For the same reasons, the editor does not let the user change the associated tileset or texture set after creating the map although the engine does support it. Note that the user can still add tiles to the tileset, so it is not a large restriction.

The details tab also supports Dialog importing as well as exporting, which will be discussed in section 7.9.8.

Music Tab

The music tab allows the user to select from any music they imported into the music editor (section 7.9.5).

Win Condition Tab

This tab allows the user to choose the condition the player has to satisfy to win the map. Although the engine supports arbitrary conditions, the editor provides the two most common conditions used in TRPG, namely defeat all enemy units, and defeat a specific unit, which allows them reasonable customisability.

Map Creation

When creating the map, the user can specify the size of map and tileset to associate with the map. An interesting addition to the editor is, as previously mentioned, that it can use Stasyk's terrain generator which can be used as a starting point for the user's creations as shown in figure 18.

7.9.7 Visual Map Creation

The visual map editor allows the user to design a map with writing any xml (the format the engine takes as input). The editor shows the available tiles in the associated tileset in the bottom split. The user can use the tools on the tool palette on the left to place the tiles. The tools include:

Move Allows the user to move the map.

Pencil Draws the selected tile in `Tiles` on to any tile that is clicked on the map.

Brush Same as Pencil but sets the height and orientation as well (from the info panel).

Paint Sets the image of *all* tiles in the selected area.

Eyedropper Sets the selected tile in `Tiles` to the image of the clicked tile.

Area Tool Used to select a number of tiles on the map.

Left Wall Sets the texture of the left wall.

Right Wall Sets the texture of the right wall.

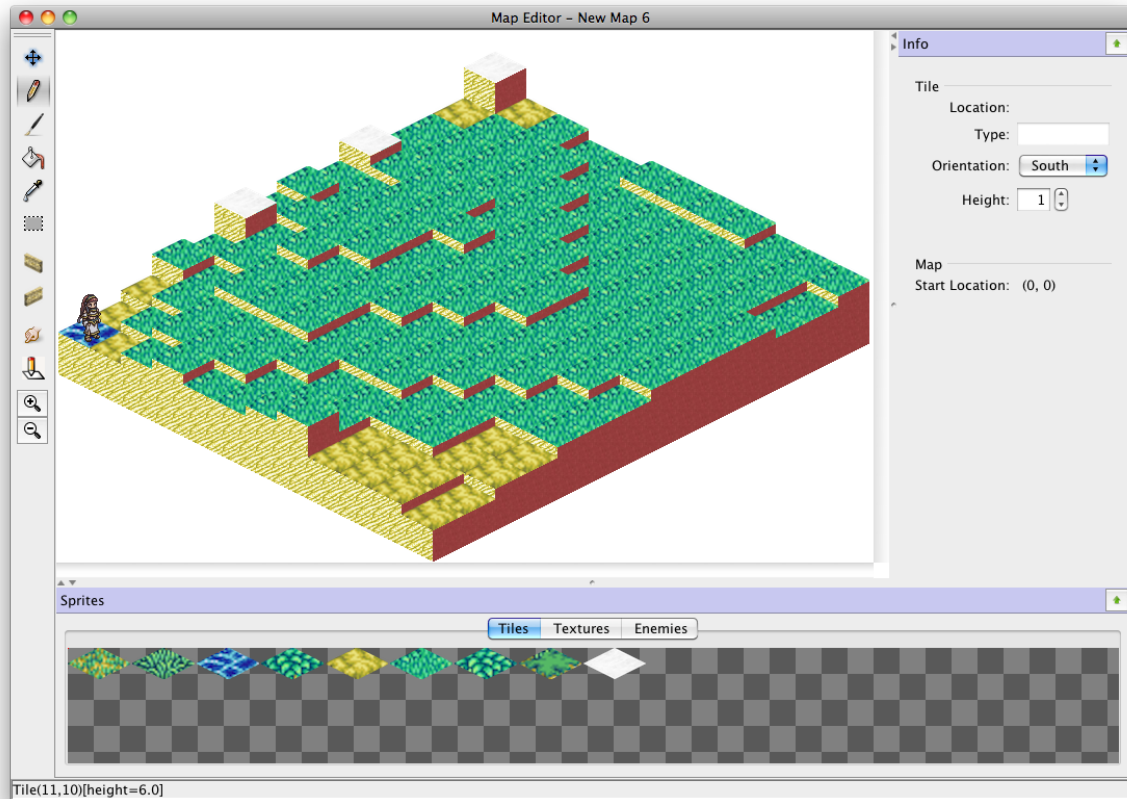


Figure 18: The map editor show a map created by Stasyk’s terrain generator.

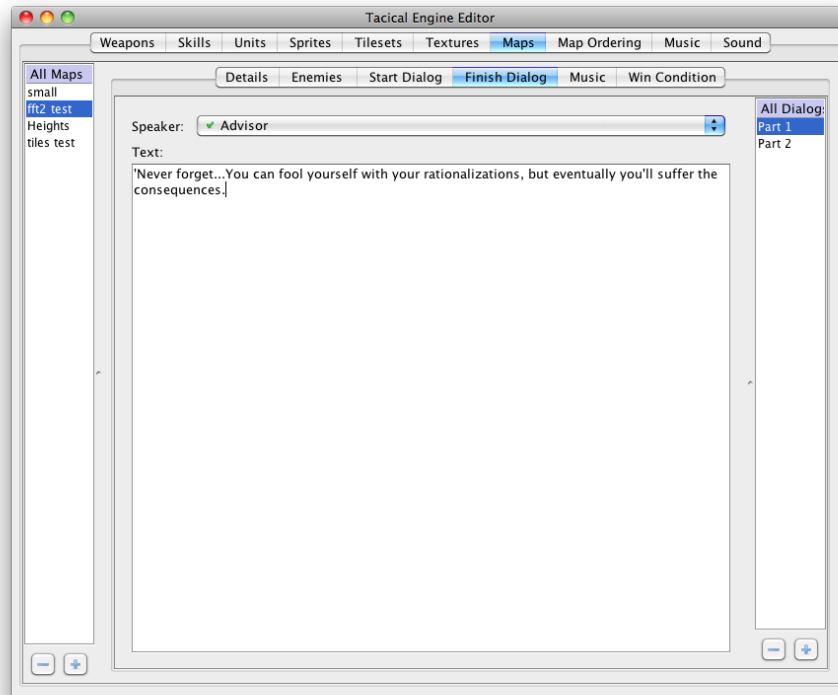
Pointing Finger Places enemy units on the map.

Pointer to Tile Sets the player’s start location.

The panel on the right displays data on the selected tile on the map. It also allows the user to edit the orientation and height of the tile. As shown in figure 7 tiles can be hidden. This allows more customisability, e.g. it could be used to make “islands” (a set of tiles with empty tiles around them), and a set of bridges between them.

The visual map editor supports editing of both textured and non-textured tiles. As discussed before, non-textured tiles allow the user more control over what is drawn, so they apply more detail. The advantage of textured tiles is that slanted tiles can be used, which easily allows the creation of slopes and stairs for example.

7.9.8 Dialog Editing



1

Figure 19: The dialog editing panel

The editor supports the creation of dialog. A dialog is a sequence of parts. Each part has the text associated with it as well as optionally having a speaker. The speaker can be selected from any unit that has already been placed on the map. This is a vast improvement on the original design where the user types the name of the speaker since there is no chance of entering invalid data.

As mentioned before, the engine takes care of pagination as well as line wrapping when displaying the dialog in the game. This frees the user from having to fit the text into a specified area.

Import/Export

The editor also supports importing as well as exporting the dialog in the format shown below.

Listing 4: Shows the format used for the dialog

```
- speaker1: Some text
- speaker2: Some more text
- none:      This part has no speaker
```

This allows the dialog to be easily written in the user's preferred application. This could be useful if a separate person writes the dialog of the game since the person does not need a copy of the editor. The format is described in more detail in the appendix [E.6.1](#)

Although the dialog xml format could be edited by the determined user, this would require significantly more effort than the above format since the user would have to find the unique id

of each unit each they want use as a speaker. It would also require creating unique ids for dialog part which would be likely be error prone, hence the above format is used in import/export, mainly for the user's convenience.

7.9.9 Project Selection

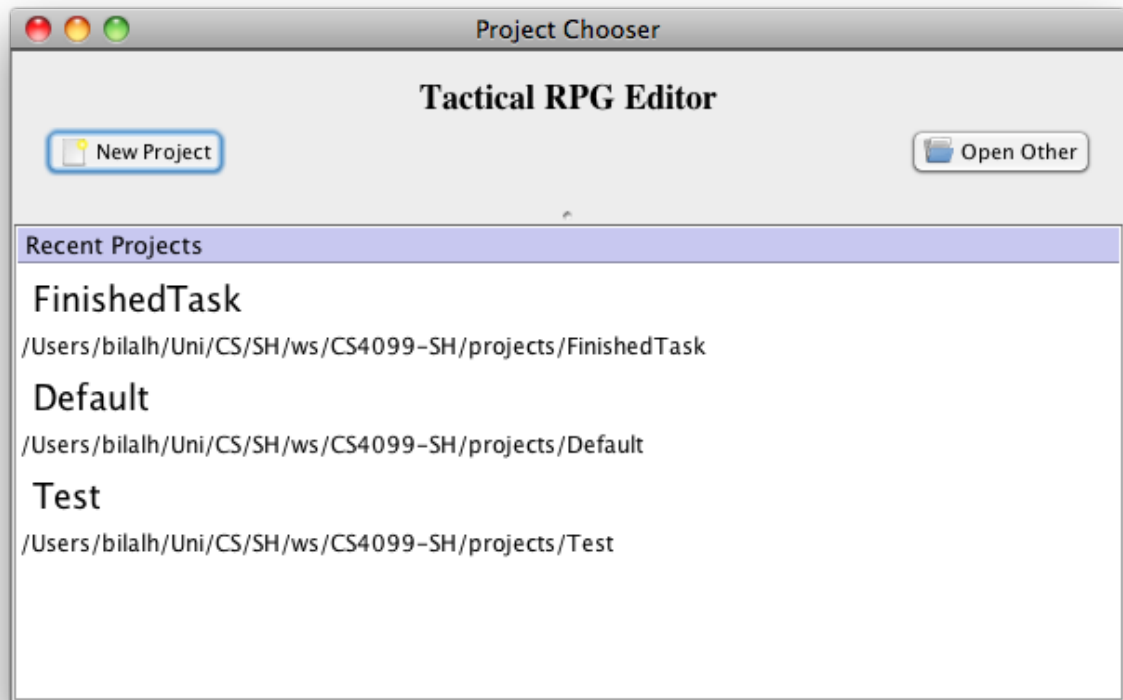


Figure 20: The Project Selection Window which is shown at startup

When the editor starts, it displays the above startup screen which allows the user to create a new project or open an existing project. Since a user is likely to work on the same project for a significant period of time, the editor keeps tracks of recent projects.

7.9.10 Exporting

The editor can export the game as a complete package, either as a Mac OS X application or as jar. These applications don't require any external resources, apart from a recent version of Java²⁷.

A prominent feature of the editor is that the jar will work on any Java enabled platform, since the jar contains all required libraries for each platform. The OS X application can even be exported on other platforms.

While most of the testing was done on OS X ²⁸, it also works well on Linux ²⁹. It even has limited compatibility with Windows ³⁰ (apart from some minor graphics issues).

7.10 Ant Build File

The task of creating the Editor as a self contained application with no external dependencies, apart from obviously Java is non-trivial and error prone. To automate this task, an Ant build file was created, which has an added benefit of allowing the creation of the distribution from the command line.

The main steps to create the self contained editor are:

- Compiling the code.
- Creating the jar of the engine.
- Creating the jar of the editor
- Creating the directory structure for the editor Mac OS X application.
 - This includes creating the plist[11] with the applications.
 - Setup the native libraries and the Java include path.
 - Adds the icons.
 - Link the Java wrapper so that the application can run, as well as having the icons appears in the Dock.
- Create the cross platform jar for the editor.
 - Combines the jars into a single jar.
 - Set up the native libraries path.
 - Set up the Java libraries path.
- Create the cross platform jar for exporting the game.
- Create Mac OS X application for exporting the game.
- Copy the resources for the starting project.

²⁷specifically Java 1.6+

²⁸Mac OS X 10.6 Snow leopard

²⁹Science Linux x.y

³⁰Tested on Windows 7 32 bit

The ant build file takes care of all the above steps and can be invoked by executing `ant dist`. The build file has many other features such as running all tests and creating a web page. These features are described at the top of the build file (`build.xml`).

8 Evaluation and Critical Appraisal

8.1 Objectives

The objectives, as listed in section 3.4, are extensive, ranging from primary objectives that required a basic engine capable of creating a Tactical RPG to tertiary objectives which required the creation of an editor which customised most aspects of the engine.

Since all the primary and secondly objectives were completed, as well as nearly all the tertiary objectives I consider the project a success, I will now discuss the objectives in details.

8.1.1 Primary Objectives

The primary objectives focus on the basic functionality of the engine, I have marked these objectives as completed. Notable improvements from the objectives include the engine handling the pagination and line wrapping of the dialog automatically, which frees the user from fiddling with the dialog to make it fit on the screen.

Combat between units was a primary requirement which was completed with many additional features, which are discussed later.

The primary requirements were to make an isometric graphical representation of the game, this was very successful. The view had useful features such as it allows the game to be played with either the mouse or the keyboard.

8.1.2 Secondary Objectives

The main goal of the secondary objectives is to allow the user more customisability. Associating attributes such as height and movement cost to the tiles was a requirement that was completed. In addition, the engine supports *empty* tiles which are impassable and are not displayed to the user. This allows the creation of more complex maps as shown in figure 7. Another enhancement is that *slated* tiles can be used, they are tiles that have a different start and end height and could be used for making stairs or cliffs.

The secondary objectives required a combat system that supports the use of weapons and non-adjacent targets for both the player and the AI opponent. Weapons in particular deserve mention since they are completely configurable. The engine, of course, provides default implementations of common weapons such as ranged weapons and spears (which shows the weapons can have extra effects such as attacking multiple targets).

The default implementation of the battle (The user can use their own battle system, but it is more complex) takes many attributes such as the units' levels and difference in height between the attack and the target to determine the outcome of a battle.

I completed the objective of allowing music and sound effects, the format used is Ogg Vorbis (Appendix E.4). In addition, wave files can be used for sound effects, this was implemented since the format seems to be commonly used for this purpose.

Saving and loading the game were implemented as required, but with the restriction that when a save file is loaded, the player begins at the *beginning* of the last played map.

Allowing the user to customise the AI behaviour is a completed objective. In addition, the engine provides default behaviours including the example of attacking the player's unit with the lowest HP. The engine also provides default actions such as while moving to a faraway target if the target is not reachable, move as close as possible and attack any opposing player's units that are in reach.

8.1.3 Tertiary Objectives

The main objectives of these requirements was to produce an editor that allowed customising of most aspects of the engine as well as combat improvements and units animations, all of them having been completed.

Combat requirement improvements include `skills` that can affect multiple units, and weapons which can attack multiple units. Further enhancements to this system include complete customisable range (e.g could be used to attack all enemy units around the attack).

The requirement for animated unit movement was completed. This was further improved by taking account of the direction the unit is traveling in, which was done by having an image for each of the four directions.

Editor

An editor that can customise nearly all aspects of the engine was created. The most prominent features are the visual map editor (section ref), unit creation(section ref), dialog editing(section ref) and exporting as a self contained application. The editor met all the tertiary requirements and it also had addition improvements. These include an easy to edit dialog format for importing/exporting and inter-compatibility with Stasyk's Terrain Generator to give a user a start point for their map designs.

Scripting & Custom Events

A tertiary requirement was to implement custom events through the use of scripting. This would allow the user to specify events such as making the player win if some enemies unit has less then 50% Hit Points.

To implement this I had planned to use the Java Scripting API[12]. This would allow embedding a dynamic scripting language. The main benefit of this is that the code does not have to be compiled, which means it does not have the same hurdles with class linking as my Extension Mechanism(Appendix E.7). The language chosen for embedding was Javascript as it is built into the JDK, so the user does not have to install anything extra and of all the scripting languages, Javascript is more likely to have been used before by the average user, these decisions are described in more detail in appendix G.

Some people such as ref advocate forgoing scripting completely, pointing out that scripting is a lazy of letting users have customisability since it can be quite difficult for users to create events. Using their advice of creating visual editors for creating events and customising unit behaviours, I allowed the user to specify common events from the editor, with the option of linking their own classes as a last resort.

Although the scripting was not implemented due to time constraints, note that it was a tertiary objective and all the given examples in the objective are supported by the engine. In particular, win conditions can be specified (section ref) and common winning conditions can even be selected from the editor. The engine supports showing dialog at arbitrary points in the game which could be used to support the requirement “Showing some part of the story when a player’s character reaches a specified tile”.

The engine supports the user using their own classes through the extension mechanism in Appendix E.7, which allows a slightly more limited form of scripting but with the benefit of being type safe and with the drawback of being more complex.

8.2 Comparison to Similar Work

8.2.1 Engine

The capabilities of the engine will be compared and contrasted with the games discussed in the context survey (section 2). Like most of the games described before, the engine supports an isometric view point which allows the user to create aesthetically pleasing map.

In particular, the turning ordering is very general to the extent that the user can completely replace it with their own code, all the described game ordering systems could be implemented. The default system resembles the ordering used in *Tactics Ogre*, as an example the supported features.

Nearly all TRPGs include weapons and skills (sometimes having other names such as ‘magic’). The engine fully supports this, and even has additional features such as arbitrary ranges (This is where the attack range of a weapon or skill can be in any shape and size. The weapon type *around*, which attacks all enemies in all the tiles around the attacker, was created as an example of this.)

Like practically all TRPG, the engine has a battle system with support for weapons, skill and which takes account of the terrain of the map. The main features the engine is missing is *uncertainty* that actions have a small chance of missing, or have an unintended consequence. This quite common feature, an example is attack missing or bow hitting an allied unit that was in the way. At the moment the engine carries out all of the users requested actions without fail, which is in some ways better since it is more predictable, hence making it easier.

Although the engine supports units levelling up and having the attributes increased, it does not support restricting skills to a specific level, that is a unit knows all of its skills at the beginning. In contrast, most TRPG usually restrict a unit’s skills to a select few at the beginning, the unit then gains new skills as it levels up. This was not an objective of the project, but will be considered for future work.

The main feature that is lacking from the engine is an overworld map. An overworld map has a series of user selectable locations, where the battles take place in each location, this is common in nearly all TRPG (although is deliberately omitted from the discussed “Fire Emblem” series). This was not an objective of the project because it would be time consuming to make the overworld maps. Nevertheless, I tried to implement this, the overworld maps are quite similar to Sasha generated maps, by giving him the idea for place names (randomly generated) at suitable

locations. He was able to generate overworld maps that I could use. Due to time constraints this was not implemented, but will probably be carried out as future work. For an example of what it would look like see (section ref)

8.2.2 Editor

Since *Simulation Maker 95* (SM) is one of the only completed Tactical RPG creators, it will be used for evaluating the Editor. Both editors support visual map editing but differ in the type of map created, my editor supports the now more common isometric viewpoint where as SM only supports a topdown view.

Whereas SM only allows changing the win conditions, my editor allows customising most aspects of the engine, including the win conditions and enemy behaviour. Another advantage my editor has over SM is image loading, my editor provides a visual interface that allows the user to import images in any of the Java supported image formats (which include, jpeg, gif and png) whereas in SM the user has to place the images in the right directory with the correct names, furthermore it only supports bitmaps, meaning that any significant uses of images would lead to huge file sizes.

One of the major features that is not present in SM is the ability to export a cross-platform jar that will work on any Java enabled platform, this is in contrast to SM which only works in windows, and can only export games for windows.

8.3 Results of User Testing

In total six participants took part in the user testing, more people were interested but could not due to time constraints. See Appendix F for the Questionnaire.

8.4 Analysis of User Responses

The participants can be grouped into three groups, those who have played a TRPG before, those who have not and those who don't play games at all.

Feedback from all groups

Both groups thought the editor supported all the features they would like if they created a TRPG. Most of the participants answered that they would like to use the editor again. Interestingly, all users who were familiar with TRPG used the keyboard exclusively, this I attribute to participants being used to the input mechanism since most TRPG are on consoles³¹. Those who had no experience playing TRPG unexpectedly used both the keyboard and mouse at the same time (generally selecting the units with the mouse then using the keyboard for performing any actions).

Feedback from those who had played a TRPG before

Participants that had experience playing a TRPG before found the engine very intuitive. They especially liked how everything was customisable. The visual map editor also gained significant

³¹such as Playstation 2

praise for it's easy of use and it's range of features. Other features that participants liked were how a project could be exported as a standalone Mac OS X application with virtually no effort.

When playing the pre-created game, all of the participants were able to play, and even win, the game!. Some of the participants were able to figure out all of the out the controls with out even reading the help screen.

Feedback from those who had not played a TRPG before

In contrast, participants who never played a TRPG before felt overwhelmed with the available options, although they figured how to use it quite quickly. They particularly liked how robust the editor was. The main features that were requested were an overview of each feature in the editor and how they interacted. The participants commented on the pleasing visual appearance of the editor.

When playing the pre-created game, some of the participants were initially confused by the interface. All participant were able to finish the game even if they could not win. The participant unexpectedly kept on using the enter key to perform actions on the unit even though the help panel stated otherwise. In response to this feedback, I added the enter key as an alias of the action key(default 'x').

8.4.1 System Usability

A System Usability Scale (SUS) was used [13]. This works by giving each even numbered questions a score of (5 - *value*) and odd numbered questions a score of (*value*-1). Questions that contributed to a high score showed that the system is usable.

Based on this schema, the maximum positive contribution is four. To get the overall usability score, the sum of the questions contributions is multiplied by 2.5. This gives a score out out of 100, which is easier to understand and use for statistical purposes.

Results

Since the average scores (figure 21) were at lest two (the middle value), which means that users responses tended to be positive.

Analysis

The system performed well in user testing, receiving a usability score of 62.4, out of 100. Taking into account that many of the users had never played a Tactical RPG before this is definitely a positive score.

The usability result was 61. This is a very good result since a score of 50 means that the system is useable. Although there is room for improvement, the usability testing shows the system has achieved the goal of being useable.

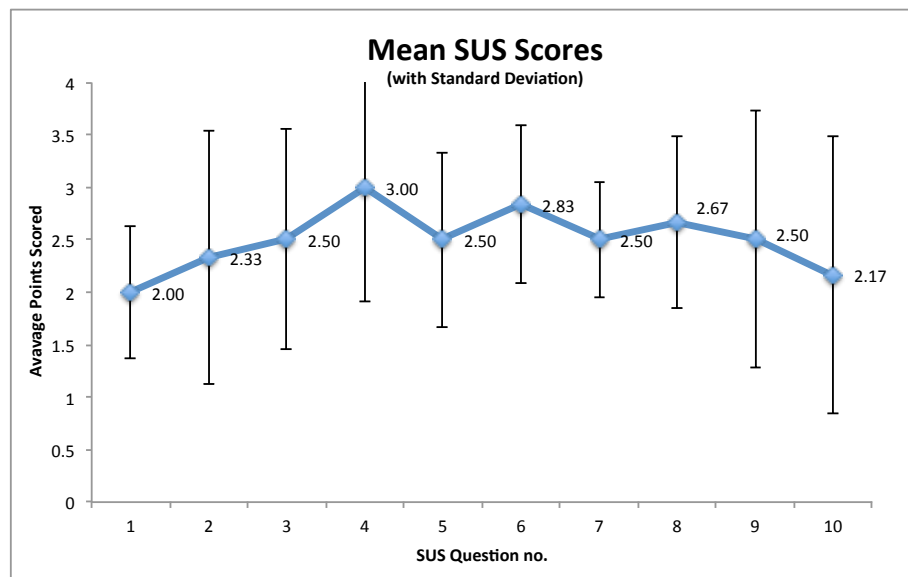


Figure 21: Mean System Usability Contributing Scores, the user responses were generally positive.

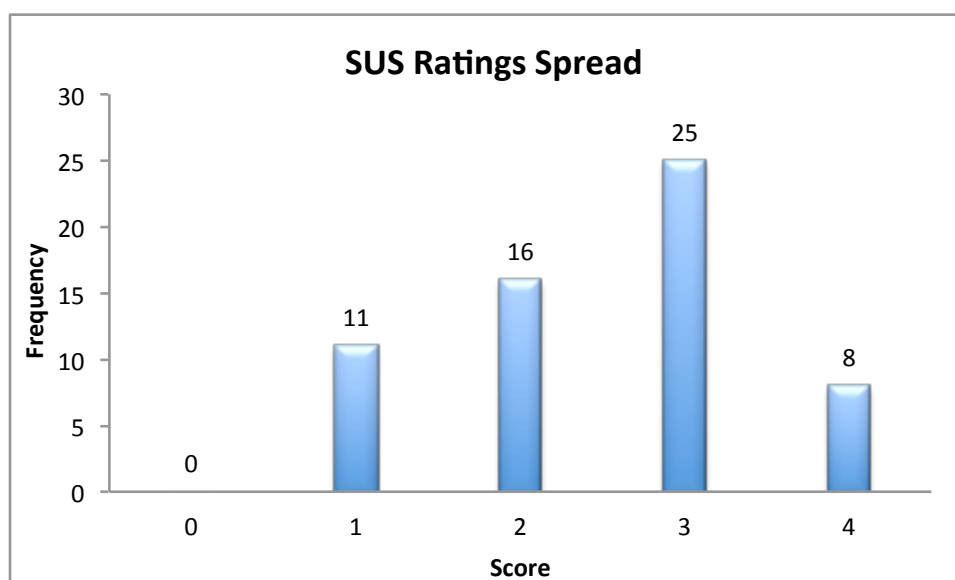


Figure 22: Spread of the user's scores.

9 Conclusions

9.1 Key Achievements

The key achievements of the project include a cross-platform extendable engine, an isometric view of the game, an editor which allows the user to create a complex tactical RPG without any programming. The engine provides all the common elements in TRPGs, and according to the user questionnaire, it has nearly all the features the users wanted. A notable feature of the engine is how extendable it is, since the user can even link their own code to further customise the engine. To support non-programmers, many default implementations of the various aspects (including weapons and skills) of the engine are provided.

The GUI provides an isometric view, which allows tiles to have height, for a more immersive environment. The GUI has many features to improve the user's experience, these include mouse and keyboard support, map rotation(to allow the user to see obstructed units), an action log(to see what happened in the game) and the ability to load and save the game at any time.

The editor's most notable feature is that it allows the user to customise nearly all aspects of the engine without writing any code, making it easy to use for non-programmers. The editor allows the user to visually design their creations, with the aid of the many specialised editors contained in the editor. These include a map editor, as well as units and weapons editor. The editor can also export the created game as a self-contained application which can run without any external dependencies apart from Java.

The system performed well in user testing, getting high marks from experienced TRPG players as well as people who have never play games.

9.2 Drawbacks

The main drawback, as highlighted by user testing, is the lack of documentation suitable for people who have never played a TRPG. In contrast, the people who had experience, these users initially felt overwhelmed by the range of options available in the editor. A high level description of what each part of the editor does and how these interact would help these users significantly.

Custom events using user scripting was not implemented but note that all the example uses can be created using the engine, without any programming, which I consider a superior alternative.

9.3 Future Work

The following is a listing of future improvements that could be implemented.

- Improvement to levelling up – Usually a unit does not have access to all of its skills at the beginning of the game, but it gains access to them when levelling up. This would make the produced game more balanced, since only skills appropriate to the unit level could be used.
- Implementation of an overworld map with a battle occurring at each location. This would allow the user to choose which map to play. A good use of this would be a branching story-

line where the plot is changed depending on which maps the player plays. By integrating Stasyk's overworld generator, this could be achieved relatively simply.

- Allow the user to preview the created game without exporting it. This would let the user test their game without having to export the game, hence saving development time. The engine partly supports this feature (which was used for debugging), adding this to the editor would be a significant improvement. In addition, allowing the user to simulate a battle (e.g. allow specifying the attributes of the units, such as their level) would let the user quickly test any map in the game, which would be especially useful for long games.
- Utilise Stasyk's terrain generator, to provide generated maps in the game. This would enhance replayability and give the player more options.
- Since the engine itself has no dependencies on the `swing` or `AWT` graphics toolkit it could work on Android unchanged. A new GUI suitable for touch screen would be needed because of the Android's lack of Java's windowing systems. Many parts of the current GUI, could be nevertheless reused, with minor changes, these including the map renderer, as well as the dialog system.

9.4 Final conclusion

A Tactical RPG is a genre that focuses on the strategic aspects of a RPG, usually with an extensive battle system. The aim of the project was to build a user-friendly engine while affording the user as much flexibility as possible. This is in addition to an editor which provides a front end to the engine, allowing the user to customise their game without any programming. The many possible future improvements could implemented to improve the system, that is already well received.

A Testing Summary

Unit testing³² was used for the testing on the model. These can be rerun in the Eclipse IDE or from the command line which produces a webpage of the results.

Listing 5: Command to make a webpage of the result of the unit testing

```
ant tests
```

In addition, I conducted user testing using a survey as described in section 8.3.

Before the formal user testing, I made the following changes in response to comments made.

- It was hard to see which unit was selected. This was fixed by displaying ‘Current’ in the selected unit’s info. The info window of the selected unit was also lightened to make it more obvious.
- It was hard to see which are my units. This was fixed by displaying the player’s unit’s info in green and the enemy’s unit’s info in red.
- Some users could not figure out the key bindings of the game. This was fixed by displaying a list of all key binding at the start of the game.

B User Manual

B.1 Editor

The editor is a self contained application, requiring only Java 6+. To run:

- For the Mac OS X application click on it
- For the jar use `java -jar 'Tactical Engine.jar'` (or click on it if using a Mac).

A new project can be created using `New Project`. To open an existing project click `open other`, navigate to the directory of a project and select the `project.tacticalproject` file. Example projects are included in the `projects` directory.

The created game can be exported from the `File` menu as either a Mac OS X application or a cross-platform jar.

B.2 Exported Game

As with the editor, the exported application can be clicked on if using a mac, otherwise run `java -jar <game_name.jar>`.

C System Maintenance

Due to the use of xml as the data format, a future modification should be that it has backward compatibility because of the reasons discussed in 7.2, namely the XStream library allows setting

³²Using the JUnit library.

the default values of missing tags and attributes. This will allow the addition of extra features without breaking any of the user's data.

The data format extension mechanism(appendix [E.7](#)) allows for extensions such as a custom turn ordering, win conditions or unique weapons without changing the xml format.

Xml schema provided would have to be updated for any structural change to the xml, but the use of *optional* tags and attributes could be used to allow older files to still be valid without any changes.

D Software Listing

The source is in the `src` directory, a pretty printed version is contained in `src_pretty_printed.html`. Pre-compiled class files are provided for convenience in the `bin` directory. Binaries for the editor and an example of a created game are in `binaries`.

E Project Structure & Specification

This appendix contains all the technical information of the ‘project’ and the data format used.

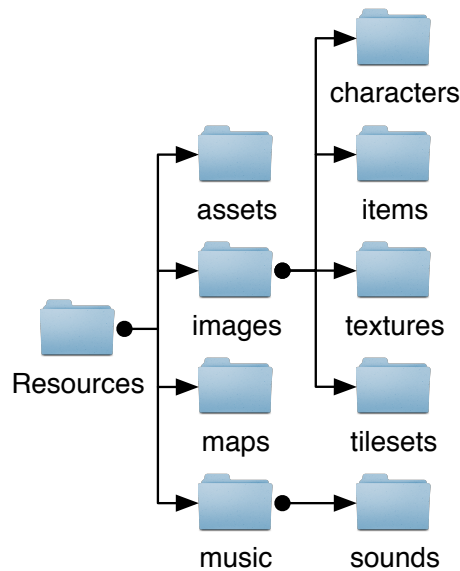


Figure 23: Project Structure

A game’s resources are organised as shown above. One of the main restrictions, is that all external links have to be relative to the `resources` directory. All xml files **must** conform to the schemas in the `schemas` directory.

E.1 Assets

Assets are stored in the following format:

Listing 6: Assets format

```

<name>
  <entry>
    <uuid>128bit</uuid>
    <resource uuid="128 bit">
    </resource>
  </entry>
</name>

```

The `assets` directory **must** contains the following files conforming to schemas in `schemas/assets`.

Listing 7: Required Assets

```

maps.xml
music.xml
ordering.xml
skills.xml
sounds.xml

```

```
textures.xml
tilesets.xml
units.xml
unitsImages.xml
weapons.xml
```

E.2 images

All images are stored as sprite sheets(see section 7.2.2). There are *three* required files for each sprite sheet.

```
name.png
name.xml
name-animations.xml
```

The sprite sheet itself is stored as a png(Portable Network Graphics) in `name.png`. `name.xml` contains the coordinates of each image in the sheet as well as the dimensions of the sheet. `name-animations.xml` contains the unique id of the sprite sheet and can optionally specify animations.

E.3 Maps

Each map needs the following *five* files:

name.xml which contains the tile data as well as references to the other files.

name-conditions.xml which includes among other information, the winning conditions.

default-enemies.xml which contains the enemies data along with their positions on the map.

default-events.xml which optionally contains the dialog which is shown at the start and end of the battle.

default-music.xml which contains the background music and sound effects.

Maps also need a `tilemapping` which maps the tile's type to their image. A default `tilemapping` is created by the editor when a tileset is saved with the name `tileset-mapping.xml`.

E.4 Music

The engine supports only Ogg Vorbis which is “a completely open, patent-free, professional audio encoding and streaming technology”[14]. Compared with other formats such as MP3, Ogg Vorbis has no licensing issues.

E.5 Sound Effects

Sound effects can either be Ogg Vorbis, or wave(.wav) format. Sound effects should be less than 7 seconds, otherwise the sound effect may be truncated.

E.6 Editor

For the editor the follow structure is used.

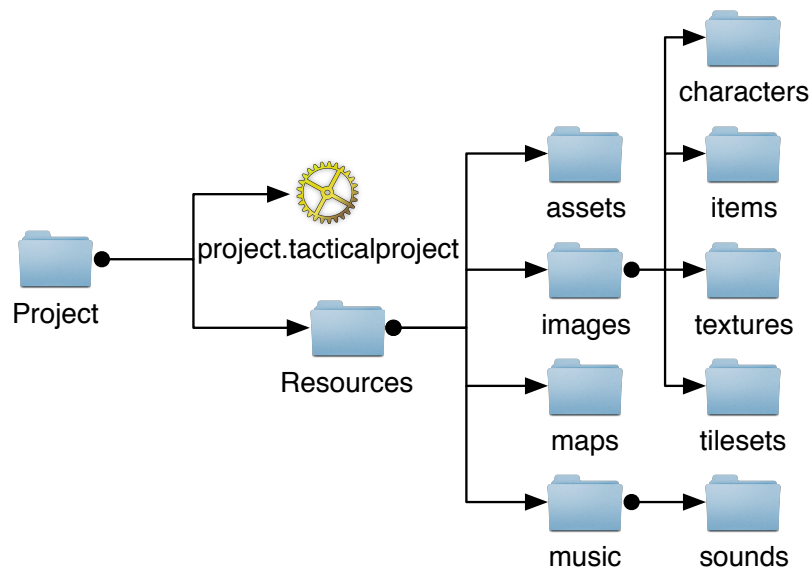


Figure 24: Editor Project Structure

The main change is the addition of the `project.tacticalproject` file which contains settings specific to the editor. It also has the added benefit of allowing the user to click on the `project.tacticalproject` to open the editor if using the Mac version.

E.6.1 Dialog Data Format

The dialog format is actually YAML[15]. This allows more formatting options as well the simple format discussed previously. The advantage of using YAML is that there are parsers available for java[16]. This saved development time since I did not have to build a parser. The main advantage of YAML is that there are very few characters that need to be escaped namely `:` if it appears at the start of the dialog's text or speaker's name. `#` also has to be escaped since it is the comment character in YAML. Since these characters are fairly uncommon in dialog, it should not pose too much inconvenience to the user. In any case the use of the form `- Speaker: |-`, then writing the text on an intended line escapes all characters in the block, solving this problem.

Listing 8: A example show the features of the dialog's data format

```

- Speaker:    Some text.
- none:       no speaker.
- New Enemy 2: |-
    "All the text in this block (until two newlines),
    are part of New Enemy 2's dialog".
    No characters need to be escaped in this block e.g #    : \
- Other speaker: Even more text.
  
```

Specifically the dialog must satisfy the following:

- At least one portion of text. A empty file is invalid
- Each portion of text must have a speaker identified by their name or none for no speaker.
- No other elements are allowed.

When the dialog is imported, if there is a unit with the specified name, it is associated with the portion of text otherwise the text is treated as having no speaker.

E.7 Data Format Extension Mechanism

The user can use their own code to further customise the engine. This section will describe the steps the user needs to take by using the Around weapon as example. This class was originally implemented using the extension mechanism before moving it to the engine.

To uses their own code the user first has implement the required interface e.g `IWeapon` for making a custom weapon. For weapons (as well as skills) there are convenient classes namely (`AbstractWeapon` and `AbstractSkill`) which provides methods for bound checking and generating a diamond of the specified size around the specified tile.

Using `AbstractWeapon` there only one required method to be implemented, namely `getAttackRange` which specify which tiles are reachable. For the Around weapon the attack range is the 8 tiles around the attacker. Users can also override the `getTargets` method to allow multiple targets, in Around's case it attack *any* unit(including allied units) on any of the 8 tiles. The `boundcheck` method which removes any invalid locations from a `Collection` can be optionally used, to save the user from having to figure out if the tiles would valid³³

One other requirement is that the custom class must be in a package (e.g `custom.Around`). To use the weapon in a game add the follow entry to the `Resources/assets/weapons.xml` file of a project.

Listing 9: Example of a custom weapon

```
<entry>
  <uuid>3e07fa06-184b-41a1-9d2a-5ae87d97f012</uuid>
  <custom.Around uuid="3e07fa06-184b-41a1-9d2a-5ae87d97f012">
    <name>Ball</name>
    <strength>4</strength>
    <range>1</range>
    <imageRef>10-1</imageRef>
  </custom.Around>
</entry>
```

As shown above the full qualified classname is used in the above xml. This is used to dynamically load the class. The fields for the class can also be specified in the weapon's tag. The class then has to be packaged inside a jar and put of the classpath when running the

³³Especially important since there are a lot of edge cases such as empty tiles, immovable tiles and units occupying a tile.

game. For the Mac OS X application it is simpler, requiring the user to place the jar in `bundle/Tactical.app/Contents/Resources/Java` and add `:$JAVAROOT/WeaponJarName.jar` to end of the `ClassPath` key in `bundle/Tactical.app/Contents/Info.plist`. This allows the Mac application to still work without any external dependencies.

F Questionnaire

Task

The task involves creating a single level of a Tactical RPG (Each level is grid based (like chess) where each player takes turns to move and/or attack the opposing player).


Weapons


Name	Weapon Type	Strength	Icon
Long Bow	Ranged	30	
Black Spear	Spear	20	
Ice Sword	Melee	10	

Skills


Name	Type	Range	Area	Strength
Air Blade	Ranged	2	0	25
Thunder Flare	Ranged	4	1	15


Units


Agrias		
	Weapon	Long Bow
	Strength	20
	Move	3
	Skills	
	Air Blade	


Elena		
	Weapon	Black Spear
	Strength	30
	Move	5
	Skills	
	Thunder Flare	

Map Enemies

Mustadio		
	Weapon	Long Bow
	Strength	20
	Move	3
	Skills	

Drukmalld		
	Weapon	Ice Sword
	Strength	30
	Move	5
	Skills	

Zalbaag		
	Weapon	Ice Sword
	Strength	25
	Move	5
	Skills	

Ajora		
	Weapon	Ice Sword
	Strength	20
	Move	5
	Skills	

Map

Figure 25: The map to create

Win Condition

Defeat Specific Unit – Elena.

Start Dialog:

Text You can not Win!

Speaker Kyou

End Dialog:

Text How did I lose?

Speaker Elena

Music:

Background Music 3-15 Faraway Heights

F.1 Editor Usability Scale

© Digital Equipment Corporation, 1986.

1. I think that I would like to use this system frequently.

← strongly disagree agree completely →

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

2. I found the system unnecessarily complex.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

3. I thought the system was easy to use.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

4. I think that I would need the support of a technical person to be able to use this system.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

5. I found the various functions in this system were well integrated.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

6. I thought there was too much inconsistency in this system

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

7. I would imagine that most people would learn to use this system very quickly

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

8. I found the system very cumbersome to use

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

9. I felt very confident using the system

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

10. I needed to learn a lot of things before I could get going with this system

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

F.2 Playing a pre-created game

1. I found the game intuitive

← strongly disagree agree completely →

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

2. The game had a appropriate level of difficulty.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

3. I enjoyed playing the game.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
--------------------------	--------------------------	--------------------------	--------------------------	--------------------------

4. Please share any comments about the game :

F.3 Questions

5. Have you played a Tactical RPG before?

6. Did Engine have features you like to create in a game?

7. How easy to use was the Engine?

8. What particular aspects of the Engine did you like?

9. What particular aspect of the Engine did you dislike?

10. What features would you like to see added to the Engine in the future?

11. Please share any other comments:

G Scripting

Scripting allows the user to customise aspects of the game. This includes customising the opponent's AI, custom winning conditions and user defined events.

G.1 Language Choice

There were three main choices using Javascript, using JRuby³⁴, or building a 'domain specific language'.

Creating a 'domain specific language' was considered initially, this would have the following advantages:

- Provides more abstraction, and allow the complex details to be hidden.
- Easier to validate since the languages contains a very few constructs.

but was rejected because:

- of the time to create and test the new language.
- of the cost of creating tools for the new language, there are already source code highlighters and debuggers for Javascript and Ruby.
- of the loss of efficiency, the Javascript parser in the JDK as well as JRuby is very efficient and provides advance features such as 'just in time compilation'³⁵ which would not be possible to implement for the new language within the time constraint of the project.

JRuby has the following advantage:

- Easier syntax for interacting with Java then javascript.
- Easy to use with the embedding API in the JDK.

Javascript was chosen over Ruby as a scripting language for the following reasons:

- Javascript embedding is build into the JDK, so the user does not have install anything extra. It also has the advantage of being cross platform.
- Javascript is easy to learn, and average user is more likely to have used it before as compared to Ruby.

G.2 Data Exposed

Events can be attached to units, tiles in a battle, globally in a battle and to the AI. All events are passed a mapinfo object which contains the following as read only data:

- A hashtable of the players unit and a hashtable of the enemies units. For each unit this includes

³⁴A Ruby implementation written in java

³⁵A method to improve the runtime performance, by translating the interpreted code into lower level form, while the code is be run

- all the unit's attributes such as the location, and hit points.
- if the unit has been defeated.
- The leader unit of each side if there is one.
- The number of turns taken.

The `mapinfo` object contains the following methods:

`win` The player wins the battle.

`lose` The player loses the battle.

`dialog` The player is shown the specified dialog (to show the user some the plot). Can be directed from a specify unit, or a global message.

`action` Executes the specified action.

This allows the user to make complex events without them changing the model to much.

G.3 Action

A `action` is a set of unit defined actions. For example a poison action could reduces the a units 'hit points' by 10%

G.4 Winning Conditions

The user can specify the winning conditions based on what occurring in the battle, examples include

- If opponent's leader's hp < 50% then `win()`.
- If <character> dies then `lose()`.
- If number of turns > 20 then `lose()`

G.5 Unit Events

Unit events get passed the specified unit as well as the `mapinfo`. the event can be specified to execute when:

1. The unit finishes its turn.
2. The unit is affected by magic.
3. The unit is attacked.
4. The unit attacks.

Example: When <unit> attacked counter attack.

G.6 Tiles Events

Tiles get passes the specified tile as well as the Unit. The event can be specified to execute when

- A unit moves to a tile.
- A unit moves though a tile.

Example: On unit moving though `action(posion)`

G.7 AI Events

The behaviour of AI can be customised, with commands such as:

- Attack the player's unit with highest/lowest hp.
- Attack the player's leader unit.
- If player's leader's hp < 20% `heal(leader)`.
- Attack player's characters of class <class>.

The AI events `mapinfo` has addition methods including:

`attack` Attack the specified unit.

`follow` Move as close as possible to the specified unit.

`heal` Heal the specified unit.

`move` Move to the specified location.

`wait` Do nothing this turn

The commands themselves can be conditional, as example

Listing 10: Conditional AI Event

```
If opponent's leader's hp < 20% then
    heal(leader).
else If player has a leader unit then
    If player's leader's hp < 20% then
        Attack the player's leader unit
    else
        Attack the player's closet unit with the lowest hp.
    end
else
    wait
end
```

H BugFixes notes

- Not adding ext to files
- Allows not ogg files for music
- Dialog import/export
- Terrain gen
-

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