

Computer Science
Advanced GCE H447
Unit F453

Name: Karol Jeziorczak
Candidate Number: 4162
Centre Name: Rugby High School
Centre Number: 31255

Contents

1	Abstract	4
2	Introduction	4
3	Analysis	4
3.1	Computational Methods	4
3.2	Researching The Problem	5
3.2.1	Risk of Rain 2	5
3.2.2	Celeste	7
3.2.3	Rain World	9
3.3	Stakeholders	10
3.4	Interview with Stakeholder	11
3.5	Letter to Stakeholder	12
3.6	Questionnaire	12
3.7	Analysing Market	15
3.8	System Requirements	16
3.9	Limitations	17
3.10	Essential Features	17
3.11	Success Criteria	17
4	Designing the Solution	19
4.1	Folder Set up	19
4.2	Main Menu	19
4.3	Dungeon Generation	19
4.3.1	Create Rooms	20
4.3.2	Spread rooms	20
4.3.3	Delete Rooms	22
4.3.4	Delaunay Triangulation	23
4.3.5	Remove random amount of edges	27
4.3.6	Make sure all rooms are accessible	29
4.3.7	Turn edges into horizontal and vertical	33
4.3.8	Generate corridors	35
4.3.9	Turn into tile map	35
4.3.10	Spawn player	35
5	Evaluation	35

List of Figures

1	[Ror] Risk of Rain 2 Screen shot	5
2	[Cel] Celeste Screen shot	7
3	[Rws] Rain World Screen shot	9
4	Questionnaire Header	12
5	[Shs] Steam OS statistics	15
6	[Shs] Steam Hardware Statistics	16
7	Room Layout	20
8	[Dis] Room Movement Direction	20
9	Flowchart for spreading rooms	21
10	Result of room separation	22
11	Flowchart for deleting rooms	23
12	Result of room deletion	23
13	Bowyer-Watson Classes	24
14	Bowyer-Watson Algorithm Flowchart	25
15	Result of Bowyer-Watson algorithm	26
16	Flowchart for Edge Deletion Algorithm	28
17	Deleting edges result	29
18	Flowchart for detecting if a new section needs to be made	30
19	Flowchart for the given pseudocode	31
20	All possibilities for points	33
21	Flowchart for the given pseudocode	34
22	Before (pink) and after algorithm (green)	35

1 Abstract

I decided to create a game for my coursework. I had researched the market to influence my game to make it more appealing to the target audience. Creating the game was very challenging and challenged my limited understanding of c#, and forced me to learn the language in greater detail, it also challenged the methods that I tend to favour when approaching a challenge forcing me to explore new ways of computational methods. I decided on a 2D rouge-like game with a heavy focus on melee combat and movement. For this I needed to make a character controller, dungeon generation algorithm, enemy AI and balanced items for the player. Each requiring it's own delicate calibration to make the game fun.

2 Introduction

For my project I intend to create a 2D rouge like game which is focuses on melee combat. This game would be like Rain World with Celeste movement. I chose this style because there are few games which focus on melee combat and this would help it stand out amongst the other games, the rouge like aspect would allow every run to be unique and distinct. Allowing people to replay the game multiple times without getting bored.

The melee combat will be close range and it will allow people to play in distinctive styles, for example people will be able to change their weapon and ability to suit the play style that they are looking for, making any play style viable.

There will be progress through floors. When the player completes one floor they can move on and enter the next floor. At the end of each floor there will be a boss that the player must defeat to progress.

The loot and map generation will be random meaning that the player cannot memorize the layout and do the same thing every time but need to adjust to the environment, making the game more challenging.

I plan for there to be different enemies that have different attack patterns that will not be entirely random meaning that the player can learn how to effectively defeat the enemy. The enemy difficulty will increase as the player progresses through the floors.

3 Analysis

3.1 Computational Methods

Computational methods are computer-based methods which are used to solve problems. They are suitable for my project since I want to make an entertaining game. And I can accomplish this by creating features using the following methods.

Decomposition – Splitting a large problem into smaller problems which are more manageable. This would help with my project as I am not going to be working in every aspect of the game at once, decomposition allows me to work on one part of the game at a time since debugging one small piece of code with a couple of errors is a lot easier than debugging the entire game code with many, many errors. It also allows me to work on different parts of the game independently from another part, since each problem is broken into it's own self contained module.

Divide and conquer – Dividing a problem into smaller problems until they are small enough to be solved directly. This would allow me to develop one aspect of the game at a time and make steady progress on the game. Since each aspect is finished and polished by the time I move on to the next aspect. This can be utilised if decomposition doesn't break the code into small enough segments.

Abstraction – Removing the additional detail allowing me to focus on the main points rather than wasting time trying to work on pointless detail that will not be noticed. This will allow me to use my time efficiently as the main features will get the most amount of time making the basics of the game reliable.

Modular design – Subdividing the problem into smaller modules in my case these would be: physics engine, movement, abilities, characters etc. These allow me to priorities the modules which need more attention and keep organized as each module can have its own separate folder for all the things needed for that module.

Algorithms – Algorithms allow me to implement features that do not need anything but computer processing to be solved. For example, enemies will use an algorithm to detect and attack the player, the scenery might be made by an algorithm etc. These allow the computer to do specialized processing for the problem that needs to be solved.

Selection – Allows for choices to be made in the code. For example, if statement is a type of selection since a condition needs to be met for the code to be executed. This is useful in many scenarios, just to list a couple: if the player is in the air, they should not have the ability to jump. If the players health drops to zero they should be sent to the game over screen and many more.

Iteration (looping) - Allows a certain piece of code to be ran multiple times, these can be count controlled or condition controlled. Loops which will continue to cycle the code until it has reached a stopping condition. These are useful since in a 2D game the players input needs to be recorded every frame to minimize latency, the code needs to sort through those inputs every to make the necessary adjustment to the character and environment all in the same frame. These tasks are repetitive therefore the code will be the same every loop and iteration is perfect for that.

Visualization – The player will not be able to process the raw data outputted by the computer therefore it needs to be put in a format which is comprehensible for humans. There will be a lot of data processing while the game is running such as player position constantly moving, enemies moving and attacking the player. If that were outputted as a string of numbers to the player, they would have no idea what is going on therefore visualization is used to allow the user to interact with the program.

Pattern recognition – It would be useful for the computer to recognize patterns as a certain pattern could be used as a condition for selection this could be useful as when the player attacks the computer could recognize this and react accordingly to make the fight interesting. Or it can be used in fighting games to make a move since in some games you can chain inputs to do a special attack.

These computational methods are suitable for solving my problem because each problem can be broken down into smaller sections that are able to be solved by a machine.

3.2 Researching The Problem

3.2.1 Risk of Rain 2



Figure 1: [Ror] Risk of Rain 2 Screen shot

Risk of Rain 2 is a rogue like, third person shooter. A rogue like game means that when you die in the game you must restart the entire game, which means that it does not take long to complete and it can be replayed multiple times, since it has a large variety of items which can be combined to make many unique runs. It has a unique concept since as the time goes up so does the difficulty, meaning that the more time you spend looting the more powerful enemies become creating a unique stressful and fast paced shooter.

Controls

Key/Button	Action
WSAD	Moving Around
Space	Jump
E	Interact with the environment (open crates etc.)
Q	Activate equipment (item that can be used by every character)
Ctrl	Toggle sprint (to move faster)
M1	Primary Skill (unique to character, usually damaging)
M2	Secondary Skill (unique to character, usually damaging)
Shift	Utility Skill (unique to character, usually movement)
R	Special Skill (Unique to character, usually heavy damage, and long cooldown)
Tab	Info Screen (shows the statistics of the current run)
M3	Ping (allows players to communicate in game)

Characters

Commando and Huntress – Both are beginner friendly characters which have a basic set of skills and utility to ease the player into the game. They are the first characters you unlock and they are both good characters even after the player has learn to play the game.

Every character apart from these two needs some sort of challenge to be completed before the player gains access to them. This allows the player to progress at their own pace.

Acrid, Artificer, Bandit, Captain, Engineer, MUL-T and REX – Once these characters are unlocked, they expand the possible play styles possible to the play allowing the player to play the game in any way they want to for example, Engineer has turrets and a shield if the player wants to bunker down, while Bandit has an invisibility cloak and shotgun allowing for the player to get close and personal.

Loader and Mercenary – Both have the highest skill ceiling (lots of things to master) and both have lots of unique tech (advanced strategies to use utility to achieve a certain result) for example Loader can launch out her pylon and grapple to it immediately after launching the player a great distance

Railgunner and Void fiend – Both DLC characters which is a good example of the developers expanding the play style since none of the other characters had long range and these characters fit that style perfectly since Railgunner has a rail-gun which is like a sniper allowing the player to keep their distance and pick of enemies one by one.

Heretic – A secret character which is unique since they cannot be unlocked, and the character is bound by the run as they are unlocked by picking up a combination of items on that run.

Aim of the game

The aim of the game is to get loot and activate the teleporter, after this a boss will spawn, which you must kill to progress. You get teleported to a different stage and the process repeats until stage 5 and after that you get teleported to the moon to kill final boss (Mythrix) or obliterate yourself which has a more secret ending which needs the player to enter a portal on stage 8 after they loop (return back to stage 1 and keep all their items), sometimes a large purple portal can appear which teleports the player to a different realm (with some pretty interesting lore) and they have to defeat Voidling which gives the player an alternate ending.

Target demographic

Teens and older since the game contain blood, drug references and fantasy violence. It is aimed at people with all skill types as the game has different difficulty rating which allows the player to play at the level that they are comfortable with.

Good Qualities

- The game is very beginner friendly because of the difficulty options provided.
- The variety of items allows the player to replay the game with many different combinations and the game does not feel repetitive.
- The different ending makes the player want to experience them all.
- The variety in character makes any play style suitable.
- The game is never “too easy” since there are eclipse challenges which get progressively harder
- The many secrets in the game allow insentiences the player to explore and solve puzzles to unlock new aspects of the game.

Bad Qualities

- Once you loop a lot the game gets very chaotic and resource intensive because there are so many enemies with different attributes that can create lots of projectiles that slow down the game a lot.
- Some things can kill you in one hit making death unavoidable in some cases which can feel unfair.
- Sometimes you get runs where you get no good items, and the game becomes a lot more difficult because of bad luck.

What I would include

- The variety in characters and the play styles that the game allows would allow my game to be playable by anyone.
- The different difficulties allowing the player to play at a level that their comfortable with, this would make the game approachable to anyone with any skill level.

3.2.2 Celeste

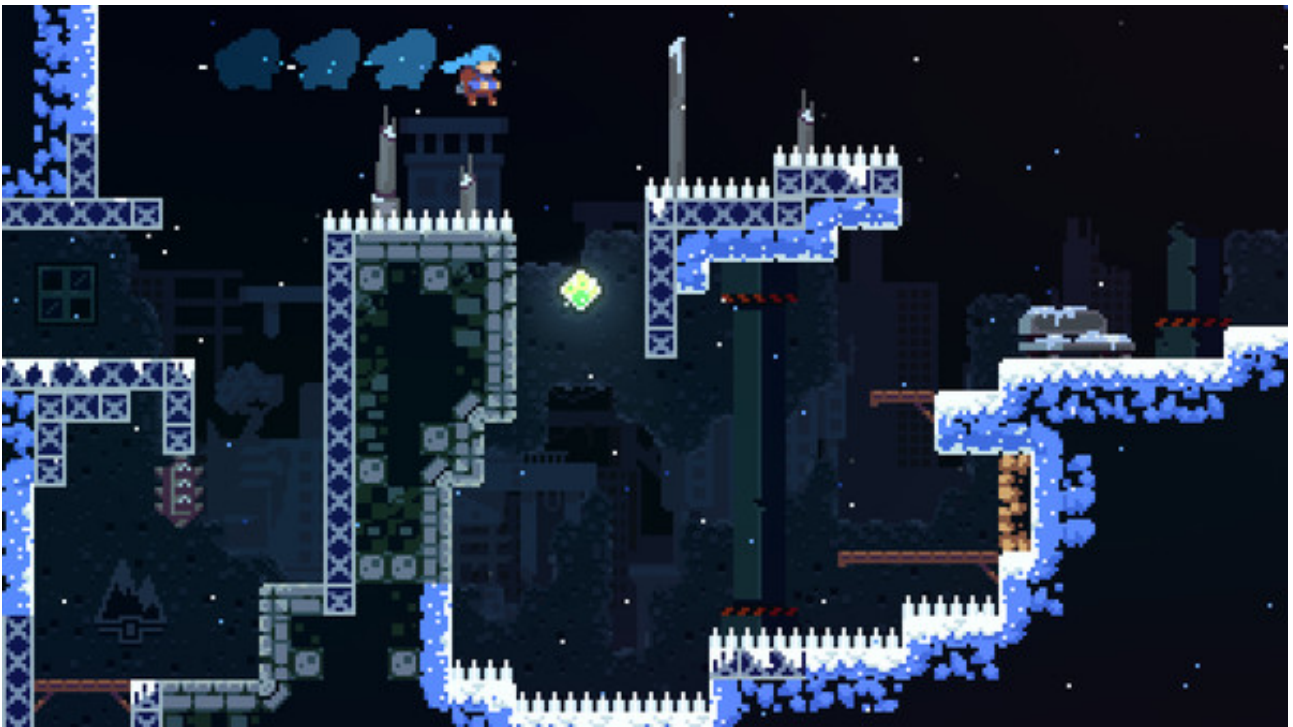


Figure 2: [Cel] Celeste Screen shot

Celeste is a challenging 2D platformer where the aim is to give precise inputs that will clear the level and allow you to progress into the next room. It takes a long time to complete as the game is very difficult and constantly introduces new features that are harder than the last.

Controls	
Key/Button	Action
WSAD	Moving Around
Space	Jump
K	Dash
L	Grab

Characters

Madeline is the protagonist of the game and as the game progresses, as the game progresses they get more and more abilities and the level design reflects this as the game presents rooms that can only be solved with the new skill that the player was shown. The game never gives the character any new skills are just shown to the player and never granted or unlocked meaning that the player can revisit earlier levels and complete them in newer and more efficient ways. The player does get an extra dash in some of the later rooms in the game and this is the only upgrade that the player gets.

Aim of the game

The aim is to get to the top of the celeste mountain climbing the mountain one room at a time. Rooms get harder the further you progress in the game, the length of these rooms can vary drastically, the same applies to the difficulty. The game itself doesn't have that much levels however each level is very difficult which makes completing one very rewarding.

Target demographic

Anyone as the game doesn't have any violent or difficult topics discussed, however it will cater better to a slightly older audience because of it's difficulty. The game also targets people who are more experience in platformers as the difficulty of the levels scales quickly.

Good Qualities

- Beating a room feels rewarding and it makes the player want to continue playing.
- The movement is very simple which makes it easy for anyone to start.
- The movement feels fun due to the combinations with different movement techniques.
- The movement feels consistent, if you die it feels like it's your fault and not the game being unfair.

Bad Qualities

- Getting stuck on one room can be very frustrating.
- To progress far into the game you need to dedicate a lot of time and have a lot of skill.

What I would include

- A similar art style, since the simple pixel art would be easier to implement than hand drawn characters.
- Similar movement system, but something that isn't as complicated so it doesn't overwhelm the player since I also want to add a combat system.

3.2.3 Rain World



Figure 3: [Rws] Rain World Screen shot

Rain world is an open world game meaning that the player can go explore anywhere to their heart's content. It's also very difficult, and focuses on treating the player as part of the ecosystem rather than a separate entity, for this reason enemies treat the player as any other rival creature and focuses on their own survival rather than killing the player, which is common in most other games.

Controls

Key/Button	Action
WSAD	Moving Around
Space	Jump
E	Grab
Q	Throw
Z	Map
Escape	Pause

Characters

The player plays as a slugcat which is a small creature with the ability to wield rocks and spears. They can also befriend other wild creatures. They can also interact with scavengers if the player's reputation is good with the scavengers, however this isn't the case for all slugcats as scavengers will become hostile if the player's reputation is low.

Monk - The easy mode of rain world, where enemies are less common and less aggressive. This character is good for people playing the game for the first time as it allows them to experience the game in a less harsh environment than usual.

Survivor - Regular difficulty of the game

Hunter - Hard mode of rain world where some special tougher enemies spawn that don't usually spawn, enemies are also more common and aggressive. There is also a time limit as the hunter has a limited amount of cycles (days) unlike any of the other characters, hunter also has the ability to consume dead animals.

Rain world also has a DLC called downpour which adds 5 new characters, where each character has unique abilities and objectives, the different characters are unique to the base game characters as they have their own

abilities which also come with their downsides. Each character is also set at a different time in the timeline meaning that the layout of the game will be similar however each room will be different for each character and the enemies in that area will also be different. These new characters each require a different approach for the game due to their different downsides, for example gourmand gets tiered after throwing a spear, forcing the player to plan their combat as they will get tiered if they spend too long in combat. Whereas the saint isn't able to use spears because it's a pacifist, but they have a grapple which it can use to traverse the land faster, forcing the player to avoid combat at all costs.

Aim of the game

The aim for each character in the game varies, however they all need to progress through the environment to reach their goal, often resulting in combat with the wildlife. The player must also gain enough food to be able to sleep in a shelter and avoid the rain that comes at the end of each cycle (game equivalent of a day). Dying results in the player respawning in the shelter they previously slept in and losing a karma point, however for each successful cycle that the player completes they will gain a karma point. Karma is important as it allows the player to traverse between regions, since regions are separated by karma gates which only let you through if your karma is above a certain level.

Target demographic

Anyone as it doesn't contain any graphic scenes or references to difficult topics. However the game caters more to people who are willing to spend time trying to understand it as it's a very challenging game which is very harsh for a new player, lacking any kind of tutorial or explanation.

Good Qualities

- Game play is fun and keeps the player engaged due to the many things that the player can do.
- Game has a high skill ceiling meaning there is always a way the player can improve.
- Movement is incredibly fun and feels exceptionally smooth.
- Lack of permanent upgrades makes the game focus on skill rather than items and unlocks.
- Completing a cycle is very rewarding.
- Player is treated as part of ecosystem rather than separate entity, meaning they are treated as every other enemy is by the other enemies which makes it feel more realistic.

Bad Qualities

- Difficult to get into due to no tutorial, there is no way of knowing what to do when you start and the player has to figure it out for themselves, which can be enough to deter some players.
- Game is very unforgiving and a small mistake can result in the player getting killed and losing a lot of progress.
- The map is very large and the in game map system is very unreliable so it's often played with a map open on a separate tab or device.

What I would include

- A similar combat system, as it is simple but still fun and has lots of ways the player can express their skill.
- Treating the player as part of the ecosystem, as it makes the game feel more alive.

3.3 Stakeholders

My game would be suited for people who have more experience with games, it will be suitable for any age over the age of twelve (might be a too violent for children under the age of twelve). A stakeholder would also be important as they could give me direct feedback for the game to improve it and make it a more enjoyable experience. They would play the game as they often play games as a source of entertainment the survey conducted in a later section shows what type of games people play and therefore would be willing to try.

Therefore, Ethan Armstrong would be a suitable stakeholder. He is 16 years of age therefore he fits the target demographic. He will give feedback through play testing and according to the feedback I will be able to adjust the difficulty and balance the aspects of the game to fit the genre and style I am going for. The feedback given to me by him will allow me to adjust the game to make it more enjoyable.

Daniel Cabrel would also be a stakeholder as they are new to gaming therefore, I will be able to make the game more beginner friendly to expand my target audience and make it more appealing to more people. He will also give feedback through play testing and interviews allowing me to make the game easy to pick up regardless of skill.

I have chosen these people since they are part of my target demographic and they will help me to make the game easy to pick up yet challenging.

3.4 Interview with Stakeholder

I – Interviewer (Karol Jeziorczak)

S – Stakeholder (Ethan Armstrong)

I: Everything you say here will be recorded and used for development of my game; however, it will not be shared with any unauthorized personnel and your data will be protected under the GDPR

S: I understand and agree to these terms.

I: Question 1. What is the most important feature to you in a game?

S: Exploration is very important to me; I love finding out hidden mechanics and secrets.

I: Question 2. How important is difficulty scaling with progress to you?

S: It is important to make the game challenging as it will make it more fun to overcome.

I: Question 3. How often should there be boss fights?

S: A bit after a new mechanic gets introduced so I have time to get used to it however the boss fight will be a test to see if the player can use the gimmicks

I: Question 4. What type of playstyle do you usually go for?

S: I usually go for a large health build with heavy weaponry

I: Question 5. Are there any specific features you would like to see?

S: I would like to see a power slide because it makes the game seem fast paced.

I: Question 6. What are some qualities of a good combat system?

S: Enemies not having insane amounts of health as it slows down the pace of the game and makes killing them seem like it takes too long. So, with melee weapons there should be more blocking and skill involved rather than just hitting enemies and them dying?

I: Question 7. What should the final boss look like?

S: The final boss should be an enemy foreshadowed by the previous environments that has different mechanics from the different bosses that combine them all into one where they need to be interchanged, with a satisfying dying animation for the final boss.

I: Question 8. How should the inventory management system work?

S: I think that there should be a very limited amount of inventory room so that management and planning become very important. Also, so that the focus of the game isn't shifted too much from the combat, as it is the main focus of the game.

3.5 Letter to Stakeholder

31 Bucannon Road
CV22 6AZ
20/11/2022

Dear Ethan Armstrong,

My name is Karol Jeziorczak. I am studying computer science (OCR specification) at Rugby High School; the coursework requires me to create a game.

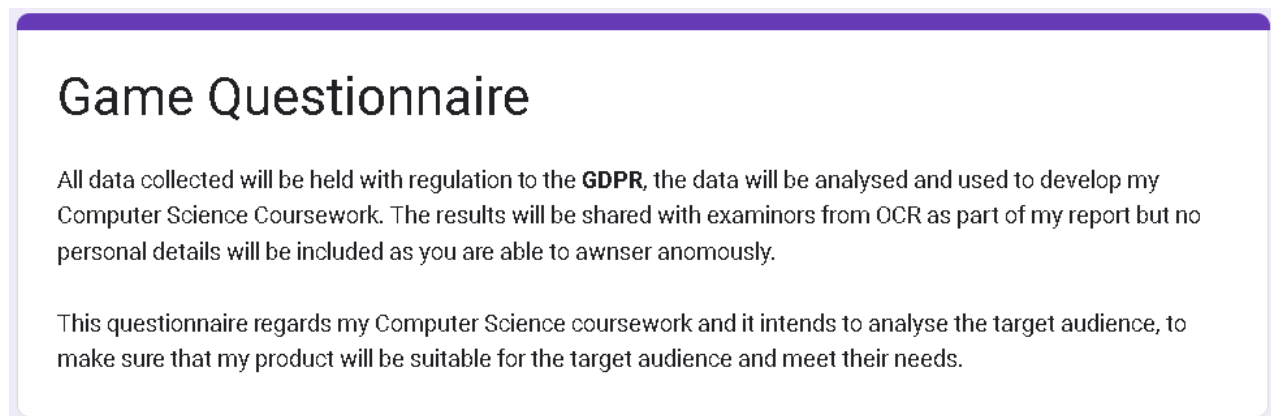
I am asking you to become a game tester for my game so that I can get feedback from you as to how to improve the game. In the future I will ask you to give me feedback on the game to improve the quality and usability of the game, this will be in the form of interviews and game testing. This will hopefully improve the quality of the game and allow me to develop this project further into a fully functional product.

All the data gathered will be kept secure in order with the GDPR (General Data Protection Regulation). This means that your data will be kept secure and will not be shared with any unauthorized personnel. I will do everything that I can to protect your data. However, if the data will get leaked, you will be the first to get notified.

Thank you for your time and co-operation (if you choose to). I am looking forward to working with you.

Sincerely,
Karol Jeziorczak

3.6 Questionnaire



Game Questionnaire

All data collected will be held with regulation to the **GDPR**, the data will be analysed and used to develop my Computer Science Coursework. The results will be shared with examiners from OCR as part of my report but no personal details will be included as you are able to answer anonymously.

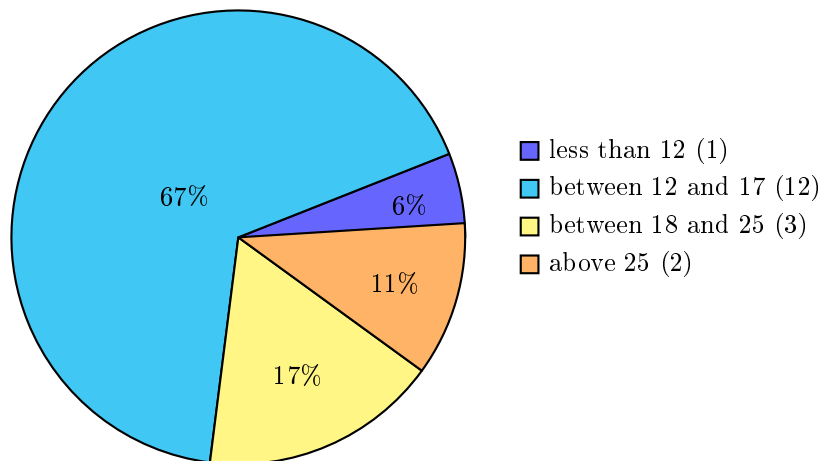
This questionnaire regards my Computer Science coursework and it intends to analyse the target audience, to make sure that my product will be suitable for the target audience and meet their needs.

Figure 4: Questionnaire Header

A questionnaire will allow me to analyse the market and make a game that people want to play. It also allows me to ask the intended audience for any features that they want.

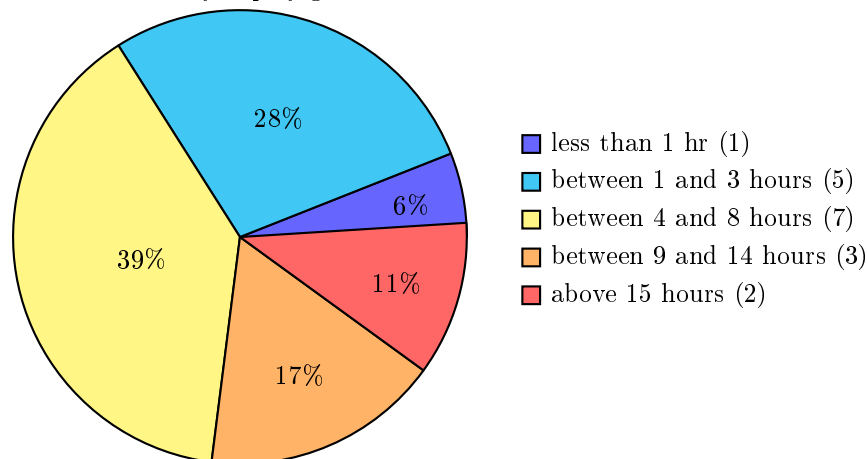
Analysis

Q1: What is your age?



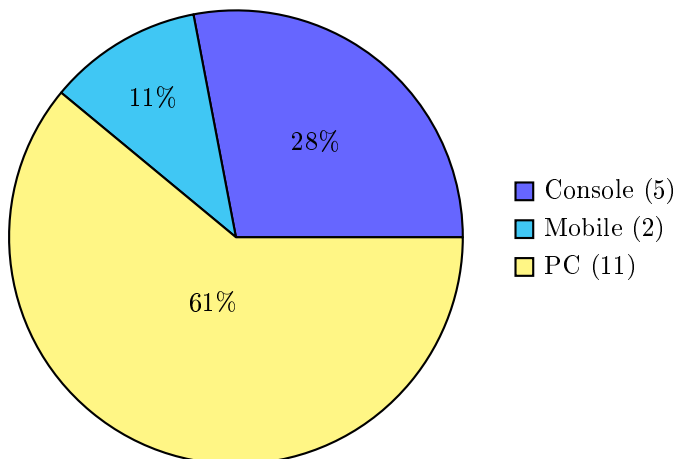
We can see that the target demographic is teens and above meaning that the game can include some violence. It is important to make the game appropriate to the target demographic as they will be the majority of the player base.

Q2: How much do you play games a week?



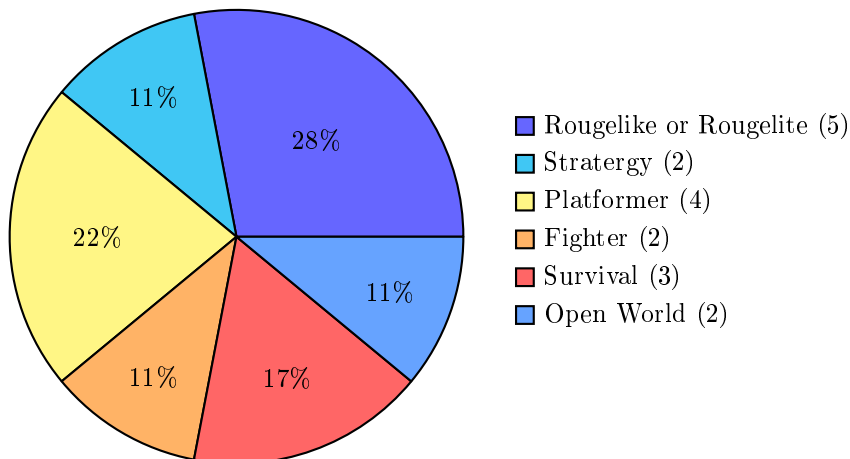
It is important to balance the progress made and the time invested as if people only play 1-2hrs a day as shown by the questionnaire, it is important to make the player feel like they made progress in that time so that they are willing to continue playing. This could be implemented by each run being 30-40 mins allowing the user to have a couple runs in a session.

Q3: What platform do you play games on?



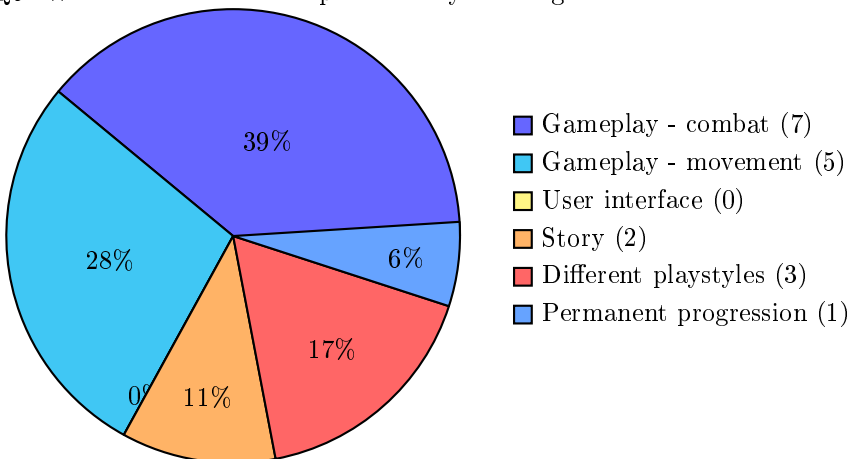
Most people answered replied that they play on pc meaning that it should be ported to pc first. A significant amount of people also play on console so it would be good to port the game to console if possible.

Q4: what genre of games do you play?



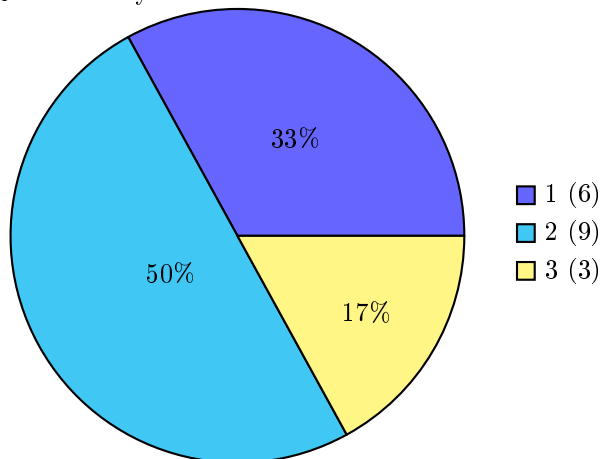
Most people answered Roguelike/Rougelite and platformer meaning I should focus on these two aspects the most when making my game. Survival will be implemented though planning ahead this might be what routes to take and the risk associated with those routes as well as the risk of combat. As well as management of resources to make sure you survive to the next stage.

Q5: What mechanics are important to you in a game?



Combat and movement were the most common option so they should be the most polished systems in the game. Though different playstyles was something I should consider. Permanent progression wasn't a popular choice so a roguelike style would be more suitable

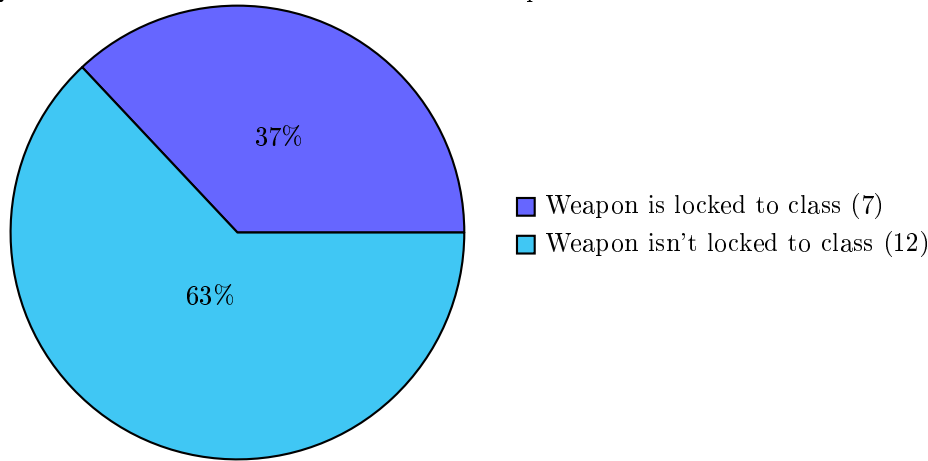
Q6: how many skills should each character have?



Most people answered 2 so it would be important to make the skills distinct and unique to allow for different

play styles. One ability could be active that the user can activate when needed e.g. throwing grenade and it will have a cool down. The other ability could be a utility skill which can be picked regardless of character and is a limited resource and refreshes once a special item is picked up e.g. throwing knife that does damage, refreshes when more are picked up. There could also be a passive ability that the player doesn't need to do anything to activate it, it will be permanently active in the background (e.g. increased movement speed), this can make every character feel unique.

Q7: Should each character have their own weapon in their class or be able to?



The majority wanted to have weapons that are picked up and not locked to a class therefore I will give each character a starting weapon and give them the ability to change this weapon if they wish to, allowing the player to experiment with different weapons that may suit their play style.

3.7 Analysing Market

Steam does a hardware analysis on all of its users every month so I will be able to make a game that will meet the requirements of the majority of players. So all the data in this section is taken from [Shs]

System OS Analysis

MOST POPULAR	PERCENTAGE	CHANGE
Windows	96.56%	-0.87%
Windows 10 64 bit	53.53%	-12.05%
Windows 11 64 bit	42.04%	+11.51%
Windows 7 64 bit	0.69%	-0.38%
Windows 8.1 64 bit	0.16%	+0.03%
Windows 7	0.06%	+0.06%
OSX	1.53%	+0.34%
MacOS 14.0.0 64 bit	0.34%	-0.06%
MacOS 14.1.1 64 bit	0.20%	+0.20%
MacOS 14.1.0 64 bit	0.18%	+0.18%
MacOS 13.4.1 64 bit	0.05%	-0.01%
MacOS 13.5.2 64 bit	0.05%	-0.05%
Linux	1.91%	+0.52%
"Arch Linux" 64 bit	0.15%	+0.05%
Ubuntu 22.04.3 LTS 64 bit	0.13%	+0.04%
Linux Mint 21.2 64 bit	0.08%	+0.03%
"Manjaro Linux" 64 bit	0.07%	+0.02%

Figure 5: [Shs] Steam OS statistics

Deciding which systems I will be able to support is going to be an important decision I have to make to make sure that the users can play the game us. Figure 5 shows us that the overwhelming majority of players use

windows, this tells me that I should prioritise porting the game to windows as it will make it available to the most amount of players as possible. Mac OS (OS x) only account for a small percentage of players. The difficulties that come with porting my game to Mac simply makes it an inefficient use of time. Linux also accounts for a small percentage of players however porting to Linux is very easy in Godot so it may be something to consider in the future if I have time.

Hardware Analysis

ITEM	MOST POPULAR	PERCENTAGE	CHANGE
OS Version	Windows 10 64 bit	53.53%	-12.05%
System RAM	16 GB	48.88%	+1.82%
Intel CPU Speeds	2.3 GHz to 2.89 GHz	21.15%	-1.40%
Physical CPUs	6 cpus	31.88%	-7.87%
Video Card Description	NVIDIA GeForce RTX 3080	4.89%	-4.79%
VRAM	8 GB	31.23%	-3.63%
Primary Display Resolution	1920 x 1080	60.09%	+1.08%
Multi-Monitor Desktop Resolution	3840 x 1080	60.02%	+0.04%
Language	English	38.02%	+9.82%
Free Hard Drive Space	100 GB to 249 GB	23.46%	+4.34%
Total Hard Drive Space	Above 1 TB	51.99%	-13.18%
VR Headsets	Oculus Quest 2	40.45%	+0.75%
Other Settings	LAHF / SAHF	100.00%	0.00%

Figure 6: [Shs] Steam Hardware Statistics

I intend to make a 2D game. These types of games don't tend to be resource intensive. The most important statistics in figure 6 are system RAM, Intel CPU speeds (More players use Intel CPUs rather than AMD CPUs so this is a valid statistic to use), Physical CPUs, VRAM, Free Hard Disk Space (the ones with a red mark next to them). None of the statistics should be limiting for my project as they would be more important to consider for a 3D game using a fancy rendering system. However my game is 2D so it should be able to run smoothly on most devices.

3.8 System Requirements

All the requirements are taken from [Spe], the official Godot 4 documentation.

Minimum Hardware Requirements

- Processor: x86_32 CPU with SSE2 instructions, or any x86_64 CPU
- Graphics Card: Integrated graphics with full Vulkan 1.0 support
- Memory: 2GB
- Storage: Fill out when done
- Sound Card: yes

Input devices:

- Keyboard – allows you to input characters
- Mouse – Inputs 2D vector coordinate for mouse position

The input devices allow the user to input signals that the computer to process and adjust accordingly based on the inputs provided.

Output devices:

- Display – Outputs image
- Speakers – Outputs sound

An example of visualisation since the raw data is presented in a way that the user can comprehend. It also allows them to understand what is happening in the game and feedback on any inputs given.

Minimum Software Requirements

- OS: Windows 7+

3.9 Limitations

Compared to the large studios that produced the games that I researched I have a significant amount of limitations that could slow down the progress of my game development. Such as manpower as studios usually consist of many specialised and trained people. However I am trying to make a game on my own, this means I will need to do everything on my own, from game assets and art to audio design and code. This could be mitigated slightly by the free assets available online which would save me time as I don't have to create them myself.

Another limitation is my knowledge and experience in developing games as I only have experience developing one small game for a game jam over the course of a couple days. The project was very limited and used GD script, whereas I would like to use c# to develop my game. I could overcome this by following tutorials and doing research to make myself more comfortable with developing my own methodology and ideas.

I am also limited by time since there is a deadline I must reach so I can't continuously develop the game over the course of a couple years. This can be less impactful with good time management and use of abstraction so that I can focus on the main points of the game when developing and spend less time on small features that will go unnoticed for the most part.

3.10 Essential Features

One essential feature is the user interface as it allows the user to navigate any menus and displays any important information to the player. The main menu is the first screen that a player would see therefore it is important to give a good first impression and set the tone of the game and allows the user to start a game and customise their settings. The pause menu is also an important feature of the user interface as it allows the player to pause the game and customise their settings. These things are standard in most games so it would be good to implement it in my game. The HUD (Heads Up Display) is the only user interface that the user sees when they are in game, so it's important to keep it clean and out of the way as it will be overlayed on the users screen at all times. It will also be important to have it display the relevant information, such as the player's health, inventory, and possibly a timer. However not all players will want all of this information on screen at all times so it will be important for the HUD to be customizable to suit a player's needs.

Audio is another key feature of games as audio queues can help players fight an enemy, or get feedback since they can hear the sound of their character getting hurt and immediately know that their health has went down without having to look at their health bar. Or when a hit from the player connects with an enemy they know that they damaged the enemy and it also adds to the user experience. This is observed in all the other games I researched, therefore it would be good to include. In game music also sets the tone of the game since if the game changes theme to a combat theme, the player can prepare for combat before the enemies show up.

The type of gameplay that I will focus on can be split into two main sections, player combat and player movement.

Having a good combat system is important as the player will engage with it very often so it's important for it to feel responsive and fun. This could be done by having a variety of weapons that work well together with the movement system.

The movement system will be how the player traverses the level, so having a responsive and fun movement system will be important as the player will always be interacting with it. Allowing for the player to combine movement and combat would create a lot of combinations the player could discover and experiment with.

Level generation will also be important as it creates the environment the player will experience the game in. So it needs to work well with the movement system for the levels to be easy to traverse through. Since if the player is unable to reach an important room that could hinder their progress in the game.

3.11 Success Criteria

1. User Interface

1.1. Main Menu

1.1.1. Does it have a new game button?

Allows the player to start the game.

1.1.2. Does it have an options button?

Allows the player to customise the game to suit them

1.1.3. Does it have a tutorial option?

Takes the player to a tutorial level where they can learn the game, important for new players who are playing for the first time.

1.1.4. Does it have a interesting background?

Gives a good first impression to the player when they open the game.

1.1.5. Does it have a quit game button?

Allows the player to close the game.

1.1.5.1. Does it ask you "are you sure"?

Makes sure that the player didn't press the button by accident.

1.2. **Pause Menu**

1.2.1. Does it pause the game?

Allows player to take a break if they need to.

1.2.2. Is there an options button?

Allows the player to change setting in game in case they need to.

1.2.3. Is there an exit to main menu button?

Allows the player to quit the current run and return to the main menu.

1.2.3.1. Does it tell you "The current run will be ended"?

Makes sure the player didn't press this button by accident and accidentally quits their run

1.3. **HUD (Heads Up Display)**

1.3.1. Is there a health bar?

Allows player to see their health

1.3.2. Is there a current level box?

Allows player to see which stage they are on

1.3.3. Is there a timer?

Allows player to see how long the run has lasted

1.3.4. Are there small indicators for status effects?

Allows player to see if they are affected by and de-buffs/buffs

1.3.5. Is the HUD customisable?

Allows player to adjust HUD to their need

1.4. **Inventory**

1.4.1. Can you drop items?

1.4.2. Are there item slots?

1.4.3. Can you rearrange your inventory?

2. **Audio**

2.1. **Main Menu**

2.1.1. Is there some sort of music?

2.1.2. Do the buttons make a sound?

2.2. **In Game**

2.2.1. Is there boss music?

2.2.2. Does the game have hitting sfx?

2.2.3. Does the game have a sound for getting hit?

2.2.4. Does the game have music?

2.2.5. Does the game have a sound for dying?

3. **Gameplay**

3.1. **Level Generation**

3.1.1. Does it create a level in a reasonable amount of time?

3.1.2. Are there objects you can interact with that give items?

3.1.3. Are enemies spawned?

3.1.4. Is there a safe starting room?

3.1.5. Is there a boss room at the end?

3.1.6. Is there variety between levels

3.2. Player Combat

3.2.1. Does the player die when they have 0 health?

3.2.2. Can the player melee swing?

3.2.3. Can the player block?

4. Visuals

4 Designing the Solution

Decomposition of the problem

This is one of the computational methods that I am going to use for my game. This is important as it allows me to think of how the game will work at a basic level.

Variables

stores some sort of data in main memory

Data Types

- Integer – whole number
- Float – real number
- Character – single letter/symbol
- String – series of characters
- Boolean – true or false

CONSTANT – represented as capitalized with underscores

variable – represented as lowercase with underscores

4.1 Folder Set up

4.2 Main Menu

The main menu will be there to greet the player once they open the game and allow them to choose what they would like to do.

These will be in the form of buttons that the user can click on.

4.3 Dungeon Generation

The Generation algorithm that I used is a modified version of the algorithm used in [Gen]. The stages I used can be summarised with the key points:

- Create rooms
- Spread rooms
- Delete rooms
- Delaunay triangulation
- Remove random amount of edges
- Make sure all rooms are accessible
- Turn edges into horizontal and vertical
- Generate corridors
- Turn into tile map
- Spawn player

Some other miscellaneous algorithms used in generation

- Turning list of edges to graph
- Turning graph to list of edges

4.3.1 Create Rooms

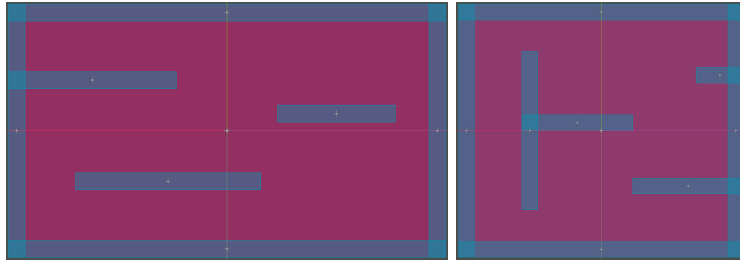


Figure 7: Room Layout

Begin with generating a defined amount of rooms. Rooms are pre-made layouts that a room as seen in figure 7. Originally I generated a cube and gave it a random size, but this would be problematic down the line since when it comes to creating a tile map it would be difficult to generate a room that would be playable.

4.3.2 Spread rooms

Once all the rooms are all generated in a confined area they need to be spread out until they are no longer overlapping. To separate the rooms I iterated through each room object and check it for overlapping areas. I found the difference in positions to get the vector of the room relative to the original room being considered, using this I can find the direction that the room should be moved in. This idea was taken from [Dis]

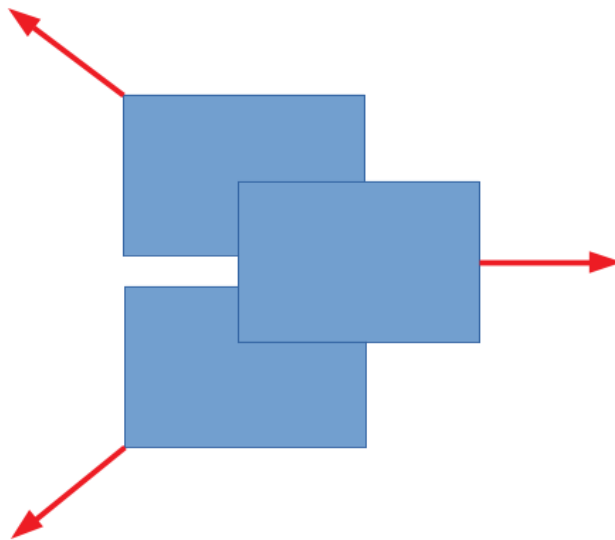


Figure 8: [Dis] Room Movement Direction

The only major difference in the way that I implemented was that I multiplied the vector by the reciprocal of the magnitude, this would make it so that when there is a colliding room closer to the room being considered it's effect on the displacement of the room is much greater than if it was far from the center of the room

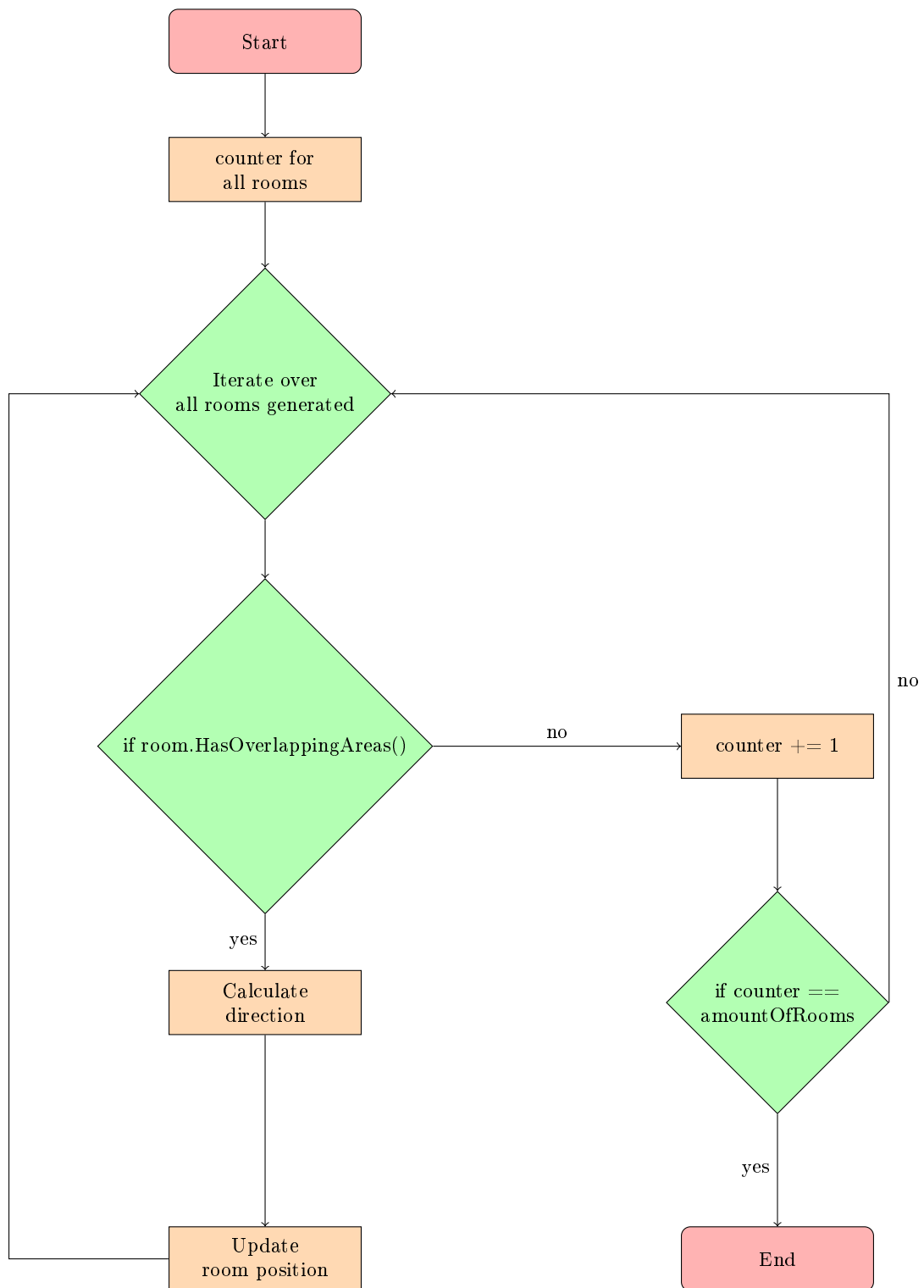


Figure 9: Flowchart for spreading rooms

Pseudocode

```
//this piece of code is called every frame until it develops as solution
checkedRooms = 0
for each room in all_rooms_generated
{
    if room.HasOverlappingAreas()
    {
        direction = Vector2.Zero //sets value to (0,0);
        for each overlappingRoom in room.GetOverlappingAreas()
        {
            displacement = room.Position - overlappingRoom.Position;
            direction += (1/displacement.Length()) *
                displacement.Normalised;
            //takes reciprocal of displacement and adds it to
            direction
        }
        //rounds towards nearest int and multiplies by step, which is a
        variable that scales up with amount of rooms as more rooms
        will need to spread further which optimizes the algorithm
        direction.X = (float)Math.Round(direction.X) * step;
        direction.Y = (float)Math.Round(direction.Y) * step;
        room.Position += direction
    }
    else
    {
        checkedRooms +=1;
    }
}
if (checkedRooms == amountOfRooms)
{
    //each room has been checked and doesn't have overlapping areas so
    algorithm finished
    //move onto next stage of generation
}
```

Once complete a result typically looks as such

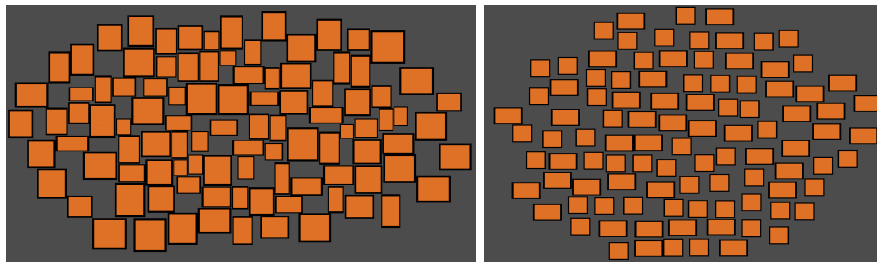


Figure 10: Result of room separation

After this process a pre-defined amount of rooms are deleted so that there are gaps in between the rooms, removing 60% of the rooms works well. On top of this the position of each room is multiplied by 2 to spread the rooms further

4.3.3 Delete Rooms

The rooms being too close together means that all the corridors will be short and it will be uneventful. Therefore deleting a certain percentage of rooms will make the level more interesting for the player as they will be spread unevenly. To spread the rooms apart further without having to generate more rooms and delete them we can also multiply the position of each room to spread them apart further. This will make the algorithm more efficient because the program doesn't need to generate more rooms to get the same effect.

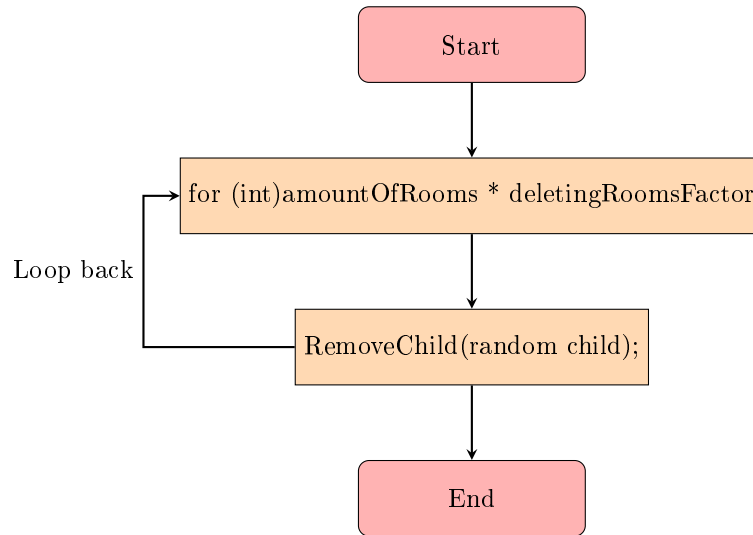


Figure 11: Flowchart for deleting rooms

Pseudocode

```

for (int)(amountOfRooms * deletingRoomsFactor);
{
    RemoveChild(random child);
}

```

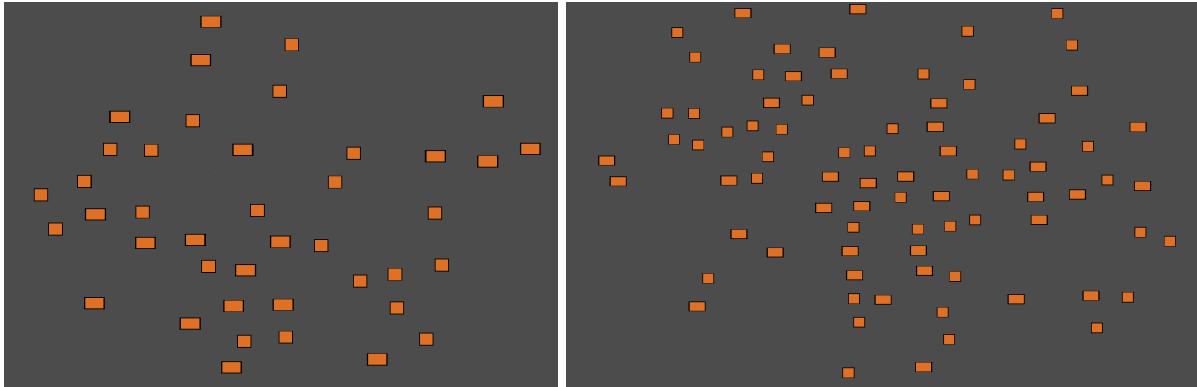


Figure 12: Result of room deletion

4.3.4 Delaunay Triangulation

The algorithm used in this section was taken from [Bwa] (Bowyer–Watson algorithm). For the algorithm to function I needed a data structure for points, which link the Area2D, position and a list of points which the point is connected to. Edges are an array of two points which represents a connection between two points. Triangles are an array of three edges and hence three points, from these a circumcircle can be drawn, which is important for the Bowyer-Watson algorithm, this is represented as a vector2 storing the circumcentre and a float for the radius.

Point
Public area: Area2D Private position: Vector2 Private connectedPoints: List<Point>
Public Constructor(Area2D area) Public Position() returns position Public ConnectedPoint() returns connectedPoints Public AlterPos(Vector2 newPos) updates position Public ConnectPoint(Point newPoint) adds point to connectedPoints

Edge
Private points: Array[2] Point
Public HasPoints(Point point1, Point point2) returns bool weather the edge has those points

Triangle
Private edges: Array[3] Edge Private points: Array[3] Point Private circumcenter: Vector2 Private radius: float
Public Constructor(List<Triangle> triangulation, Point point1, Point point2, Point point3) Public IsWithin(Point newPoint) returns a bool if a point lies within a triangles circumcircle Private ContainsEdge(Edge edgeToCompare) returns the edge if it already exists Private FindCircumcentre() updates circumcenter Private FindRadius() updates radius

Figure 13: Bowyer-Watson Classes

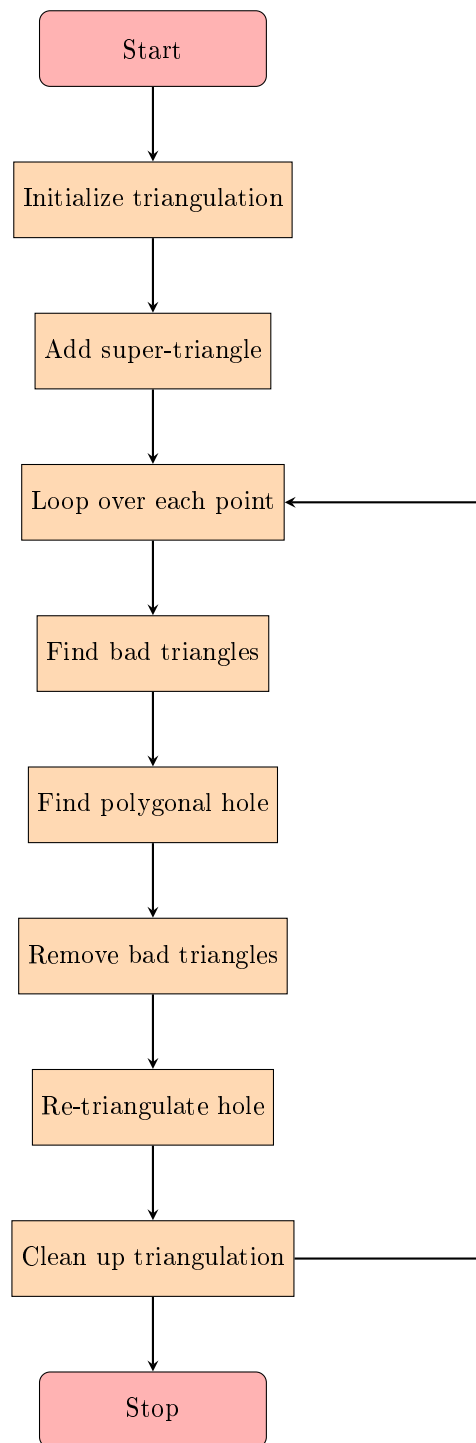


Figure 14: Bowyer-Watson Algorithm Flowchart

Pseudocode

The pseudocode was taken from [Bwa]

```
function BowyerWatson (pointList)
    // pointList is a list of points defining the points to be triangulated
    triangulation := empty list of triangles
    add super-triangle to triangulation // must be large enough to completely
    contain all the points in pointList
    for each point in pointList do // add all the points one at a time to the
    triangulation
        badTriangles := empty list of triangles
        for each triangle in triangulation do // first find all the triangles
        that are no longer valid due to the insertion
            if point is inside circumcircle of triangle
                add triangle to badTriangles
        polygon := list of edges
        for each triangle in badTriangles do // find the boundary of the
        polygonal hole
            for each edge in triangle do
                if edge is not shared by any other triangles in badTriangles
                    add edge to polygon
        for each triangle in badTriangles do // remove them from the data
        structure
            remove triangle from triangulation
        for each edge in polygon do // re-triangulate the polygonal hole
            newTri := form a triangle from edge to the new point
            add newTri to triangulation
    for each triangle in triangulation // done inserting points, now clean up
        if triangle contains a vertex from original super-triangle
            remove triangle from triangulation
    return triangulation
```

The pseudo code states that there needs to be triangles, edges and points. These structures can be achieved with object oriented programming as I can make a class with all the relevant attributes and methods for each data structure mentioned.

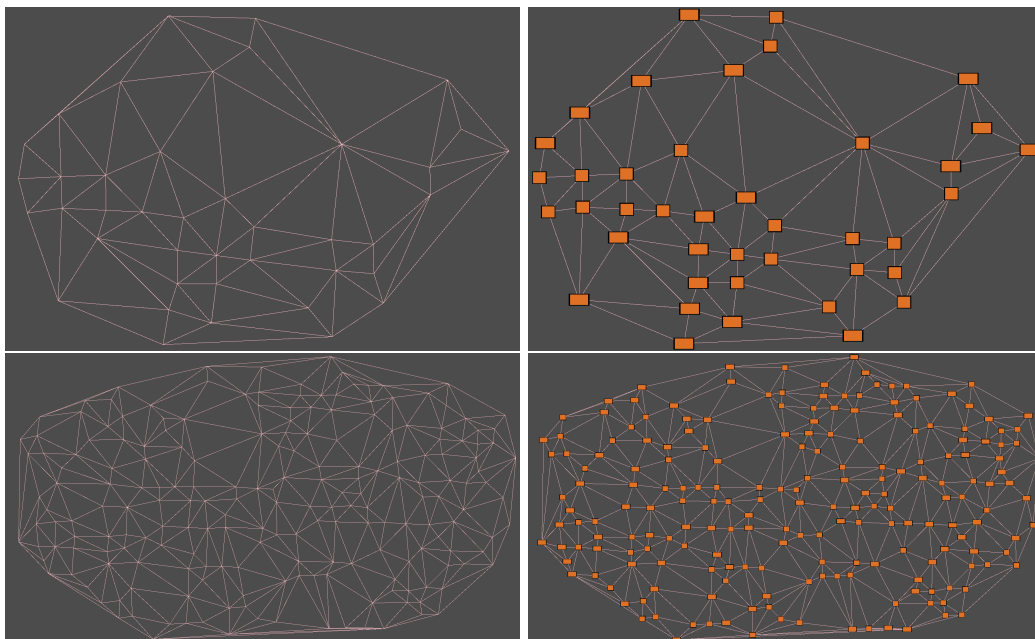


Figure 15: Result of Bowyer-Watson algorithm

4.3.5 Remove random amount of edges

Figure 15 shows the result of the algorithm, however this many corridors would be overwhelming for players and would result in each room having 4-5 corridors leading out of it, which would could overwhelm the player. Other rouge-like games usually contain 2-3 corridors leading out of it, this would mean I needed to delete some of the edges but still make sure all the rooms are accessible.

Currently the mesh is stored as a list of edges. So to remove a certain amount I can make a copy of the list and then remove a random amount of edges. However C# passes the list by reference so any alterations on the copy of the list will also alter the original. Therefore I made a new empty list and added a random amount of edges from the original list.

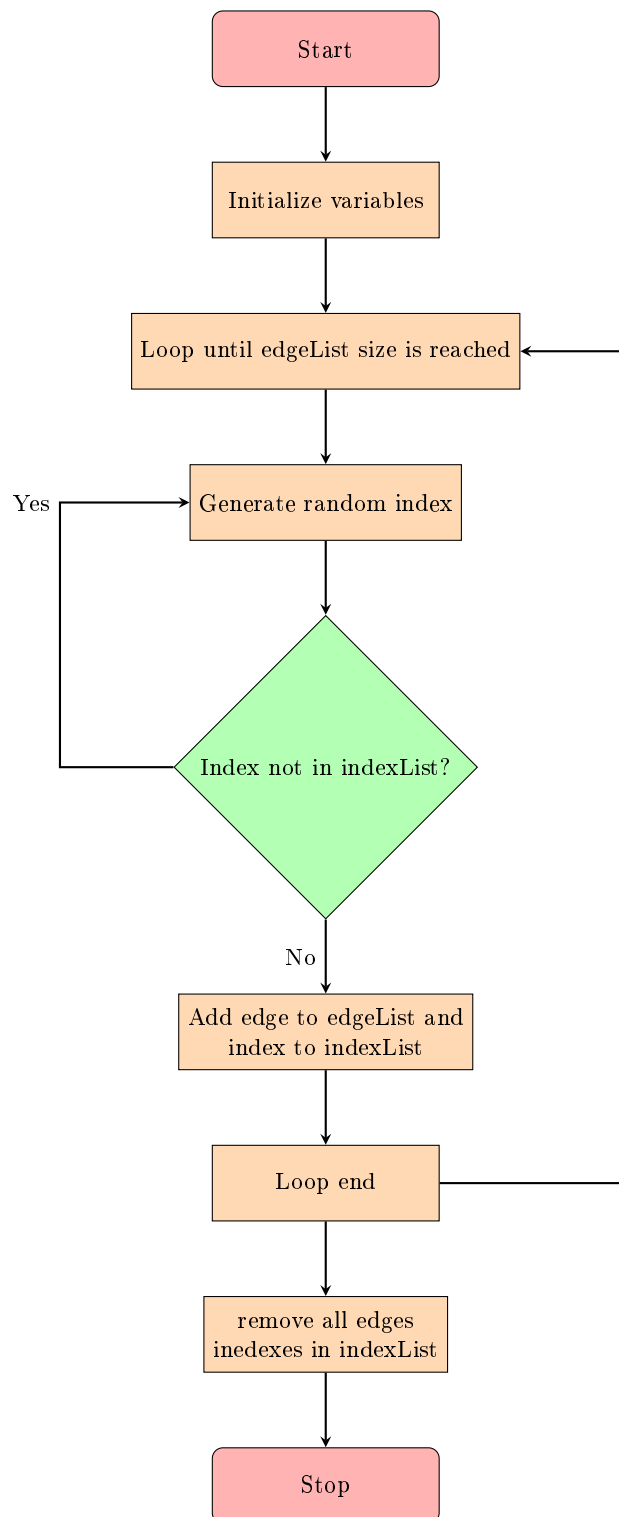


Figure 16: Flowchart for Edge Deletion Algorithm

Pseudocode

```
float edgeDeletingFactor; //number between 0-1 representing how much edges to
    keep
List<Edge> polygon; //List of edges from triangulation stage
List<Edge> edgeList = new List<Edge>();
List<int> indexList = new List<int>();
int newIndex;
while (edgeList.Count() < (int)(polygon.Count()* edgeDeletingFactor))
{
    newIndex = RandomIntBetween(0,polygon.Count())
    //this part ensures there is no duplicates in edgeList
    if (!indexList.Contains(newIndex))
    {
        edgeList.Add(polygon[newIndex]);
        indexList.Add(newIndex);
    }
}
```

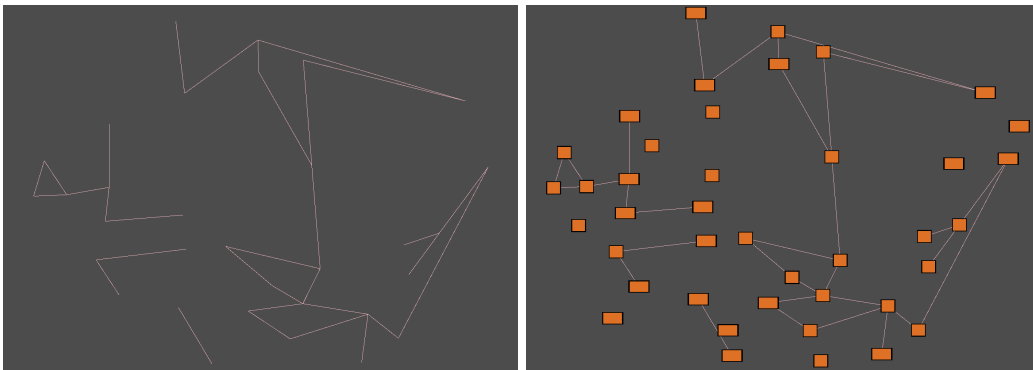


Figure 17: Deleting edges result

However this creates a problem as now some of the rooms are inaccessible because they have no edges connecting to them or are in another inaccessible section. This is solved in the next section.

4.3.6 Make sure all rooms are accessible

This section can be decomposed into smaller problems. That being detecting sections and connecting sections. First comes detecting sections, this is accomplished more easily when the the graph is represented with list of points along with each point having a list of points it's connected to. Currently the graph is represented as a list of edges. This can be done with a simple algorithm explored further in the "Turning list of edge to graph" section.

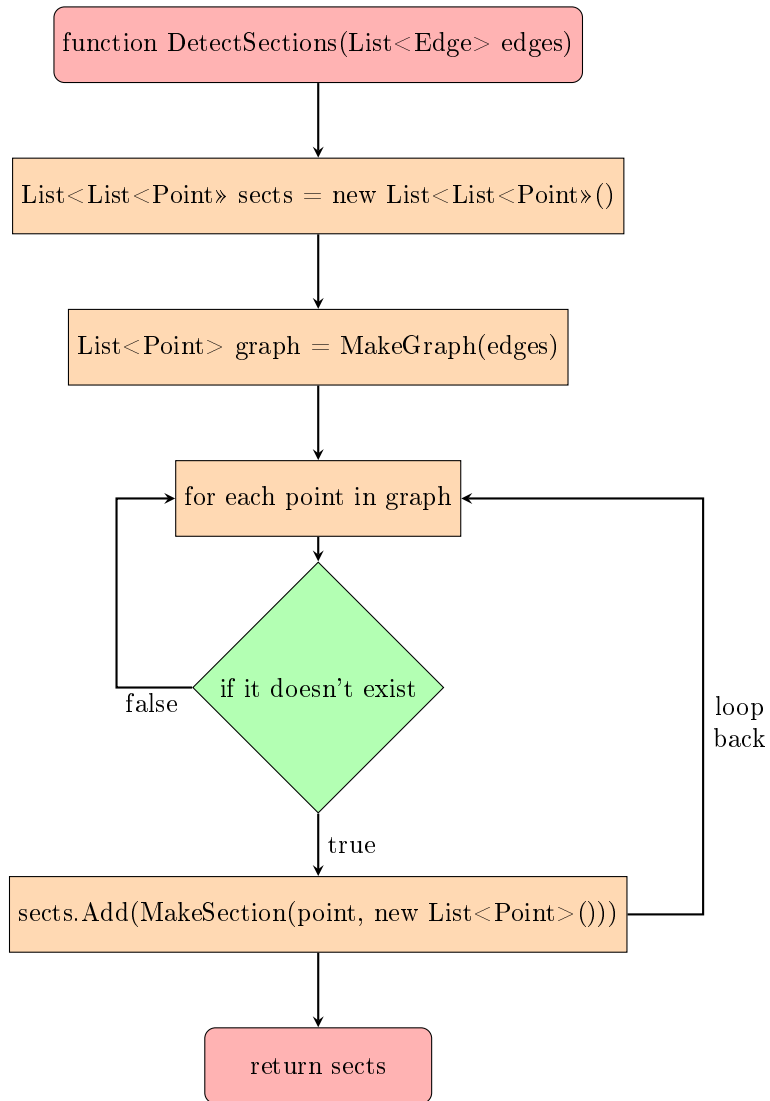


Figure 18: Flowchart for detecting if a new section needs to be made

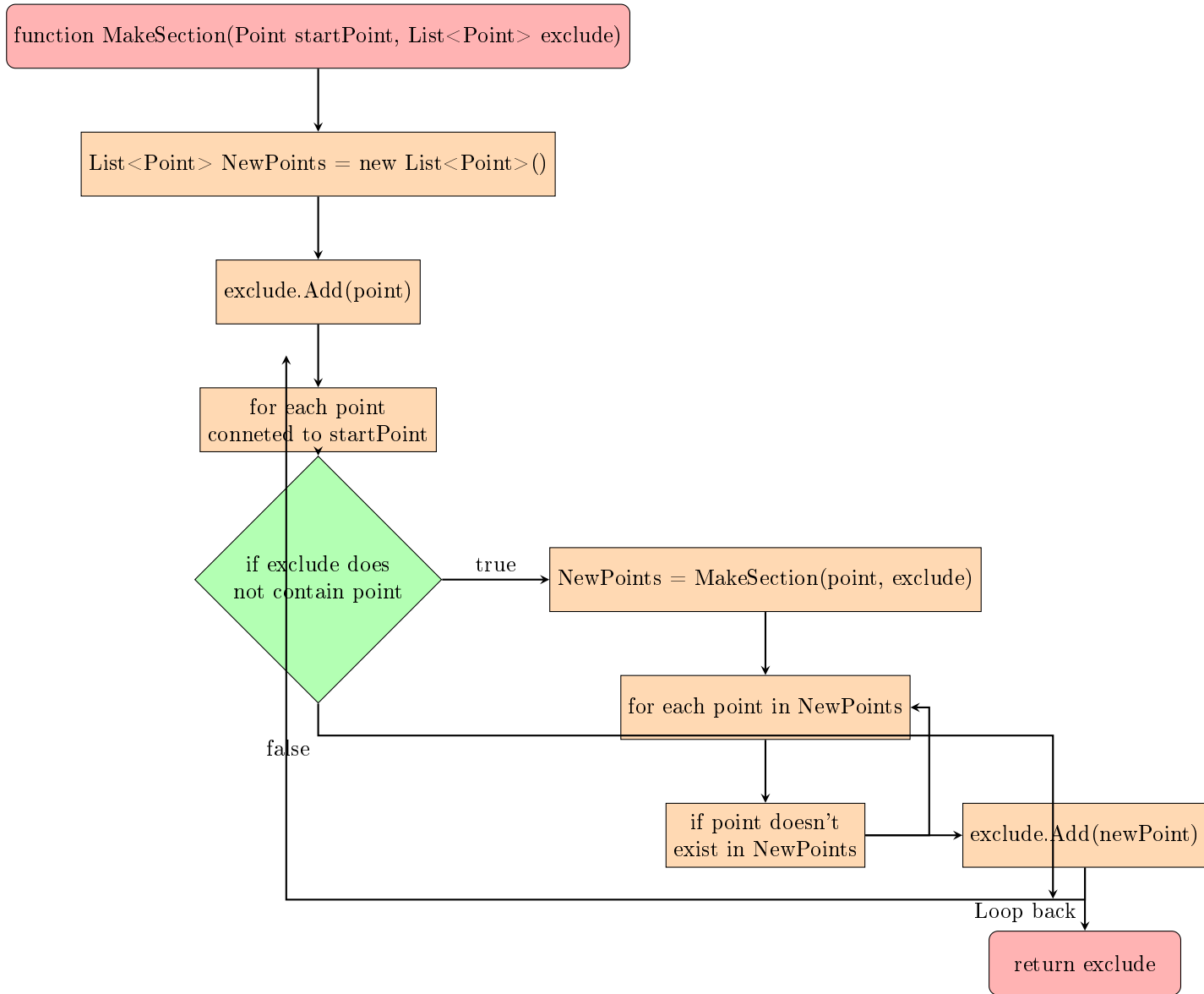


Figure 19: Flowchart for the given pseudocode

Pseudocode

Algorithm for detecting whether a new section needs to be made given a list of edges

```
function DetectSections(List<Edge> edges)
//list of section, each section is a list of points
List<List<Point>> sects = new List<List<Point>>()
List<Point> graph = MakeGraph(edges)
for each point in graph
{
    check whether point already exists in sects

    if it doesn't exist start a new section with the not existing point as
    starting point
    {
        //add section to list of sections
        sects.Add(MakeSection(point, new List<Point>()))
    }
}
return sects
endfunction
```

Recursive algorithm for detecting a section, given a starting point

```
function MakeSection(Point startPoint, List<Point> exclude)
List<Point> NewPoints = new List<Point>()
//add current startPoint to list of points to exclude
exclude.Add(point)
for each point in startPoint.Connectedpoints
{
    //branch out when point isn't already detected and is connected
    if exclude does not contain point
    {
        NewPoints = MakeSection(point, exclude)
        for each newPoint in NewPoints
        {
            if (newPoint doesn't exist in NewPoints)
            {
                exclude.Add(newPoint)
            }
        }
    }
}
return exclude
endfunction
```

Now that I am able to detect sections we want to connect them. This is done by saving the list of edges from the triangulation section and finding the difference between the list after removing edges.

```
//code called once before main loop is started
//polygon is all the edge after triangulated
//polygonEdgeList are the edges left over after deleting a random amount
//polygonDifference is polygon - polygonEdgeList
List<Edge> polygonDifference(polygon, polygonEdgeList)
List<List<Point>> sections = DetectSections(polygonEdgeList)

//code inside the main loop that runs every frame
if (sections.Count != 1)
{
    //need to add points until there is only one section left
    int index = RandIntInRange(0, polygonDifference.Count - 1)
    //remove random edge from polygonDifference and add it to
    polygonEdgeList
    polygonEdgeList.Add(polygonDifference[index])
}
```



```

polygonDifference.RemoveAtIndex(index)
sections = DetectSections(polygonEdgeList)
}
else
{
    //remove rooms with no edges connected to them
    List<Point> graph = MakeGraph(polygonEdgeList)
    //all rooms are represented with an Area2D data type (custom structure
    //made by godot) and need to check if children(the rooms) of the
    //object are a point in the edgeList
    for each child in GetChildren
    {
        if (a point in graph doesn't have same position as a child)
        {
            //In this case the child isn't considered for in the
            //edgeList
            RemoveChild(child)
        }
    }
    //move onto the next stage of generation
}
}

```

4.3.7 Turn edges into horizontal and vertical

The movement system isn't optimised for edges that are angled in such obscure ways as seen in figure 17. Therefore it's important to change the edges into it's vertical and horizontal components to make the level more traversable for the player. Originally I was going to create an advanced network to connect all the points in the most efficient way possible, but looking at how long it took me to implement delaunay triangulation I decided against it as it would take too long. So instead I created an algorithm that generates all possibilities to make sure all rooms are accessible.

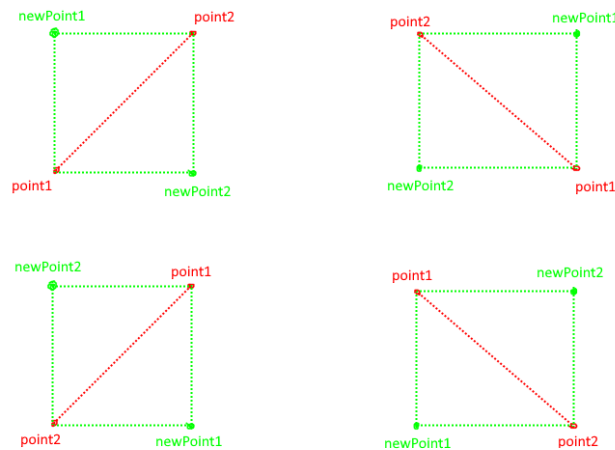


Figure 20: All possibilities for points

The green dotted lines in figure 20 shows where the new edges would be placed when they are replacing the old red edges. This does mean that each edge creates 4 new edges that will likely overlap with other edges, however once this is turned into a tilemap this isn't a problem as all these objects will be deleted.

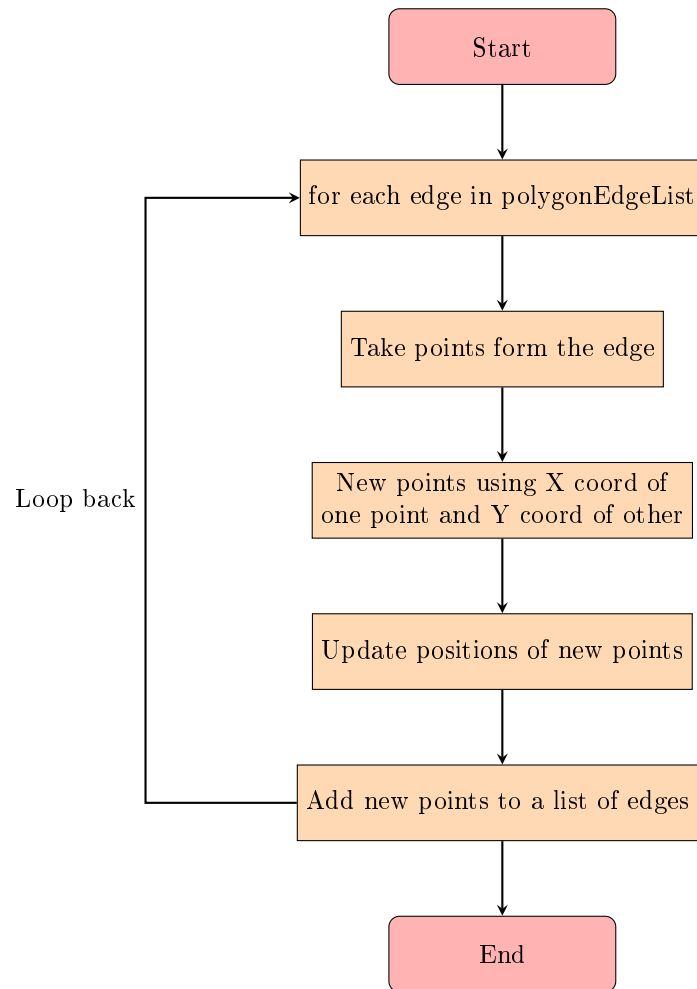


Figure 21: Flowchart for the given pseudocode

Flowchart[h]

Pseudocode

```

polygon = new list of edges
//polygonEdgeList is a list of Edges from previous section
for each edge in polygonEdgeList
{
    //take position from points in edge in list
    Point point1 = edge.points[0];
    Point point2 = edge.points[1];
    //new temp point with no values
    Point newPoint1 = new Point(null);
    Point newPoint2 = new Point(null);
    newPoint1.AlterPos(new Vector2(point1.position.X, point2.position.Y));
    newPoint2.AlterPos(new Vector2(point2.position.X, point1.position.Y));
    //all possible paths made and stored in new list of edges (polygon)
    polygon.Add(new Edge(point1, newPoint1));
    polygon.Add(new Edge(point2, newPoint1));
    polygon.Add(new Edge(point1, newPoint2));
    polygon.Add(new Edge(point2, newPoint2));
}
  
```

The pink lines are the edges before the rooms were generated. The green boxes are the result of this algorithm plus the generate corridors algorithm but it shows the algorithm well so it's included in this section.

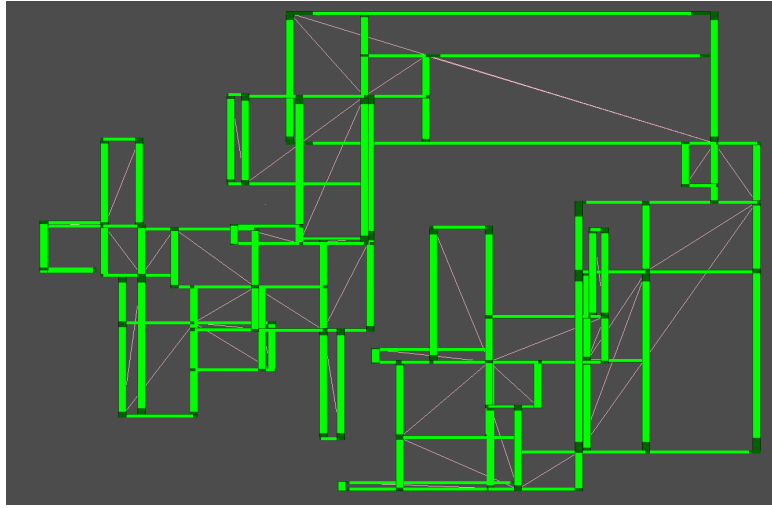


Figure 22: Before (pink) and after algorithm (green)

4.3.8 Generate corridors

4.3.9 Turn into tile map

4.3.10 Spawn player

5 Evaluation

References

- [Bwa] *Bowyer–Watson algorithm*. Accessed: 07/12/23. URL: [https://en.wikipedia.org/wiki/Bowyer–Watson_algorithm](https://en.wikipedia.org/wiki/Bowyer%E2%80%93Watson_algorithm).
- [Cel] *Celeste on Steam*. Accessed: 25/09/2023. URL: <https://store.steampowered.com/app/504230/Celeste/>.
- [Dis] *Comparing Algorithms for Dispersing Overlapping Rectangles*. Accessed: 05/12/23. URL: <https://mikekling.com/comparing-algorithms-for-dispersing-overlapping-rectangles/>.
- [Gen] *Procedurally Generated 3D Dungeons*. Accessed: 05/12/23. URL: <https://www.youtube.com/watch?v=rBY2Dzej03A>.
- [Rws] *Rain World on Steam*. Accessed: 25/09/2023. URL: https://store.steampowered.com/app/312520/Rain_World/.
- [Ror] *Risk of Rain 2 on Steam*. Accessed: 25/09/2023. URL: https://store.steampowered.com/app/632360/Risk_of_Rain_2/.
- [Shs] *Steam Hardware & Software Survey: November 2023*. Accessed: 21/12/2023. URL: <https://store.steampowered.com/hwsurvey/Steam-Hardware-Software-Survey-Welcome-to-Steam>.
- [Spe] *System requirements*. URL: https://docs.godotengine.org/en/stable/about/system_requirements.html#exported-godot-project.