Level Design Parameterization & Automated Playtesting in 3D Action Games

Bachelor's Thesis

Video game design and development

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Index

Summary

In the current video game map-making era, automated workflows have begun to arise as industry standards. Beyond automated map generation, there exists a technique which combines human design with AI feedback: automation testing.

Unbeknownst to many, an automated playtesting can be carried out with a heavy focus on level design. That is to say, a video game level can be numerically designed so that an AI navigates said level to then extract feedback via objective evaluations.

These evaluations must be based on a level design "parameterization" model, in which the designer defines which variables are involved in the map's fitness as a proposal and, at the same time, how these variables affect each other.

Beyond map navigation, the AI is meant to recreate human behaviour, by implementing some sort of player type, with different motivations and skill levels so that each AI variation prioritizes certain actions above others.

Figure 0.1: Unity logo

Unity Game Simulation, an extension of the video game engine *Unity*, the tool of choice, offers up to 500 simulation hours, which translates to the possibility of running each instance with different parameters to recreate a sample of players.

Key Words

Parameterization, game, level, design, Unity, automated, playtesting, AI, simulation

Tables Index

Figures Index

Glossary

1. **Weighted graph**: representation with nodes that have numeric values and connections between them which can also have numeric values.

2. **Shooter**: video game subgenre where a player engages in combat by using firearms (can include use of grenades, armor, etc)

3. **A-RPG** (also “Action-RPG”): video game subgenre that combines action and RPG elements

4. **Beat ‘em up**: video game subgenre that emphasizes hand to hand combat with large numbers of surrounding opponents.

5. **Dungeon Crawler**: video game subgenre with a labyrinth-like map and elements such as treasures, traps, etc.

6. **Platformer**: video game subgenre where a great part of the challenge relies on moving between disconnected points.

7. **RLD** (Rational Level Design): paradigm where each element (obstacles, distances, etc) within a video game level is quantifiable.

8. **Player persona**: set of psychological nuances that represents a human-like profile.

9. **Unity**, **Unreal**: free to use, popular game engines in the world.

10. **Engine**: set of pre-made tools designed for game creation and similars.

11. **Package**: in the context of Unity, an extension to the core engine.

12. **Triple A** (also “AAA”): video games classification according to high standards in terms of budget, publishing, quality, innovative technologies involved, etc.

13. **Convolutional Neural Network (CNN)**: deep neural network applied to images.

14. **Genetic algorithm**: algorithm inspired by natural selection; focused on crossing variables of instances with the best fitness function

15. **Fitness function**: function used to the determine the best performing instance in a genetic algorithm

16. **Bartle type**: classification of video game players according to their preferred actions within the game [Wikipedia]

17. **Playthrough**: from start to finish, in the context of a game, level or prototype

1. Introduction

1.1. Motivation

From the very moment I discovered video games, I have been inevitably attracted to their maps and environments.

Those maps, as I would discover on my own while creating levels, are crafted by employing vast amounts of design guidelines and all sorts of tricks.

As a map creator, I thus concluded that, in order to speed up the process and better the result, I could apply those techniques by means of an automated workflow.

Said workflow would permit level designers analyze their work by using AI capable of translating those design guidelines into map navigation and feedback.

Finally, I decided to delimit my thesis inside the 3D action genre provided that therein lie a series of subgenres with substantial map differences that can share level design variables/principles, albeit with some singularities.

Figure 1.1: CSGO's (a tactical shooter) popular map, "Mirage"

1.2. Problem Formulation

Traditionally, to test and iterate their work, level designers had one tool at their disposal: human playtesting.

This concept, however, quickly became tied with a set of hindrances:

- Humans give highly subjective and likely contradictory feedback.
- Human playtesting is slow in comparison to computation.
- Humans require accommodation.

Therefore, video game companies have shyly started to combine human playtesting with AI automation.

Concretely, some studios rely on automated tests to evaluate isolated mechanics in their games, although there are no guidelines for automated playesting applied to maps.

That is to say, *"level design parameterization"*, also referred to as the phenomena where a set of variables with different magnitudes are attributed to a level, lacks a reference model in the global map making scene and thus an automated playtesting nowadays cannot emanate from said model.

1.3. General Objectives

- Study parameterization in different 3D action subgenres. Design a weighted graph[1] model for the main subgenres
  - *Shooter*[2]
  - *A-RPG*[3]
  - *Beat 'em up*[4]
  - *Dungeon Crawler*[5]
  - *Platformer*[6]

  The weighted graph would contain variables such as "cover", with a value ranging from 0 to 10. In this particular case, a *Shooter* would have a much higher value than a *Beat 'em up*

- Create an automated playesting environment and gather level data via AI.
  In order to achieve this ecosystem, the automated playtesting must be based in one of the above subgenres. The following elements are therefore needed:
  - A navigable map based on *RLD*[7]
  - Intelligent AI that can analyze the level and compare it with the model.
  - A simulation tool that permits several playthroughs with input variations.
  - Enemies, coins, and/or similar perks that can entail challenge and/or objectives.

- Compare the automated playtesting with human playtesting. Within the same conditions, humans will play the level and give their corresponding feedback. Analyze the advantages and disadvantages of both in regards to giving useful feedback that can convert into tangible level improvements.

1.4. Specific Objectives

- Gather or create an RLD based map. Either way, said map must be based on RLD and must also have apparent imbalances that should be pointed out during both playtestings.
- Implement different *player personas*[8] for the AI. These variations will be used as input parameters to provoke different results and to mimic real-life player motivations, i.e. “kill all enemies”, “gather all coins”, etc.

1.5. Project Scope

As previously mentioned, the theoretical section will encompass a total of 5 subgenres and, in order to define a model for each, it is my intention to expand on map case studies.

As for the prototype, the tool of choice is *Unity*[9] and its *Unity Game Simulation package*[10], which provides for up to 500 free simulation hours.

The resulting tool (and even the theoretical parameterization models) could be used by level designers around the globe, although the prototype is meant to be case-specific, since it has map design requirements.

2. State of the Art

Automated playtesting is not an industry standard per se. Concretely, this technique is usually limited to simple puzzle games. Moreover, other techniques such as procedural level generation are more established.

Commercial video games, even *triple A*[12] games, are beginning to introduce automated playtesting into their pipelines.

However, there are three main domains that provide valuable information on the topic:

- Commercial video games.
- Video game engines with automated playtesting plugins.
- Various papers that propose techniques so as to expand on level analysis and automated playtesting.

As far as level parameterization is concerned, there are no studies that define a model that represents level design by means of pure numbers. In relation to the topic, nonetheless, there is one concept that is needed for a level to be measured accordingly: *rational level design (RLD) [6]*

2.1 Unity

Unity provides for a framework, *Unity Game Simulation* [1], that offers up to 500 cloud simulation (using their own servers) hours. In their proposal, the application in context is executed a certain number of times.

The simulation is composed by metrics, parameters and test cases:
“Metrics are the results of a playthrough that are important to the balance or health of the game. Test cases are the different scenarios that you’d like to measure within a game. Finally, parameters are the configurations that can change your game, thus directly impacting your metrics.” (Willis Kennedy, 2020, p.1) [1].

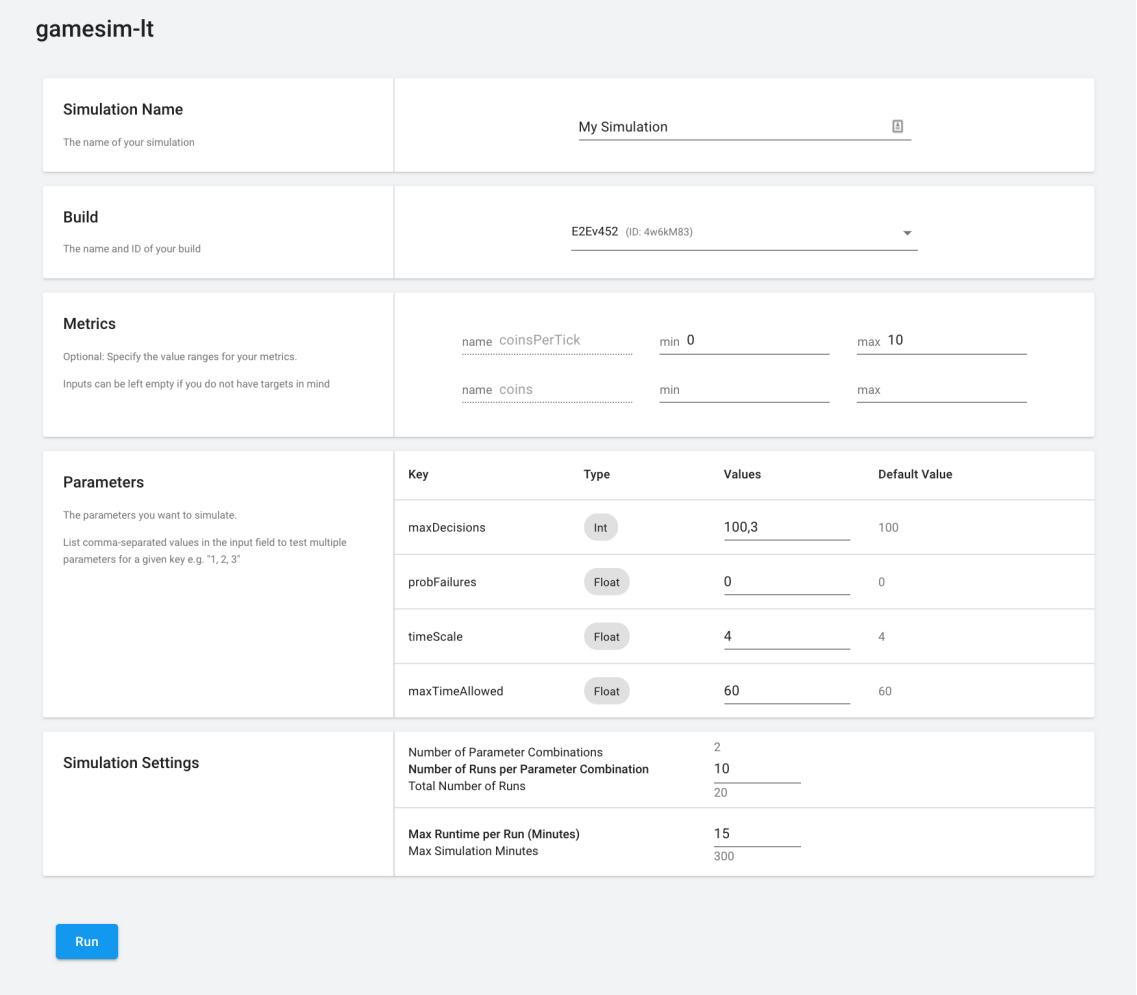


Figure 2.1: Simulation details and settings in *Unity Game Simulation*

2.1.1 Death Carnival

Death Carnival, developed by *Furyion*, *"is a fast-paced top-down shooter with extreme weapons and online multiplayer mayhem" (Furyon Team, year not specified, p.1) [2].*

As mentioned in the article, *Death Carnival* utilized *Unity Game Simulation* to balance the weapons in the game. Concretely, three base weapons were used as test cases, weapon variables as parameters and survivability was the chosen metric.

According to the development team, by using this package they were able to achieve the equivalent of 165 million human playthroughs in limited time.

2.1.2 Rogue Racers

Rogue Racers, developed by *iLLOGIKA*, *"is a mobile freemium racer pitting heroes against each other as they dash through richly illustrated landscapes".*

In the case of *Rogue Racers*, each character's cards (powers or abilities), chosen from a pool, needed to be balanced.

Instead of having to manually balance each possible combination, they were able to run 25000 games in four hours.

2.2 Unreal

Unity's competitor, *Unreal*, also incorporates an automation system.

Test Type	Description
Unit	API level verification tests. See **TimespanTest.cpp** or **DateTimeTest.cpp** for examples of these.
Feature	System-level tests that verify such things as PIE, in-game stats, and changing resolution. See **EditorAutomationTests.cpp** or **EngineAutomationTests.cpp** for examples of these.
Smoke	Smoke tests are just considered a speed promise by the implementer. They are intended to be fast so they can run *everytime* the Editor, game, or commandlet starts. They are also selected by default in the UI . **WARNING** All Smoke tests are intended to complete within 1 second. Only mark Unit Tests or fast Feature Tests as Smoke Tests.
Content Stress	More thorough testing of a particular system to avoid crashes, such as loading all maps or loading and compiling all Blueprints. See **EditorAutomationTests.cpp** or **EngineAutomationTests.cpp** for examples of these.
Screenshot Comparison	This enables your QA testing to quickly compare screenshots to identify potential rendering issues between versions or builds.

Figure 2.2: *Unreal*'s Automation System test types

Unlike *Unity Game Simulation*, Unreal's proposal does not provide for options such as running the test a certain amount of times per simulation or altering parameters for each simulation instance.

2.2.1 Sea Of Thieves

The triple A[12] video game *Sea Of Thieves* (about sailing and pirates) expanded *Unreal*'s automation system to fit their needs.

Although they did not provide any example of what a "map test" constitutes, one can still notice that map tests are relatively less employed than actor tests ("actor" meaning entities such as a character).

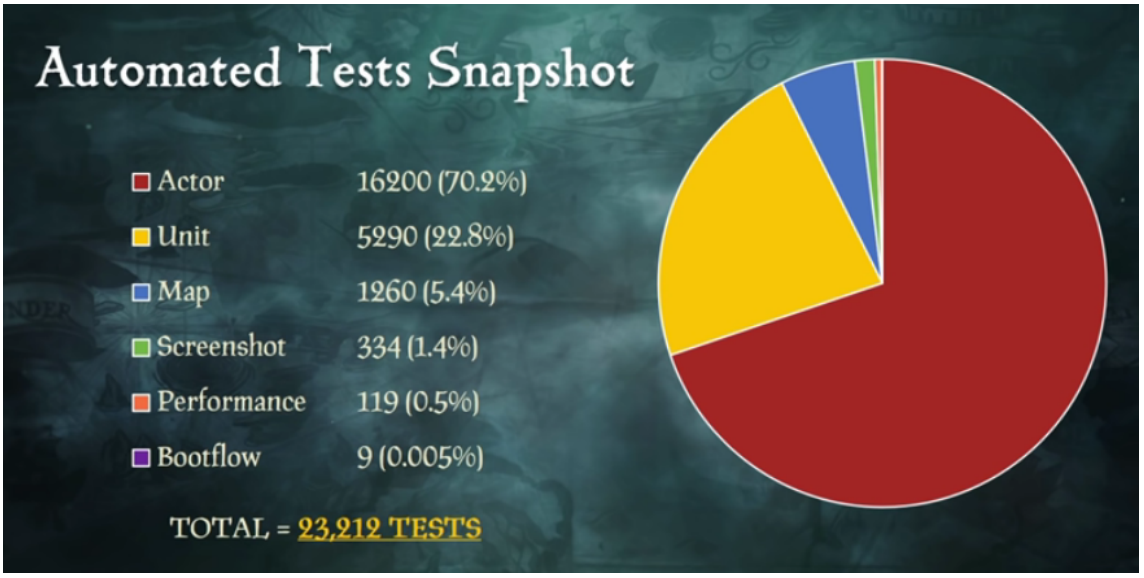


Figure 2.3: Proportion of tests according to type

Actor tests are commonly performed by mimicking the player's input.

Figure 2.4: Sample test where the boat's wheel is steered

Another aspect about automated testing, and in video games in general, is latency. They expand on how latency can alter a test result, since the time it takes to communicate with the simulation server can result in the logic being executed in bigger time intervals.

This phenomenon can lead to, for instance, a cannonball being represented before and after hitting a ship, but not while inside the ship's area, so collision may not be detected.

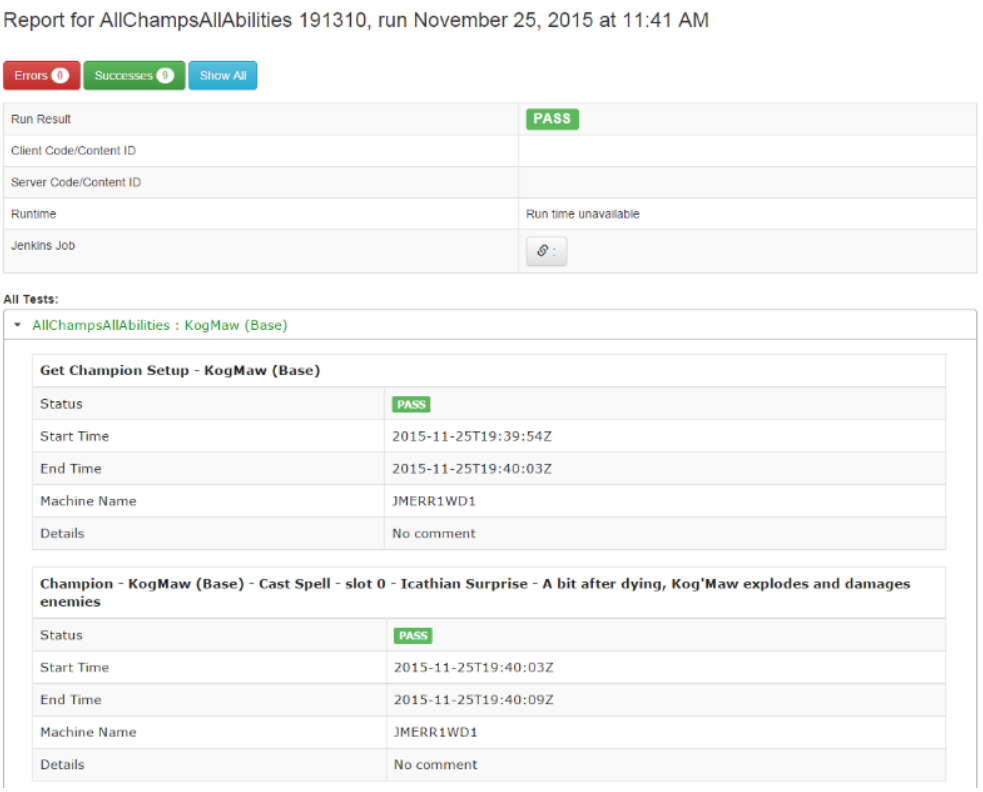
2.3 Other Games

Beyond the mainstream video game engines, other games use their own solutions.

2.3.1 Riot Games

Similarly enough to *Unity*, *Riot Game*'s star game's (*League Of Legends*) automation system is suited for, but not exclusively, altering input parameters for each test instance in order to, for instance, test each champion's' (character) abilities.

Figure 2.5: Sample test in *League Of Legends*



Report for AllChampsAllAbilities 191310, run November 25, 2015 at 11:41 AM

Errors 0 | Successes 9 | Show All

Run Result	PASS
Client Code/Content ID	
Server Code/Content ID	
Runtime	Run time unavailable
Jenkins Job	

All Tests:

AllChampsAllAbilities : KogMaw (Base)

Get Champion Setup - KogMaw (Base)	
Status	PASS
Start Time	2015-11-25T19:39:54Z
End Time	2015-11-25T19:40:03Z
Machine Name	JMERR1WD1
Details	No comment

Champion - KogMaw (Base) - Cast Spell - slot 0 - Icathian Surprise - A bit after dying, Kog'Maw explodes and damages enemies	
Status	PASS
Start Time	2015-11-25T19:40:03Z
End Time	2015-11-25T19:40:09Z
Machine Name	JMERR1WD1
Details	No comment

Figure 2.6: test result interface in *League Of Legends*

2.4 Level Design Parameterization & Other Approaches

Although popular video game *engines* and several video games in general have begun to incorporate automation testing into their pipelines, there is a lack of real-world examples in the field of level design parameterization.

Nonetheless, there is not a lack of research. Concretely, there exist papers that expand on innovative techniques more targeted towards level design.

2.4.1 Learning the Patterns of Balance in a Multi-Player Shooter Game [3]

This first experiment proposes the use of a *Convolutional Neural Network (CNN)*[13] with the purpose of evaluating the balance in a level with two teams, depending on the weapons used in each team.

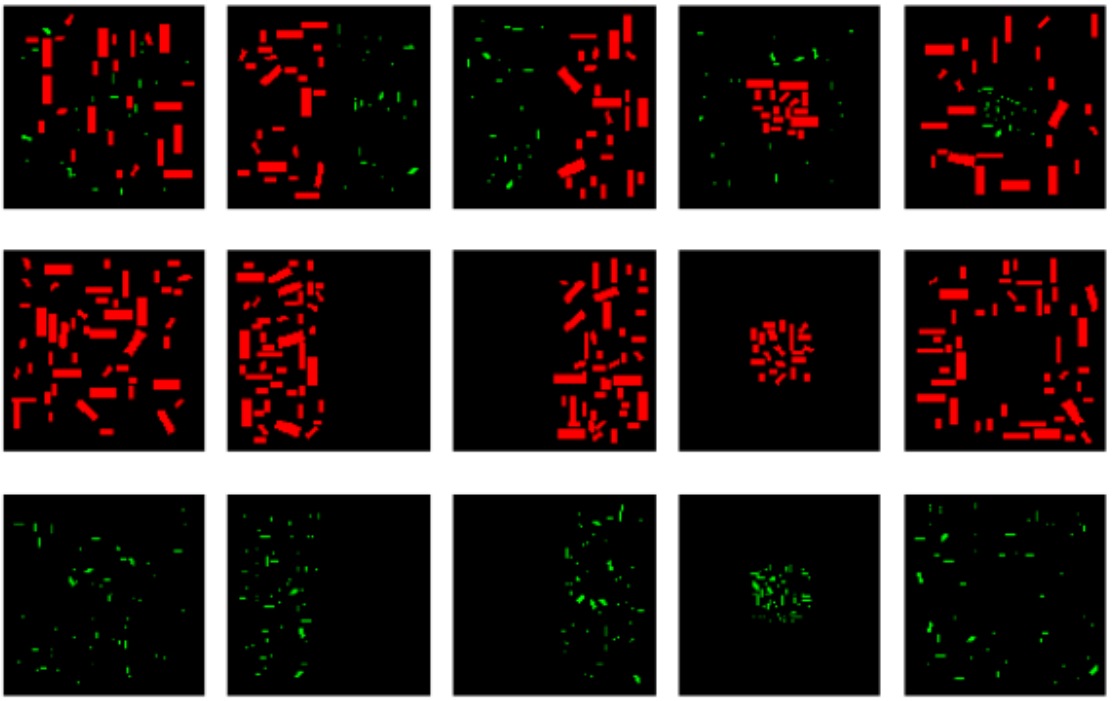


Figure 2.7: Sample level top-down images

To achieve that goal, levels are represented as the image above, from a top-down view where 3 types of geometry configure the map: wall, high wall and empty space. The *CNN* then receives these images as input, along with weapon type by team, to calculate balance and conclude if the level is one sided or balanced.

2.4.2 Evolving Interesting Maps for a First Person Shooter [4]

This paper combines the concepts of *genetic algorithm*[14] and *fitness function*[15].

Firstly, the experiment employs 4 different generators to create a set of maps. To evaluate these maps, the *fitness function*, which is represented by the sum of:

- Average fighting time per player
- Surface of all empty tiles

Only then, a *genetic algorithm* is applied, for 50 generations, in the case of each generator. That is to say, each of the generator's levels were evolved 49 times by tweaking parameters, selecting the ones with the best fitness score and then crossing their variables.

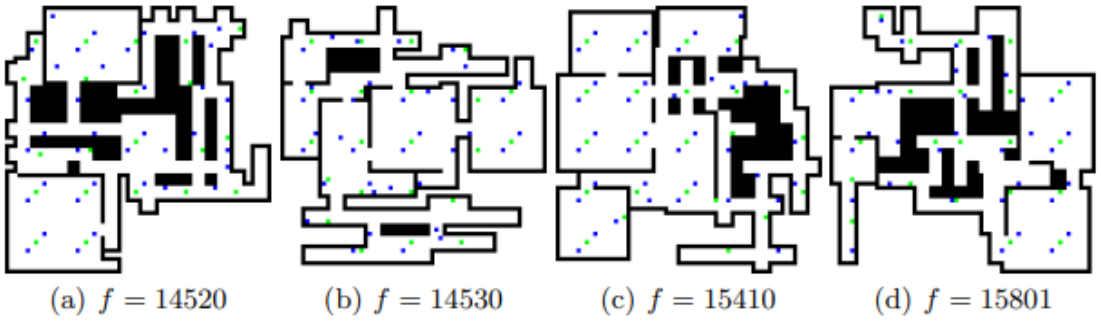


Figure 2.8: 50th generation maps pertaining to one generator

2.4.3 Automated Playtesting with Procedural Personas through MCTS with Evolved Heuristics [5]

In order to achieve an automated playtesting, the video game is in need of an entity, a character, that can represent humans in regards to their primal needs and psychology.

In the study, a total of 4 "*player personas*" are generated, which, in practical terms, means that for each of them there is a function that prioritizes certain actions/goals according to their *Bartle type*[16]: killing monsters, collecting coins…

Each player has a set of altered variables and the experiment employs the same technique as the study above, genetic algorithms. although applied to players instead of levels.

Evolving personas can simulate real-life imbalances between different skill levels and mimics more accurately a sample of gamers.

2.4.4 Rational Level Design (RLD)

The concept of Rational Level Design stems from that of Rational Game Design, which overall refers to a design that can be measured and therefore scaled and evaluated numerically.

The example provided in [6] proposes a series of platforms that are numerically displaced and their numbers altered in order to increase difficulty in a controlled manner.

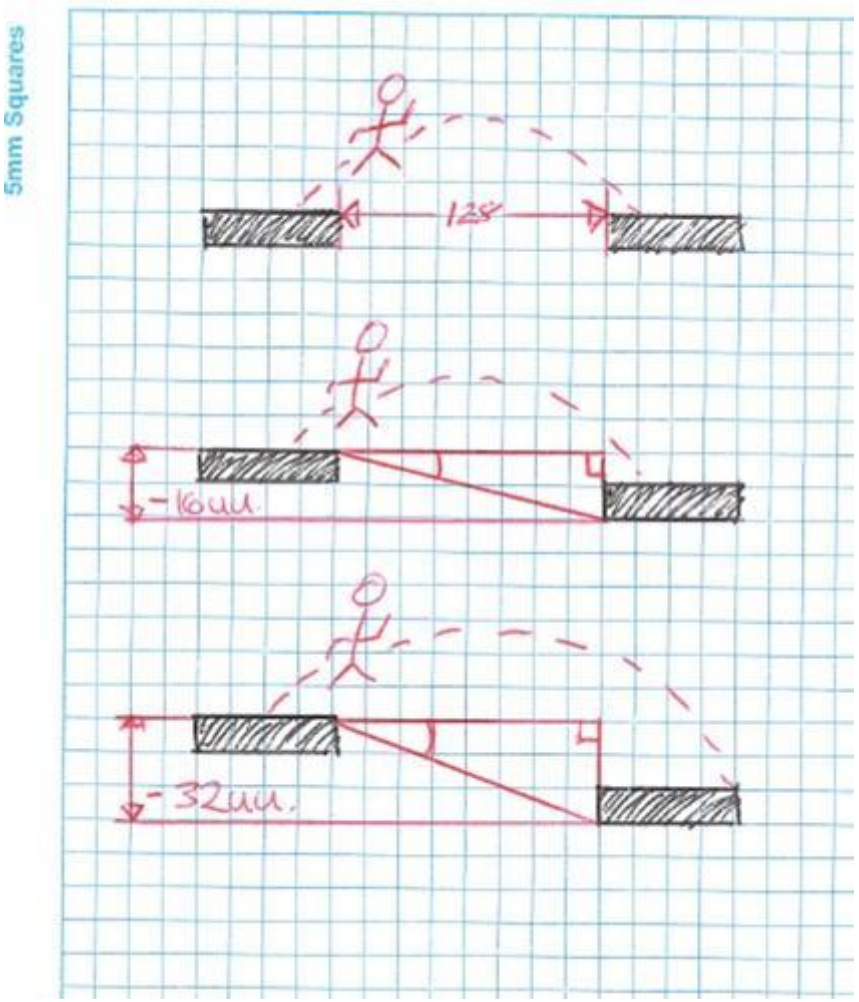


Figure 2.9: As shown in [6], an example of a numerically designed level section

In terms of automated playtestings, this approach to level design facilitates the AI's evaluations while navigating the level.

2.4.5 Level Design Theory

Although not expressed in terms of concrete parameterization, ample research has been done in the field of level design, with a popular forum specially dedicated to the shooter genre, *Mapcore*.

Concretely, a level design website is cited, http://level-design.org/, which contains a section for relevant level design elements.

Amongst others, there are selected few that could potentially be evaluated in an automated playtesting, or at least be more suited:

- **Balance**:

  From creating team vs team environments with equal possibilities for both (although with some imparities that offer interest to each side) to the art of tweaking events in the level to keep the match competitive (*rubberbanding*), balance is a key element in level design across the genres.

Map	Play Rate	Attack Winrate	Defense Winrate	Attack K/D	Defense K/D
Haven	23.9%	48.1%	51.9%	1.01	1.1
Icebox	4.9%	48.9%	51.1%	1.04	1.04
Bind	24.1%	46.8%	53.2%	1.01	1.11
Split	23.4%	46.3%	53.7%	1	1.11
Ascent	23.7%	46.5%	53.5%	1.01	1.11

Figure 2.10: map balance in the competitive online shooter *Valorant*

In regards to automated playtesting, balance is one of the most, if not the most, common element of interest to be tested.

As explained in 2.4.1, Daniel Karavolos *et al.* trained in 2017 map generators that would create different levels. The results of this experiment were expressed both in terms of balance between each team (win rate), also depending on weapons used.

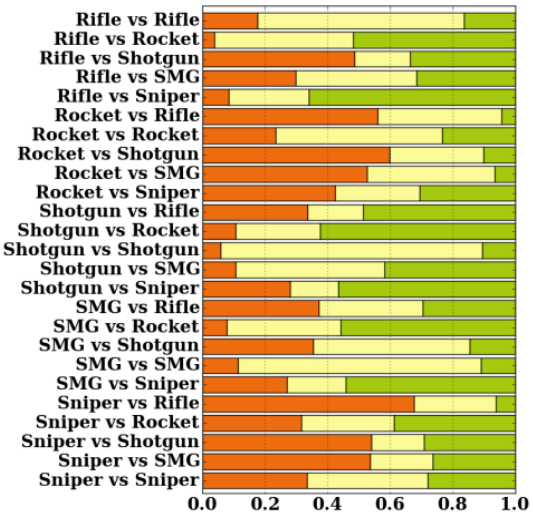


Figure 2.11 (D. Karavolos *et al.,* 2017, p.5)

- **Challenge, Fun, Flow**:

  Within any game level, the element of challenge arises. In an automated playtesting, the AI is meant to replicate a player with a certain skill level.

  Basic human psychology tells us that challenge and fun are directly related and thus a flow theory can be generated, where "flow" represents a satisfactory mind state where the player is neither overwhelmed nor underwhelmed by the gameplay.

  A possible method for evaluating the AI's flow state is to take into consideration the amount of surrounding enemies, time between combats, skill level of the machine, *etc.*

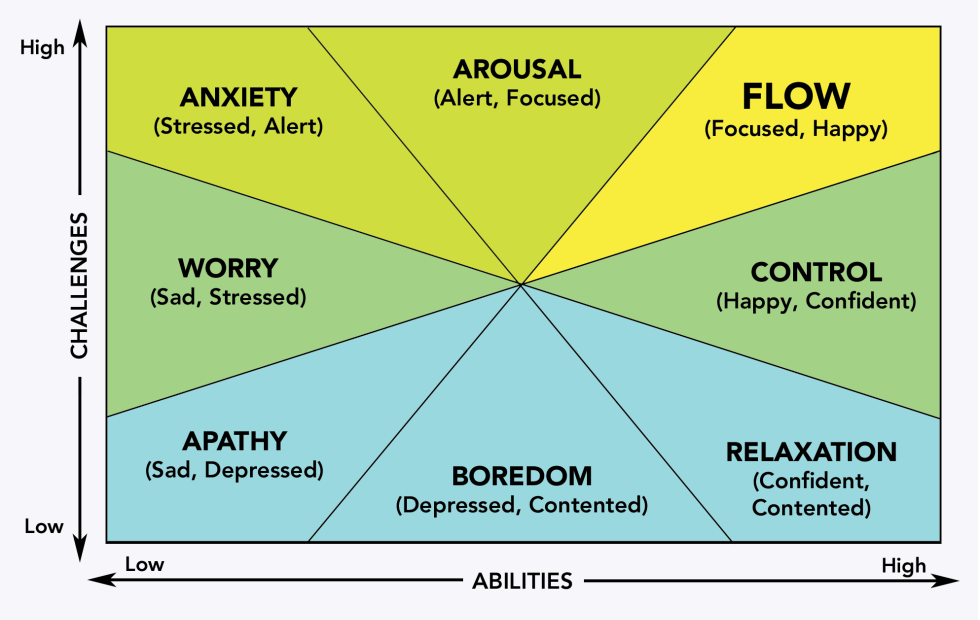


Figure 2.12 Game flowchart

- **Covers, Obstacles, Negative Space**:

  Negative space is a term that has been proposed as the absence of geometry or obstacles.

  Within each action genre, there is a different amount of negative space that suggests more or less exposed combat situations. Not only is negative space used in combination of cover and obstacles, but also as a way to aid navigation and avoid over-crowded levels, both physically and visually.

In regards to cover, normally shooters offer the most out of any 3D action genre.

Overall, in an automated playtesting negative space and obstacles can be evaluated via raycasts, or lines from the character to the world, for instance a certain amount in different directions, to check how much time they intersect with the level and at which distance.

- **Enemy placement**:

  Since the behaviour of an enemy is more of a combat design decision, there is a remaining task for level designers to take on: enemy placement.

  There is no better example of enemy placement than the *Half Life* saga.

  Half-life is a series of sci-fi FPS games with a narrative and episodic nature. The game's maps are designed firstly on a per-room basis. That is to say, every room has a series of items, enemies and possible interactions.

Figure 2.13: Original *Half-Life* barnacle

In the above image, a *barnacle*, pertaining to the first game of the series back in 1998, is spawned on the roof and has the ability to catch humans, some enemies and items with an elongated sticky tongue.

Within a typical room, barnacles would be placed so the player can force enemies into their tongues without the need of wasting ammo.

More often than not, barnacles served a double-purpose and did also present a challenge to the player while moving forward, usually by offering two ways: one slower, more secure, without entering in contact with them, and the other with a barnacle sequence.

In the saga, enemy placement and introduction is directly related to the player's current weapon:

"Players love having exactly the right weapon for a particular job, but having the wrong weapon out to deal with the next problem - just for a moment - helps elevate the sense of tension and excitement" (Valve, unspecified date, Enemies and item placement) [12]

Indeed, a new type of enemy or even an enemy group with an innovative mix on a tough spot will force the player to evaluate their current weapon, and said though process can be translated to an automated playtesting, where the AI could potentially "try out" different weapons and strategies based on the upcoming enemy spawns.

- **Pacing**:

  In the field of level design, pacing is often linked to the time between events. Within the action genre, said events could be enemy encounters, map destruction, weapon upgrades, etc.

  Normally, and specially in combat-focused games (*hAck 'n slash),* pacing is subsequently related to *time to kill (ttk)*, or the time delta between kills.

  Calculating the *ttk* in a simple level is a suitable test within an automated playtesting and said *ttk* variable is a popular metric of choice to determine a level's fitness, or score (a similar metric is explained in 2.4.2).

- **Playstyles, Strategy, Choice**:

  Most video games rely on *Bartle's taxonomy*, a solution that divides players in 4 basic groups, according to which is their ultimate goal or desire.

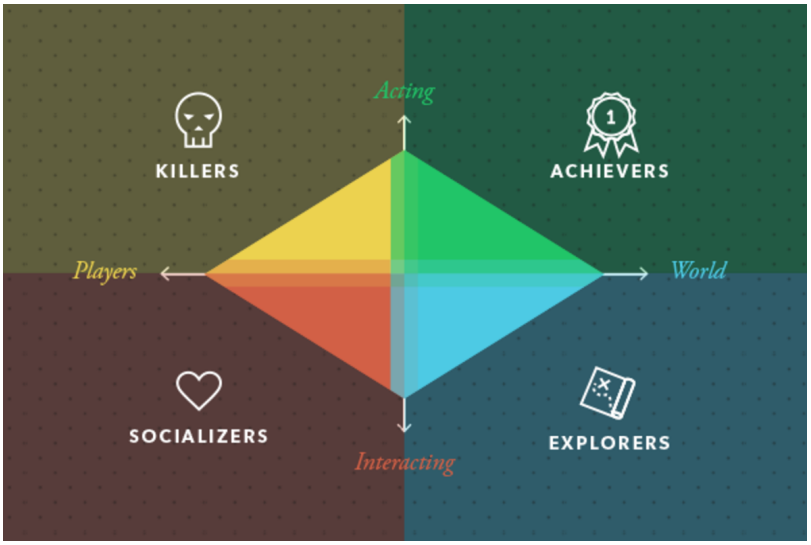


Figure 2.14: Bartle taxonomy

In practise, 3D action games address bartle types so that in every area or room there are many choices for the player to make.

Within the automated playtesting realm, every room can be coded as having strategies represented by finite routes of actions that the AI can take, for instance:

- Room 1 has got a health item and 2 enemies surrounding a treasure.
- A “killer” type of player would directly run into the enemies and maybe pick the treasure by convenience once they are killed.
- A collector would lay out a plan to separate the enemies from the treasure and then sneak in to take it and quickly exit the area.
- An explorer or completionist would first gather the health item if needed to then kill the enemies with time and collect the loot.

- **Vantage Point, Choke Point**:

  Vantage and choke points can be traced back to the medieval era where archers inside a castle launched arrows from high, well-protected towers (vantage point) to intruders that had to enter the fortress via a single narrow, exposed entry, which led to many casualties (choke point).

  The same architectural paradigm applies nowadays in level design.

  As for shooter games, *CSGO’s* map *inferno* provides us with a choke point example.

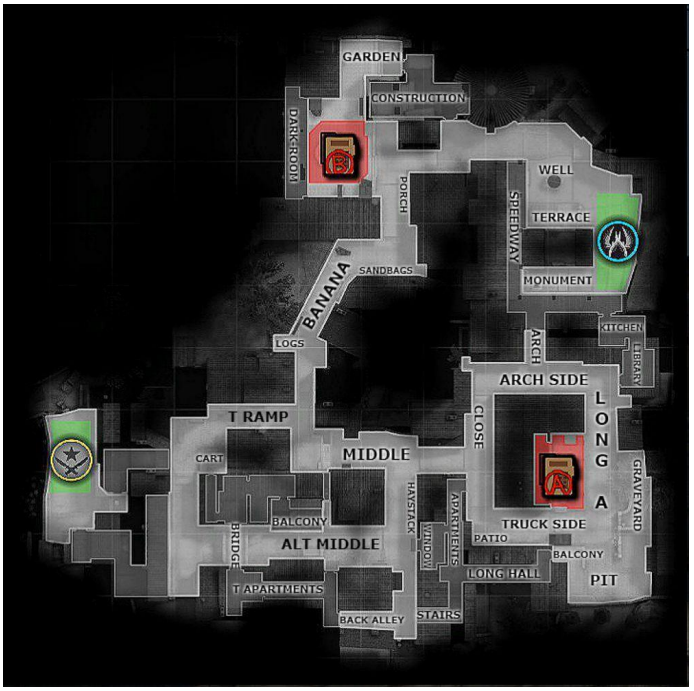


Figure 2.15: *Inferno* map layout, viewed from the top

Within the above image, an area called “banana”, a choke point, stands out, since it is the only immediate option for the attacking team to reach bombsite B. Said area is cramped and represents a choke point for both teams, since the defending team does not have a clear vantage point either to defend.

Another example, which belongs to the A-RPG genre, resides in *Dark Souls 3’s* MAP *Anor Londo.* The area is based on gothic architecture and there are multiple high flying buttresses that the player can navigate on top of.

While navigating those buttresses, a handful of archers shoot arrows from ledges above. The composition of this area, thus, represents an example of both a choke point (the lone, uphill buttress) and a vantage point (the ledge from where archers shoot downwards, with the possibility of making the player fall to death).

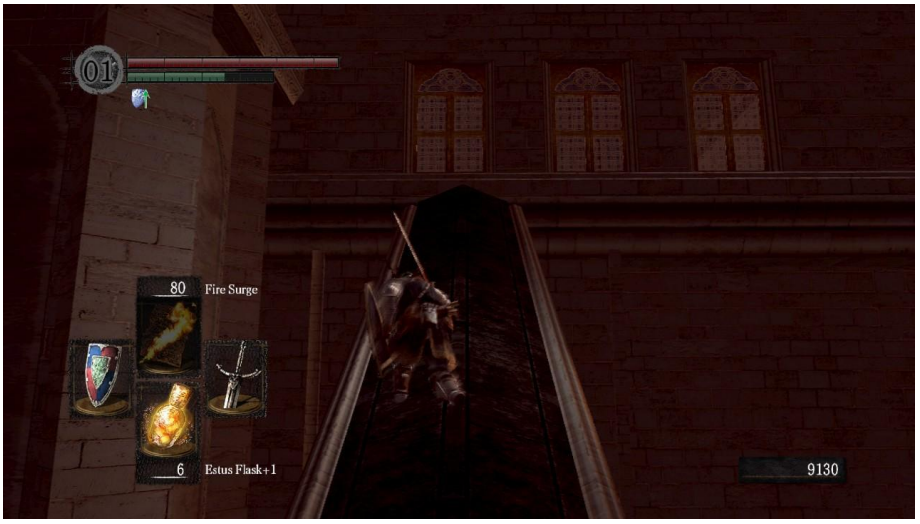


Figure 2.16: *Anor Londo's* flying buttresses and ledges, in first person

Figure 2.17: *Anor Londo's* flying buttresses and ledges, in third person

In an automated playtesting, one can create visualization maps that represent where the player killed an enemy and the opposite, which would give hints towards the existence of a vantage point in a more concentrated kill area.

3. Project Management

3.1 Tasks Management

3.1.1 Timeline: GANTT

The project is divided in theory and a prototype, the latter being scheduled after the first rubric deadline.

As for the prototype, the main pipeline consists of first producing a navigable map with variants, then coding the AI and lastly performing automated tests.

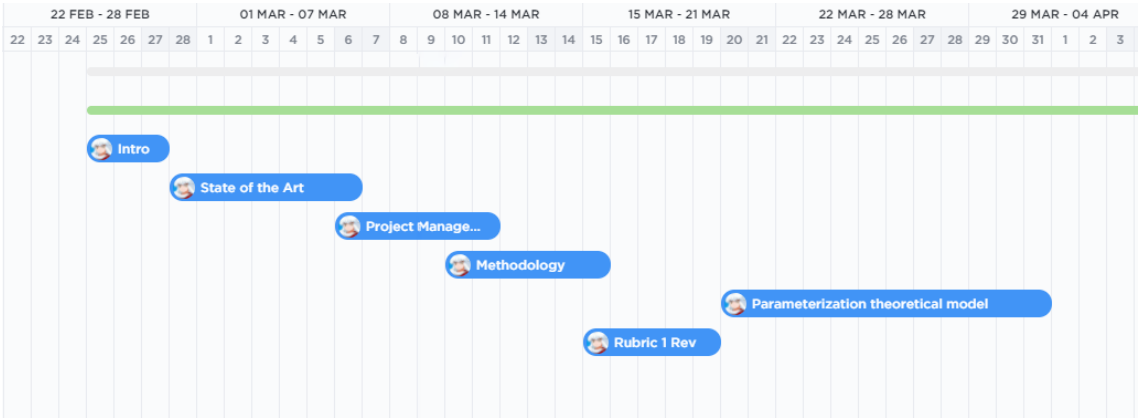


Figure 3.1: Rubric 1 Documentation

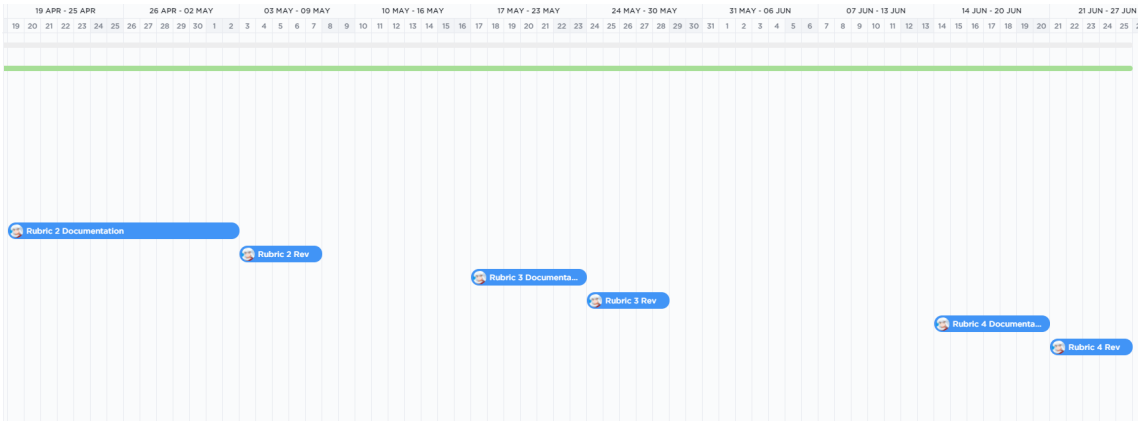


Figure 3.2: Rubric 2,3 & 4 Documentation

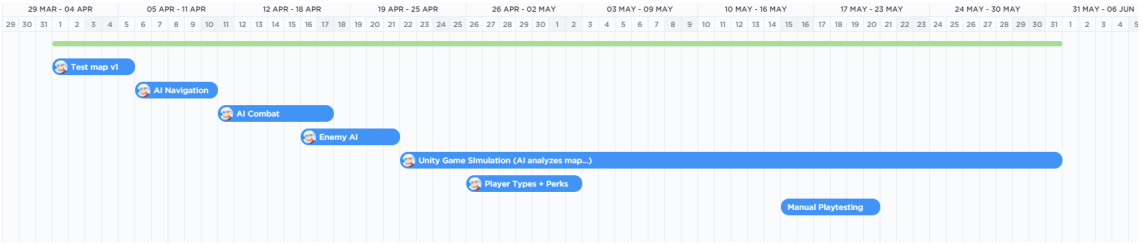


Figure 3.3: Prototype

3.1.2 Task Dashboard: ClickUp

ClickUp is a workplace suited both for personal and enterprise environments. Some of the functionalities include: multiple task views (list, board, GANTT…), task dependencies, time tracking, *etc*.

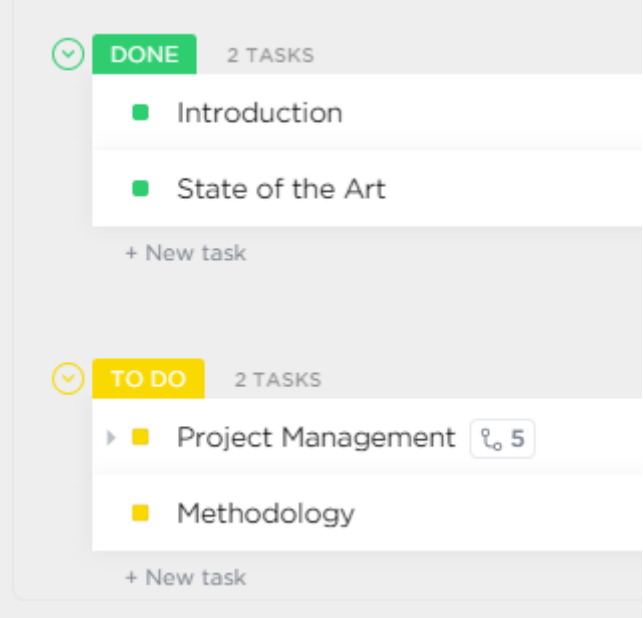


Figure 3.4: *ClickUp* tasks “List” view

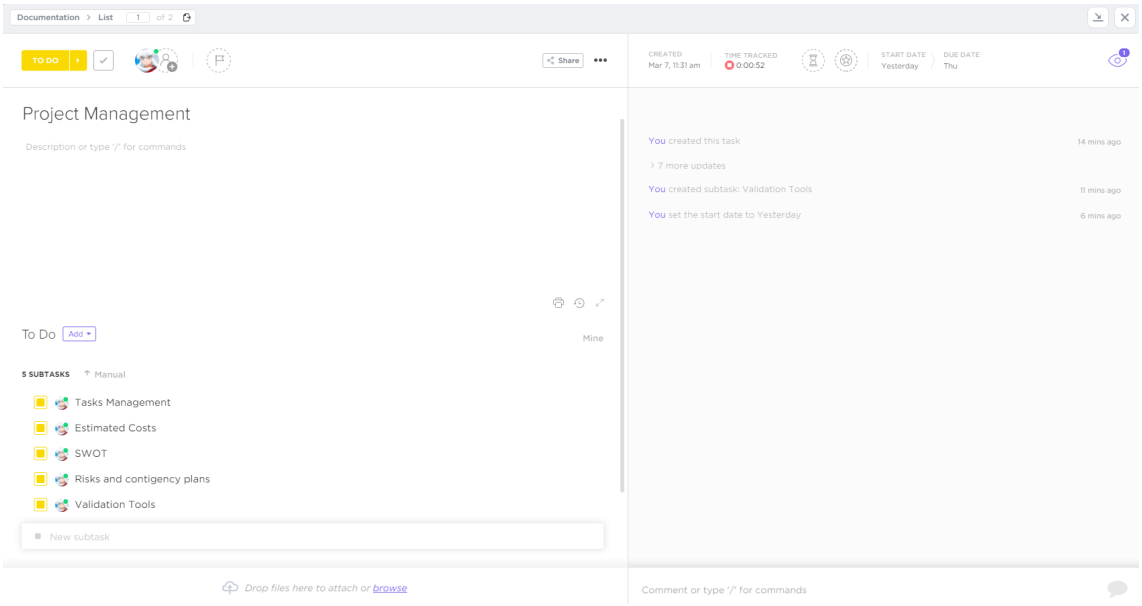


Figure 3.5: *ClickUp* task view

3.1.3 Cloud Repository: Github

Github is a free-to-use cloud repository and source control tool that offers a workspace of ideally up to 5GB of total files.

The site provides a ".gitignore" file with different options to choose from, in order not to push unnecessary files linked to your application of choice (for instance, *Unity*).

Amongst other utilities, *Github* offers: working in different branches with the ability to merge code between them, an issue dashboard to post problems and feature requests with tags, licensing, *etc*.

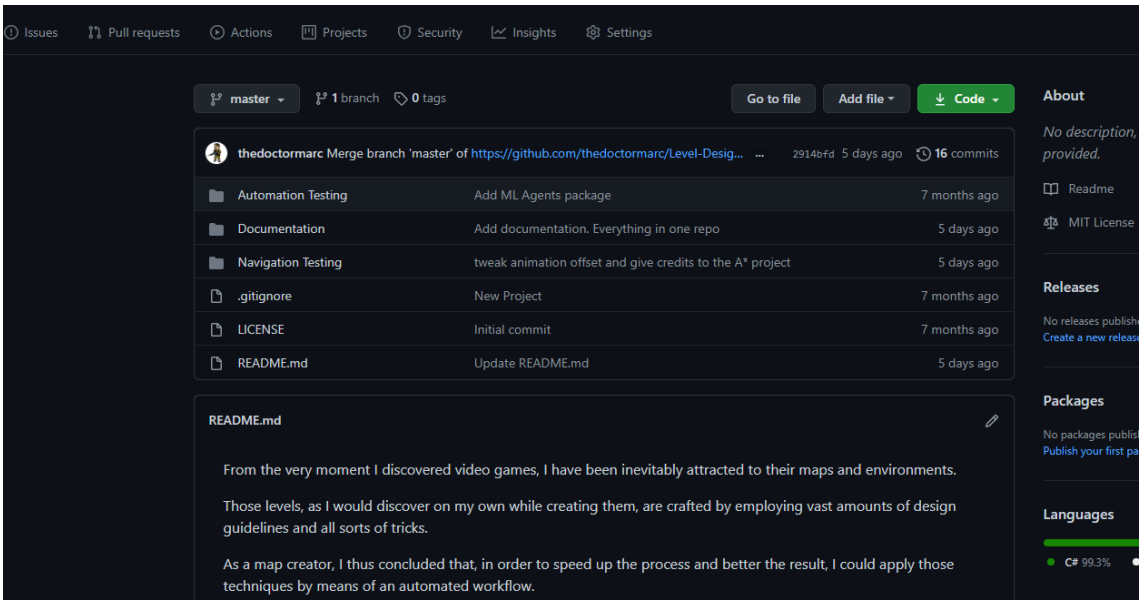


Figure 3.6: *Github* project view

3.2 Validation Tools

Firstly, in order to validate the theoretical level design parameterization models, the AI character that navigates the level will make evaluations based on said model, according to the map genre.

Secondly, so as to incite more interesting findings, the AI will be tested in contrasting map variants, that will present obvious biases in map design.

Only when the first iteration of evaluations is complete, the obtained feedback will be used to manually modify the levels accordingly.

Thereafter, many iterations will follow, until the levels' design has a palpably higher quality.

Lastly, manual playtesting is going to be employed as another validation tool. That is to say, the maps are going to be shared within a game development community so that human feedback can be compared with the machine and thus conclusions are drawn.

3.3 SWOT

This analysis has been generated prior to the development phase:

Strengths	**Weaknesses**
- Level design knowledge and avid 3D action gamer - Experience with Unity3D and AI behaviour	- Lack of experience with Unity Game Simulation - Unipersonal team that has to coordinate many areas of expertise: design, programming, analytics...
Opportunities	**Threats**
- No generic automated playtesting tool targeted to level design - Area of little to no research that lacks design models	- Triple AAA video games do not usually employ automated playtesting on a large level design basis - Automated playtesting may be too case specific for a generic tool: each studio creates their own solutions

Table 1.1: SWOT

3.4 Risks and Contingency plans

This analysis has been generated prior to the development phase:

Risk	Plan
3D Pathfinding for the AI in Unity has no proper native solution (NavMesh is poor)	Use an external plugin, such as: https://arongranberg.com/astar/
Credibility of the automated playtesting analysis depends on player skill	Develop an AI with different skill levels or evolve the base skill
Gameplay and analytics code interference, which could cause logic problems, lack of readability, performance issues, etc	Implement the observer pattern
Difficulty to **compare automated and manual playtesting** feedback	Propose a form that lets manual playtesters address their feedback in a numerical way similar to the AI

Table 1.2: Risks and contingency plans

3.5 Estimated Costs

The table below emulates an environment where different specialists co-develop the tool: a designer, due to the level design theoretical model, a programmer, an analyst and finally testers that would evaluate both the tool and serve as playtesters for the manual playtesting comparison experiment.

Section	Cost	N Units	Unit Value ($) x Month	N Months	Total ($)
Personel					
	Programmer	1	2701,91	3	8105,73
	Designer	1	2876,66	2	5753,32
	Analyst	1	2840,69	2	5681,38
	Tester	3	2021,39	1	6064,17
Software					
	Unity (Pro)	2	150	3	900
	Visual Studio (Business)	2	45	3	270
	ClickUp (Unlimited)	3	9	3	81
	Github (Team)	2	4	3	24
Office Equipment					
	Desktop computer	6	400	1	2400
	Computer accessories	6	600	1	3600
	Desk, chair...	6	250	1	1500
Office Maintenance					
	Rental	1	300	4	1200
	Gas	1	50	4	200
	Electricity	1	50	4	200
				Final Cost ($)	**35979,6**

Table 1.3: Estimated Costs

4. Methodology

Since the proposal encompasses design, programming and analytics, the pipeline will be divided as follows:

4.1 Research Phase

Firstly, one video game is going to be selected for the five genres to be studied.

Each game's levels represent case studies which contribute to the ultimate goal of formulating a level design variables graph, similar to a weighted graph, as explained in section 1.3.

These weighted graphs will be translated to functions. For the selected genre, three map variants will be developed and thus the function is going to determine their score.

4.2 Development Phase

Once the theory is laid out, all tasks will orbit around creating an environment suitable for an automated playtesting. These tasks focus mainly on developing an AI that mimics a human player, to later explore the concept of different player types and skill levels.

Apart from the AI, there are plans for map perks and items such as coins or weapons.

4.3 Analytics Phase

Only when the prototype has enough logic to go through a *playthrough*[17] will *Unity Game Simulation* come into play.

That is to say, automated tests are scheduled to start before the gameplay development is fully complete, and is meant to prolong until then.

In this phase, the AI character will have input variables designed for the simulations, which will evaluate the player's results within the level, upon completion.

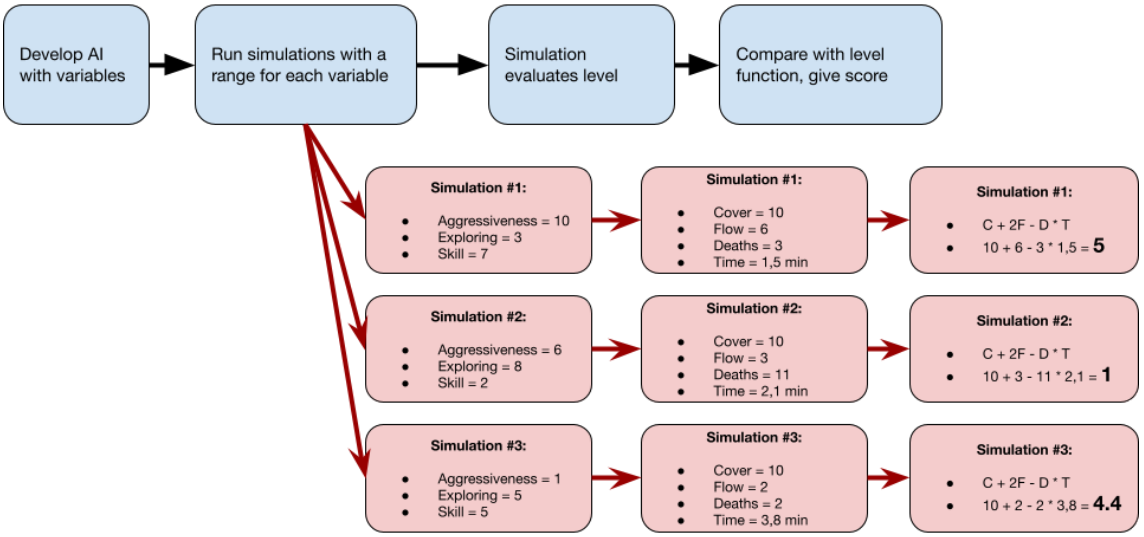


Figure 4.1: Automation pipeline

4.4 Manual Playtesting Phase

Once there is enough data on the previous simulations, a manual playtesting is scheduled in order to compare human vs machine feedback.

Playtesters will have access to the same levels and will be asked to play a certain amount of times each.

Once the playthroughs are completed, they will be handed a *Google Forms* to express their feedback so as to be compared with the AI's.

Figure 4.2 Google Forms logo

4.5 Agile Methodology

The thesis will follow a more *Kanban* approach rather than the usual, more advanced *Scrum*, because of the following reasons:

- The project is developed by an unipersonal team, which almost nullifies the value of Scrum sprints, reviews, etc
- Between all phases there are 4 roles involved, a fact that complicates task workload estimation, among others.

5. Development

6. Conclusions and Future Projects

7. Bibliography

1. **Unity Game Simulation**
   https://blogs.unity3d.com/2020/12/11/automate-your-playtesting-create-virtual-players-for-game-simulation/?utm_source=linkedin&utm_medium=social&utm_campaign=ml_global_generalpromo_2020-12-11_virtual-player-game-simulation-blog

2. **Creating perfectly balanced gameplay with Unity Game Simulation**
   https://unity.com/case-study/death-carnival#balancing-complex-weaponry-takes-substantial-resources

3. **Learning the Patterns of Balance in a Multi-Player Shooter Game**
   http://antoniosliapis.com/papers/learning_the_patterns_of_balance_in_a_multi-player_shooter_game.pdf

4. **Evolving Interesting Maps for a First Person Shooter**
   http://julian.togelius.com/Cardamone2011Evolving.pdf

5. **Automated Playtesting with Procedural Personas through MCTS with Evolved Heuristics**
   https://arxiv.org/pdf/1802.06881.pdf

6. **The Rational Design Handbook: An Intro to RLD**
   https://www.gamasutra.com/blogs/LukeMcMillan/20130806/197147/The_Rational_Design_Handbook_An_Intro_to_RLD.php

7. **Automated Testing at Scale in Sea of Thieves | Unreal Fest Europe 2019 | Unreal Engine**
   https://www.unrealengine.com/en-US/events/unreal-fest-europe-2019/automated-testing-at-scale-in-sea-of-thieves

8. **Automation System Overview**
   https://docs.unrealengine.com/en-US/TestingAndOptimization/Automation/index.html

9. **Automated Testing For League Of Legends**
   https://technology.riotgames.com/news/automated-testing-league-legends

10. **Level Design Help Files**
    https://www.mapcore.org/topic/3598-level-design-help-files/

11. **LEVEL-DESIGN.org Knowledge Base**
    http://level-design.org/?page_id=2468

12. **Single-Player Mapping Tips**
    https://developer.valvesoftware.com/wiki/Single-Player_Mapping_Tips