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Master Project Report

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Abstract

The development of this project is centered on examining traditional methods of procedural content generation (PCG) for environments, and how these methods replicate discourses of dominance and colonialism. The intention behind this examination is to propose alternatives to the common approaches to PCG, and to explore an alternative in the form of a game prototype.

This report describes the use of a cellular automaton combined with an evolutionary algorithm to create a dynamic environment that could change at runtime, using input from the player to promote solutions using a mixed initiative PCG approach.

Introduction

The project aims to reflect on the available possibilities for game designers looking to create more fair and responsible spaces for production in the frame of climate action and sustainability. This project perceives video games as a fertile ground to communicate alternative conceptions of nature, and as a medium where ideas of ecology can be reexamined to create new strategies for engagement.

Games are part of a broad cultural and social sphere intertwined with our economic activities and our attitudes towards the natural world. Many games of exploration, farming, and resource gathering frame nature as a stage for consumption and extraction, and in them, the exploitation of the natural is replicated in the virtual. As part of society, game designers can perpetuate established design patterns of domination and extraction, supported by traditional environment creation and generation tools that relegate the "play environment" to a static backdrop existing for the consumption of the player.

Understood as the area/land relevant for the outcome of the game.

Extractivism is a key concept in this project used to highlight the relationship between games and the cultural and economic space in which they are produced. The concept is adapted from the work of the social activist Naomi Klein, who describes Extractivism as a "*nonreciprocal, dominance-based relationship with the earth, one purely of taking*" (Klein 2015, 145).

This concept was useful as a means to interrogate common assumptions in the systems of play environments and the mechanics contained in them. It revealed common tropes around exploration, consumption and expansion, and was used as a guide to delineate a design space.

Problem

With the above introduction, the problem is **to find ways in which extractivist practices in the design of game mechanics can be avoided**. This includes the world creation tools that relegates the environment as a static backdrop for the consumption of the player.

Approach

For this project, thinking of the tools available for solving the problem was an important consideration, in part due to the technical limitations and the underlying design of the systems that support game development. When it comes to the creation of environments, the tools inside popular engines like Unreal Engine and Unity support the creation of worlds that fit the idea of endless exploration. These engines already make the creation of large extensions of terrain possible, and the instancing of large amounts of assets to recreate the appearance of a natural world.

The assets for these large worlds are often self contained objects. However, the interaction with the space they inhabit is often limited to being placed over a surface in a way that is consistent with the natural environment they are describing.

Instead of taking the direction of recreating large biomes and expansive vistas, this project was constrained to creating a small set of entities that could share internal states and be connected between them. The initial shared connection for the entities was geographical and during the game their state was allowed to change over time in relation to their neighbours.

Inspired by **Into the Breach**, Subset Games. 2018

The direction described above is very similar to a well known computational model: the cellular automata. This model has been widely used in video games to generate levels, simulate environmental systems, and investigate emergent behaviours from simple rules.

According to Georgios N. Yannakakis and Julian Togelius in the book *Artificial Intelligence and Games* the model is defined as:

" (...) *cellular automata are a set of cells placed on a grid that change through a 'number of discrete time steps according to a set of rules; these rules rely on the current state of each cell and the state of its neighboring cells. The rules can be applied iteratively for as many time steps [...] Each cell can have a finite number of states; for instance, the cell can be on or off. A set of cells surrounding each cell define its neighborhood. The neighborhood defines which cells around a particular cell affect the cell's future state*" (Yannakakis 2018, 166).

In terms of gameplay, this approach is favorable for games that are interested in creating emergent behaviours from rudimentary rules, but it has the downside of being prone to unpredictable results, and might require arduous testing to find stable states (Fullerton 2018, 147). In this model, adjacency is central to determine the internal state of a single entity. For the project, unpredictability was embraced as a means to construct and evolve the state of an environment, even if the result flowed towards a disordered state.

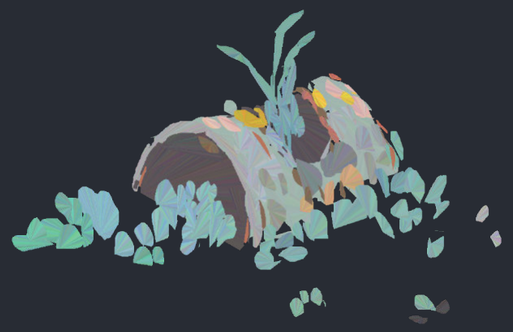
Creating a game that advances towards disordered states resonates with the observations made by game theorist Alenda Chang in her book *Playing Nature*. Here, Chang borrows the concept of Entropy from the field of physics as a way to re-imagine the idea of nature in the realm of video games. The author also uses the concept to criticise the lack of engagement of video game natures with the material means of their production.

"*...entropy best conveys the neglected material aspects of games and game platforms, and perhaps more important, their inevitable demise. Entropy guides our attention to the shadowy source/sink dynamics of game-related manufacturing and, the omission of waste, disorder, and unspectacular forms of excess from most games*" (A. Y. Chang 2019, 146).

For this project, the mentioned omissions of waste and disorder made by Chang became a desired feature. First as an objective for the artistic style of the assets. Second, as a way to examine game rules for game environments and techniques of procedural generation. And last, as a way to consider the implications of the production of video games.

Research Question

Using the cellular automata and the entropy model, the project was developed with the following research question: What techniques of procedural generation and environment creation can be implemented to avoid extractivist game mechanics?



Ecology and systems

To answer the question, this project aimed to simultaneously gain insights into the techniques for procedural content generation by implementing them, as well as considering their relation with ecology and economy in an attempt to give to all these aspects equal importance. As Chang also describes in her idea of entropy in games:

"Ecology, with its roots in cybernetics, and games, which are ultimately indebted to developments in computing and machine intelligence, share a fundamental predilection for systems theories. Not surprisingly, then, most attempts to define the essential traits of games stress their orderliness -that they are rule- based, spatially and temporally delimited, and in the case of digital games, creatively constrained by code and platform" (A. Y. Chang 2019, 146).

Report structure

The connections made by Chang highlight how the analysis of games and their systems are related to other fields. Taking a similar approach, this report starts by describing the bounds of the designed prototype, the techniques used for PCG and why they are relevant in solving the research question. After, the report will describe the details of the algorithms implemented while commenting their connections with the ideas other authors.

Theory State of the Art

As the techniques of this project are centred on PCG methods, finding a good overview of the field was an important step. For this purpose the Paper 10 Years of the PCG workshop: Past and Future Trends by Antonios Liapis was used to grasp the state of the academic research produced in the context of video games and PCG.

The paper is an overview of the International workshop on Procedural Content Generation. The text resumes the activities of the workshop and surveys popular research trends and topics over the last 10 years by categorising 95 submitted papers published for the workshop (Liapis 2020).

It is important to highlight that from the survey, only 2 papers are concerned with what Liapis calls "philosophical issues" or the underlying design ideas of PCG.

The two papers are: Little Procedural People: Playing politics with generators by Kate Compton, and What Do We Value in Procedural Content Generation? by Gillian Smith.

In What Do We Value in Procedural Content Generation? Smith argues that PCG systems " (...) embody and promote values through their design" (Smith 2017) and argues for a need for critical awareness of the values embedded in the design of PCG systems. Among the identified values by Smith, three of them are the most relevant for this project:

- **Accommodation and conflict avoidance**, where the player is entertained in a personalised experience, designed to maximise enjoyment and retention.
- **Productivity and efficiency**, in the frame of mixed-initiative PCG, where the systems are designed to be supportive of humans, allowing to save time and produce more.
- **Democratisation of design**, in the form of user-created content, seeking a more enjoyable creation experience for the player, while exploiting unpaid labour.

From the list of values it is evident that the field of PCG promotes the maximisation of productivity by automating or assisting processes with a set of problematic issues related to labour. This will be expanded later in this report.

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An interesting design paradigm mentioned by Smith was explored in the project: Mixed initiative Procedural Content or MI-PCG. In contrast to other traditional generators, like the cellular automata, mixed-initiative automates only a part of the process of generation requiring more input from the user during the process (Shaker, Togelius, and Nelson 2016, 195).

Going further, a special case from this branch of generators is Interactive Evolution or Interactive Evolutionary Computation (IEC). In this variant of evolutionary computation the input of the user is used to evaluate the created content. Borrowing the idea of survival of the fittest from Evolution theory, a human selects which individuals create offspring and which are eliminated (Shaker, Togelius, and Nelson 2016, 215).

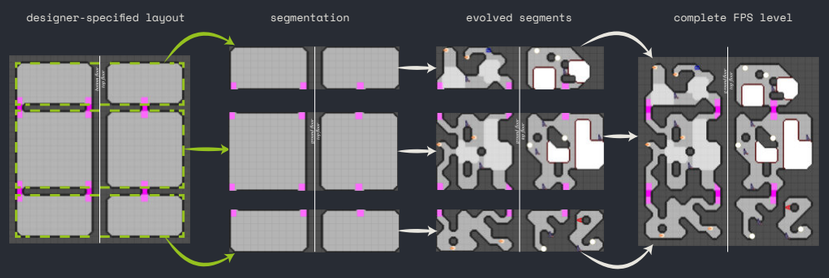
In the context of PCG, individuals can mean configurations or solutions that satisfy the user evaluation or predilection. Going back to the cellular automata, this project identifies IEC as an opportunity to create assets combining the idea of environment selection and user input. This is because the two methods share similar traits such as life cycles, generation of populations and selection by environmental pressure.

The literature referenced above deals with problems specific to the field of PCG and are not directly related to ecology in games and environmental problems. To solve this issue this project opted to use as a reference the work of Alenda Chang and her essay *Playing Nature: Ecology in Video Games*. Chang's text collects the ideas of other contemporary environmental thinkers such as Donna Haraway in *Staying with the Trouble*, the literary ecocritic Timothy Morton in *Dark Ecology*, and the journalist Naomi Klein in *This Changes Everything: Capitalism vs. the Climate* among others, weaving their ideas into the problematic issues of natures in video games, finding intersections with the ideas of other games scholars like Jesper Juul in his book *The Art of Failure*.

Game State of the Art

Pipelines

Returning to the specifics of PCG, a common complaint found around newer procedural generation techniques and their use is the lack of adoption by a risk averse games industry. In the paper *Mixed Initiative Generation: Three Pillars of Industry* by Gorm Lai, William Latham, and Frederic Fol Leymarie, this lack of adoption is attributed in part to the lack of publications describing the ways in which developers can use their research in the context of a game pipeline.

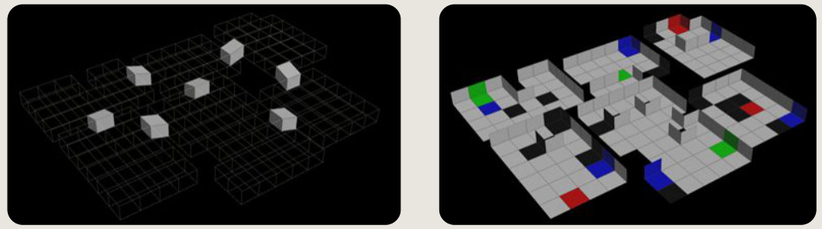


Evolutionary Level using a designer input (Liapis, 2018)

To solve this problem, the authors describe three key characteristics for PCG tools to be used successfully: **Respect Designer Control** where the emphasis is to give the designer the control to get their vision out. **Respect the creative process** allows the designer to use a short iterative loop which provides immediate feedback that does not break the creative process, and finally **Respect the Existing Work Processes** is concerned with how PCG tools are embedded in an already existing workflow within an organisation (Lai, Latham, and Leymarie 2020).

As an example of the last pillar and the integration of academic research in a production environment, the paper *Piecemeal Evolution of a First Person Shooter Level* by Antonios Liapis (Liapis 2018) describes the interaction between a researcher and a technical artist developing a game prototype using an evolutionary computation approach.

The companion conference PCG shotgun: 6 Techniques for Leveraging AI in Content Generation shows the implementation of the academic research by a Technical Artist using Houdini Engine (Kruel 2017)



Houdini level from an evolutionary model (Kruel 2017)

Commercial games

For this project, a set of games where the play environment impacts the outcome of the game were selected. The selection is not limited to exploration games but also includes a wide collection of interesting and diverse game ideas. In this collection is Noita, a relevant game that has many elements in common with the cellular automata model. The game is a 2D platformer with the special characteristic of having a destructible environment where all the pixels or terrain elements are simulated. In Noita, the player goes inside a holy mountain to dig gold and gain new powers while going deeper into a procedurally generated cave system. The extracted gold in Noita is used as currency to buy new weapons and spells, allowing access to new abilities that change the interaction and destruction of the environment.

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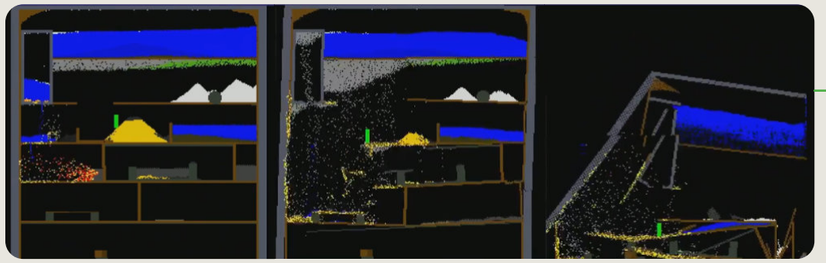
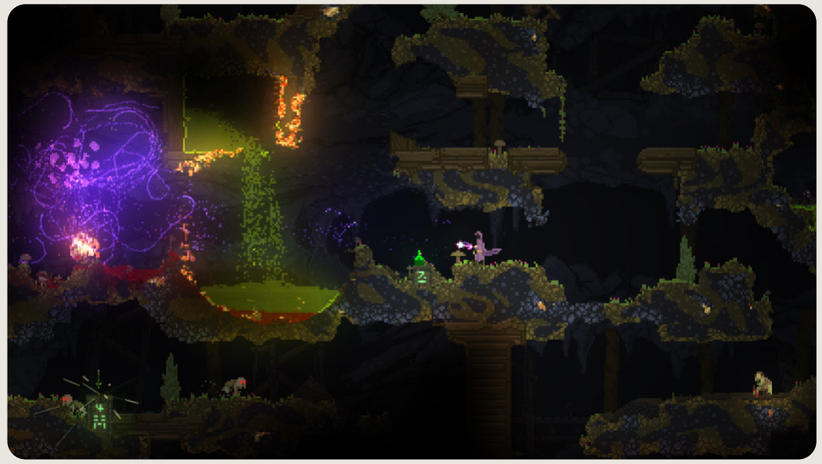
The relevancy of this game as an example for this project lies on how the environment is made up of small and discrete elements. In Noita the world is described by the specific material and state that make up a single grid cell instead of a self contained asset. The developers have been open on how the simulation of the environment works, and what type of algorithms and programming techniques are used to simulate the interaction between all the elements of the game (Purho n.d.)



Early experiments of Noita, Purho, 2019

In their 2019 GDC conference *Exploring the Tech and Design of 'Noita'*, the developers explained the hardship of adding gameplay and mechanics on top of their simulation. For them, producing interesting gameplay was a complicated task because the emergent properties of the system were unpredictable and caused game breaking glitches. This characteristic made it necessary to prototype many games that could support the underlying simulation to create interesting gameplay.

As in Noita, this project found that the search for interesting gameplay can be a bigger challenge than the technical implementation of the simulation. For this reason, more time was allocated to have a flexible system that could be adapted to different design directions.



Noita, Nolla Games, 2020

Role

This prototype was developed in an attempt to think around the implementation of game mechanics in the light of critical theories and novel techniques of PCG. My work for this project involved the design of the ecology of the system, the technical implementation, and the tools to create the assets.

Resampling and interpretation of photogrammetry assets

Original Raw scan by Renanfox CC BY 4.0. Sketchfab

A common problem in creating environments is the distribution of the assets of the game world. To solve this problem the Paper *Fast Poisson Disk Sampling in Arbitrary Dimensions* from Robert Bridson was implemented to distribute all the assets in the terrain. (Bridson 2007)

To create the connectivity graph describing the geographical relations between the assets, an implementation of the wonderful *Polygonal map generator* from Amit Patel (Patel n.d.) and the C++ port to Unreal Engine by Jay Stevens (Stevens 2021) was used, along with many modifications to accommodate the map generator to the needs of the system. In particular, to the case of a cellular automata.

For the procedural creation of the meshes at runtime, the project *Runtime Mesh Component*(Conway 2021) for UE4 was implemented as a way to obtain acceptable frame rates with infrequent and localised updates to the assets of the game.

The assets in the prototype are the result of a process of re sampling and adapting models from the website sketchfab. This process is a mix of automated tasks in Houdini and manual creation using Blender.

Summary

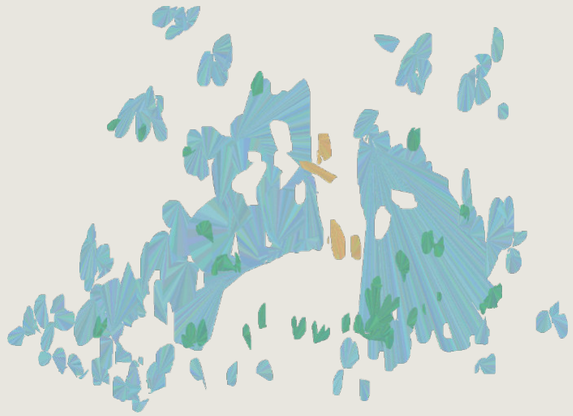
The designed system for this prototype was guided by an interest in the field of green game studies. This field can be understood as a way to examine " *(...) the potential of digital games to raise environmental awareness, even to foster action, while engaging candidly with how games and gamers may be complicit in, or at least uncomfortably close to, legitimating unsustainable practices whether at a political or sociological level*" (A. Chang and Parham 2017)

Design Constraints

Using critical theory from the field of green games, the development of this prototype searched for connections between high level design decisions, the underlying implementation of the game mechanics and the creation of the necessary tools to generate the environment of the system.

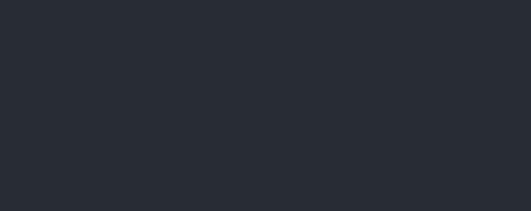
The aim of this approach was to find opportunities for ecological awareness and to reflect on the means by which the play environments of video games are generated.

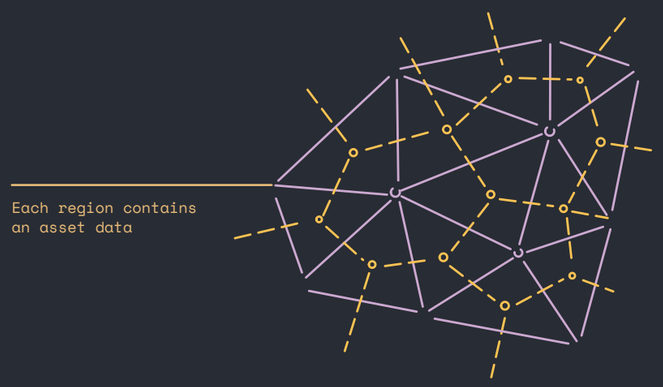
To reduce the design to be more narrow and defined, the work was centred on how the environments for exploration games are produced and how passiveness is a characteristic of games that conceive nature as a resource as opposed to a complex interconnected system.



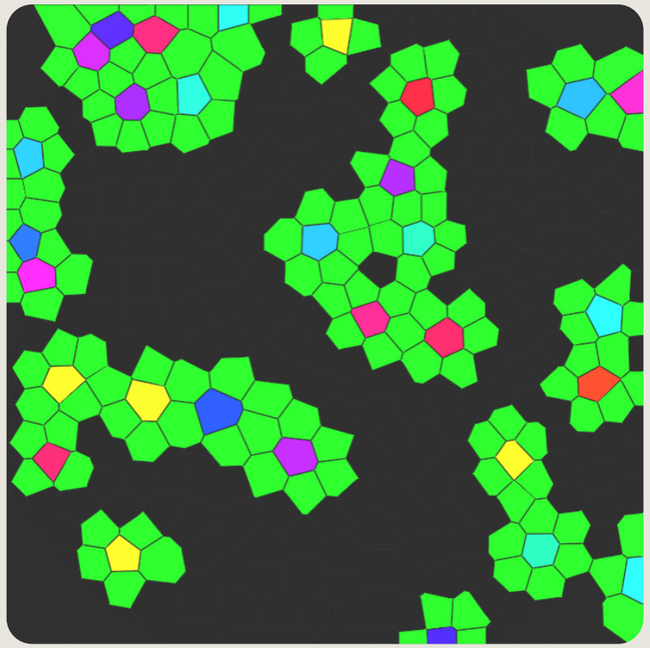
Graphs and Connections

From these constraints, the idea of creating a two way relationship between the game environment and the player was conceived. Often the easiest way to start creating such relations is to give the system a way of accessing geographical information. For example, a measure of how close other entities are to one another, or the amount of neighbors for a given element.



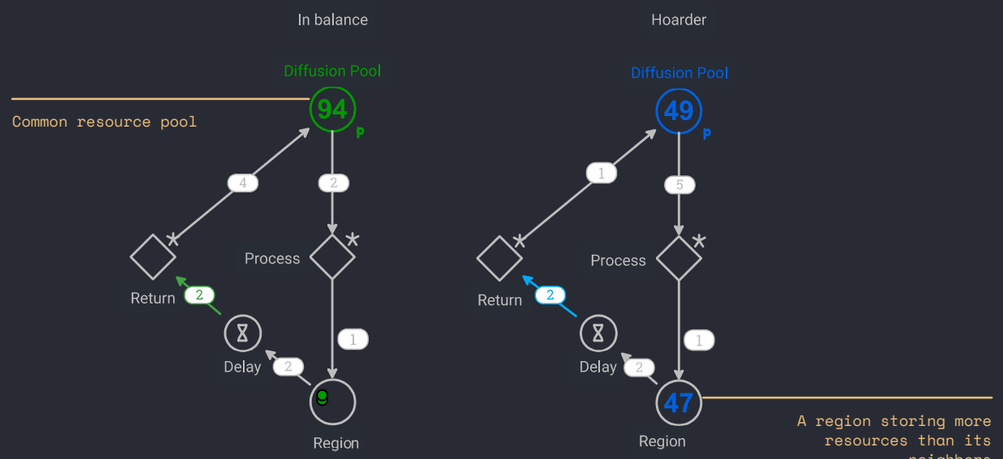


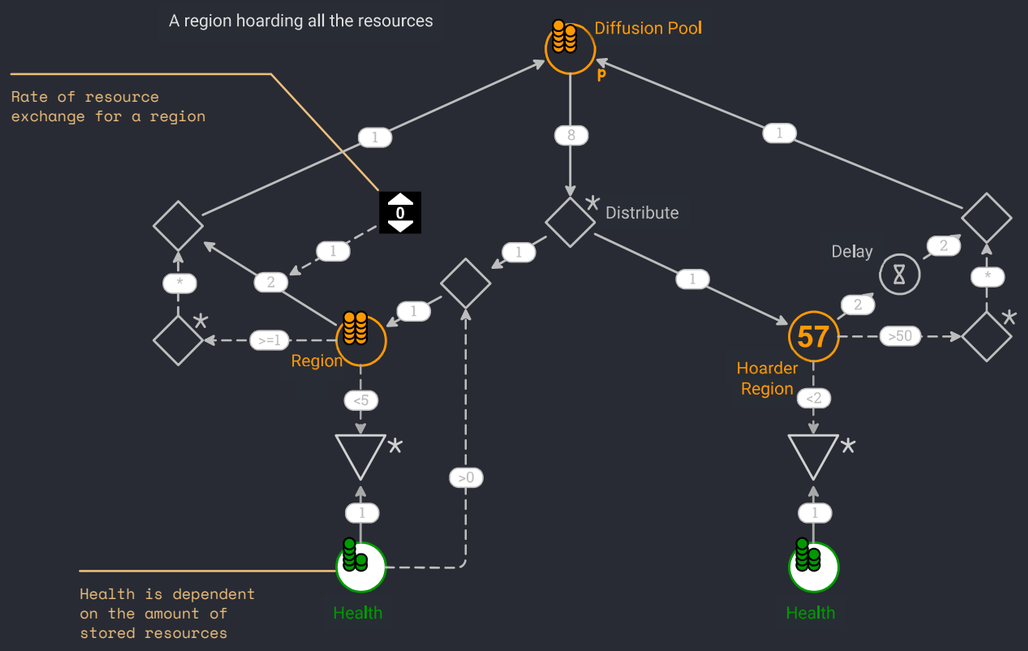
With the idea of geographical relations in mind, the prototype began with the creation of a connectivity graph. The graph was used to keep track of all the location relations between the various elements in the environment. Specifically, this project relied on a Delaunay/Voronoi Dual Graph to create the data needed to create and store the adjacency of each element in the game.



Adjacency in a Voronoi graph, colored in green is the frontier of the current selected regions

System mechanics





After completing the groundwork of the connectivity graph, the next step was to model the interactions between the elements of the game by satisfying the following requirements:

- Avoid mechanics of natural resources' extraction.
- A clear two way interaction between the player and the environment.
- Create a self contained ecology from the elements of the game.

For this task, the online tool Machinations was used. With it, the system was designed to work as a circuit, where a common resource circulates around all the elements and at the end of each cycle, the common resource was returned to a ground state.

Machinations was understood as a tool to model interactions and exchanges, and through various attempts at balancing the system, it became clear how the system was susceptible to imbalances of resource distribution and storage. Small changes in the rate of resource circulation for a single entity were compounded over time, and the effect propagated to all the entities of the environment.

This inclination towards imbalance was used to find the interaction performed by the player in the system: to affect the rate of resource exchange between entities.

Runtime assets

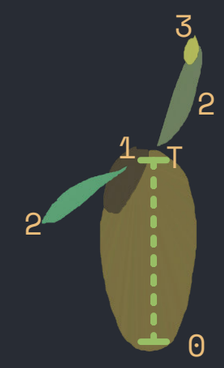
It is often the case that once a game environment is created manually or generated using procedural content generation tools, the environment is static and passive, waiting for an interaction with the player. This is in part done for practical reasons, such as memory capacity or processing power constraints.

It is very common for the generation of elements in an environment to be concerned with the distribution of assets or the creation of playable terrain topologies. Ultimately, this ignores the opportunity for continuous generation, and with it, the possibility of creating relationships between the generated elements.

An approach considered to address this criticism was to simulate the natural phenomena of the created biomes and terrains, however, this approach was in turn charged with suppositions about how nature works following a path of mimetic reproduction that was not aligned with the values of this project.

Following the observation of Bridget L. Sellers, in Pixelated Frontiers: Videogames And The Sublimation of nature (Sellers 2019, 33)

Instead of pursuing ecomimesis, this project was centred on creating a sense of dynamism from continuous change in the play environment. In this approach, each asset was made of separate polygon islands, creating complexity through the aggregation of simple parts. The assets were internally organised as a tree structure, each part having a parent and children, keeping track of the transformation of individual polygon islands. A leaf in this tree structure included a **weight** to control the health of the asset, and as a whole the summatory of these weights gave the asset a maximum possible health score.




```
Struct PolyTreeElement
    Name(GUID)
    Parent
    Children
    Section
    Shape
    Transform
    GameWeights
        MaxHealth
        Capacity
        InRatio
        OutRatio

Map PolyTree
    Name | PolyTreeElement
```

region **a**

With this setup, the visual aspect of an asset was coupled with data needed for evaluating the rules of the game. By swapping parts between assets, not only the visual side of an asset changed but also how it affected the simulation.

|0|1|2|3|4|

Likeliness of a swap

Crossover

region **b**

The ability to swap parts at runtime happened without the player action. In this ecology model the natural world has an internal cycle, where the exchange of characteristics does not rely on the player to continue, instead the player is able to affect the rate of swapping in a specific location of the play environment.

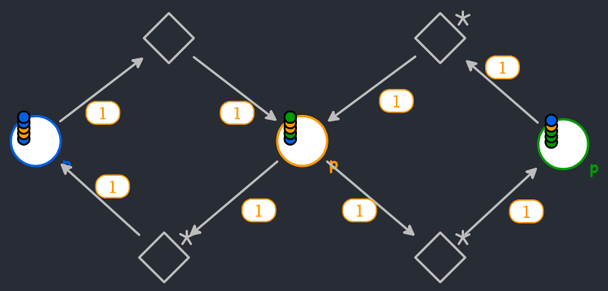
Game Weights

$$1W_1 + \tfrac{1}{2}W_2 + \tfrac{1}{3}W_3 + \tfrac{1}{n}W_n$$

Influence of a swap

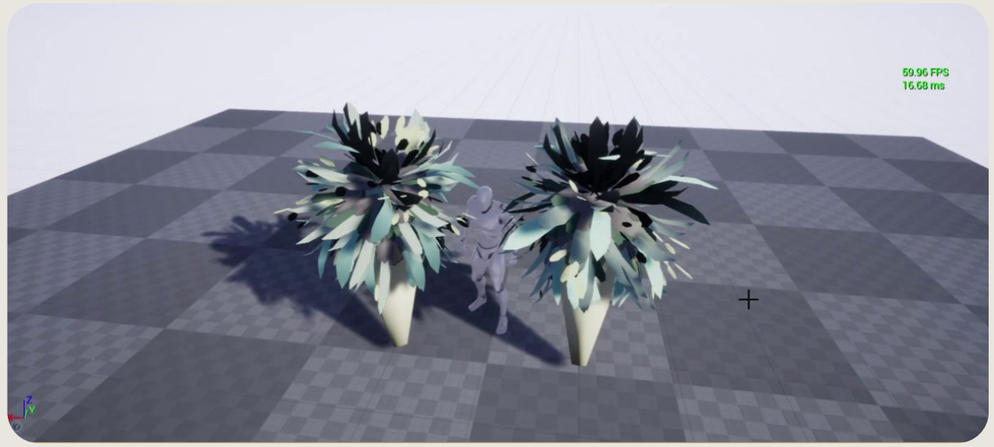
Weights range = [-1,1]

The relation between the data transformation, the algorithmic nature of the ecology and the visual style of games has been studied before. A good precedent for this approach is described by the game theorist Amanda Phillips in her essay (Queer) Algorithmic Ecology. The author describes Minecraft's terrain generation connection with the gameplay as more than a numbers game, that *"[is] in fact the heart of the platform, and its mixing with ecological aesthetics creates a strange form of nature—an algorithmic ecology—that is simultaneously ripe for capitalist exploitation and full of alternative queer embodiments and relations"* (Phillips 2014, 109).



Exchange of characteristics

In the case of Minecraft, the relation between generation and exploitation is related to how the content is created as an ever expanding reserve for the player. For this project instead there is no expansion of the terrain, but continuous transformation, retaining the connections and structures between the elements of the game. This is a way for alternative embodiments and relations that Phillips describes as an opportunity to consider alternative ecologies, that challenge traditional conceptions (Phillips 2014, 113).



Mutants: Accumulation without clearing the render mesh

Fitness function

Until this point, the effort was situated on creating separate systems, one for evaluating locally each cell/region, another to circulate a common resource and a third to swap characteristics. To integrate the systems and promote changes in the assets, the introduction of an objective that included the implementation of the interaction with the player was necessary.

Following the approach of evolutionary computation, where the best solutions for a problem are found through random variations and subsequent evaluation (Yannakakis 2018, 49), the question of **what characteristics and configurations should be promoted** became more prominent.

Under the values of this project, an ideal system would promote:

- Consequences for hoarding resources
- Dependency to other neighbour regions
- Stability in the health of all regions

With these requirements in place and in order to integrate the systems, the following process was implemented:

1. The player increases the chances of a swap at a selected location.
2. Swap the characteristics of two regions.
3. Evaluate the health of the region after a period of time.
4. Evaluate the health of the system as a whole during the same period of time.
5. Finally ask, did the health of the asset/region increase or decrease? and at the same time, was the health of the system as a whole increased or maintained?

If both questions were positive, the solution was considered as a better configuration. After running the simulation many times, the visual appearance of the assets were chaotic, but the underlying health of the system maintained a balance. However, one significant pitfall of this approach is the fact that the feedback that the player is getting is exclusively in terms of the appearance of the environment, and it is hard for the player to judge if swapping is beneficial for the system. In this regard, a better way to communicate with the player should have been implemented. The approach of Mixed Initiative PCG

asks the player to guide the selection of better solutions. Therefore, it is important to consider not only how the player is going to interact with the system to promote change, but also what are the player's intentions. In this case, the player might be more inclined to promote configurations that are visually pleasing, to the detriment of the health of the system as a whole.

At this moment, it is a good time to consider that exploration in games does not necessarily mean to traverse a play environment to find a resource. It can also show how the actions of the player affect the environment in unpredictable ways through the playful exploration of unknown game rules.

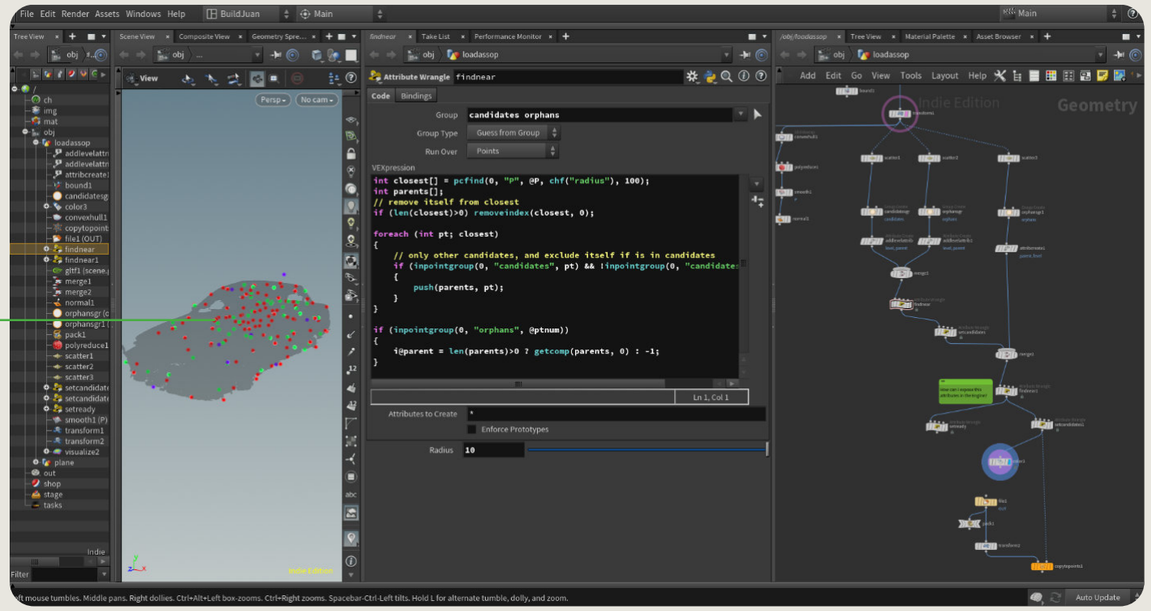
A similar concept is used by Naomi Klein when she refers to the logic sacrifice zones, places that don't count and are destroyed, for a supposed greater good and economic progress (Klein 2015, p. 149)

The rhetoric of optimization

As mentioned in What Do We Value in Procedural Content Generation? by Smith, productivity and efficiency are a major concern of PCG. The initial cost of the development of these tools is offset by the future gains in terms of an abundance of assets, a production in less time, and an application to parts of the creation process that are conceived as repetitive or dull. These tasks previously and often outsourced to countries with cheaper labour, become candidates for this type of optimisation. In the lecture *Automated Futurisms in Digital Game Production* for the AI and games summit of 2021, Aleena Chia identified PCG and automation as a discourse that erases and denigrates the labour of marginalised people that is perceived as less creative and more robotic.(Chia 2021) Under these assumptions, the discourse of optimisation mirrors the same views held over the environment that this project wanted to avoid. Such as, where the peripheries of disposable labour are, and how the efficiencies are created in a glittering centre from where the creative work flows in only one direction. If the creation and adoption of newer PCG techniques keeps being advertised as a tool for efficiency, a project like this takes the risk of contradicting itself by failing to acknowledge the role that tools have in shaping the relations of production, consumption and labour.

In an approach similar to Mixed Initiative PCG, the idea of efficiency is encoded on how the fitness function is designed to evaluate the produced content, and frames creation under a "solution to a problem". As a whole, procedural content generation, and the way in which it is advertised can be framed as a set of solutions to a labour problem (Chia 2021). A solution that can be charged with colonialist overtones.

Hierarchy of samples / distance from root sample. Blue samples are shallow, red are deeper.



Creation of an *asset sampling tool* using Houdini

Little procedural entropy

This project is called Little Procedural Entropy which highlights the small scale of the environment, how the assets were generated and the expected visual outcome of the system, respectively.

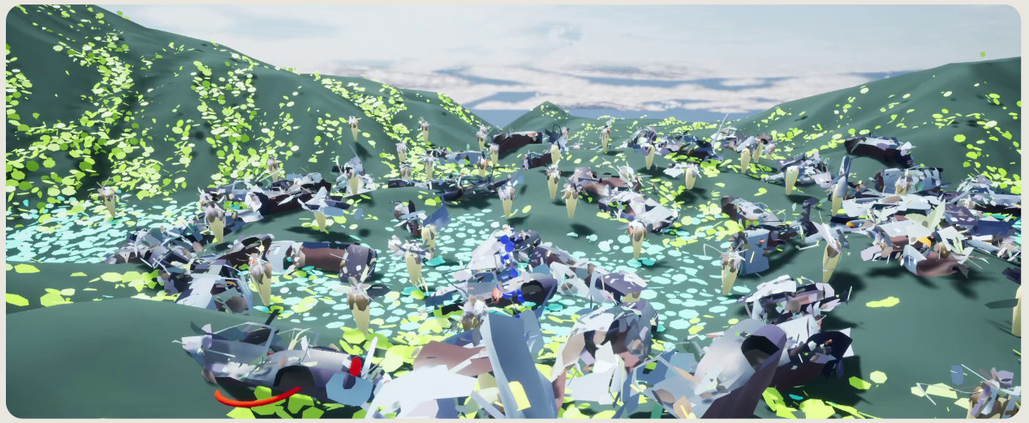
The initial motivation to pursue PCG methods for this project began with a small conversation I had with Julian Togelius, when he was invited to KADK to give a lecture on Games and AI in 2020. Having read a few of his books but not having a bachelor in computer science, I asked him if I had the required abilities to start implementing some of the new techniques shown during the lecture. I was suggested to start with Monte Carlo Tree Search and Evolutionary Algorithms as a way to begin understanding the basics of AI methods.

For this project, I recognised that game design is intertwined with the tools we use to create games and the systems that underpin them. This seems like an obvious remark, but exploring games and PCG from another perspective other than the technical side opened the door to consider new directions in design.

The project page will be available at
https://juancaflorez.github.io/

This text is an integral part of my thought process and through it I wanted to find an excuse to read theory and implement algorithms that were outside of my understanding as a designer and artist. However, more importantly, I wanted to gain a more critical approach to game making beyond the novelty of new technologies. In this regard, I consider reading outside of technical texts as a need for my practice as a professional.

This report jumped between texts that made references to environmental issues, ecology, tools, labour and tried to narrow those issues to a selection of algorithms that could be aligned with the design values of this project. Through the text, some quotes and references were left as open ended or unexplored branches that reflect the tree-like nature of the method that I found. This not only makes sense of the information, but also weaves the various strands that are involved in making video games.



Future

With the time left before the examination and with the aim of narrowing my efforts, the tasks I expect to implement revolve around making variations of the rules and measuring how small tweaks in the fitness function affect the outcome of the game. In addition, I want to improve the variety of the assets and to explore the ways in visualising the state of the system, and communicate this information to the player.

Through my research and journey into the new methods for procedural content generation I found the approach taken by Antonios Liapis in his paper Piecemeal Evolution of a First Person Shooter Level and his collaboration with the industry a great example. This is because it integrates with other tools in a pipeline, making emphasis on creating "i*terative, modular and parameterizable processes*".(Liapis 2018)
While my initial objective was not to create a template code that could be shared and independently evaluated, I recognise now the need to share my work so it can be expanded and independently evaluated.

Fortunately, the code in this project was built in a modular way, to facilitate re-usability and break dependencies that could make it unintelligible in the future. In hindsight, I recognise that there are some design decisions that are convoluted and specific to the values of the project, and could be streamlined with the aim of sharing the code as an open source repository. These efforts could be a precursor to create a more generalised version that could be turned into a research paper in future.

At the end, I found the closing remarks made by Aleena Chia in her lecture Automated Futurisms in Digital Game Production (Chia 2021), a great insight into the possibility of creating sustainable business practices by re-framing PCG as a tool for creating more integrated gaming communities and collective processes, while taking advantage of the good aspects of relational labour.

"work premised on building and maintaining relationships"(Whitson, Simon, and Parker 2018, 616)

Reflections

At the beginning of this project, it was not clear to me why the cellular automaton is a good computation method to create interrelated elements and simulate systems with dependencies. It was only through writing the actual code and adapting the grid method of creating neighbours to a Voronoi map that I could gain an insight. Here, I could locate with more precision why it was a good solution to create environments that could react and have inner processes, instead of being part of a static background awaiting the player.

Regarding the AI methods for games mentioned through this report and the implementation of the evolutionary algorithm in this project, the process demystified a field that was cryptic to me, and opened the door to continue honing my abilities to read academic research and technical resources by translating these materials into usable tools.
I also recognise how opening a space for writing about video games and reading academic papers was a key factor in promoting critical thinking for my practice.

By promoting connections with studios and with scholars, this master program engaged with fields I would have not dared to discover by myself.
As a game designer, reading theory on game development and translating some of the criticism made by the authors into an actual implemented design added another layer of complexity, but also served as a way of reevaluating old assumptions through new perspectives. Thus giving me a new understanding of my practice embedded in a more complex web of discourses and labour realities.

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Appendix

Factorio

As a logistics-oriented game, it features endless production, expansion of the complexity of the game elements, and relationships. But at the same time is a sort of capitalist dream. All of the basic resources of the game are obtained by mining and the environment is used as a backdrop for exploitation, where the inhabitants of the game are literal bugs that need to be squashed.

However, the game plays with the concept of rate of change(rate of production output). I would argue that managing the rate of production is the main activity of the game.

This game is relevant as an example in two ways, is a good example of the creation of complex relations with simple elements, and at the same time is an example of the kind of relationship with the environment I wish to avoid.

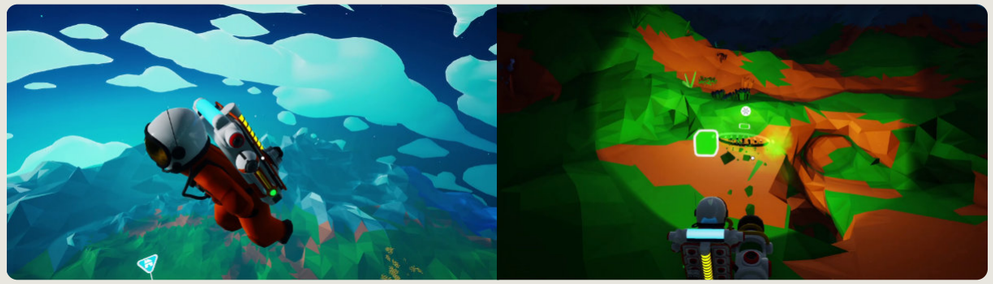
Key elements: rate of change, optimisation, expansion, relations.

Astroneer

As a 3D exploration game, with a terrain modification tool. The game is a good example of an environment that is generated using PCG. The algorithms used for the game are well understood and studied and the developers have been open on how their tech works.

This game is relevant as an example because of the one-sided modification of the terrain by the player, and the lack of consequences of changing the entire topography of a landscape. As with other games in this list, the basic resources are obtained by mining.

Key elements: Terrain modification, static environment

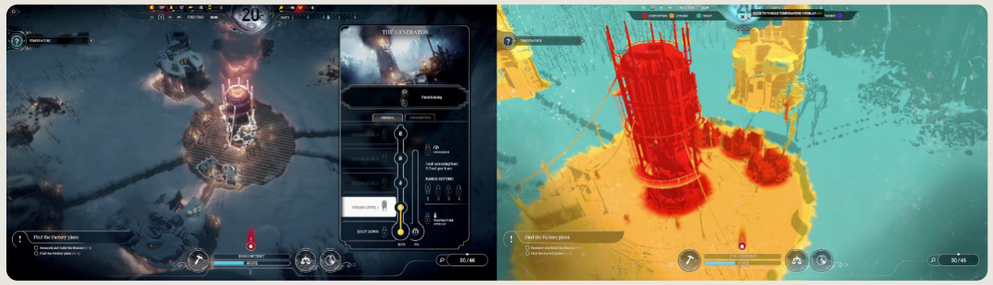


Frostpunk

The game exposes heat as a central element that needs to be managed. Heat comes from extracting coal from the environment and burning it on a central generator. The interesting part of the game comes from presenting the resources to produce the heat as finite.

The difficulty of the game comes from balancing the following elements: The needs of the workers, the economy, the weather and the society attitudes.

Weather is the most relevant here and is a point to examine because this element of the game flows in one direction, the decisions of the player and how he decides to play do not influence the severity of the cold or the time a storm hits the city.



Below

Below is a top-down dungeon exploration game that uses procedural generation to create the mines and caves the player explores. The player's task is to collect shards or souls in the caves and steal sacred gems. Through environment clues and the actions afforded to the player, the player learns that the controlled avatar is evil, and the act of exploration is also a violation of a sacred place. The inversion of using the player as a negative force is a good twist for this sample of games, but at the same time, the player only has the option of being evil to complete the game.

Key elements: negative exploration, the player is the antagonist of the environment, limited procedural generation

Into the Breach

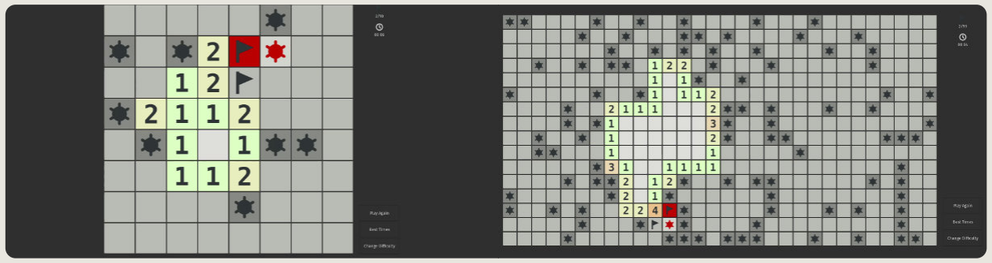
Into the Breach is a turn-based strategy game where the player has the task of protecting buildings from and invading alien species. The game is played in a grid tiling with procedurally generated environments. Protecting the buildings in the game has a higher priority than protecting the player units, and many parts of the environment are used to defeat the enemy. However, when the progression of the campaign is not going as expected and the losses in units and buildings are significant, the player has the option of abandoning the campaign timeline and restarting the game, saving the progress of one unit. This element of abandoning reality for one with better odds has a narrative impact on the story of the game and is a good point for the player to stop and think about the decision of discarding a reality or an environment.

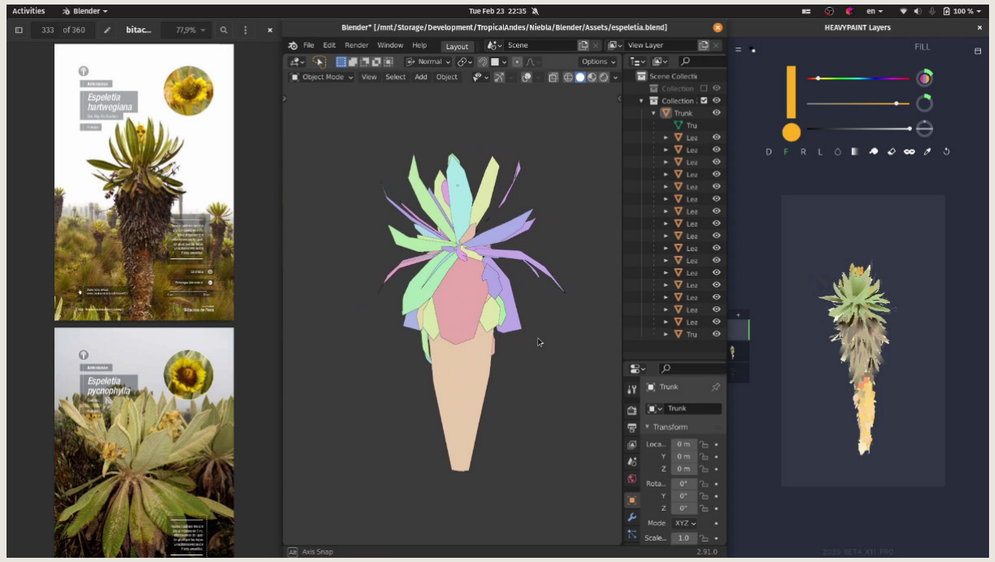
Key elements: discard reality/campaign, awareness of the environment, defend environment/structures

Minesweeper

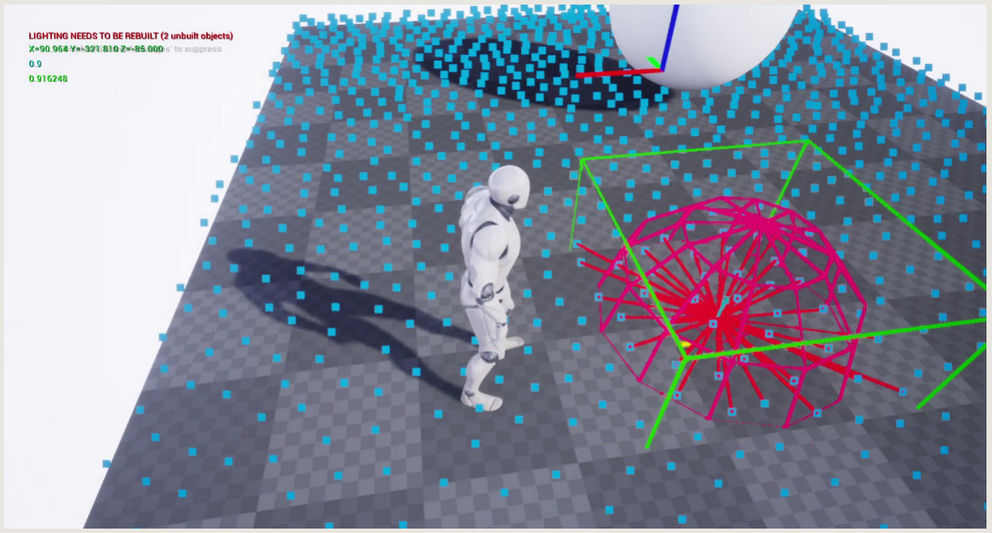
A classic game of finding mines by guessing their location by counting tiles. Not exactly an exploration game but the idea of probing a terrain while balancing the danger of triggering a mine is an interesting element.

Key elements: probe the environment, sampling terrain, abstract setting

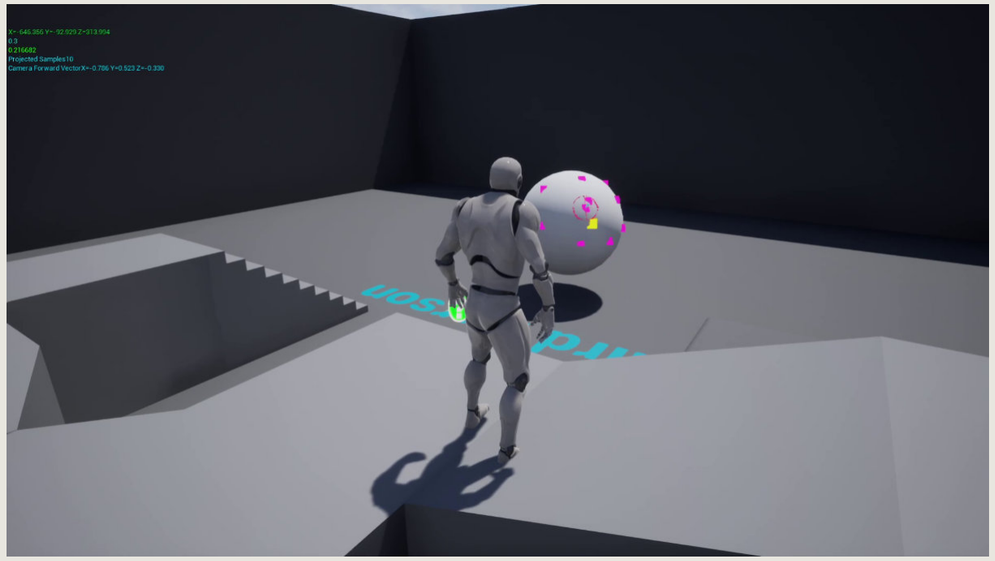




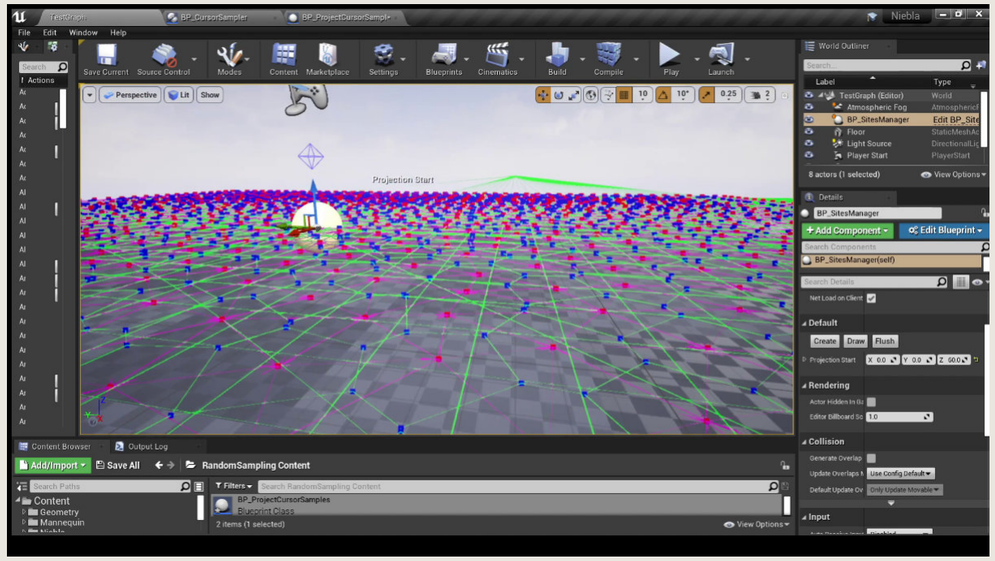
Basic asset hierarchy



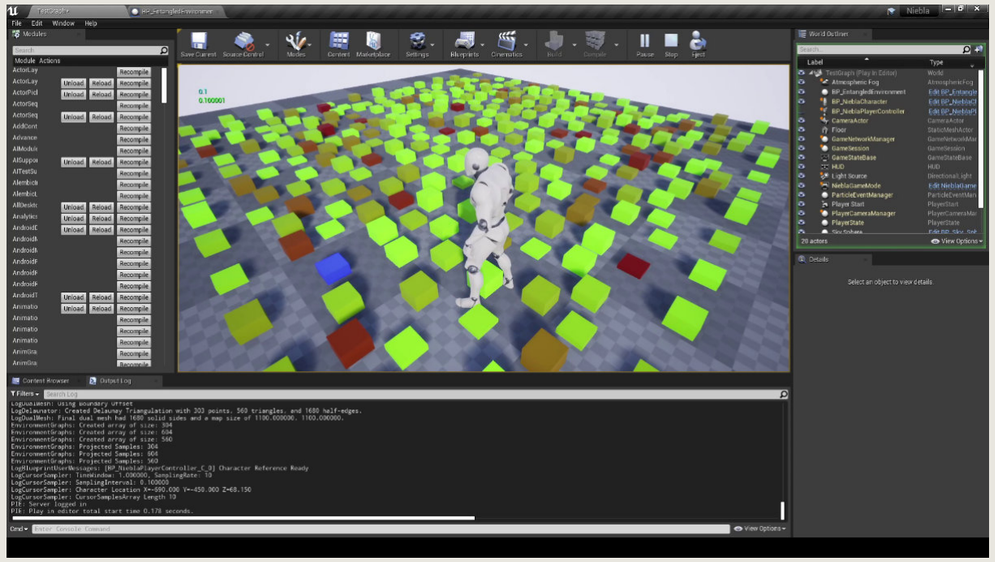
Octree to access the regions in an efficient way



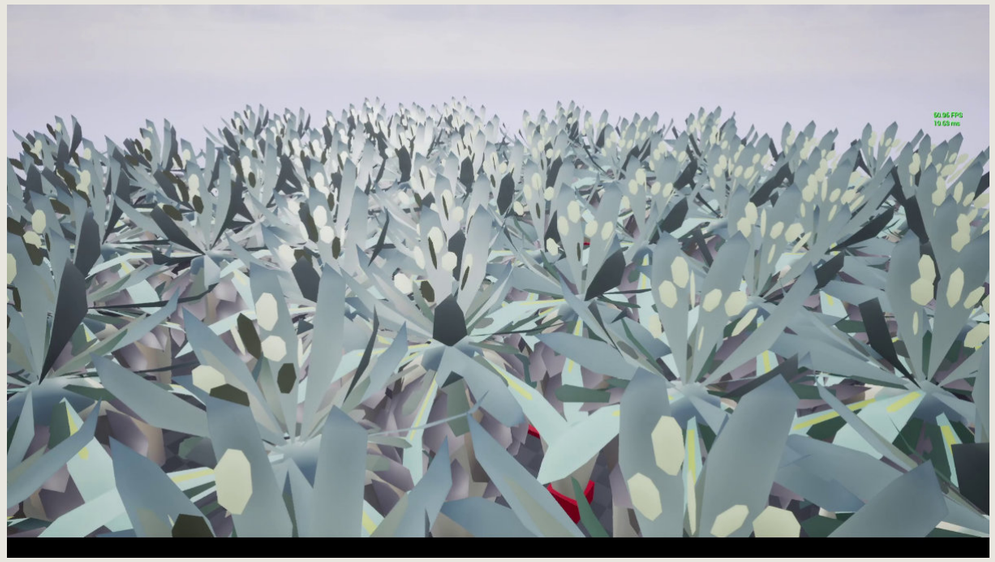
Controller and cursor sampler



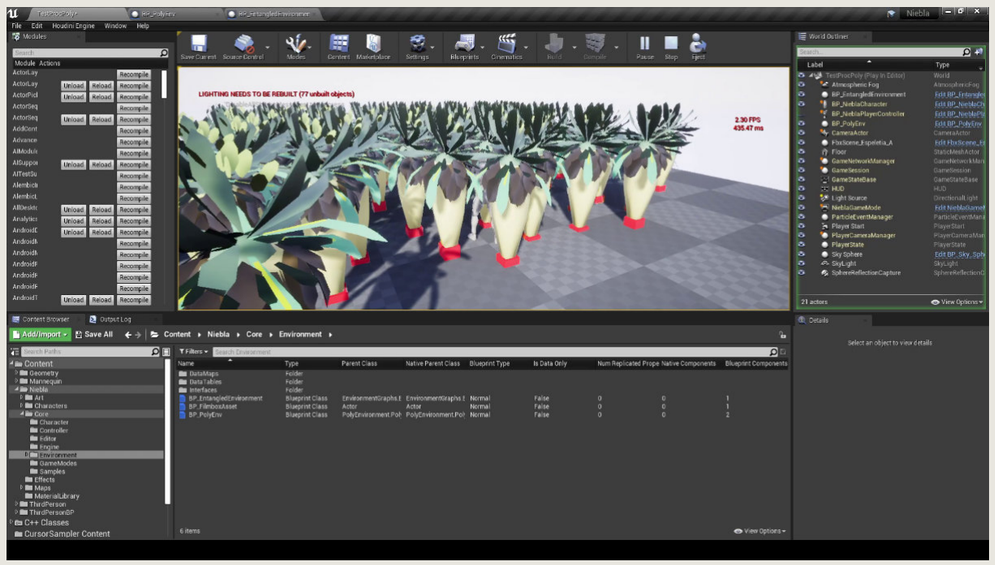
Vorononi map



Visualisation of region type



80 instances running at 50 fps after switching
to custom Runtime Mesh component module



Early test of the native procedural mesh component from
Unreal, running at 2 fps

Changing and updating collision mesh
at runtime