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VISUAL AESTHETICS IN PROCEDURALLY GENERATED ENVIRONMENT DESIGN
Creation of explorable locations in Barotrauma

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Abstract

Procedurally generated content has shown its popularity in video games in recent years. However, it is crucial to guarantee the visual aesthetic aspects of computer-generated content in order to enhance the players' gaming experience. The objectives of the thesis are to find the balance between procedural generation and human-made design while maintaining the importance of visual aesthetics in environment design.

The thesis analyzed the significance of procedural generation in video games while showing its difficulties in the application following with an example of how game developers handled procedural generation's disadvantages while managing to maximize its benefits. Eventually, a project called Barotrauma and how procedural generation is implemented into the game is thoroughly analyzed.

The author also focuses on the importance of visual aesthetics in video games' environment design and its effects on players. Theories related to the topic are discussed to demonstrate how visual elements evoke players' emotions during gameplay. Additionally, the thesis also highlights the relationship between visual aesthetic and procedurally generated environment by analyzing different game titles' production workflows. Their workflows are used as references for the later stages in the production.

The thesis's productive outcome is one of Barotrauma's outpost locations, an explorable area generated by artificial intelligence. The author provides a workflow of creating a collection of assets with different techniques and programs in order to illustrate the application of visual aesthetics in a procedurally generated environment. The thesis and its productive outcome also show potentials in other features of the game and as a reference for future projects.

Keywords

environment design, procedural generation, visual aesthetics, game design

CONTENTS

1 INTRODUCTION

The game industry has been growing tremendously for the last decades. Thanks to the development of new technologies, game developers have managed to provide players with growingly immersive video games, which results in players' constant cravings for unique and unexpected gaming experiences. In recent years, procedurally generated content in video games has been emerging as a storming trend to embrace such needs. According to Short & Adams (2019): *We want generators to make something a human would make, or more precisely, something we didn't expect would be made, a spark of genuine creativity. We want to be pleasantly surprised.*

The author seeks to answer the question about the significance of visual aesthetics for procedural generation in environment design. To approach the main question above, the author needs to address two different aspects, which are the use of procedural generation and the understanding of visual aesthetics in video games, as well as their relationship and how to fully apply them in environment design. To methodically examine the uses of them in video games, a game project called Barotrauma is carefully analyzed. The project's workflow is broken down into different parts to serve the purpose of the thesis, along with the problems and difficulties that happened during the process. Additionally, solutions are introduced to fix existing issues. The author also included and examined examples of released games that successfully applied visual aesthetic elements with procedural generation in an environment design to consolidate the theory.

2 FAKEFISH OY AND BAROTRAUMA

2.1 Fakefish Oy

Fakefish Oy is an indie game studio based in Turku. Established in 2014, the studio concentrates on developing games in different genres on PC and mobile platforms as well as subcontracting for other studios. The studio launched its

major commercial project, Barotrauma, as an early access game on Steam in June 2019.

The studio is divided into multiple departments with more than 20 employees, both full-time and part-time workers. Under the visual direction of Pekka Saari, former creative director, the author is responsible for the environment design of Barotrauma. The author works jointly with Jamsen, lead designer of Barotrauma and Rikkonen, lead programmer and founder of the project during the production of the thesis.

2.2 About Barotrauma

Barotrauma is a 2D co-op online multiplayer simulator game. Rikkonen (2018) talks about the game's inspiration as Space Station 13, Pressure, Link-Dead, and Minecraft. The development of Barotrauma began as a free source in 2015 and soon gained popularity from the indie community with its survival horror elements. Noticing Barotrauma's potential in gameplay and world design, Fakefish Oy decided to launch the game as a commercial product. Currently developed as an early access title, Barotrauma is estimated to be fully released in late 2020.

Barotrauma's world is set in a fictionalized version of Europa, one of Jupiter's moon. Most of the activities take place in Europa's ocean, under the planet's icy surface. In the campaign mode of Barotrauma, players are responsible for protecting and directing their submarines, moving from different locations from the third-person perspective while freely exploring Europa's ocean. The game's Campaign mode is analyzed as the main focus of the thesis.

2.2.1 The campaign mode of Barotrauma

The heart of the campaign mode is a procedurally generated map consisting of numbers of nodes that represent locations around the world, within nine concentric rings. The players' journey takes place between these nodes. Each

ring represents a deeper level of the aliens, with a corresponding increase in difficulty.

Every node on the map is connected by at least two edges, forming a transit graph. The length of the transit depends on the distance between two nodes. The probability of random events happening during the transit, with longer transits is more likely to bring random encounters than shorter ones.

The campaign's goal is to help the spread of the last remnants of humanity towards the icy depths of Europa. Any attempt by players to rush from their start location within the outermost ring to the center will lead to failure since the overall difficulty of gameplay is higher than the difficulty of the ring before it.

Handcrafted locations in the campaign mode in Barotrauma

Handcrafted locations are an in-game area generated from the game's algorithms created by designers. These locations have enough survival equipment to maintain its functionality, such as full electrical, oxygen generation systems, autonomous NPC crews who maintain and operate the various systems, patch up hull damage, repel aliens and human griefers, and provide rewarded quests.

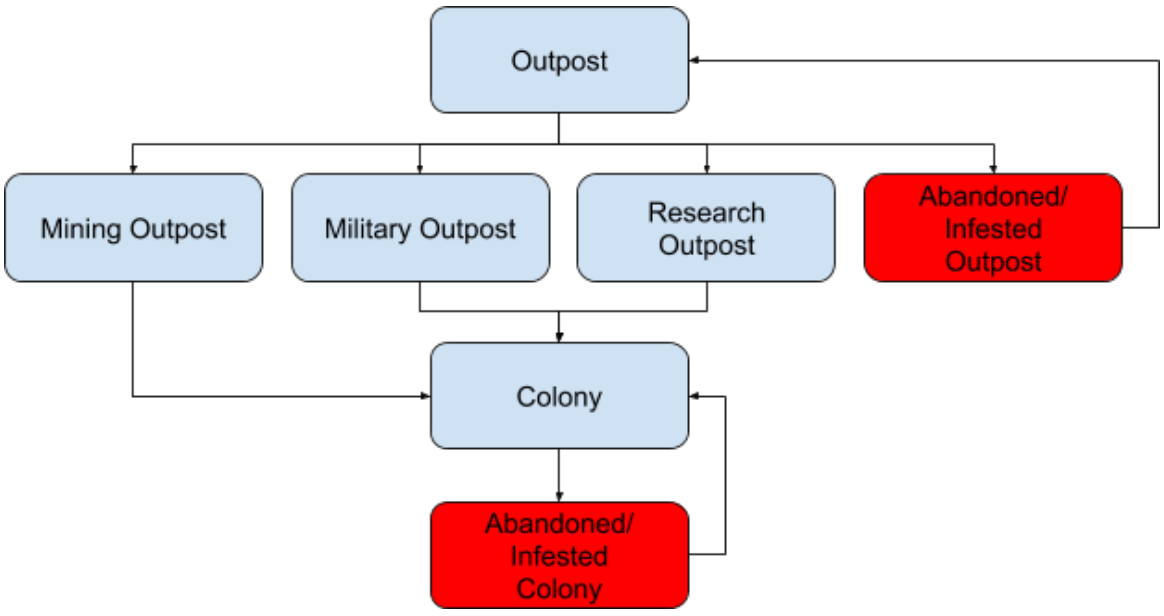

Figure 1. Handcrafted location design in Barotrauma (Rikkonen 2019)

The handcrafted locations include outpost areas and colonies, gradually develop throughout the process of the game, only speed up when players complete missions related to them. The outposts are the seed from which all other human-made locations are generated. They could be divided into four categories, located in a specialized area of the map. Each outpost performs different roles: habitation, research, military, and mining. All of the outposts share similar functions, such as providing specialized employers as crew members, trading items, and producing rare and specialized equipment depends on the type of outposts themselves. However, they are designed to be distinctive and diverse. Depending on the in-game events or players' progression, an outpost might be evolved into a colony, where it provides a more extensive range of employers, items, submarines, equipment, quests, and similar. A colony is designed with a more significant population and becomes more protective than an outpost, yet it still can be infected and abandoned based on the in-game events. (Figure 1).

2.2.2 Art Direction

To summarize the aesthetic of Barotrauma, Jamsen (2018), mentioned hopelessness, paranoid, dread, isolation, and fear as being the key emotions Barotrauma deals with. Players must feel they are always in a bleak, hostile and unsafe world where anything can happen at any time, and where the monsters outside the submarine are perhaps less a threat than the monster within.

The art direction is established by Pekka Saari, former Art Director of Fakefish. The graphics of the game are designed with a semi-realistic style along with a dark, eerie atmosphere to increase the depressing and suffocating feelings and to emphasize the theme of isolation, claustrophobia, and cosmic horror. (Saari 2018.) This art direction serves as a guideline throughout the development process.

Figure 2. Objects in Barotrauma (Dinh 2019)

Figure 2 illustrates Barotrauma's art direction through its dark, low saturated color scheme while offering its overall aesthetic look of the game through its high contrast and detail. Light and shadow are rendered during the developing process, due to the limitation of the game engine.

3 PROCEDURALLY GENERATED ENVIRONMENT

3.1 Definition

Procedural generation is a special term for data creation algorithmically by artificial intelligence, commonly called AI, for the content creation process in video games. It is easily mistaken for random generation, which is a mathematical algorithm that produces random numbers, yet they both can be distinguished. Procedural generation lets the AI in charge of creating different content from various materials and instructions, while random generation creates a list of numbers and values for the AI to pick on a smaller scale. Procedural generation has the potential to bring the unexpectable value and replaceability for players, which makes it the developed form of random generation. (Bycer 2016.)

3.2 **Advantages and disadvantages**

This section discusses the advantages and disadvantages of procedurally generated design over a hand-crafted approach to create a solid technical foundation for the eventual creative process. Short & Adams (2017) stated that humans' strengths are estimation, prediction, combining experiences and knowledge, while computers have the benefit of invaluable calculation accuracy and time efficiency can increase satisfaction.

Procedural generation has a certain level of dominance over hand-made design thanks to its ability to overcome technical limitations, and its advantages in time-saving, expandability, replayability, reusability, rules enforcement, modeling reality, and scales. Uniqueness in design is also the strength of procedural generation, as it provides players with individual experiences, new gameplay interaction modes, player input, unpredictability, living system, inhuman creativity, reflections, and refractions of humanity, the inspiration of infinity, and fun. (Short & Adams 2017.)

On the other hand, the procedurally generated design has some defining flaws that can somehow limit its application. Reliance on procedural generation could cause a bland level design. Besides, a procedural design requires a much more technical and elaborated requirement to function correctly. Otherwise, the gameplay quality could be inconsistent and messy, and the difficulties between each level are uneven or repeated. These issues can confuse players and affect the game’s performance. (Saltsman 2016.)

In order to investigate how to maximize the benefits of procedurally generated design to create a unique and compelling gaming experience while still avoiding its existing disadvantages, the author looked into Dead Cells. This video game has successfully implemented a procedural level generation system. According to Benard (2017), the lead designer of Dead Cells, the studio first created a frame for the procedural generator to generate content. This frame contents its fixed

rules game mechanic, which were set by designers. From there, the designers carefully create prototypes of rooms with different purposes used for multiple environments. They all have different requirements that are in charge of how players interact with the game and are arranged systematically by a set of instructions created to allow the algorithm to generate the environment. The algorithm works as it tests if the room qualified, and it leaves if the room does not match the requirement. Once the rooms are ready, the designers set up a scale of numbers for the algorithms to generate obstacles and monsters. On the final step, the algorithm randomly generates valuable items as rewards for players to explore. This pipeline-has many promising features to be applied in other games, including the hand made location generation in Barotrauma.

3.3 Application of procedural generation in Barotrauma

Before making assets for the game, it is crucial to understand how procedural generation is used in the game environment.

To procedurally generate quality content, one of the most common methods used is Distribution. Due to its efficiency and time-saving in the workflow, it is considered the easiest way. This method allows AI to choose between various options under specific structures, where it decides the variability in distributing options based on their condition. (Short & Adams 2017.) This method was used in the human-made location generating process of Barotrauma under three stages (Rikkonen 2019).

Figure 3. Room prototypes creation (Rikkonen 2019)

In the first stage, designers manually created variance room prototypes for the outpost in the Sub Editor. Specified assets were provided by the author to fit the theme of the room. The algorithm speeded up the process by randomizing assets in the game, which included moving assets around, choosing between different items and structures. Designers finalized the room to fit the requirement (Figure 3).

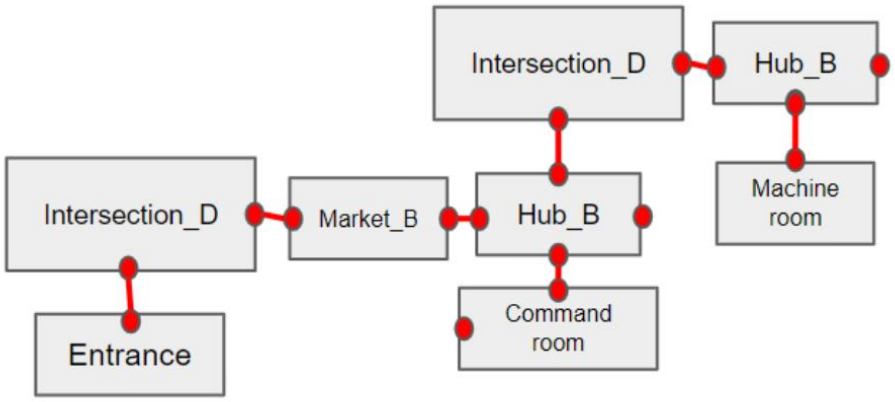

Figure 4. Outpost map creation (Rikkonen 2019)

Figure 4 illustrates the second stage of the process. It starts when the designers start creating the map of the outpost. They configured the requirements of the

outpost, and the computer would randomize the rooms to fulfill these requirements. Once the designers were fully satisfied with the map of the outpost, the third stage started.

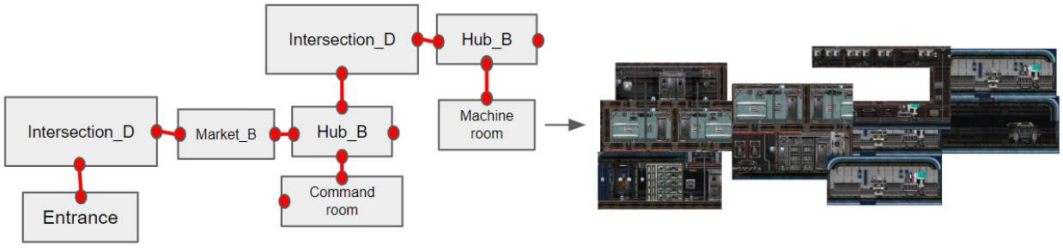

Figure 5. Room generation (Rikkonen 2019)

The third stage is called placing rooms, where the computer loaded the room modules based on the generated map. Figure 5 illustrates how the stage works in theory. The designers needed to connect different rooms using hallways generated by the algorithm. The designers added electricity and created oxygen to the outposts to meet the living requirements and finalized the outposts.

4 VISUAL AESTHETIC IN ENVIRONMENT DESIGN

Environment objects cover a significant part of the game's visuals, as they are put in consideration of the whole picture's composition. Therefore, environment design should serve as narrative obstacles to the character. (Solarski 2017.) This chapter focuses on the relationship between the aesthetic of procedurally generated assets and environment design.

4.1 Shape and silhouette

This subchapter focuses on the significance of the strategic usage of shapes and silhouettes in visual design and its application in the specific case of Barotrauma.

Figure 6. Wooden sphere, cube, and star (Solarski 2013)

Shapes are associated with their corresponding concepts based on players' personal experience and perception. Environment artists benefit from the experience that players already have in real life to transfer them into the artwork. Solarski (2013) explained the statement by introducing a photo of a wooden sphere, cube, and star (Figure 6). He asked the readers to imagine a scenario where these objects are placed on a moving surface. The cube remains in the same position, while the sphere rolls due to its curvy shape. He explains how circular objects are usually considered young, soft, and energetic since they relate to real-life objects like balls, balloons, in contrast to rectangular-shaped objects with their aesthetic of steadiness, balance, and maturity. In the second scenario, Solarski wanted the readers to catch these objects while they were thrown toward them. The star with its sharp angles was considered to cause the most damage compared to the cube and the sphere since the star, and its pointy form was easily associated with sharp objects like knives, horns, thorns, which are symbolized for dangerousness, hurtfulness, and hostility.

Figure 7. Rectangular objects in Barotrauma (Dinh 2019)

In Barotrauma, most objects are designed to have a rectangular shape (Figure 7). Interactable objects in Barotrauma, which mostly are machines and architecture walls, are solid and required to be placed in a fixed position in-game and hardly be moved by players. Therefore they are designed to be rectangular to fit the visual aesthetic of the game. These assets are spawned in a random way when players enter the game. They need to maintain an aesthetic rhythm throughout the experience.

4.2 **Repetition, pattern, and rhythm**

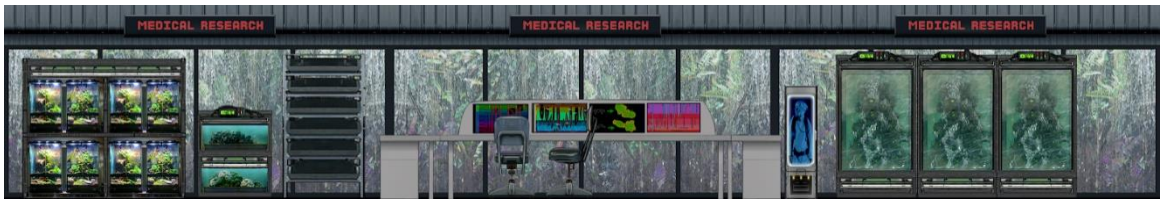

Figure 8. Rhythm in environment design of Barotrauma Distribution (Dinh 2019)

Repetition is the act of combining several similar elements to create a form of visual attraction, which generates a pleasing and appealing environment design (Wang 2012). A pattern is the application of repetitions in more than one design element. Every pattern has a rhythm, which is a movement of speed generated from a different variation of the elements (Soeagaard 2019). Soeagaard (2019) also pointed out that in environment design, unified patterns are used frequently to enhance the aesthetic of the environment as well as to improve the experience

of players. Repetition, pattern, and rhythm are widely used in 2D video games, especially for backgrounds. By strategically applying the combination of pattern, repetition, and rhythm in the environment design, the game developers can effectively orchestrate the gaming experience (Figure 8).

4.3 **Colors and tone**

Chapman (2010) has published research about the use of colors in design and how they evoke the feelings of players depending on social culture and individual desires. Warm colors, which are the variations of red, orange, and yellow, are associated with fire, heat, warmness, anger, strength, and positivity. In Barotrauma, they are only used in a few situations and are tuned down by the surrounding dark and cooler colors due to their positive nature. However, in some cases, they are used to invoke a sense of emergency (Figure 9). Cool colors are a combination of blue, green, and purple. They represent water, coldness, calmness, and mystery. Since Barotrauma gameplay happens in the ocean, underneath a thick layer of ice, the cooler tones are primarily used (Figure 10).

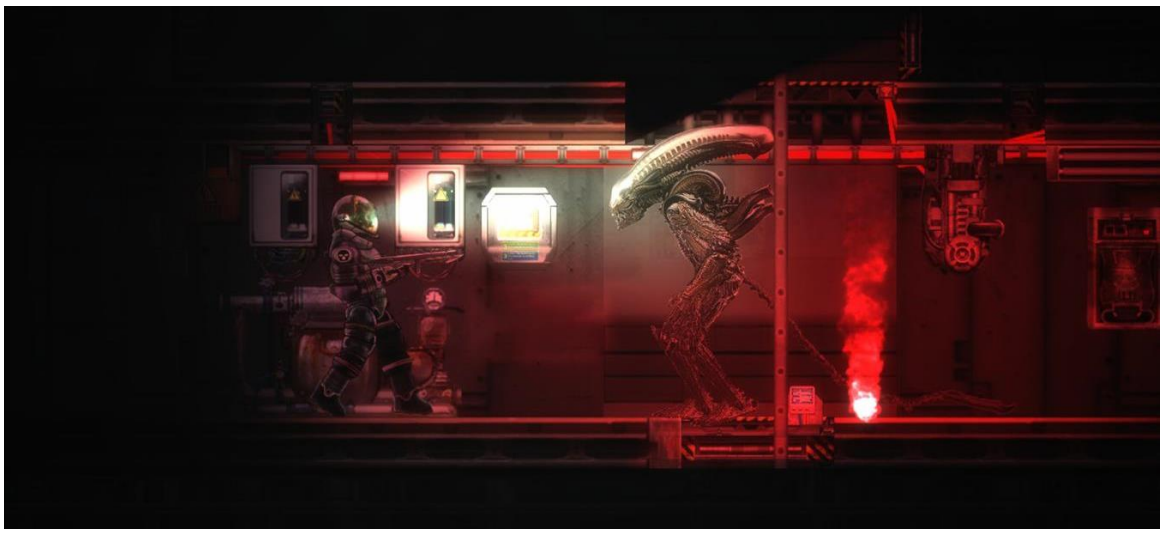

Figure 9. The use of warm colors associated with an emergency in Barotrauma (Rikkonen 2019)

Figure 10. Application of cool colors, neutral colors. and the artificial aesthetic of human-made locations (Dinh 2019)

Neutral colors are mainly used in the background of the game. They offer a functional transition space between various saturated colors. The uses of colors in some cases are applied based on real-life reference. Figure 10 has the primary color of purple, which is based on the references of LED grow lights used for laboratory areas to symbolize the human-made products with an artificial aesthetic.

4.4 **Relationship between players and the environment**

Solarski (2017), in one research mentioned that environment objects had an essential role as the narrative obstacles that either has a harmonious or opposing relation to the playable characters. Solarski examined the game of Super Mario Galaxy to illustrate four different situations.

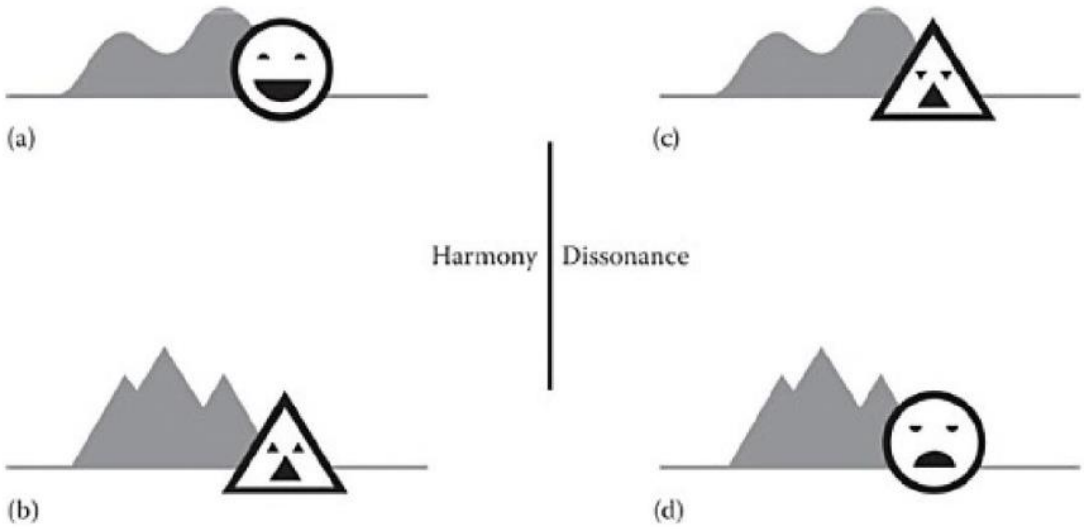

Figure 11. Relationship between players and the environment (Solarski 2017)

When the characters share a similarity in the visual design with the surroundings, players have a sense of safeness since it reminds them about the character's home (Figure 11a and 11b), or a hazardous area when they are placed in the opposite (Figure 11c and 11d). This relationship is made by the harmony or dissonance between players and the environment.

5 VISUAL AESTHETIC IN PROCEDURALLY GENERATED ENVIRONMENT

5.1 A case study of Dead Cells

As it is mentioned above, the studio of Dead Cells used procedural generation to create their in-game environment with an appealing graphic. This subchapter focuses further on how visual aesthetic is used in a procedurally generated world by analyzing Dead Cells' production workflow.

Massé & Vasseur (2018), two artists who were in charge of the visual graphic of Dead Cells, shared their pipeline and principles of the game's art direction. A combination of a color palette with unsettling elements is the first principle Massé & Vasseur mentioned, as it vibrates the art direction of the game. Despite the stereotypes of dominant desaturated aesthetics in hardcore games, which are the

overuses of low contrast and the lack of usages of saturated colors, the artists expressed a preference in a saturated color palette for the game. By using the unsettling background elements as the key factor that leads to an obscure and mysterious environment, the game has successfully brought a sense of abomination and danger to players' experience. For example, Dead Cells introduced the main character standing in front of a heroic and dramatic light, yet players could easily spot a rotten giant corpse with a spear on its chest, lying on the left side of the room (Figure 12). Not only the scene brought a dramatic atmosphere, but it also brings a fresh and new impression of a hardcore genre type of game.

Figure 12. Combination of colors and background elements (Massé & Vasseur 2018)

Since Dead Cells features its fast-paced rate with quick combat and responsive systems, it is crucial for players to quickly respond to the events happening in-game. By effectively distinguishing the background with interactable objects, the legibility of the scene is indicated. Massé & Vasseur (2018) pointed out that the level's collisions need to be separated from the background by a degree of contrast to reflect its importance. Besides, the background required a color palette that can blend into each other. An analogous color palette is a suitable

choice for this situation since these colors are harmonious to each other since they are adjacent (Malamed 2015). Figure 13 illustrates the uses of analogous colors in Dead Cells.

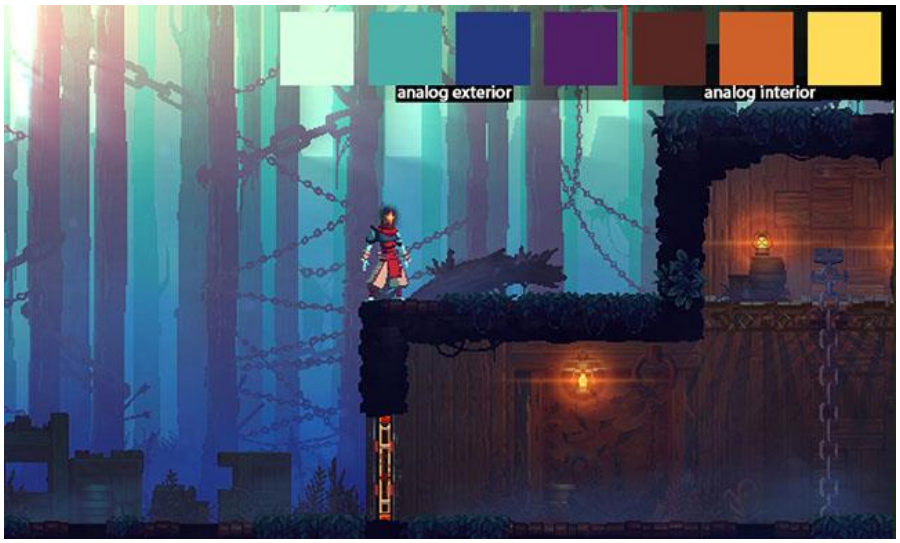

Figure 13. The uses of the analogous palette in Dead Cells (Massé & Vasseur 2018)

Interactable objects also hold an essential role in the game. They need to be recognizable and share the similarities in design. These objects need to stand out in the most pronounced shape and have the highest contrast between brightness and darkest value compared to other in-game elements. Figure 14 shows the similar design of two different game components, the Fountain of Youth and the Elite's Grave. They both have a dominant element in the center with the support of various background elements as generic rectangular shaped objects.

Figure 14. Consistency in interactable objects (Massé & Vasseur 2018)

To sum up, Dead Cells has proven its success in implementing an appealing visual aesthetic in a procedurally generated environment while maintaining and improving players' experience. By combining a wise choice of a color palette with unsettling elements, the graphic appears to be visually impressive to players. Also, a proper value of contrast between in-game components and background elements, as well as the consistency in interactable objects, really enhances players' experience.

5.2 **A case study of Hades**

Before making the assets for Barotrauma, the author centers the pipeline of visual development in video games by analyzing the visual production process of Hades. This chapter focuses on answering the question of how to create high-quality gameplay components in a technical aspect properly.

Hades is a narrative-driven, rouge-like dungeon crawler game developed by Supergiant Games released as early access in December 2018. The game is known for its over the top art style with vibrant color palettes with the isometric camera angle (Figure 15). Understanding the workflow during the production

process of Hades helps answer the thesis's research question about the optimization in the workflow of using 3D and 2D in environment design.

Greg Kasavin, Creative Director of the project (2018), shares his idea about the game as the events of the game happen where players take part as a protagonist battles his way out of the Underworld of Greek mythology. The studio developed Hades as their fourth title to bring the replayability value to players with the attention of world-building and narrative story-driven.

Figure 15. In-game screenshot of Hades (Kasavin 2018)

Jen Zee, art director of the studio (2018), shared the pipeline of making the protagonist of the game, Zagreus, during the production process. The art director first consulted with the creative director to understand the storyline behind the in-game character. To fully establish the right concept, it is crucial to go through the research stage, as Zee mentioned, to acknowledge the root of the character, including how he was written and visualized in ancient Greek culture. The first concept was usually the concept of the object in an isometrical angle. It must satisfy the requirement of the design and art side before the art director moved forward to create the concept in an orthogonal angle (Figure 16). This step

focused on clarifying any illegible details from the isometric version, as Zee called it “the industry standard” due to its importance to the workflow process. The final concept was modeled, textured, and animated by the 3D artist to strengthen the accuracy of the perspective of the object. The object was 2D rendered and finalized by the artist to prepare for the implementation process. This step focused on the translation of the concept into the in-game environment, as Zee specifically mentioned that most of the art was changed and polished at this stage to suit the whole aesthetic of the game.

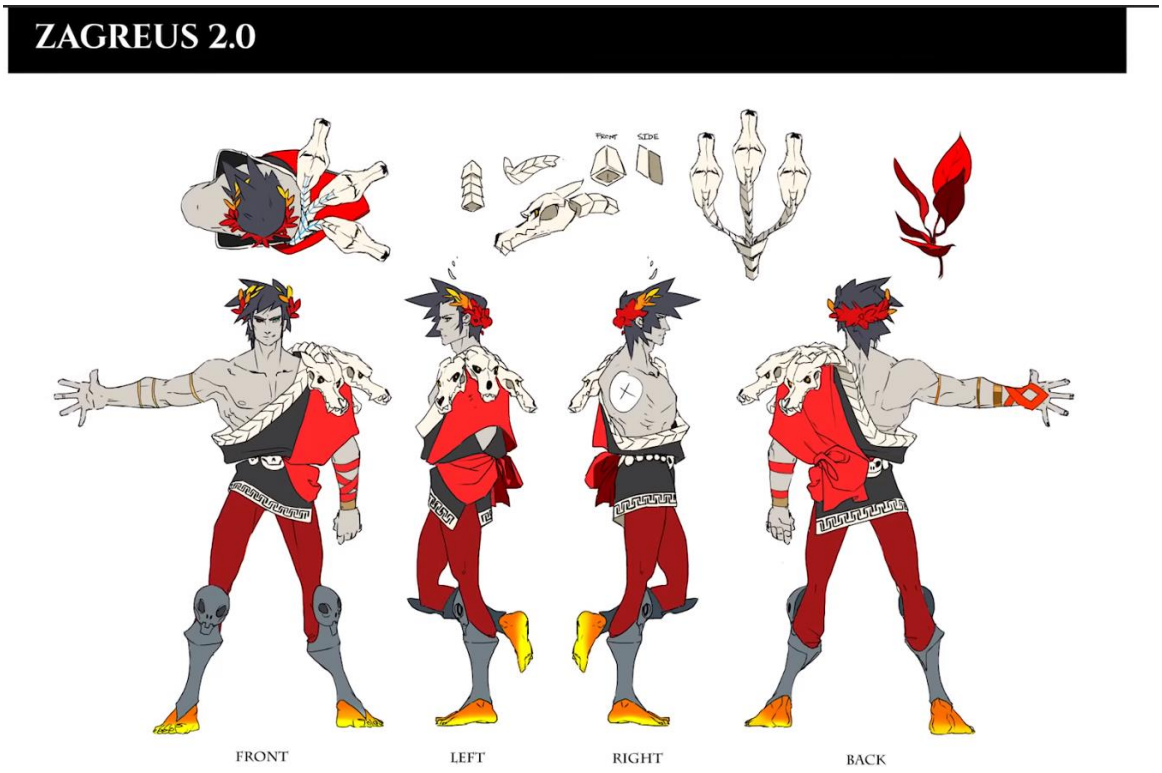

Figure 16. Character concept in orthogonal view (Zee 2018)

In conclusion, the workflow of the art production in Hades has answered the question of how to successfully visualize in-game assets using 2D and 3D art to create a polished aesthetic design. By combining different methods with the understanding of the design’s purpose, the final product is well received. After carefully considered the efficiency in Hades’s visual development, the author decided to apply the following workflow to Barotrauma.

6 ASSET CREATION FOR PROCEDURALLY GENERATED ENVIRONMENT IN BAROTRAUMA

6.1 Asset specifications

This step focuses on forming the concept of the assets. It requires the author's common understanding of the procedural generation and the requirements of the outpost. During this stage, the author worked closely with the game designer Ez Jamsen and the programmer, Joonas ”Regalis” Rikkonen to establish a solid understanding of the functionality of the outpost.

The author chooses a human-made area of the generic outpost called “the storage.” The storage is designed to be a base for other types of storages, which are military storage, mineral storage, research storage. Assets created for the basic storage can be used for other types of storage, where different items and background walls are modified depending on the usability of the storage.

The design of the outpost's storage needs to answer the following questions about how players will interact with the outpost, how the outpost will benefit the gameplay of the game, as well as how the visual assets represent the functionality of the storage. Jamsen (2019) describes the storage as it should give the impression of there being some amount of space to store supplies along with its functionality, which should be interacted by players to serve the in-game mission. Besides the primary purpose of storing items, the storage is designed to be an area where players can walk by while traveling between different locations, as well as to stop by searching for random generated valuable ones (Jamsen 2019).

6.2 Asset categorization

To create a systematic process that fully optimizes the workflow, a step of categorizing assets is made during the process. This subchapter explains the criteria used to categorize these assets and how they benefit the whole process.

The assets in the game are categorized into two types: background objects and interactable objects. Each type of object can be subdivided into common assets and specialized assets. While common assets can be used universally in various outposts, specialized assets are tailored to be used in specific locations (Figure 17).

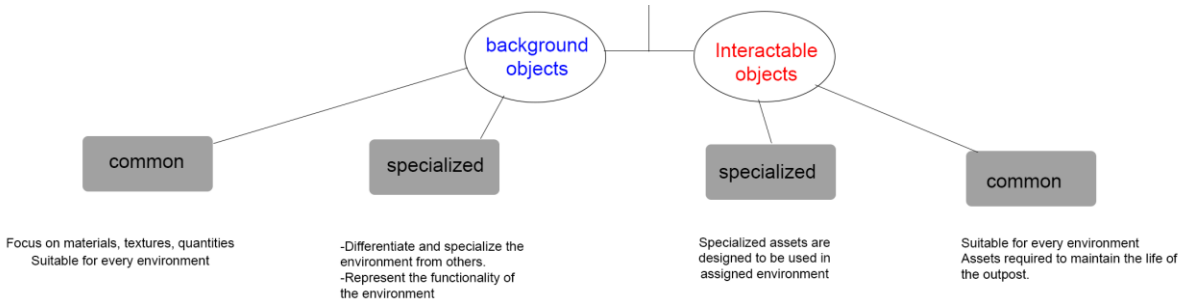

Figure 17. Asset categorization in Barotrauma (Dinh 2019)

The common asset is designed to be the interior component of all the environments in the outposts. They are objects that are commonly used in daily life with an essential design fit with different types of rooms. They have generic shapes with unsaturated colors scheme inspired by real-life objects. Not only do they effectively suggest functionality based on users' real experiences, but they also benefit the visual aesthetic by offering a cohesive and harmonious look

Specialized assets are objects that can only be used in specific locations. They are mostly interactable machines and items. They are required to have more elaborate shapes to catch players' attention since many of the in-game interactions involve these objects. They take a small number in the total assets, yet cannot be replaced, due to the assets' specialties in shapes and functionality.

Categorizing assets based on their functionality not only prioritizes the asset creation but also fastens the production process. While common assets are repeatedly used in the production stage, thanks to their convenience and necessity of them in the design by allowing artists and game designers to reuse

the same 3D and 2D design in different locations, specialized assets finalize the design due to it specific looks. They differentiate one outpost from the others, without confusing players.

6.3 **Conceptualization**

According to research by Hagen (2004) on concept art in design, the process was divided into two parts, the recycled part, and the innovative part. This concept art creation process started with gathering references and inspirations in real-life environments and objects called the “recycled part” and ended with where the idea got developed creatively to add authentic value to the game, called “innovative part” (Figure 18).

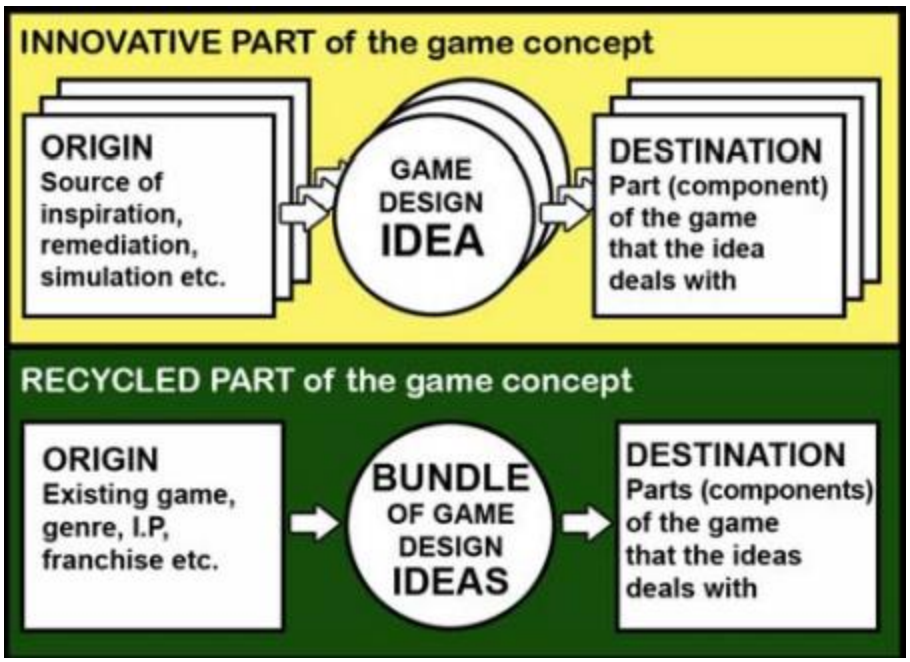

Figure 18. The game design concept (Hagen 2004)

In the case of Barotrauma, the concept pipeline is based on Hagen’s research. Material for the recycled part is collected from different sources and gathered in a mood board, while the innovative ideas are implemented during the conceptualization stage to serve its purpose.

6.3.1 Material gathering and sketch

Since the outposts are built in the world of Barotrauma, its visual direction concentrates on applying existing materials as well as finding new ones to keep a cohesive look of the game. The author reused a collection of the gathered materials provided by the company(Figure 19). The company then purchased the suitable materials to use for the project.

Figure 19. Compilation of reference photos (Dinh 2019)

The storage area in Barotrauma, due to its purpose and convenience in functionality, needed to be displayed for players to be aware. The author followed the pipeline of Hagen (2004) about the Recycled part in conceptualization, where the most typical objects appeared in the references, such as shelves, racks, which were added into the design so the storage would be fully recognizable.

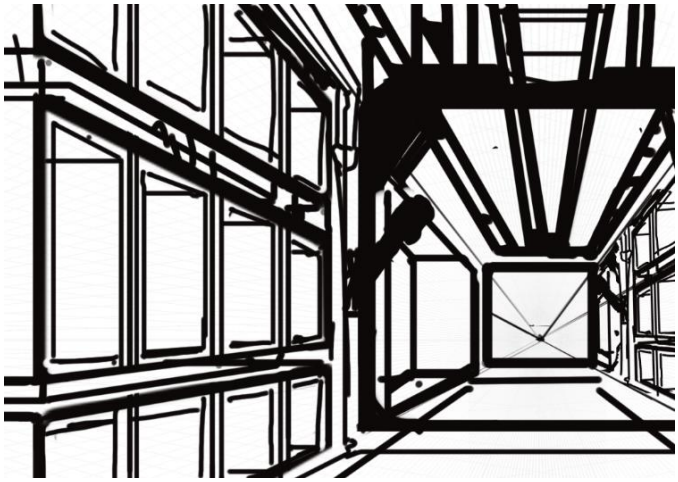

Figure 20. Sketch version of the outpost (Dinh 2019)

To quickly visualize the main idea about the concept gathered from the reference photos, a rough sketch was quickly made. It was performed digitally on Photoshop in a short amount of time, mostly visualizing the environment roughly while leaving out the detail (Figure 20). However, the design was changed and adjusted frequently throughout the process, which explains the final design may not share many similarities with the sketch version in the beginning. Once the sketch is finished, a three-dimensional render and color scheme are made based on the design of the outposts

6.3.2 3D base

This is the stage that will decide the atmosphere and the theme of the outpost. It is essential to understand that Barotrauma's world is built in a post-apocalyptic era. Therefore the outposts must share a similar theme of danger and unpredictability. To start the process, the author used Blender as the primary 3D program for the concept stage due to its easy accessibility and supportive community. The texture, on the other hand, was placed as the lower prioritized element. The basic blocks will only indicate the position of the assets in the concepts. (Figure 21).

Figure 21. 3D rendered base of the outpost (Dinh 2019)

The 3D base combines mostly geometric blocks with basic lighting rendering and simple texture. This stage focuses on lighting, atmosphere, and structure of the outpost since they help identify the dimension in building the environment (Shorter 2012). Once the 3D rendered base is done, it is crucial to be evaluated by the author and the art department.

6.3.3 Evaluation and adjustment

The concept went through a private feedback session by the art department from which specific points were taken into consideration to be improved visually and was prepared for the upcoming stage of production. It received positive and constructive critiques about the compositions and color palette, yet the theme of Barotrauma should be more embraced by the variance of in-game objects along with some water elements. The author received feedbacks and improved the quality of the concept.

Figure 22. Final concept art for the outpost (Dinh 2019)

The concept was adjusted and photo-bashed in a short amount of time to follow the given instructions. The color theme of the outpost was also changed from warm colors to cool colors to represent the underwater environment of the game as well as the existence of water elements and different objects' reflection on the floor. Ladders, packages, dripping water from pipes, metal crates with in-game labels were placed in a disorganized way to give players a chaotic and untidy feeling and to fully express the signature atmosphere of Barotrauma. Unsettling element is implemented, as a lightly opened roll-up doors with unpredicted smoke and light appeared in the concept to add more cryptical volume to the concept (Figure 22).

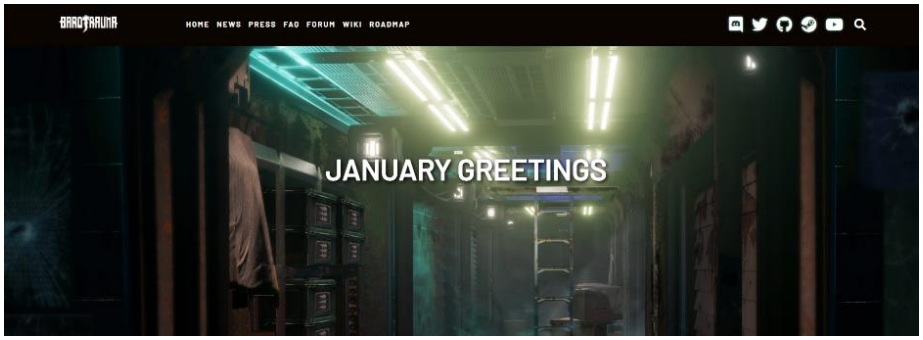

Figure 23. Applications of the final concept in marketing (Dinh 2020)

Not only the final concept was acceptable and ready to be used for the production process, but it is also qualified as marketing assets. It is used as the main banner for one of the main updates on the games' website (Figure 23). The concept also shows its potential for future merchandise.

6.4 **Assets rendering in 2D**

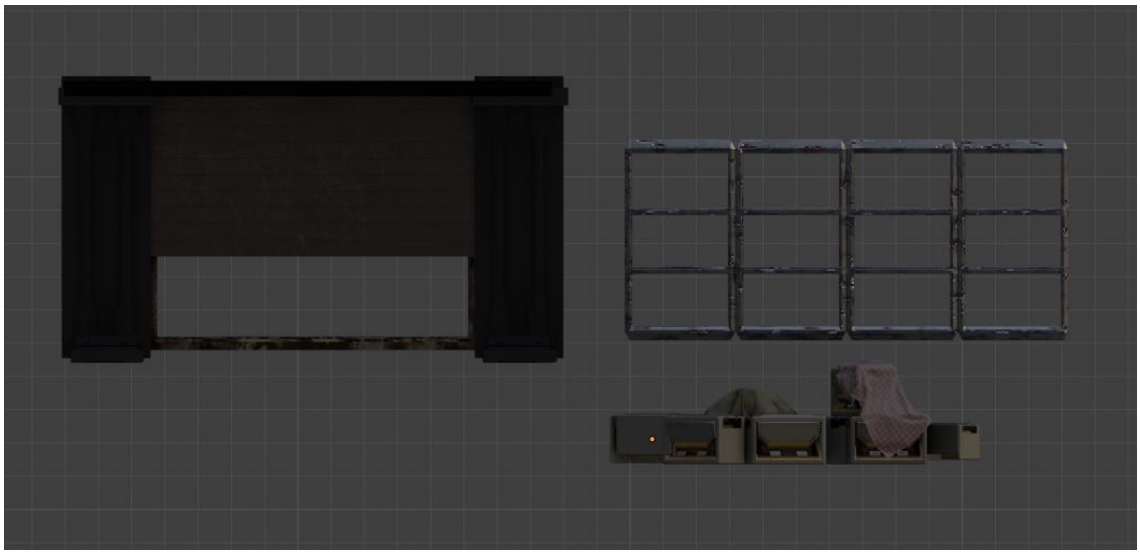

Figure 24. Asset rendering in Barotrauma (Dinh 2019)

Assets used for the concept were lined up to render the 2D version. These renderings need to satisfy the criteria of shape, texture, and lights. Multiple iterations of the asset were made from which only the most suitable one can be chosen to meet the requirements of the game. The assets should have a suitable scale compared to textures. Blender's Eevee renders engine and Photoshop were used to finalize the concept as well as to render the assets used for the outposts (Figure 24).

Texturing

The texture is the physical side of the substance that helps identify itself from others. Along with colors, texture brings experiences to the audience visually (Shorter 2012). It strengthens the atmosphere of the environment from the existing build-up 3D models.

Textures are used in Blender during the concept art process for the first iteration as well as the polishing process in the second iteration. The Eevee rendering system of Blender is mostly used in the project due to its stability and efficiency in realizing the images. These assets are set to have a transparent background for easy modification in Photoshop as well as exporting them for implementation. These steps are considered beneficial for the progress since the textures can be replaced fast and effortlessly until it reaches the requirements.

The author first used Substance Painter to customize the texture due to the program's flexibility and reliability. However, the texturing process shows Substance Painters' disadvantages due to unnecessary workflow and time-consuming. It required the author to unwrap and export the object as a .fbx file, create a texture with multiple files, including albedo map, normal map, height map, ambient occlusion map, then to import the texture back to Blender. This workflow took too much time and effort in exchange for inefficient results. Since all of the assets in Barotrauma is 2D, there is no need to create texture maps for them. Therefore, this step is unnecessary for the process.

Figure 25. Assets rendering in Barotrauma (Dinh 2019)

The author used Photoshop and the UV projecting option of Blender. This workflow brings high quality renders in a short period. The author first modified the textures in Photoshop, then projecting the UV on the texture (Figure 25).

Technical requirements

Figure 26. Asset organization in Barotrauma (Dinh 2019)

To maintain the performance statues of the game, final assets are required to be suitable with the game engine. They are categorized in different folders to be implemented systematically, depending on their purposes. Assets are organized in square power of two sprites with a transparent background under .png files of format (Figure 26). The scale and proportion of the assets need to be in unity with others to benefit the implementation and testing process.

6.5 Testing and finalization

Throughout the process, multiple implementations and quality tests are made to improve the quality of the assets. The studio used Visual Studio program as the primary tool to implement the sprites directly into the game. To test the quality of the assets, they are placed next to multiple objects in the game to make sure they are in unity with others. If the assets are not satisfactory, they will be adjusted in Photoshop until they match the requirements. Once the assets fit the

in-game world, the final sprites which contain the lastest assets will be forwarded to the programmers who are in charge of adding these assets into the game.

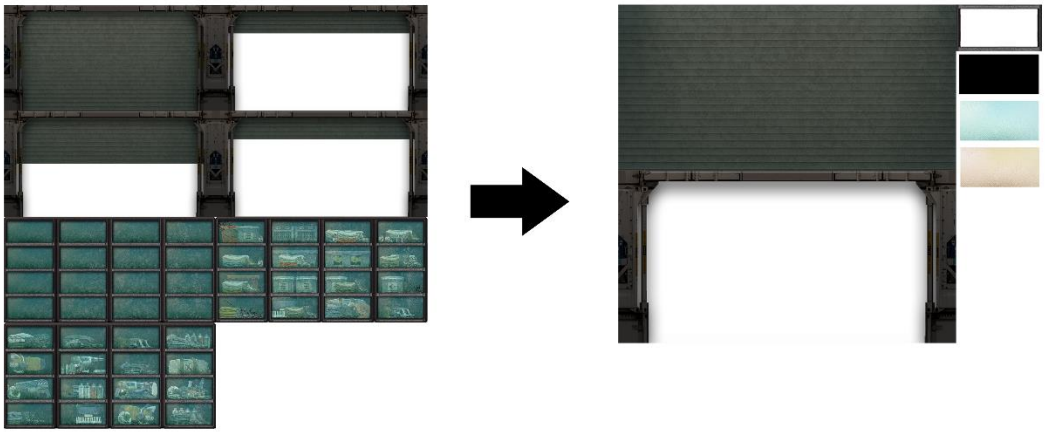

Figure 27. Applying procedural generation in Barotrauma (Dinh 2019)

Thanks to the efficiency of procedural generation, the memory needs for the game engine has been dramatically cut down. The algorithm generates multiple assets in a room while adding items inside the shelves. This part saves the author from manually adding individual objects in Photoshop. This workflow not only saves time and effort during the production process but also enhances the diversity and quality of the game (Figure 27).

Figure 28. Screenshot of the final product in Barotrauma (Dinh 2019)

The final product is approved by the art department and has been implemented into the game. Due to the gameplay's efficiency as well as the optimization in the game's memory, the workflow has been widely used in different in-game locations for various purposes. Not only the storage enhances the player's experience, but it also shows the potential in future production (Figure 28).

7 CONCLUSION

The thesis managed to define the framework of creating a procedurally generated environment with an appealing visual aesthetic. The thesis approaches the advantages and disadvantages of procedural generation, as well as addressing the visual aesthetic principles in video games.

By analyzing two case studies of Dead Cells and Hades, the pipeline of making a procedurally generated environment that satisfies the critical elements of visual aesthetic has been successfully approached. In addition, the technical aspect of how to create a collection of in-game components has been analyzed to create a concrete reference for Barotrauma's production process.

To further illustrate the pipeline of asset creation for the procedurally generated environment, one of Barotrauma's in-game locations has been created. The process includes multiple steps with the involvement of different programs and techniques in order to archive the best result. In the end, the location has met the expectation and requirements of the game. A collection of a dynamic and functional variety of assets has ready for implementation. The final product can be used for locations while the final concept is qualified for marketing materials such as commercials, banners, and DLCs. The uses of theory provide the potential solution in different projects related to environment design using procedural generation.

In conclusion, while a procedurally generated world may succeed in delivering gaming sessions full of surprises, there are still many details that require human's craftsmanship to ensure that every moment of these sessions is memorable and emotionally striking. By applying theories about visual aesthetics and adapting them to the technology of procedural generation, Barotrauma's feature of explorable locations has shown promises in offering a unique and innovative gaming experience. While the thesis has achieved its objectives, the developers

are still looking forward to further improving the feature after introducing it to the players. Users' reception is going to be taken into consideration to perfect the feature visually and technically.

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