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Nuno Daniel Correia Fernandes

A Case Study in Generative Game Design

Dissertation in the context of the Master in Design and Multimedia advised by Prof. Dr. Licínio Gomes Roque and presented to the Faculty of Sciences and Technology / Department of Informatics Engineering.

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Abstract

In the field of videogame production, it is quite unusual for truly innovative game design to take place. The market is often focused on repeating the same approaches that were already proven successful in the past. Therefore, it is important for game designers to think about providing players with new and meaningful experiences. In this context, Procedural Content Generation (PCG) is a promising set of methods that has the potential of giving each player a unique experience by influencing the actual gameplay activity. With this type of approach, it is possible to automatically create original and quality content that increases the game's replayability and also the player's engagement with the game.

This dissertation aims to create an original game that employs procedural generation techniques to provide this kind of dynamic experience by applying such methods to the game's systems and scenarios, while also providing players with opportunities for learning through the gameplay experience, in particular about real world systems. Therefore, a game concept was created that, through the modeling of a gameworld based on ecosystems present in nature, allows players to manipulate the traits of living creatures and explore the effects of such changes on the creatures and consequently the entire modeled ecosystem's balance. After the creation of the game concept, a prototype was developed that applied generation techniques to the gameworld's creation and to the creatures' interactions with each other and with their habitats. Afterwards, tests were performed to the prototype in order to collect data and feedback about its usability and gameplay. The subsequent analysis of the gathered results allowed for improvements to be made to the prototype and game model. With additional testing and development, there is an opportunity to further perfect the prototype and provide a more complete and meaningful gaming experience to players.

Keywords

Game Design, Procedural Content Generation, Gameplay, Experience, Videogames

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Acronyms

2D	2 Dimensional
3D	3 Dimensional
AI	Artificial Intelligence
NPC	Non-Playable Character
PCG	Procedural Content Generation
UI	User Interface

Chapter 1

Introduction

In the Game Design area, due to its constant evolution and high competitiveness, it is often necessary to create large amounts of content to produce engaging and meaningful game experiences. In the gaming industry, it is very common for the creation of these contents and experiences to be based on past approaches (Craveirinha & Roque, 2011). This normative thinking can lead to a decrease in creativity and originality in the games developed and a stagnant market, and therefore a less interested and engaged public. With the gaming audience growing at a considerable rate (*Prepare for 2021 with new gaming audience insights*, 2021), the industry will inevitably face increasing challenges to meet the demands and expectations of its audience. Also, as the available technologies evolve, whether their purpose is academic, entertainment or other, video games have become increasingly complex and costly to produce (Beattie, 2020). In order for game designers and creators to respond to such demands, game content creation has increased in terms of the amount of work required by the production teams.

Therefore, it is necessary to develop ways to create content quickly and automatically and thus reduce the manual work of game developers. This is exactly where Procedural Content Generation (PCG) intervened. As a set of powerful generation techniques, PCG is of great value for creators, both at a creative and logistical level. Thus, in this dissertation we intend to explore the role of these techniques in the actual gameplay, in order to create dynamic experiences with high engagement, meaningfulness and replayability. Through the creation of a game concept and the development of a prototype, we intend to apply these techniques to the gameplay context and, following a Design Science Research methodology, analyze and evaluate the process in order to correctly adjust and improve the game model. It is also our intention to explore the potential for learning of such experiences, specifically by providing a game context modeled after real systems and through which the players can have a participative approach that grants them with useful knowledge about these systems in the real world. As such, we expect that this project gives a clearer idea about the general potential of PCG, and more specifically the effectiveness of the designed game, in achieving these goals.

In this report, the work done during the development of the project is documented. The report is formulated with the following structure: in Chapter 1 we briefly explained the context and challenge of the project; in Chapter 2 the State of Art is presented, detailing the necessary knowledge and concepts for the development of the project, collected in the research phase; in Chapter 3 we present the objectives of the project, as well as the methodology that we used and the work plan that we followed; in Chapter 4 we show the game concept and the design proposal; in Chapter 5 we document the development process of the game prototype; in Chapter 6 we detail the evaluation and analysis, through usability tests, of the prototype; and finally in Chapter 7 we conclude the document with a few final remarks about the project.

Chapter 2

State of the Art

2.1 Play and Games

2.1.1 Definition of Play

In the context of play and games it is important to firstly define what constitutes the act of play. This is an important concept to understand in the field of game design, especially for creators and designers who aspire to create fulfilling experiences for players. In his 1938 influential book *Homo Ludens*, Johan Huizinga provides a definition of play and a contextualization of its role in culture and society. According to Huizinga (1949), play can be defined as activity with a special set of characteristics. The first, and most important one, is that play is a voluntary activity which "*marks itself off from the course of the natural process*" because of its quality of freedom. When we play, we do it because we want to, and because we choose to engage in a temporary activity that interrupts our normal life and represents something or is a contest for something.

This temporary nature of play relates to another characteristic presented by Huizinga (1949): the fact that play is not "real life", but rather "*a stepping out of real life into a temporary sphere of activity with a disposition all of its own*". Furthermore, it's an activity that occurs within spatial and temporal constraints. It starts at a certain place and moment and it's over in the same manner. The activity creates this "*magic circle*" whose boundaries define the temporary world of play. This sense of limits in play is an important factor that contributes to the activity's detachment from "reality".

Another characteristic described in Huizinga's work is also related to this isolated nature of play: its own sense of order (Huizinga, 1949). When any form of play is unfolding, there's always a certain set of rules which need to be respected by everyone involved, otherwise it is spoiled and its purpose is broken. This demand for order is also emphasized when play includes seriousness. As the author explains, "*seriousness seeks to exclude play, whereas play can very well include seriousness*". As such, when the player is immersed in the activity of play, "*the consciousness of it being merely a game can be thrust into the background*". When this happens, any disturbance in this sense of order can take the player out of this immersed state.

In summary, Huizinga (1949) describes play as a free and voluntary activity that stands consciously outside of "ordinary life", has its own certain fixed limits of time and space, proceeds in an orderly manner according to a set of rules and can absorb the player intensely and utterly.

Roger Caillois (1958/2001), in his book *Man, Play and Games*, both pays tribute and challenges some of the concepts of play presented by Huizinga and provides a definition of game derived from it. Like Huizinga, Caillois also insists that the act of play is free, as the player chooses to participate in the act of play of his own free will, for his own pleasure and without obligations. Caillois' definition also shares other characteristics with Huizinga's: he also describes play as an activity which occurs in a "second reality" apart from real life, defined within its own constraints of time and space and that is governed by a special set of rules. His definition is completed by arguing that play is unproductive, because it produces neither goods nor wealth, and uncertain, because its course and result cannot be determined beforehand.

2.1.2 Definition and Classification of Games

After defining the concept of play, it's also necessary to define what is a game and how games can be classified. A complex task, as many authors provided their definitions and these can be quite different from each other.

Chris Crawford (1984) proposes his definition by first naming four major categories of games: board games, card games, athletic games, and computer games. Then he lists four fundamental elements commonly present in all games: representation, interaction, conflict, and safety.

- ***Representation*** refers to games as closed formal systems that subjectively represent a subset of reality. This means that the game is a complete and self-sufficient structure and doesn't need references to outside of the game. It also means that it has its own explicit rules and can be seen as a collection of parts which interact with each other, forming a system. This idea of games as systems is very valuable and will be further inspected below.

- ***Interaction*** refers to the dynamic nature of games, where elements are tied together and change over time due to relationships of cause and effect. For the players, this experience of interaction is important in providing them with a sense of exploration and achievement. Also, interaction is represented in a continuous range of values which can vary from meaningless to emotional significance.

- ***Conflict*** is a concept derived from the previous one and happens naturally when the player faces obstacles which prevent him from achieving a goal. This element can present itself in a direct or indirect manner but is always present in a game.

- ***Safety*** refers to the game's ability to provide "*psychological experiences of danger and conflict while excluding their physical realizations*". It enables the player to experience a safe reality apart from the "real world" and therefore the game's real consequences are always less severe than the situations represented in it.

Another valuable definition is provided by Salen & Zimmerman (2003), in the book *Rules of Play*, where the authors state that "*a game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome*". Then they proceed to highlight the definition's main characteristics:

- ***System:*** probably the main concept in the authors' work, systems are described as "*a group of interacting, interrelated, or interdependent elements forming a complex whole*".

Therefore, since it is clear that games can also be understood as a set of parts that relate to constitute a complex whole, games are systems too.

- ***Players:*** another essential part of the definition of games is the players themselves. Games need players to actively participate in it, providing interaction with the system and generating the experience of play.

- ***Artificial:*** as already mentioned in the context of play, games are purposely distanced from "real life" in time and space and have their own special boundaries in both dimensions.

- ***Conflict:*** a concept shared with Crawford's definition, where the authors reinforce that all games represent some sort of "contest of powers" that can manifest itself in a variety of forms such as cooperation, competition or conflict with the game system.

- ***Rules:*** another concept already described, games possess their own rules and these provide a structure of play that limits what the players can and cannot do in the game's context.

- ***Quantifiable outcome:*** lastly the authors emphasize that games usually distinguish themselves from other less formal play activities by having a goal or outcome that can be quantified by some sort of score or represented as a win or loss.

Additionally, in his previously mentioned work, Caillois (1958/2001) proposes that games can be classified into four main categories "*depending upon whether, in the games under consideration, the role of competition, chance, simulation, or vertigo is dominant*".

- The first case is called ***agôn***, which is dominant in competitive games that are designed to create conditions of equal opportunity of winning to each adversary, like chess or football for example.

- The second case, called ***alea***, is in all games of chance, when their outcome is not dependent on players' control, from dice to casino games.

- The third case, called ***mimicry***, is present in games where play requires a suspension of disbelief to temporarily accept an "imaginary universe", where the players let their imagination create the game's narrative, as for example role-playing games.

- Finally, the last case is called ***ilinx*** and dominates games that are designed to temporarily distort the player's perception and create sensations such as fear, anxiety and adrenaline. Most psychological horror videogames are examples of this type of game.

2.1.3 Computer and Videogames

Representing the latest type of game, and arguably the one with the most potential, videogames have had their own set of challenges and advantages since their recent inception. As development in computer technology accelerated, so did the increasing number of possibilities associated with videogame design. The computer represented a brand new tool and platform for providing revolutionary gaming experiences. Even in this technology's somewhat early days, Crawford

(1984) managed to point out some of the computers' characteristics that possessed the most potential for the future development of games.

One of them is its responsiveness and dynamic nature. A feature vital to interaction, responsiveness is potentially provided by the computer at a higher level than other gaming tools. This is emphasized by the fact that computers impose very low restrictions, in the sense that the opportunities to change game parameters, both during the game design process and during the game playing activity, are far greater than in any other medium. A computer is able to dynamically change the game's world, characters and even rules. The importance of this kind of flexibility, and the opportunities that it provides to the game designer, cannot be overstated.

Another characteristic of the computer is its ability to handle the administrative responsibilities of the game and doing so at a faster pace than the players can play the game. This characteristic is advantageous on two fronts: firstly, it allows the implementation of complex arithmetic and logical rules in the game system and also the possibility of real-time play; secondly, it allows the players to be free from the concern of overseeing or mediating the game and thus allowing them to concentrate on playing.

Another substantial advantage is the fact that computers can communicate and transfer data over a great distance by using networks that allow for the creation of game structures with dimensions out of reach of other tools. It allows a huge number of players to play the same game at the same time and do it from virtually anywhere, granting them unique multiplayer experiences while also granting game designers a whole new set of opportunities to develop said experiences.

Despite these advantages, computers also have a few weaknesses. One of them is the limitations of input and output devices, which can jeopardize an otherwise great gameplay experience. Although a lot of progress has been made in the field of user interfaces, keyboards, mouses and controllers continue to be the main devices for input and screens continue to be the main devices for output, by a long margin. Other technologies, like motion sensors or virtual reality devices, are still somewhat inconsistent and need further development in order to provide players with immersive and meaningful experiences. Likewise, their improvement will also enable game designers to create a wider variety of gameplay experiences and forms of interaction. Additionally, videogames and computers need to be programmed, which imposes a high demand on the game designer, both because the game production becomes a long and difficult process and because it requires a high amount of technical knowledge and skill.

As videogame designers need to understand the characteristics of computers, they must also understand what is valuable in a videogame experience. Craveirinha & Roque (2011) mention the importance of this question, along with the questions of how to define a videogame and what ideas and emotions are expressed through videogames. The authors argue that often the answers to these questions are normative in nature and present the drawbacks and dangers of this kind of response, advocating for a greater effort in noticing such traps. Most of the products available in the market of videogames follow this normative pattern, where their design and production is influenced by earlier works and results in a cycle of development that constrains creative approaches.

Craveirinha & Roque (2011) demonstrate that most definitions of games, and therefore videogames, are based on "ludus" play, or in other words, are a goal oriented type of play focused on skill mastery, goal conquering and conflict. This observation was also made by Crawford (1984) when he claimed the main motivation for all game-playing is to learn, due to games providing a safe way to do so. As such, Craveirinha & Roque (2011) argue that these definitions are also largely normative precisely because they are so common to most if not all videogames. All these factors lead the authors to conclude that videogames "*can only be defined in the most wide of senses, completely open to interpretation and future revision*" and give their own definition by stating that videogames are "*all creative artifacts that exist in a digital medium (computers, consoles, cellular phones) that have non-functional traits*".

2.2 Game Design

In addition to having a clear understanding of the concepts of play and games, a game designer needs to know what constitutes a good game and how to create it. These types of questions are part of any *game design* process and having valuable design practices is important in order to competently answer them. As Salen & Zimmerman (2003) stated, "*game design is the process by which a game designer creates a game, to be encountered by a player, from which meaningful play emerges*". Thus, just as Costikyan (2002) mentioned, a game designer has to understand games, what they are and what makes them interesting. He links games to art and the game designer to an artist, who master techniques in order to combine them to create the intended product. In a way, as Crawford (1984) identified, "*the demands on the game artist are greater than those on other artists, for the game artist must plan the experience indirectly, taking a special interest in the probable and possible actions and reactions of the audience*". This is due to the fact that games are inherently participatory and game designers need to plan and create the conditions and rules for the intended experience to emerge in the individual player. Therefore, the carefully planned application of good game design practices is paramount to the game designer, in order to increase players participation and consequently increase their attention and the intensity of their experience. As such, in this section, a number of these game design practices will be presented and analysed.

2.2.1 Games as Systems

Already mentioned above, the idea of games as systems was highlighted by Salen & Zimmerman (2003), who proceeded to dive deeper into what makes this a valuable concept in game design. They do this by firstly examining what constitutes a system:

- ***Objects***, that refers to the parts, elements or variables within a system and can present themselves as physical, abstract or both.

- ***Attributes***, which means the qualities and properties of the system itself and each of its objects.

- ***Internal relationships***, which refers to how the objects are linked to each other and the types of these relationships within the system.

- ***Environment***, that relates to the context that surrounds the system and which inevitably affects it.

Then the authors proceed to frame these four elements in a purely formal manner, by viewing the system as a strictly mathematical and logical set of rules, but also in an experiential manner, by considering the system as a form of interaction between the players and the game. They do this by using the example of the game of Chess. So, by framing it in these ways, the game of Chess has:

- ***Objects*:** in a formal manner, the objects in Chess are the board and the pieces on it, while in an experiential manner, the objects are the two players.

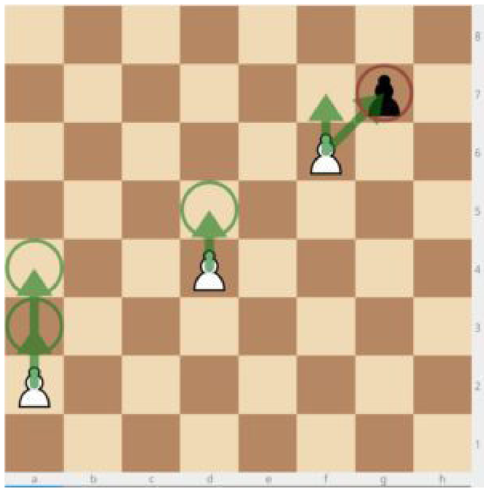

Fig. 2.1 - In chess, pawns have movement rules that are innately complex (Schell, 2008) depending if they are moving normally during the game (middle example), if they are in their first move (left example) or capturing a piece (right example) (iChess.net, 2018).

- ***Attributes*:** in a formal manner, attributes in Chess correspond to the rules associated with each piece, such as their starting position and the way they move on the board, while in an experiential manner, they correspond to the pieces currently controlled by the players and subsequently the state of the game itself.

- ***Internal relationships*:** in a formal manner, this relates to the spatial positions of the pieces and the strategic options that arise from them, such as a piece giving protection to another or an opportunity to check the king. In an experiential manner, this relates to the interaction between players such as their strategic interaction and their social and psychological communication.

- ***Environment*:** in a formal manner, the environment in Chess is the activity of play itself which provides the context for all other elements. In an experiential manner, the environment is the context of play that contains the board, the pieces and also the two players. For example, in the case of online Chess, this includes the software through which the game is played.

Considering games as systems can prove very valuable to the game designer, as it allows for a formal conceptualization of the game and for a clear description of each of its elements. This provides opportunities for improvements in the creation process, where adjustments can be made in individual elements and the results of said changes can be measured, creating an iterative process.

2.2.2 Game Design through Lenses

In his influential book *The Art of Game Design: a Book of Lenses*, Jesse Schell (2014) presents an approach to game design based on a number of perspectives through which a game can be viewed as. As the author asserts, the game is not the experience but rather an artifact that enables the experience. The game designers care more about the latter and, for them to produce meaningful and valuable experiences, it's useful to view the design through as many perspectives as possible. These perspectives, or lenses, are presented as a set of questions to ask about the design. Therefore, they can prove to be valuable tools to analyse artifacts or examine the design process itself. In this section, I will present ten of these lenses that I considered the most useful.

- ***Lens of Emotion*****:** Schell (2014) explains that experiences are different for each player and this peril of subjectivity results in a trap that designers can fall into: "I like playing this game; therefore, it must be good". Thus, in this lens, the author recommends that game designers dissect the feelings and emotions experienced during the act of play in order to properly create designs that provide the right ones. To do so, Schell suggests that game designers ask themselves these questions:
    - What emotions would I like my player to experience? Why?
    - What emotions are players (including me) having when they play now? Why?
    - How can I bridge the gap between the emotions players are having and the emotions I'd like them to have?

- ***Lens of Essential Experience*****:** In this second lens, the author explains that every experience has a particular collection of essential elements that define it and therefore the game designer should try to find ways to create them and include them in the game design. The author proposes these questions for game designers:
    - What experience do I want the player to have?
    - What is essential to that experience?
    - How can my game capture that essence?

- ***Lens of Fun*****:** Despite not being a clearly defined concept, fun is often regarded as the purpose of any good game. As Craveirinha & Roque (2011) pointed out, although it has an elusive definition, the idea of fun is associated with the idea of pleasure. Schell (2014) adds to this notion by stating that fun is pleasure that has a special sparkle and excitement associated with it. Thus, in order to augment the fun in a game, the author recommends that the game designer asks:
    - What parts of my game are fun? Why?
    - What parts need to be more fun?

- ***Lens of Curiosity*****:** In this Lens, the author argues that play is an activity that is usually motivated by curiosity and subsequently leads to a wilful action of manipulation. The player's motivations become key to the game designer because they are the reason the player wants to participate and achieve the game's goals. To maximize these motivations, the author suggests the questions:
    - What questions does my game put into the player's mind?
    - What am I doing to make them care about these questions?
    - What can I do to make them invent even more questions?

- ***Lens of Problem Solving*****:** Schell (2014) introduces this lens by suggesting a simple, new definition for game: "a game is a problem-solving activity, approached with a playful attitude". From this arises the perspective of considering what problems the game provides

and need to be solved by the player. When using this perspective, the game designer should focus on these problems and answer the questions:
  - What problems does my game ask the player to solve?
  - Are there hidden problems to solve that arise as part of gameplay?
  - How can my game generate new problems so that players keep coming back?

- ***Lens of the Toy*****:** This perspective focuses on the distinction between game and toy, that is, something that we play versus something that we play with. By taking this under consideration, the game designers can improve the game's quality by making it more approachable and fun to play with, giving it more toylike qualities. To do this, they should ask the questions:
  - If my game had no goal, would it be fun at all? If not, how can I change that?
  - When people see my game, do they want to start interacting with it, even before they know what to do? If not, how can I change that?

- ***Lens of the Player*****:** This lens suggests that game designers should always be thinking about the players and the experience the game provides them. Using this perspective means that the game becomes secondary and the player is the primary focus of analysis. It is especially useful if the game designer observes them while playing the game because it becomes easier to predict what they will enjoy. The author recommends the following questions:
  - In general, what do they like?
  - What don't they like? Why?
  - What do they expect to see in a game?
  - If I were in their place, what would I want to see in a game?
  - What would they like or dislike about my game in particular?

- ***Lens of Meaningful Choices*****:** In this lens Schell (2014) asserts that players, during gameplay, often find themselves with difficult questions of where to move, what strategies to use in a given situation and how to manage resources, for example. These are choices that the game designer should focus on, by giving options that will have a real impact on the game and the experience. When the player feels that choices matter and have consequences then the game becomes rather more meaningful. To do this, game designers should ask themselves:
  - What choices am I asking the player to make?
  - Are they meaningful? How?
  - Am I giving the player the right number of choices? Would more make them feel more powerful? Would less make the game clearer?
  - Are there any dominant strategies in my game?

- ***Lens of Skill vs Chance*****:** Since skill and chance can be understood as two opposing forces in the context of game design, if one is much more present then the other is negated. It is imperative that the game designer balances both and the author suggests a method to do it: make the game provide an alternating pattern of tension and relaxation. This can be very appealing to players and create addicting experiences. The questions related to this lens are:
  - Are my players here to be judged (skill) or to take risks (chance)?
  - Skill tends to be more serious than chance: is my game serious or casual?
  - Are parts of my game tedious? If so, will adding elements of chance enliven them?
  - Do parts of my game feel too random? If so, will replacing elements of chance with elements of skill or strategy make the players feel more in control?

- ***Lens of Simplicity/Complexity*****:** This last perspective focuses on finding a balance between simplicity and complexity. For game designers, it is often tempting to keep adding rules to the game until the desired behavior is met. The author argues that this is "*called 'artificial* *balancing' as opposed to the 'natural balancing' that can come when a desired effect arises naturally from the interactions in a game*". He also argues that, ideally, game designers create a simple ruleset and from it emerges a "stream of balanced surprises" that becomes incredibly addicting to the player. The questions used in this lens are:

- What elements of innate complexity do I have in my game?
- Is there a way this innate complexity could be turned into emergent complexity?
- Do elements of emergent complexity arise from my game? If not, why not?
- Are there elements of my game that are too simple?

2.2.3 Participation-Centered Game Design Model

In the game production process, the challenge of providing a meaningful and satisfying player experience is often a key concern for the game designer. As Brathwaite & Schreiber (2008) said:

> *"Good game design is the process of creating goals that a player feels motivated to reach and rules that a player must follow as he makes meaningful decisions in pursuit of those 8 goals … Good game design is player-centric. That means that above all else, the player and her desires are truly considered."*

This means that the player, and the experience the game enables him to have, can become the primary focus of the game designer. Since it is difficult to conceptualize experience in a formal way, due to its holistic and multi-dimensional nature (McCarthy and Wright 2004; Hassenzahl 2010), and since videogames materialize in many diverse formats, attempting a comprehensive and systematic approach in videogame design can be a complex task (Pereira and Roque, 2013).

Pereira and Roque (2013) argue that by explicitly considering experience in the design process may help to guide it towards producing outputs that promote the forms of participation intended by the game designers. As such, the authors propose a model to support the production and characterisation of videogames that aims to "***achieve a rationalization between how the designer intended for the game object to promote a specific playing experience and the emerging experience as interpreted by players***".

This model helps the designer to consider the player perspective in the gameplay and proposes six dimensions to rationalize player's participation (Pereira et al., 2019):

- ***Playfulness*** - this dimension views the game as an opportunity of informal and unstructured exploration, discovery and customization. Some examples of mediators of this type of perspective include game resources, avatars or even the game world itself. A few indicators that can characterize the participation in this perspective are the degree, variety and tendency of exploration.

- ***Challenge*** - this dimension sees the game in the context of a structured and formal goal, or set of goals, that the player tries to complete. Participation is measured by the player's performance in trying to overcome or actually completing the goal(s). The mediators of participation for this perspective include the proposed challenge and types of penalties and rewards. Performance can be analyzed by observing indicators such as pace, amount of progress and efficiency in achieving tasks.

- ***Embodiment*** - in this dimension the videogame takes on the context of a medium for physical performance and participation is regarded by the physical relationship between it and the player. This relationship can happen through virtualization of the player's body or by interpreting it as an interface with the game. Therefore, physical involvement and performance constitute key components of the player experience and participation, which can be mediated, for example, by "*the representation of the physical game world, the player's representation on the game world, the interpretation of player's movement, etc*" (Pereira et al., 2019). Some indicators that characterize participation in this dimension are control, rhythm and aesthetics of the player's movement.

- ***Sensemaking*** - this dimension refers to videogames as mediums of expression and of significant and meaningful participation. The semantic space represented in the videogame is fundamental to player participation and the experience involves activities such as role-playing, self-expression and critical thinking. Some mediators of participation in this dimension include the theme of the game, the narratives presented and the roles and motives of the characters. In regard to the indicators that characterize participation in this perspective, a few examples consist of "*the alignment between actions and roles*" and "*understanding and or critique of the represented phenomenon*".

- ***Sensoriality*** - in this dimension the game is viewed in the context of multisensory involvement, with participation being regarded as "*feeling, perceiving, contemplation, sensorial expression, wondering, etc*" (Pereira et al., 2019). This perspective is strongly related to the Embodiment dimension, but the former represents characteristics of space and movement while the latter represents characteristics of style and atmosphere. A few mediators of participation for this perspective are the nature of the stimuli, the visual and sonic compositions and the videogame style. Characterization of participation in this dimension is conveyed by indicators like "*the degree of exposure and responsiveness to stimuli, interaction or engagement with sources*".

- ***Sociability*** - this dimension relates the videogame to a context of explicit and implicit socialization between players and considers participation as communication, cooperation, competition and establishment of relationships. In this perspective, a few mediators of participation are the "*diversity and nature of social interactions and relationships*" and some indicators that express the characterization of participation include "*the intensity and types of interactions between players*" and "*affective bonds*" (Pereira et al., 2019).

Furthermore, the model proposes three operational levels of analysis that focus on "*defining design intentions, characterizing game artifacts and mapping and analyzing player participation*" (Pereira and Roque, 2013). These focuses are Intention, Artifact and Participation.

- ***Intention*** - this operational level refers to the participation ideal suggested by the videogame and analyses the "*style of the proposed or idealized game, meaning, the essence or value of the game activity*" (Pereira and Roque, 2013).

- ***Artifact*** - this level refers to the ways in which the produced artifact contributes as an interaction context that supports the intended forms of participation and "*analyses and rationalizes the artifact videogame as network of mediators that support*" (Pereira and Roque, 2013) said participation.

- ***Participation*** - this last operational level refers to the analysis and characterization of the actual player participation and comparing it to the idealized participation, measuring the level of alignment between the game activity and the design intent and using observed indicators and metrics to improve the progress towards that intent.

2.3 Procedural Content Generation (PCG)

2.3.1 What is PCG?

Procedural Content Generation, or PCG, can be defined as "*the algorithmic creation of game content with limited or indirect user input*" (Togelius, Kastbjerg, et al., 2011). Along with this ability for computers to produce game content on its own, or with human players or designers, PCG also has the responsibility of filtering the content produced by selecting the best instances generated. This is especially useful for companies because it eliminates, or at least minimizes, the need for manual production and therefore it may be useful to reduce costs and production times. As such, smaller companies or independent creators can have the opportunity to produce games that compete with larger companies.

However, it is often difficult to correctly implement PCG, as much of the best techniques need "*not only computational power, but also the ability to judge the technical and cultural values of the generated instances*" (Hendrix et al., 2013). If this is not a part of the PCG process then the outputs become completely random and so does the player experience, due to the lack of meaning in the content. Therefore, it is imperative that the human creator has the knowledge about the operations of the implemented algorithms and that the control over the generation procedures is not lost. This can be achieved by allowing designers to influence the generation procedure by adjusting its parameters. Ideally, this leads to a wide variety of quality content that increases the potential for player-adaptive experiences and maximizes learning and/or enjoyment of the game (Shaker et al., 2016).

2.3.2 History of PCG usage

In the early times of PCG, the gaming industry had many limitations regarding technology and hardware of the time, as for example processing power, memory and storage capacity was limited. Arguably this latter constraint was the reason PCG began: as a way to compress and store data more efficiently. The solution was to randomly or algorithmically produce content such as level layouts and items. Also, PCG was (and still is) a way for producers and designers to explore and develop new game mechanics and new building tools for game design (Smith, 2012).

In the 1980's, many of these first developments were done in games such as: *Rogue* (A.I. Design, 1980), a dungeon-crawler RPG that created an unlimited replayable experience by always generating different dungeons (Fig. 2.2) and enemies; *Elite* (Bell, I. & Braben, D., 1984), a game about space exploration that generated entire galaxies and will be detailed further below; *The Sentinel* (Crammond, G., 1986), a game with 10,000 levels stored in less than 64 kilobytes and where each landscape seed is given at the completion of the previous one. All of these examples, despite the technical and graphical limitations of the time, were able to introduce and effectively explore powerful new concepts in the gaming industry by using PCG algorithms.

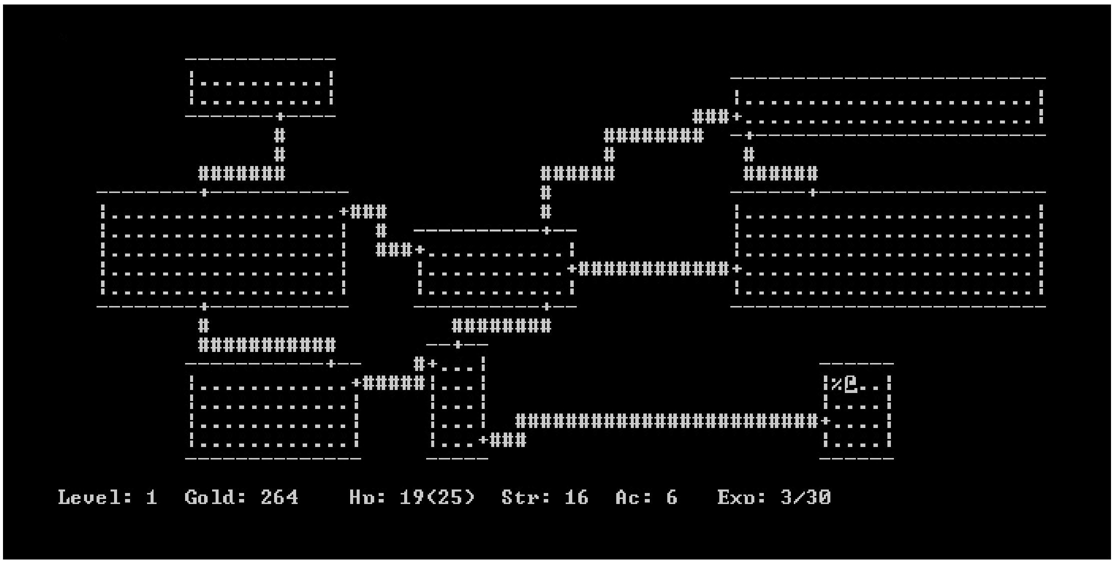

Fig. 2.2 - Example of a generated dungeon in *Rogue* (The Rogue Archive, n.d.).

In the 1990's and 2000's, with improvements in storing capacity, games started to include increasingly larger worlds that required a lot of content to fill. At this time PCG was focused as a way to reduce the manual labor of producing and placing larger quantities of assets such as trees, rocks or enemies (Aversa, 2015). One example was *SpeedTree* (IDV, 2002), a famous PCG tool that generates trees and other organic assets (Fig. 2.3). As Aversa (2014) explained, notable game examples included *Diablo* (Blizzard North, 1997), a rogue-like dungeon-crawler that used procedural generated dungeon layouts and was a commercial success, and *Dwarf Fortress* (Bay 12 Games, 2006), a game that had a world generator that included generation of weather, biomes, cities, history, animals and many others (Fig. 2.4). This game later inspired Notch to create *Minecraft* (Mojang, 2011) and incorporate many of the same concepts.

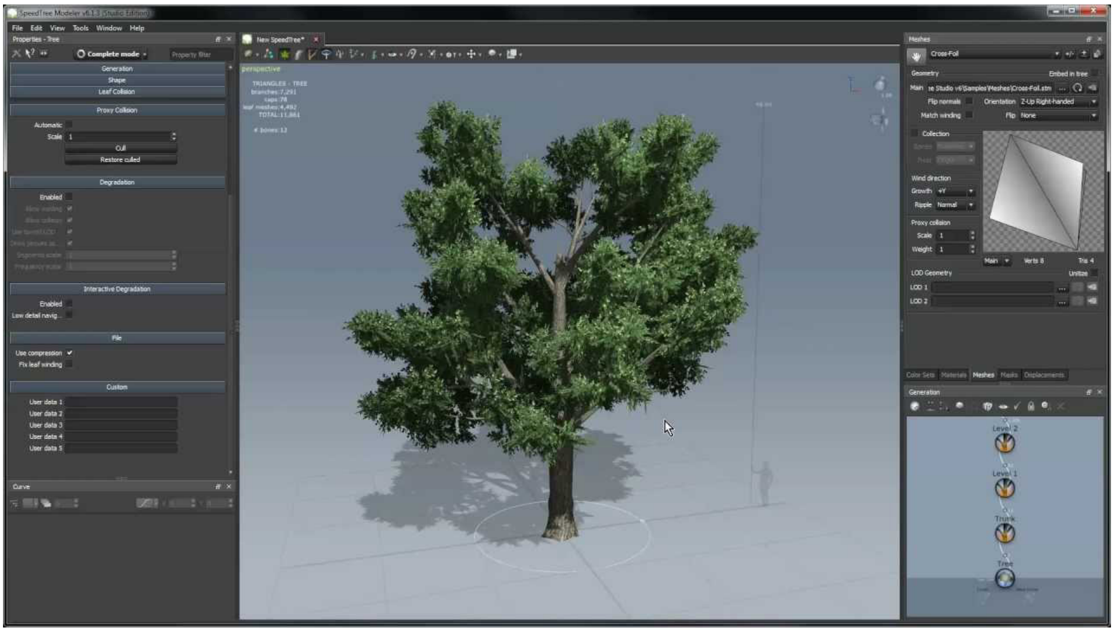

Fig. 2.3 - Screenshot of a tree being modeled in *SpeedTree* (SpeedTree, 2012).

Fig. 2.4 - A world created by *Dwarf Fortress*' generator (Martins, 2019).

Nowadays, PCG is an influential technique in the gaming industry that reduces production costs, increases replayability, allows for greater customization, among many others, but also tries solve new challenges such as provide dynamic player-specific experiences, create narratives and allow for enough flexibility to respond to designer's and player's increasing demands. Ideally, procedural content generators should not only understand "*what pieces can be put together, but how they should be connected and what impact the combination of pieces has on player experience*" (Smith, 2012). Moreover, they need to allow for human communication and control over the created content, whether it may be from designers or players. Only in this way it is possible for designers to tailor the intended experience for players and new market demands in the gaming industry can be addressed by these types of algorithms.

2.3.3 PCG Techniques

2.3.3.1 Runtime Random Level Generation

This technique is probably the most famous type of PCG and relates to the generation of game levels and game worlds in the gameplay or loading phase of the game (Aversa, 2014).

While dynamic generation in two dimensions is greatly developed with a wide variety of robust algorithms, procedural content generation in 3 dimensions is an area of research that still deserves a considerable amount of effort (Doull, 2008). Although many of the algorithms and concepts used in two dimensions can be applied to 3D, these mostly apply to fractal-based world generators that use simulation of geological and meteorological processes to create map height-fields. Because of this, there's a lack of solutions to produce fully populated three dimensional world spaces, due to the complex challenges regarding connectivity between parts of the map, such as bridge placement and constraints on slope steepness (Doull, 2008).

2.3.3.2 Dynamic Systems

Dynamic Systems refers to "*PCG applied to agent behaviors*" such as NPC dialog, crowd behaviour and weather (Aversa, 2014). These systems allow for a reduction of much of the workload related to the development of objective and AI scripting. For example, *Oblivion* (Bethesda Game Studios, 2006) uses the Radiant AI system to provide the player with dynamic quests and *Crysis* (Crytek, 2007) uses dynamic weather and day and night cycles to provide unpredictability to enemy encounters (Doull, 2008).

Another promising application of this technique relates to speech synthesis and natural language generation, both of which have the potential to deliver highly complex and dynamic dialog to the player experience, despite still being somewhat limited to context dependent deciphering or contextual clues (Doull, 2008).

An example is the game *S.T.A.L.K.E.R.: The Shadow of Chernobyl* (GSC Game World, 2007) which uses this technique in order to contain a thousand non-scripted characters (Fig. 2.5).

Fig. 2.5 - Non-scripted characters in *S.T.A.L.K.E.R.: The Shadow of Chernobyl* are generated via dynamic systems (S.T.A.L.K.E.R.: Shadow of Chernobyl, n.d.).

2.3.3.3 User Mediated Content

These techniques use the input from players as a source to produce new procedural generated content by gathering the parameters chosen by users and mediating with other PCG techniques and frameworks (Aversa, 2014).

This combination between PCG and user generated content allows the newly created content "*to be tuned by intelligent feedback, compensating for the main weakness of PCG in that human intelligence is only indirectly in control of what is produced*" and allows the users to have the final say regarding the appropriateness of the choices made for the content produced (Doull, 2008).

An example of a game that uses this concept is Spore (Maxis, 2008), which provides players with a procedural framework that enables them to create various creatures and objects without technical knowledge.

2.3.3.4 Experience-driven Procedural Content Generation

This approach to PCG has the intent of linking player experience to the actual generation process. Yannakakis and Togelius (2011) stated that, by viewing game content as indirect building blocks of player experience, it's possible to control the affective loop in games by assessing the quality of the game content building blocks that synthesize the game, by searching through the available content and by generating content that optimizes the experience for the player.

The authors give an example described in a paper by Pedersen et al. (2009), which used a modified clone of the game *Super Mario Bros* (Nintendo, 1985) that allowed for personalized level generation.

2.3.4 Taxonomy regarding PCG usage

Since Procedural Content Generation has become an important method in game design practices, it's important to clarify concepts regarding its usage in game design roles and procedures. Despite being around for decades and despite the existence of several proposed taxonomies, Craveirinha et al. (2016) argues that there's still a need of creating a unified perspective for identifying and cataloguing PCG systems, especially in order to allow a "*clear understanding of how humans can interact with them in a game production context*". Therefore, the authors also make their own proposal for such a taxonomy with the intent of providing this type of perspective, which will be detailed further below. A taxonomy by Togelius, Yannakakis, et al. (2011) (and revised by Shaker et al., 2016) for their work on Search-Based PCG will also be presented, which focuses on "*what kind of content is generated, how the content is represented and how the quality/fitness of the content is evaluated*".

2.3.4.1 Taxonomy by Togelius, Yannakakis, et al. (2011)

This taxonomy proposed by Togelius, Yannakakis, et al. (2011) was made for their work on Search-Based PCG and aims to classify distinctions between PCG approaches and to offer ways to analyse artifacts using PCG. These distinctions are represented in a number of dimensions that form a continuum where the content generation problems and methods can be placed between the ends of said dimensions, and therefore the differences and similarities between them are highlighted.

- ***Online versus Offline***: This first distinction refers to whether the generation of content happens as the player is playing the game (online) or as the game is being developed (offline). The former can make the game extraordinarily replayable because it allows for the generation of endless variations and for the generation of player-adapted content, although it requires faster and more efficient algorithms. An example is *Left 4 Dead* (Valve South, 2008) (Fig. 2.6) that provides a "*dynamic experience for each player by analysing player behaviour on the fly and altering the game state accordingly using PCG techniques*" (Shaker et al., 2016).

Fig. 2.6 - Combat experience in *Left 4 Dead* changes according to the player's performance (Left 4 Dead on Steam, n.d.).

- ***Necessary versus Optional Content***: In this distinction generated content is classified as necessary or optional. Necessary content should always be correct because it is required by players to progress in the game, such as enemies that need to be defeated and levels that need to be generated. An example is the structure of the levels in *Super Mario Bros* (Nintendo, 1985) and the items those levels contain (Shaker et al., 2016). On the other hand, optional content can be avoided altogether and therefore can be more experimental, such as the weapons (Fig. 2.7) in *Borderlands* (Gearbox Software, 2009).

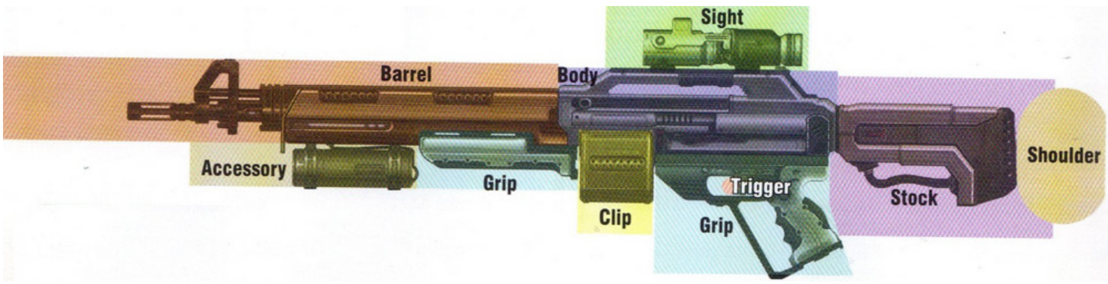

Fig. 2.7 - Weapons in *Borderlands* are made of these various components and their combination builds a unique weapon via procedural techniques (Weapons | Borderlands Wiki | Fandom, n.d.).

- ***Random Seeds versus Parameter Vectors***: This distinction relates to the inputs received by the PCG algorithms and whether they are simply a random seed from which the content is created or whether they are a set of specific multidimensional parameters that specify the properties of the generated content. *Minecraft* (Mojang, 2011) famously uses the former method to generate its game worlds (Fig. 2.8), so the same world can be regenerated endless times by using the same seed.

Fig. 2.8 - Game world generated procedurally in *Minecraft* (Hindy, 2020).

- ***Stochastic versus Deterministic Generation***: Another distinction states that PCG algorithms can be deterministic and therefore can recreate the same content if given the same parameters, or they can be stochastic and recreating the same content is usually impossible. Examples of this distinction are *Elite* (Bell, I. & Braben, D., 1984) as a deterministic use of PCG for the generation of galaxies and most roguelike games with dungeon-generation algorithms.

- ***Constructive versus Generate-and-Test***: In this distinction, algorithms are divided between constructive, which means they generate the content just once, and generate-and-test, which means they alternate generating content and testing reliability, all of this in a loop that repeats until a satisfactory result is generated (Shaker et al., 2016).

- ***Generic versus Adaptive***: This distinction was added in the revision made by Shaker et al. (2016) and it states that generated content is generic if it doesn't take player behavior into account and is adaptive if it's personalised and player-centered. As mentioned before, *Left 4 Dead* (Valve South, 2008) is a good example of the latter, where the pacing of the game is adapted to the player's performance.

- ***Automatic Generation versus Mixed Authorship***: This final distinction, also added in the revision made by Shaker et al. (2016), happens between PCG that allows limited input such as tweaking of algorithm parameters that guide the generation process, and PCG that allows for cooperation in the design process between the generation algorithm and human input, be it from the game designer or from the player.

2.3.4.2 Taxonomy by Craveirinha et al. (2016)

The proposed taxonomy by Craveirinha et al. (2016) aims to provide a classification system that clarifies the multiple role configurations that designers, algorithms and players have in design and production of videogames using PCG techniques (Fig. 2.9). The authors define Procedural Content Generation as "*the process by which an algorithmic method can, autonomously or semi-autonomously, be capable of generating videogame content*".

Additionally, they propose PCG can include three different types of variants: "*PCG designer*", "*PCG (as a) design tool*" and "*PCG games*". "*PCG designer*" refers to a computational agent that produces videogame content and replaces the role of a human designer or producer. "*PCG (as a) design tool*" refers to a design instrument made to help an human author to produce procedurally generated videogame content. "*PCG games*" refers to videogame outputs that result from PCG methods or techniques, made either by a human, a PCG design tool or both. As such, three different types of actors in the PCG-aided videogame production emerge: the Designer, which is the human author of the game; the Computer, which includes the devices and algorithms that autonomously produce the procedural generated game content; and the Player, which refers to any human who plays the finished videogame artifact.

Furthermore, Craveirinha et al. (2016) also propose a distinction regarding the role of these actors in the PCG production process: *generation* and *evaluation*. This interpretation comes from viewing the creative act as a recursive process that loops between various phases: preparing by gathering knowledge from an area, trying multiple combinations and finally finding a solution. According to the authors, these phases constitute a generation procedure (where actors possess a generation role), while the subsequent assessment of the solution's quality and the possible refining of said solution constitute the evaluation role. They argue that by separating these two phases it's possible to identify more accurately the impact and responsibility that each actor has in the output. Succinctly, the *Generation role* includes "*all processes with the goal of creation, recreation or iteration of a game content solution, irrespective of its validity or quality*", while the *Evaluation role* "*refers to any procedures or acts, be they formal or informal, that end up determining the attributed value of any generated solution, in a way that guides the creative generation process in subsequent iterations*".

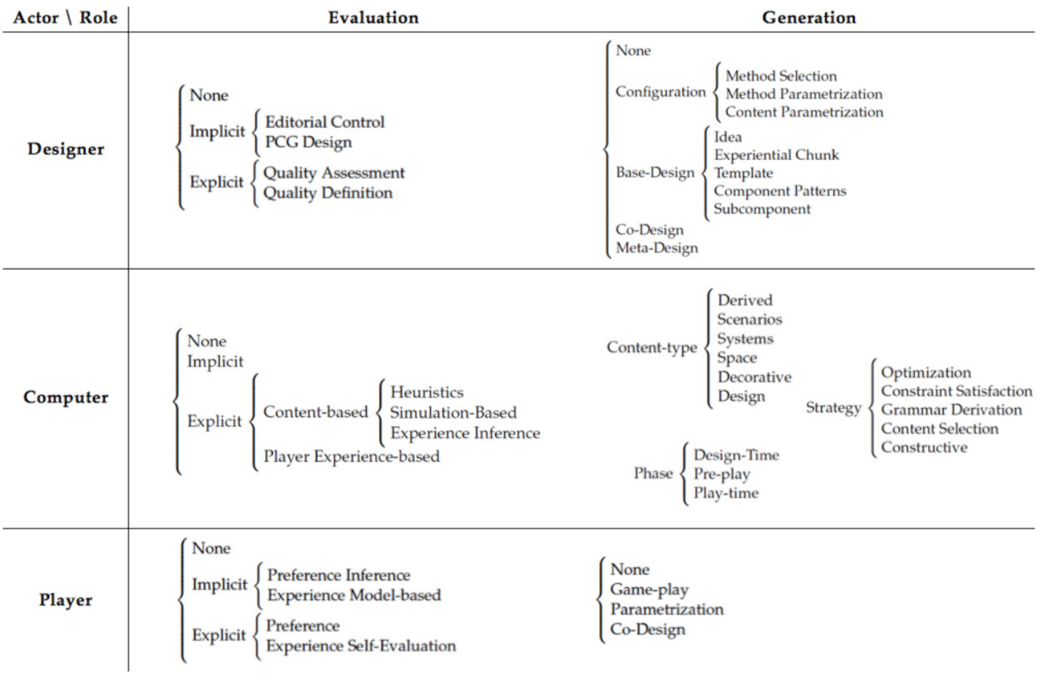

Fig. 2.9 - Schematic of the taxonomy proposed by Craveirinha et al. (2016).

2.3.5 Examples of PCG-enabled Games

2.3.5.1 Elite

Elite (Bell, I. & Braben, D., 1984) is a space exploration and trading game that was one of the earliest games that was able to generate a full game world procedurally (Hendrikx et al., 2013). Despite only having 22 kilobytes of memory, the game could generate 8 massive galaxies with 256 solar systems each, essentially making its content generator also a data compressor (Smith, 2012). Additionally, each solar system in *Elite* has 1 to 12 planets, where each has a name, position, local details, personal terrain, prices of commodities and a space station in its orbit (Fig. 2.10). The game uses a hardcoded seed to generate all of this content (Aversa, 2015).

A new version of the game, named *Elite Dangerous* (Frontier Developments, 2014), is able to generate a 1:1 replica of the Milky Way with more than 400 billion star systems, which means that without using PCG the game's full system could occupy more than 400 Terabytes (Aversa, 2015).

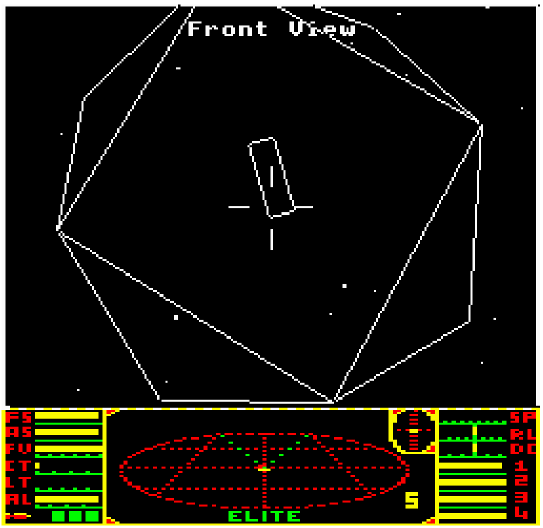

Fig. 2.10 - Player approaching a space station in Elite (Wikipedia contributors, 2007).

2.3.5.2 Spore

Spore (Maxis, 2008) is a game where the players can construct and "evolve" an organism by adding new or alternate parts (faster tails, different eyes, more offensive or defensive parts, etc) to improve their creature. These different parts can be purchased with "DNA points" that are obtained by consuming enough food. Despite this gameplay feature being mentioned as "evolution", the outcome of reproduction and evolution is manipulated directly, which is not a scientific representation of the evolutionary process (Bean et al., 2010). This direct manipulation actively alters the generated content to provide additional constraints to the generator (Smith, 2014). As such, it is better described as a PCG-enabled design tool rather than an usual PCG generator or an evolution-based game.

The game's central features, which are the designs created by the players (Fig. 2.11), are animated using procedural animation techniques and are subsequently used to populate a procedurally generated galaxy (Shaker et al., 2016).

Fig. 2.11 - Examples of creatures generated in *Spore* (SPORE™ on Steam, n.d.).

2.3.5.3 Endless Web

Endless Web is "*an experimental 2D adventure/platformer that explores how to deeply integrate procedural content generation into both game mechanics and aesthetics*" (Endless Web | Rescue the Dreamers from Their Collective Nightmare, n.d.). As the player moves in the game, the game world is generated procedurally according to the player's decisions, using player interaction with the generator to integrate PCG in both the game's mechanics and the game's aesthetics (Fig. 2.12). Therefore, it can be considered a PCG-based game that "*has the potential to provide greater agency and a wider variety of player experiences*" (Smith, 2012). The game has been developed at UC Santa Cruz and Northeastern University with the intent of studying how PCG systems can influence game design and vice-versa.

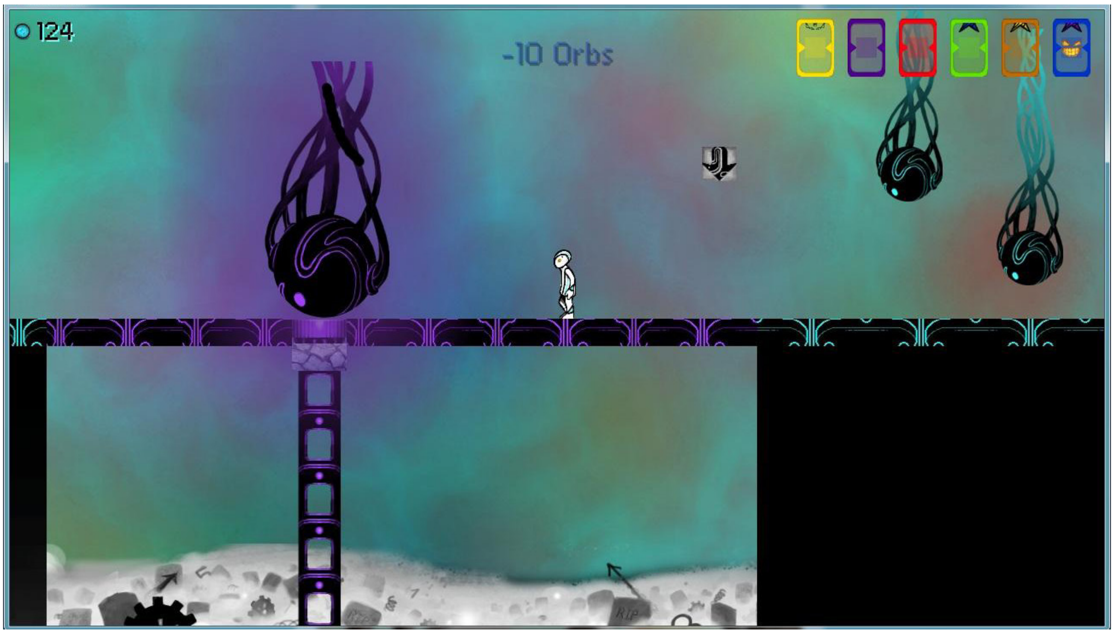

Fig. 2.12 - Screenshot of the game *Endless Web* (Endless Web, 2017).

Chapter 3

Objectives, Methodology and Work Schedule

3.1 Objectives

Primarily, this dissertation has the goal of creating an original game, as an opportunity to implement procedural generation techniques that provide players with dynamic experiences throughout the course of gameplay. This would enable an unlimited amount of replayability and also a different and meaningful experience driven by each player. In order to do so, the concept and prototype should explore the use of PCG techniques to innovate concepts of Game Design. Additionally, they should also provide players with the means, during the gameplay activity, for learning about the real context being modeled in the game.

The game concept which we will study for this dissertation is based on the idea of ecosystems and the interacting elements within them. From the research done, we concluded that this was an appropriate design context to explore the concepts mentioned above and was an interesting subject to apply in a game that could connect with players in a meaningful way, especially in current times where ecological concerns are paramount. As such, through the act of play, the players will encounter challenges that require strategic interaction and thoughtful decision making that will enable them to learn more about the kinds of challenges that impact nature in real life. The ecosystem in play will present players with both biotic and abiotic elements which will interact and affect each other. This will require modelling of the system, the elements within it and the types of interactions that can happen during the course of the game. Moreover, it is fundamental to design the interactions that the player can perform on the system's elements and the resulting impacts both to the system and to the intended player experience. Lastly, we intended for the design prototype to be tested and the respective design parameters to be adjusted according with the results found.

3.2 Methodology

In order to complete the objectives mentioned above, the work done in this dissertation will follow a Design Science Research (Fig. 3.1) methodology, with the goal of producing new interesting knowledge by creating artifacts to solve problems. This methodology comprises five steps: Awareness of problem, Suggestion, Development, Evaluation and Conclusion (Vaishnavi & Kuechler, 2004):

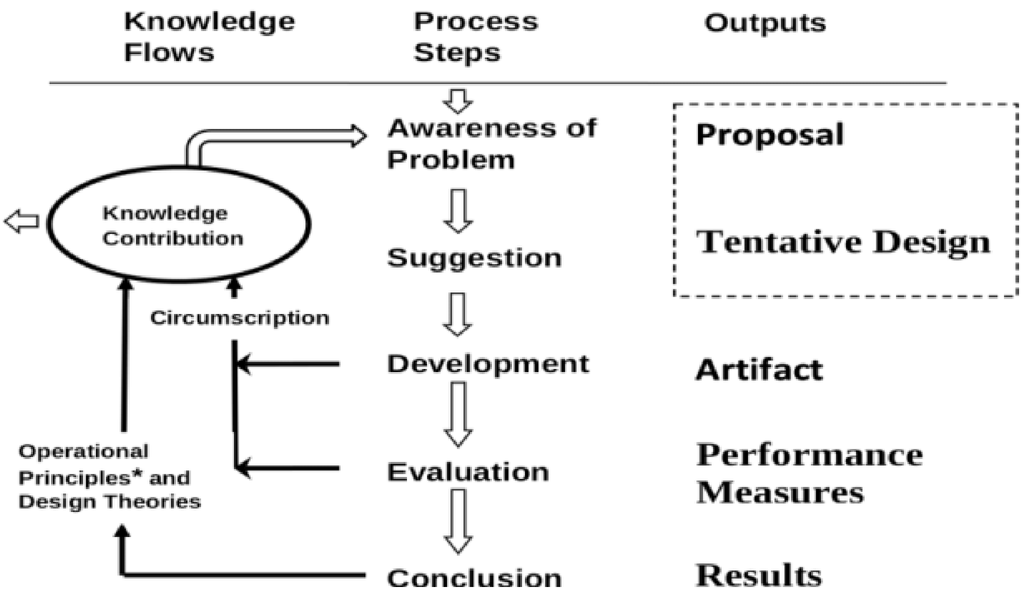

Fig. 3.1 - Design Science Research Process Model (Vaishnavi & Kuechler, 2004).

- ***Awareness of problem***: this step consists of the research of necessary knowledge to identify the problem at hand and to start the design process. As such, it produces the State of the Art and Objectives of the dissertation.

- ***Suggestion***: this second step comprises the creative effort to provide a solution for the previously defined problem and therefore it produces a Design Proposal with the proposed game concept and the design choices made to implement it.

- ***Development***: this phase is defined by the actual implementation of the prototype, following the established game proposal. Thus, in this phase, the artifact produced is the game prototype itself.

- ***Evaluation***: in this phase, the game prototype is evaluated through testing, according to the criteria laid out in the previously identified objectives. The results gathered are compared with this criteria and deviations from the intended solution can lead the process to a previous phase in the Design Science Research loop, where this cyclical process will produce adjusted results.

- ***Conclusion***: this final step consists of the end of the research effort where the produced knowledge is consolidated, its contribution is laid out and the final results of the entire process are formalized.

Following this method, the dissertation will consist of several sub-processes that are comprised within these five steps, as detailed in the following diagram (Fig. 3.2):

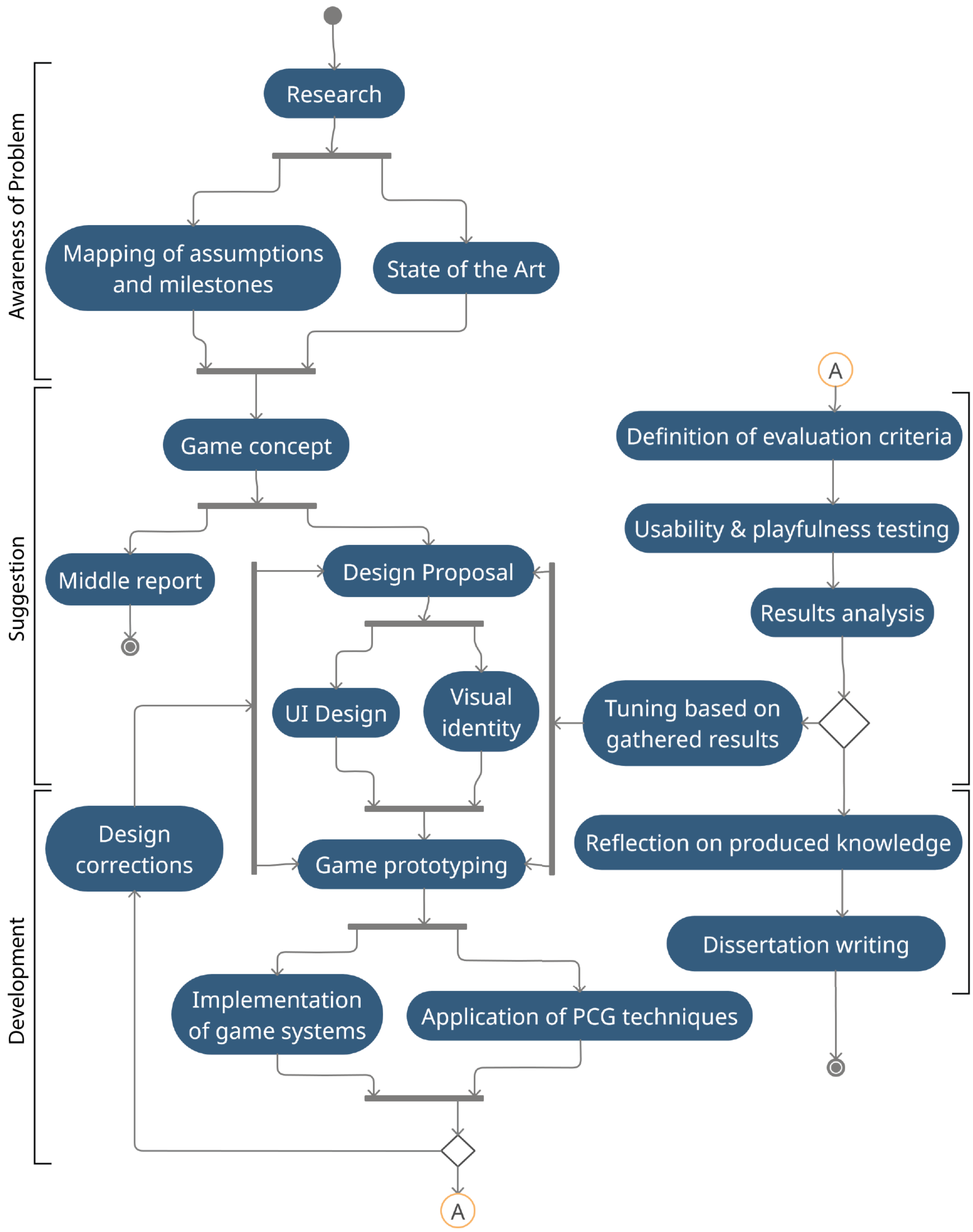

Fig. 3.2 - Activity diagram depicting the planned work phases for the dissertation.

3.3 Work Schedule

As explained above, the work plan for the dissertation will comprise several phases that will be developed throughout the year. Each of these phases are laid out in the following Gantt diagram, detailing their planned distribution across the available time (Fig. 3.3).

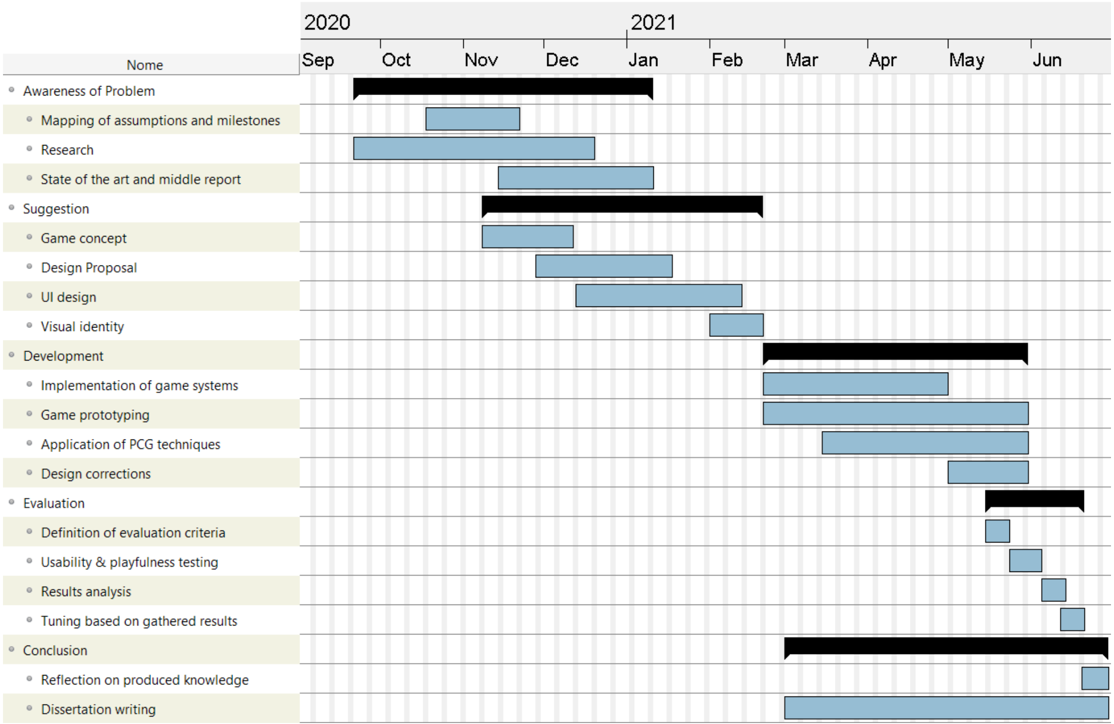

Fig. 3.3 - Gantt diagram depicting the planned work schedule for the dissertation.

Chapter 4

Game Design Proposal

4.1 Game Concept

The proposed game has the intention of providing the player an opportunity to understand some of the many nuances of maintaining an ecosystem in harmony. In the game, the player is able to interfere with the evolutionary process of a number of species in an ecosystem, more specifically by choosing traits in new elements of each species that will make an impact in that population's adaptiveness and survivability. These evolutionary changes in a species will also indirectly affect the other surrounding species and consequently the whole system may sustain consequences of these player's decisions. Therefore, the player has to strategize his/her decisions on what new traits are introduced in every species, in order to sustain the various creatures' populations and keep the whole system from collapsing.

In addition to the existence of biological entities, the game world is also composed of abiotic elements that are modeled to be updated over time. These dynamic transformations in the habitats and living conditions of each species will affect their growth and survivability and the player must assess how to deal with threats to the system's balance. Through the use of generative techniques, the game will represent dynamic world elements. It's our intention to provide a different challenge and a unique gameplay experience in each game iteration. This concept was developed using the Participation-Centered Game Design Model and canvas (Pereira et al., 2019) in Fig. 4.1.

Participation (exploring/ discovering/ recreating/ customizing)

• What spaces of free exploration does the videogame support?
– N/A

• What elements support player's free/willing activities?
– The evolution system provides various choices for the players to evolve their lifeforms

• How do you characterize players' space of possibilities?
– The player can choose any affordable possibility of evolution from any lifeform, although some may be detrimental to the progress in the game

Challenge (overcoming a challenge/ creating a strategy/ defeating an opponent/ mastering a skill)

• What goals does the videogame propose?
– Maintain the gameworld's constantly changing ecosystem in balance for as long as possible

• What is the nature of the videogame's challenge?
– Strategy and problem-solving

• What feedback is awarded to players' performance?
– Player's performance is measured by how well and for how long the player can maintain the balance in the ecosystem and this balance is shown on screen as a graph indicator

Sensemaking (interpretation of a role/ fantasy/ self-expression)

• What phenomenon is represented in the game/is meant to be interpreted by players?
– The game presents an abstract representation of a natural ecosystem and its meant to be interpreted as such by the player

• What significant events are represented/elicited in the game?
– The events revolve around the changes made by the player to the traits of the various biological organisms and their subsequent evolutions, as well as dynamic abiotic elements that the player needs to pay attention to

• What roles do players act out?
– The player plays the role of "nature itself" in order to control the evolution of the lifeforms

Sensoriality (contemplation/ wonder)

• What is the nature and intention of sensorial stimuli?
– The player will be provided with visual information, in the game's interface, regarding the state of the gameworld's ecosystem.

• What opportunities for contemplation does the game offer?
– Through the information provided, the players are given the opportunity to contemplate about the consequences of their actions to the overall ecosystem

• What opportunities for aesthetic exploration does the player have available?
– Aesthetics are present visually in the representation of the creatures of the gameworld

Embodiment (physical involvement/ physical performance)

• How do you manifest players' presence in the game world?
– Limited indirect interaction with the gameworld, with a god view visual perspective

• How do you characterize the game world?
– Finite 2D gameworld, with a infinite and continuous time progression

• How do players interact with the gameworld?
– Point and click through mouse or other similar input

Sociability (competition/ cooperation/ friendship/ identification/ recognition)

• What interpersonal relations does the game propose or promote?
– N/A

• What is the structure or topology the game promotes?
– Player vs Game

• What is the type of inter-player mediation?
– N/A

Fig. 4.1 - Draft of Game Concept framed by the Participation-Centered Game Design Canvas.

4.2 Game Elements and Mechanics

In the initial phase of the game, a layout for the gameworld is generated, consisting of a percentage of land and sea (Fig. 4.2). This layout is used to generate a map of the habitats in the gameworld, which are characterized by their abiotic elements, and where the creatures will live. The details of this map generation process and the gameworlds' characteristics will be discussed in the development section further below.

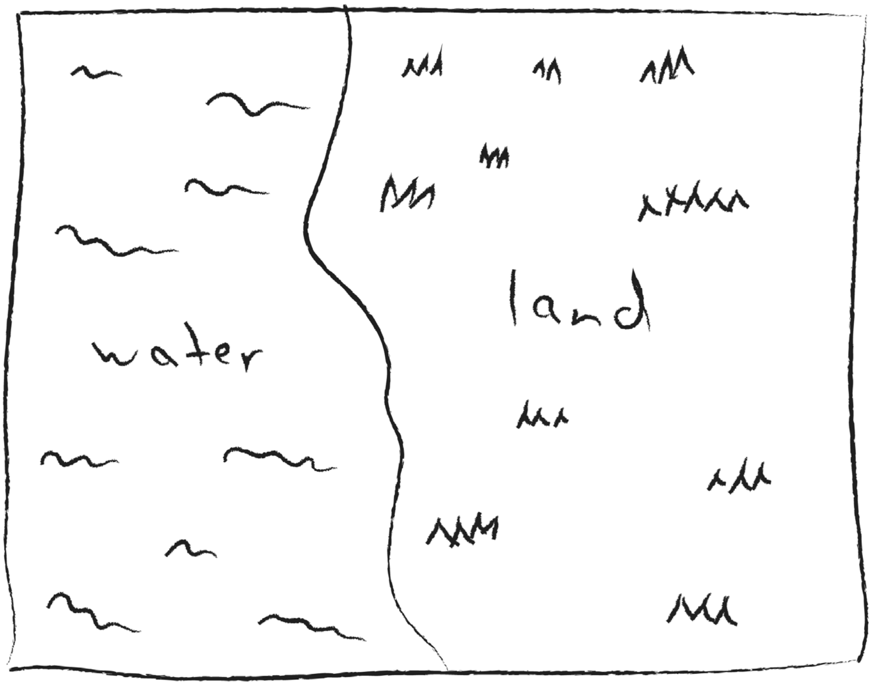

Fig. 4.2 - Sketch depicting the concept for the game screen after the map generation phase.

After generating the map, the habitats are occupied with populations belonging to 6 proto-species of life forms, according to their type (Fig. 4.3). These types of species also represent the categories, or classes, that each species later created by the player can belong to. Each of these species will be affected by each other and by the environmental factors in the game world, i.e. the abiotic elements of their habitat. These proto-species are:

- ***Land plant*** - a plant species that inhabits the land portions of the map. It is eaten by herbivores, sitting at the bottom of the food chain.
- ***Water plant*** - same as the land plant but it inhabits the sea portions of the game world.
- ***Land herbivore*** - an herbivore creature that lives on land. It feeds on land plants and is hunted by carnivores.
- ***Water herbivore*** - an herbivore creature that inhabits the sea and feeds on water plants. It's also hunted by carnivores.
- ***Land carnivore*** - a carnivore creature that lives on land and feeds on herbivores and other carnivores.

- ***Water carnivore*** - same as the land carnivore but it inhabits the sea portions of the game world.

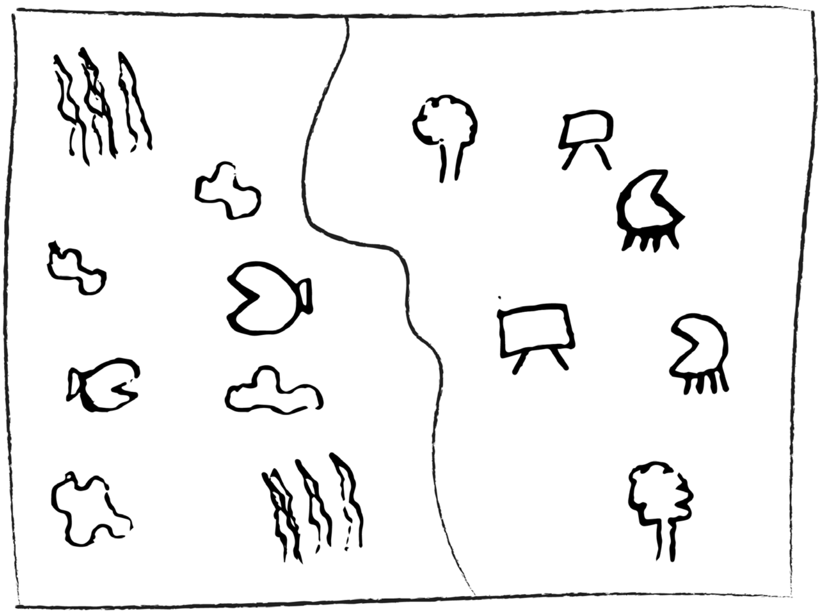

Fig. 4.3 - Sketch showing the concept for the different types of species interacting in the game world.

Regarding the abiotic elements, each area of the gameworld is characterised by these 4 elements that are fluctuating over time. These dynamic elements are:

- ***Temperature*** - as with all abiotic elements, this first one fluctuates between a minimum and a maximum value. All creatures have an ideal range of temperature values at which they can survive.

- ***Water*** - an element needed for every lifeform to survive. Present in much higher levels in sea areas than in land areas.

- ***Oxygen*** - the gas needed for all the herbivores and carnivores to breathe and survive.

- ***Carbon Dioxide*** - a gas consumed by the plants in the gameworld and key to their survival.

Each species has specific survival needs regarding these elements and, as such, some habitats will be more suited for them to thrive than others. The characteristics of the types of creatures and the abiotic elements, as well as the interactions between each of them, will be detailed further in the development section.

After this setup phase, the actual game begins and the player can start to manage the ecosystem by trying to balance the creatures' populations and adapting them to the characteristics of their surrounding environment, i.e. the abiotic elements, by altering their genetic characteristics and traits. To do this, the player is presented with information about the growth/decline in the populations of each class of creature and also about the state of the abiotic elements in each area of the map, at that point in time. The passage of time in the game is done following a turn-based system, where each turn happens after a fixed amount of real time. When each of these turns happens, the game's calculations are made regarding the behaviour of the creatures, the fluctuations of the abiotic elements and the interactions between the two. Therefore, with the passage of each turn, new information about these elements is produced and provided to the players for decision-making and feedback purposes.

With this information, the player accesses the main gameplay component - the evolve system - in order to create new species of creatures by evolving the already existing ones (Fig. 4.4). This component can be accessed through an interface at any time, through the clicking of a button displayed on the screen, at which point, as soon as this interface is opened, the passage of time in the game is paused (i.e. no new turns are calculated) and only resumes when the player exits this interface. The interface displays the option to select one of the 6 classes of species, along with the species present in each of them, and in doing so it displays the various traits the player can choose from to add to, or remove from, a species, as well as their cost to do so. This cost is subtracted from the amount of points that the player gradually gains as the game's turns pass. The player needs to manage the amount of points available and carefully consider which traits to spend them on by considering the potential consequences they may have on that particular type of creature and consequently the entire food chain's populations. Also, each of these traits has some advantages but also drawbacks, as one trait can give creatures a characteristic that impacts one or more aspects of their survival in a positive way but others negatively. To help the player in this decision-making process, the information regarding the aspects affected by each trait is given in the evolution interface. When the new traits are selected, the player can also see a visual preview of the created species, before making a final decision.

When the player uses the evolve system, adds one or more new traits to one species and saves the changes, a new species is created, derived from the one the player evolved, and a few individuals appear in the game world. The original and the newly created species will then coexist and compete in the game world. Finally, as the game continues and more and more new species are added, the more challenging it will be to keep the ecosystem's populations in balance.

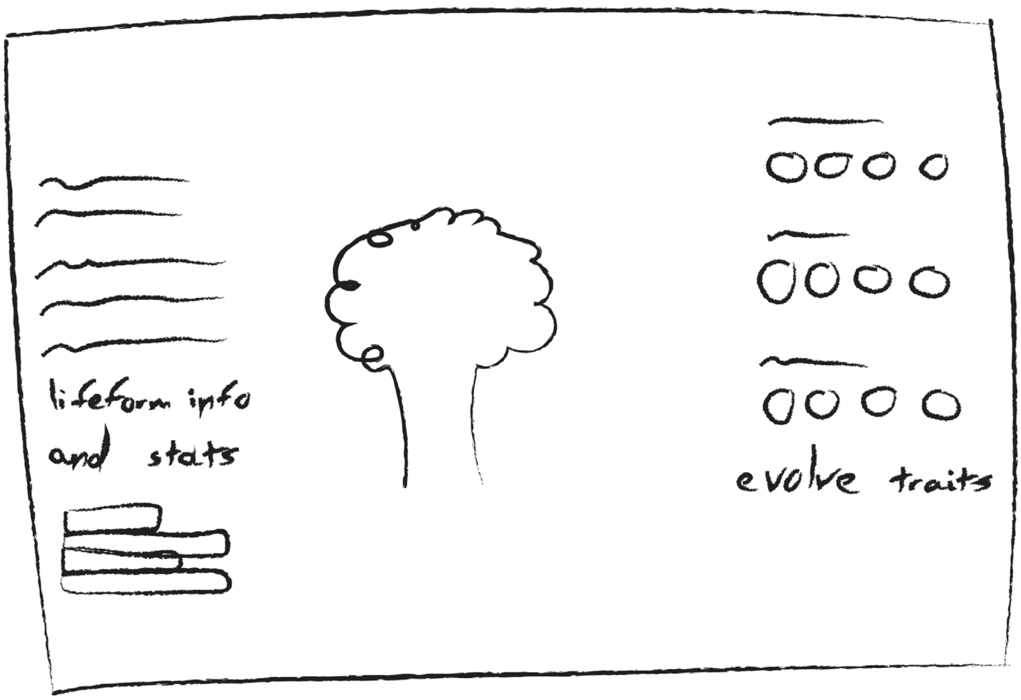

Fig. 4.4 - Sketch showing the initial idea for the evolution system's UI.

Some other elements were considered early in the conceptualization of the game, as for example the addition of amphibian creatures that would inhabit both land and sea areas and the addition of geological and atmospheric events that would greatly impact the map's layout and the abiotic values. These ideas were ultimately put on hold due to their complexity and a lack of available time in order to implement them successfully.

Chapter 5

Prototype Development

After the establishment of the design concept, the development process of the game prototype began. The process went through many stages, from the development of the visual representations of creatures and their traits, to the coding of the game's interface. The technology chosen for the implementation was the Processing programming language, mainly due to its flexibility and potential regarding visual projects, and also because it was a language that I was already familiar with and could be readily productive in. This process of implementation and the characteristics of the developed prototype will be detailed in this section.

5.1 Creatures Visual Representation

In order to represent each of the classes of the initial organisms, a study was initially made regarding the shapes and characteristics of some types of species existing in nature, corresponding to these categories. Some examples considered are shown in the following pictures:

Fig. 5.1 - Examples of shapes of real-world living organisms that were analyzed: in the case of plants, the water lily (Barnett, 2018) and the clover (*Shamrock Vs Four Leaf Clover*, 2021).

Fig. 5.2 - More examples of shapes of real-world living organisms that were analyzed: in the case of herbivores, a common fish (*r/Fish - Clipart aquarium fish*, 2017) and a cow (Wikipedia contributors, 2019).

Fig. 5.3 - More examples of shapes of real-world living organisms that were analyzed: in the case of carnivores, the sea lion (*California sea lion*, 2020) and the tiger (Wikipedia contributors, 2020).

These and other animals' bodies in nature are "designed to interact with their environments" and have evolved in order to respond to pressures provided by such environments (*Boundless*, n.d.). Similarly, plants' shapes, especially the shapes of their leaves, are "largely a consequence of the anatomical and physiological adaptations that plants employ to cope with their environments" (Lowe, 2017). In particular, leaf area and ratio of leaf area to its weight are two measures that help to assess the efficiency and survival of these plants.

As such the body shapes of each of these organisms are primarily a result of adaptation to their lifestyle, in the same way as the shapes chosen to represent each of the classes aim to provide a quick and efficient distinction and identification of the habitat and type of diet of these classes.

Given this objective, some sketches were made in order to associate some of these classes with simple shapes (Fig. 5.4). Regarding the plants' shapes, these were based on commonly recognized shapes of plants and leaves that exist in nature, both on land and water habitats. The main examples that were used as a basis for the sketches were grass, algae, water lilies and clovers. Regarding the animals, one of the criteria used in the design of these shapes was based on the perception between angular and rounded shapes, given the fact that an abstract shape with more smoothly curved contours makes it more pleasant (Palumbo et al., 2015). This is due to rounded shapes being associated with perceptions like sweet taste, quiet or calm sound and relieved emotion, while angular shapes are associated with sour taste, loud or dynamic sound and excited or surprise emotion (Blazhenkova & Kumar, 2018). Thus came the idea of distinguishing between herbivores and carnivores using this criterion, with carnivores presenting more angular shapes and herbivores presenting more rounded shapes. The colors used to draw the shapes was also designed to help with this distinction regarding the creatures' place in the food chain: for the plants, the color green was chosen, as it is the naturally recognized color for these organisms in nature; for the carnivores, the color red was chosen in order to represent the aggressiveness that is natural to these creatures; finally, for the herbivores, the color yellow was chosen, mainly due to its high contrast with both of the previous colors.

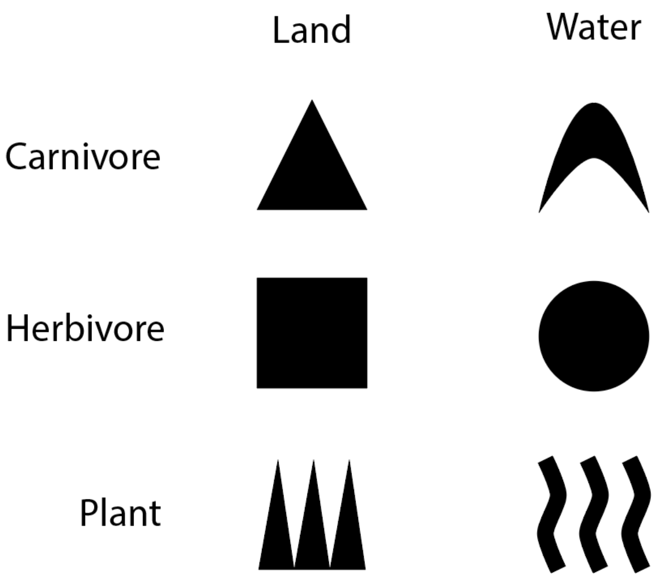

Fig. 5.4 - First sketches made to associate each class with simple shapes.

For the distinction between habitats, another criterion regarding the organisms' shapes present in nature was considered: the fact that "aquatic animals tend to have tubular shaped bodies (fusiform shape) that decrease drag" while "terrestrial animals tend to have body shapes that are adapted to deal with gravity" (*Limits on Animal Size and Shape*, 2020). This led to the terrestrial bodies being conceived in more rectangular shapes while the aquatic ones were more tapered. Yet another criterion considered was that of symmetry, which is present in most organisms in nature. Thus, based on all of these criteria, the following shapes were produced for the 6 classes of organisms designed:

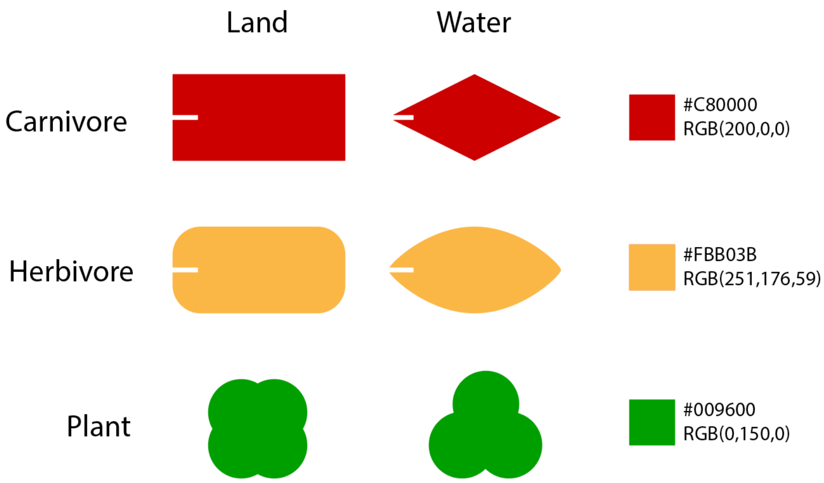

Fig. 5.5 - Final shapes made for each class and their respective colors.

In addition to this representation of the initial shapes, a way of representing the traits that these species will acquire over the gametime was also conceived. Each of the traits is represented by a smaller shape that is placed upon the main shape of the organism. In order to do that, some sections were distinguished in each main shape, where the various traits will be placed when they are chosen by the player:

- Head
- Mouth
- Tail
- Dorsal
- Bottom
- Center
- Outline

Thus, each of the traits available to the player belongs to one of the categories represented by these sections and is placed in that designated section of the main shape when the respective trait is added by the player, as depicted in the images below (Fig 5.6).

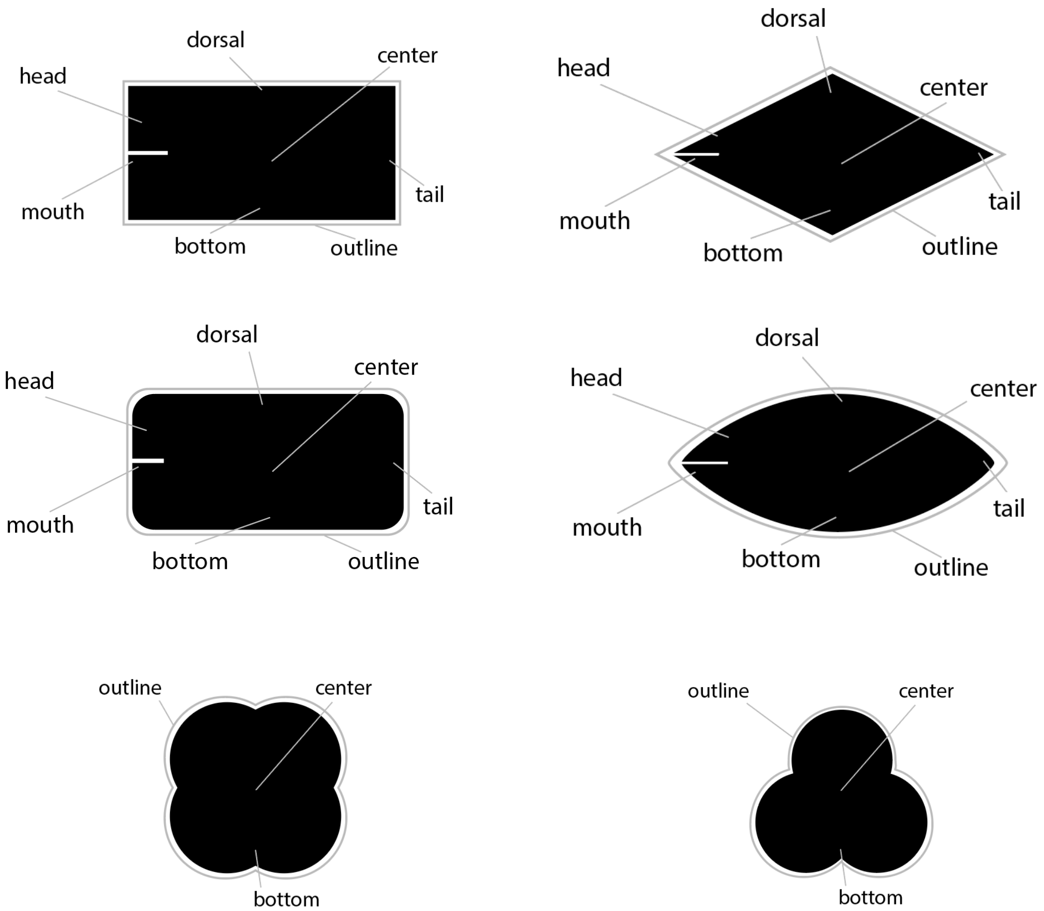

Fig. 5.6 - Sections, of each main shape, where the traits are added.

However, this approach had some problems. The traits' shapes were made using SVG files and, due to limited rendering capabilities of the renders in Processing, the shapes wouldn't load onto the program if the trait's shape was too complex and had too many curved lines. Given that these issues were only discovered late in the development process, the solution that was devised for the prototype to work was to redevelop some of the traits' shapes using only straight lines.

5.2 Main Components and Interactions

As the implementation of the prototype began, the game's main components were established and coded into classes of objects in Processing. In this section, these components and their interactions with each other will be detailed further. The first of these components is the game's organisms, defined by the class *Creature*. Each organism is characterised by a main set of attributes which are implemented in the class *Creature* and are used to define each organism existing in the gameworld and to generate its behaviour at each game turn:

- ***type:*** represents the species the creature belongs to.
- ***location:*** stores the current location of the creature on the map, represented by x and y coordinates.
- ***habitat:*** indicates the type of area the creature lives in i.e. land or water.
- ***foodType:*** indicates the creature's type regarding its place in the food chain i.e plant, herbivore or carnivore.
- ***gasConsumed:*** represents the type of gas that the creature needs to consume to survive.
- ***storedEnergy:*** indicates the value of energy, gained from feeding, the creature has currently stored.
- ***lifeCycle:*** indicates the remaining turns the creature has left to live.
- ***combatPower:*** represents the capacity of the creature to hunt prey or to defend itself against predators.
- ***reproductionRate:*** represents the probability that the creature has of producing offspring each turn.
- ***amountOfMovement: indicates the amount of distance that the creature moves at each turn***.
- ***minTemperature:*** indicates the value for the minimum temperature the creature is able to withstand.
- ***maxTemperature:*** indicates the value for the maximum temperature the creature is able to withstand.
- ***minGas:*** indicates the minimum level of gas in the creature's area it needs to survive.
- ***minWater:*** indicates the minimum level of water in the creature's area it needs to survive.
- ***minEnergy:*** indicates the minimum energy the creature needs to have stored at each turn in order to survive.
- ***buffsDebuffs:*** stores which buffs and debuffs are currently being applied to the creature, as a result of the creature's interaction with the surrounding environment.

The information regarding each of these effects is stored by using the class *BuffDebuff*, which is also used to characterize the effects of each trait added to the creature, as stated in the next item.

- ***traits:*** stores the evolutionary traits, added by the player, that the creature possesses. Each trait is represented by the class Trait whose main attributes include the cost the trait requires to add or remove, the visual shape of the trait and the buffs and/or debuffs it gives to the creature, again by using the *BuffDebuff* class.

With these attributes established, it is possible to model the 3 different aspects of the creatures' behaviour:

- **Movement*:*** this is the first aspect of the creatures' behaviour to be generated at every given game turn. It's calculated for every creature except plants, which all have their *amountOfMovement* value set at 0 in the prototype. The procedure to generate this behaviour for each creature starts by randomly selecting one of four directions for the creature to move: up, down, left or right. After this, the *amountOfMovement* value owned by the creature is added to its location vector, adding it to or subtracting it from the x or y value, according to the direction previously determined. Finally, the last step involves a verification of the current location of the creature, in order to check if the creature went out of bounds of the gameworld or to an area with a different habitat (for example, a water creature entering a land area). In such cases, the movement action is reversed and the creature returns to its original position at the start of the turn.

- **Feeding*:*** the second aspect to be generated is the creatures' feeding. In order to do this, every turn the creatures which are in the same area of the gameworld are compared with each other regarding their place in the food chain. When a comparison happens between a carnivore and an herbivore or between an herbivore and a plant, a calculation is made to determine if the predator successfully fed of the prey, according to the boolean result of the following logical condition:

  (predL.dist(preyL)<D) AND (random(100)<(C+(predCP-preyCP)))

  where *predL* is the ***location*** of the predator creature; *preyL* is the ***location*** of the prey creature; the function *dist()* calculates the Euclidean distance between the two locations; *D* is a constant value defined at the beginning of the program (with the value of 5 in the current iteration of the prototype); *random(100)* generates a random numerical value starting at 0 and up to (but not including) 100; *C* is a constant value defined at the beginning of the program (with the value of 50 in the current iteration of the prototype); *predCP* is the value of the predator creature's ***combatPower***; and *preyCP* is the value of the predator creature's ***combatPower***. If the condition is true, the prey creature is removed from the game and the predator creature is not able to feed again this turn. Also, a constant value is added to the predator's ***storedEnergy*** value (in the current iteration of the prototype, this constant value is 5 for the herbivores and 20 for the carnivores). Finally, if the creature's ***storedEnergy*** value is less than its ***minEnergy*** value, the creature gains a debuff representing its state of hunger and its ***lifeCycle*** value starts to decrease at a rate of 50 per turn, instead of the normal decrease of 1 per turn.

- **Reproduction*:*** the final aspect of the creatures' behaviour to be generated each turn is their reproduction, which is dependent on the value of their ***reproductionRate***. This value is a percentage which represents the probability of each creature to reproduce and, therefore, each turn a random value between 0 and 100 is produced and compared to this percentage value; if the generated value is lower than the ***reproductionRate*** value, then the creature reproduces and a new individual creature of the same species appears in a random location, but in the same area of the gameworld as the parent. For plants, an additional verification is required in order for them to reproduce successfully, which consists in verifying if this random location of the potential offspring already has another plant at an Euclidean distance of 5 or less from that point. If that's the case, the plant does not reproduce that turn. Also, after a successful reproduction, the ***storedEnergy*** value of the parent creature is divided equally with the child creature.

Both the feeding and reproduction aspects were designed based on the model *Wolf Sheep Predation* (Wilensky, 1997) available within the application *NetLogo* (Wilensky, 1999), a "multi-agent programmable modeling environment" used for many academic and research purposes. This model was relevant as a basis for the design because it allowed for exploration regarding "the stability of predator-prey ecosystems" (Wilensky, 1997), by providing an interface in which several parameters, such as reproduction rates and energy gains, could be changed to test if the populations of the species involved would tend to maintain itself over time (Fig. 5.7).

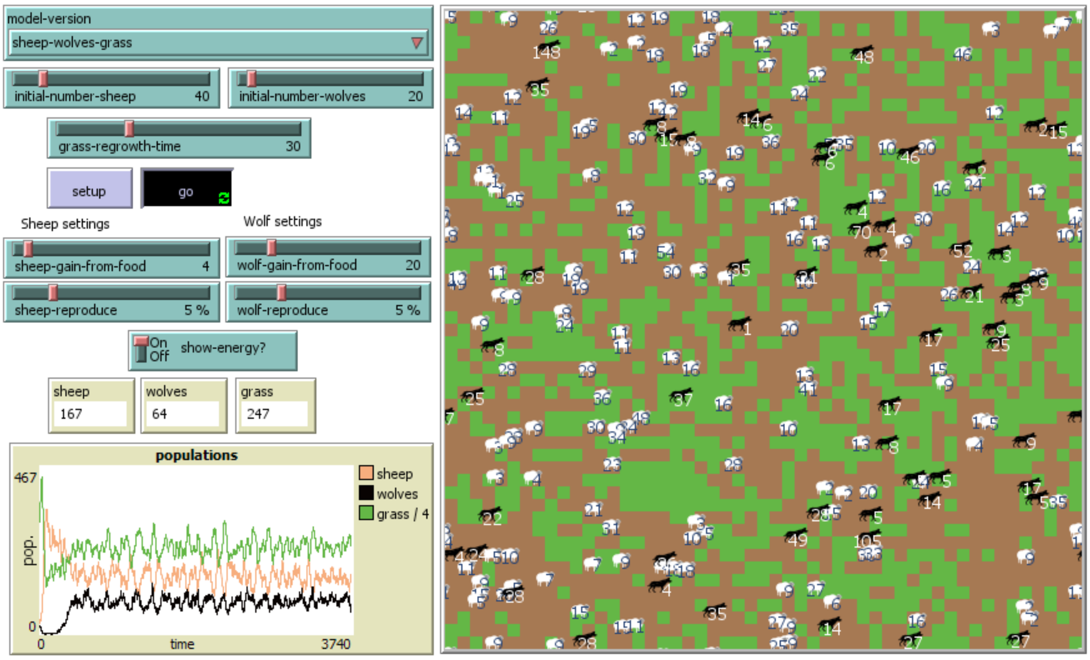

Fig. 5.7 - Screenshot of the model *Wolf Sheep Predation* (Wilensky, 1997) available within the application *NetLogo* (Wilensky, 1999).

In addition to their behavior, the creatures depend on the environmental conditions of the area they are in, represented by the abiotic elements. Each of these elements is represented using the class *AbioticElement* and is present with different instances in the various areas of the map. As such, these areas can have, for example, very different temperature values at the same point in time. Every element is characterized by a few main attributes:

- ***type:*** indicates which type the element belongs to i.e. temperature, water, oxygen or carbon dioxide.
- ***amount:*** stores the current value for this abiotic element.
- ***min:*** indicates the minimum value the element can adopt.

- ***max:*** indicates the maximum value the element can adopt.

All these elements, in each area of the gameworld, fluctuate independently of each other and of the same elements in other areas of the gameworld. These fluctuations are calculated every turn according to the following formula:

*nextAbioticValue=randomGaussian() * ((max-min)/2)/3 +(min+max)/2*

where the function *randomGaussian()* generates a number fitting a normal distribution, which is then stored in the ***amount*** attribute. This approach allows for the values produced by the fluctuations to be mostly concentrated around the central value of the range defined by the minimum and maximum values, while still allowing some possibility of generating more extreme values.

Every turn, the ***amount*** values of the abiotic elements of each area of the gameworld is compared with the respective attributes of survival of the creatures located in that same area. As such, the temperature value is compared with the ***minTemperature*** and ***maxTemperature*** values of the creature, the water value is compared with the ***minWater*** value and the oxygen or carbon dioxide (depending on the type of gas consumed by the creature) is compared with the ***minGas*** value. If these values do not meet the creature's requirements for survival, the creature gains a debuff related to the respective requirement: if it's related to temperature, the creature's ***lifeCycle*** value starts to decrease at a rate of 10 per turn; if it's related to water, the ***lifeCycle*** value decreases at a rate of 4 per turn; and if it's related to a gas, the ***lifeCycle*** value decreases at a rate of 6 per turn. All of these debuffs can be stacked with each other, if multiple survival requirements are not met at the same time.

5.3 Map Generation

Another essential part of the prototype's development was in regards to how the generation of the gameworld would occur. This is an important step because, as the game begins and this process ensues, it is used to define the characteristics of the abiotic elements present in the areas of the gameworld and, therefore, to define the spaces where the first creatures will be placed. Also, it was intended that this process would be able to generate diverse layouts for the gameworld, so that each time the game was played it felt distinct and unique.

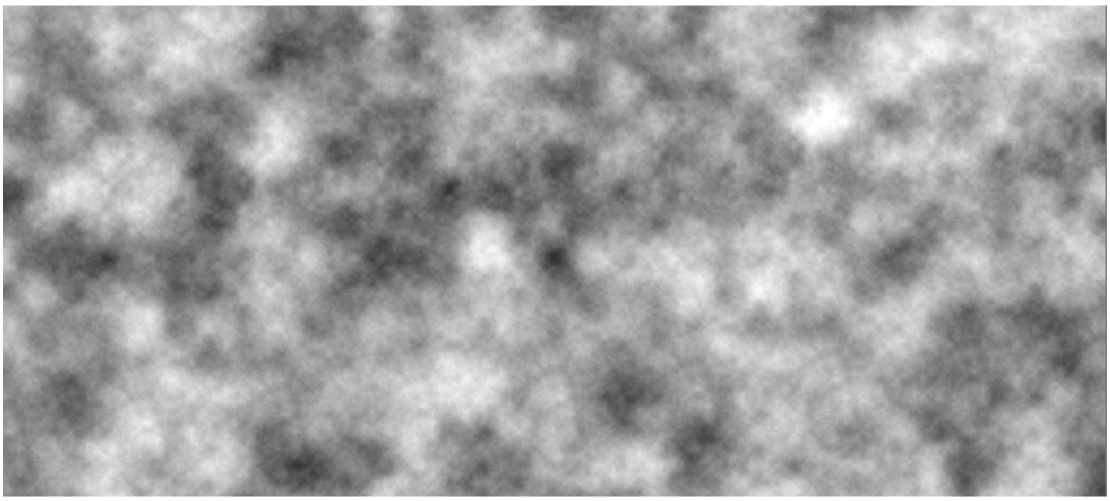

Fig. 5.8 - Example of a texture produced by Perlin noise.

The approach that was followed had the goal to produce a map layout with several areas, hereby also called tiles, of land and water that would resemble a map of continents and oceans in real life. In order to do so, this approach uses Perlin noise to produce a two-dimensional grid of values, all of them between 0 and 1, that can be interpreted as a natural and realistic terrain texture (Fig. 5.8). These values are then mapped to a range between -1000 and 1000, representing the lowest and highest possible values of altitude of each tile. After that, these altitude values are used as a basis to generate the remaining characteristics of each tile, which are stored using the class *Tile*:

- ***type:*** indicates the tile's type, i.e. land or water, and it is determined by the altitude value: if it is equal or greater than 0, it is a land tile; if it is less than 0, it is a water tile.

- ***color:*** represents the color of the tile and it is dependant on two factors: the first one is type of tile stated above, that decides which of two gradients is used to determine the color (blue gradient for water tiles, brown gradient for land tiles); the other factor is the altitude value, which is used to interpolate between the two colors at the ends of the determined gradient, as shown in Fig. 5.9.

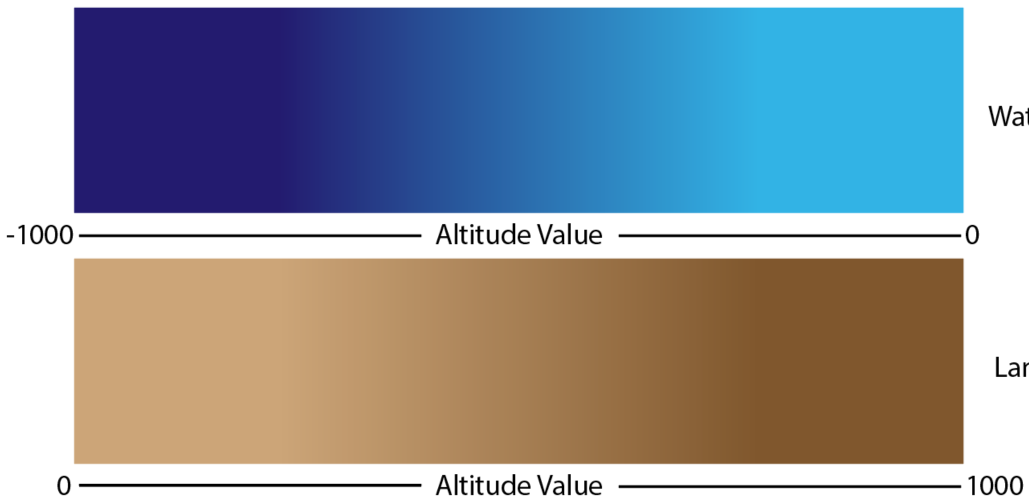

Fig. 5.9 - Color gradients used to define each tile's color.

- ***variant:*** indicates the variant of habitat the tile has: if the altitude value is less than -500, the variant is *deep*; if the value is equal or greater than -500 and is less than 0, the variant is *shallow*; if the altitude is equal or greater than 0 and is less than 500, the variant is *plains*; and finally, if it is equal or greater than 500, the variant is *hills*.

- ***abioticElements:*** stores the 4 abiotic elements of this tile. The ***min*** and ***max*** values of each abiotic element, that were described before, are determined based on the tile variant and also using the altitude value. The altitude is used to map these values between a set of ranges pre-determined for each tile variant and for each abiotic element. In the current prototype, they are mapped as follows:

    - if the variant is ***deep***: the *min* value for the ***temperature*** is mapped between 0 and 5, while the *max* value is mapped between 10 and 15; the *min* value for the ***water*** is mapped between 70 and 65, while the *max* value is mapped between 100 and 95; the *min* value for the ***oxygen*** is mapped between 0 and 10, while the *max* value is mapped between 30 and 40; the *min* value for the ***carbon dioxide*** is mapped between 40 and 30, while the *max* value is mapped between 70 and 60;

- if the variant is ***shallow***: the *min* value for the ***temperature*** is mapped between 5 and 10, while the *max* value is mapped between 15 and 20; the *min* value for the ***water*** is mapped between 65 and 60, while the *max* value is mapped between 95 and 90; the *min* value for the ***oxygen*** is mapped between 10 and 20, while the *max* value is mapped between 40 and 50; the *min* value for the ***carbon dioxide*** is mapped between 30 and 20, while the *max* value is mapped between 60 and 50;

- if the variant is ***plains***: the *min* value for the ***temperature*** is mapped between 10 and 0, while the *max* value is mapped between 40 and 30; the *min* value for the ***water*** is mapped between 40 and 30, while the *max* value is mapped between 70 and 60; the *min* value for the ***oxygen*** is mapped between 50 and 40, while the *max* value is mapped between 80 and 70; the *min* value for the ***carbon dioxide*** is mapped between 30 and 20, while the *max* value is mapped between 60 and 50;

- if the variant is ***hills***: the *min* value for the ***temperature*** is mapped between -10 and -20, while the *max* value is mapped between 20 and 10; the *min* value for the ***water*** is mapped between 20 and 10, while the *max* value is mapped between 50 and 40; the *min* value for the ***oxygen*** is mapped between 40 and 30, while the *max* value is mapped between 70 and 60; the *min* value for the ***carbon dioxide*** is mapped between 20 and 10, while the *max* value is mapped between 50 and 40.

In the current iteration of the prototype, the map generated is always a 12x8 grid with 96 tiles (Fig 5.10). After this grid is generated and all tiles are created, the tiles are populated with creatures of the 6 initial species, according to their habitat. The starting values, used in the current prototype, for each characteristic of these 6 initial species are stated in the table in Appendix A.

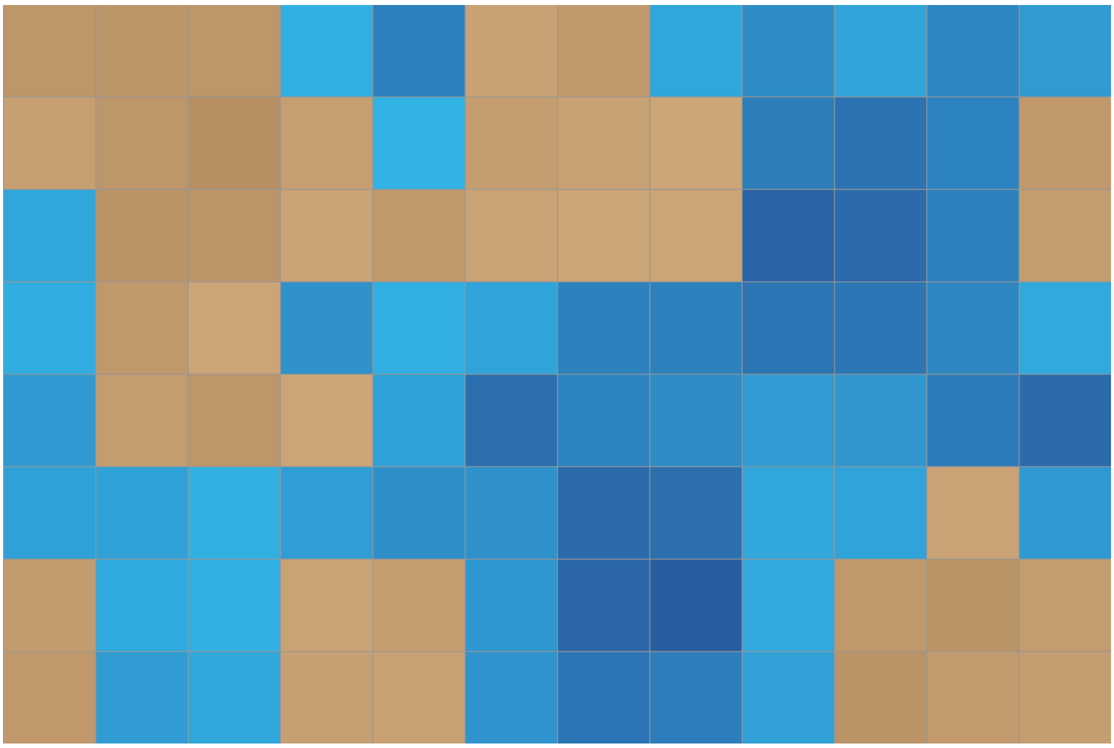

Fig. 5.10 - Example of a map generated when the prototype is started.

5.4 Game Interface

In this section, the details and functioning about the prototype's interface will be explained. When the game starts, the player is presented with a general view of the gameworld's map and from here it is possible to access a more detailed view of each tile or enter the evolution system's interface directly, where the player will be able to evolve the various species.

5.4.1 Map View

The first view of the gameworld presented to the player is the Map View (Fig. 5.11), where the entire map is visible and each tile is represented by a square. The color of each square is the one assigned to the tile in its creation, as explained in the Map Generation section. Each of the represented squares can be clicked by the player in order to access the next view, called Tile View, where the selected tile is displayed with more detail.

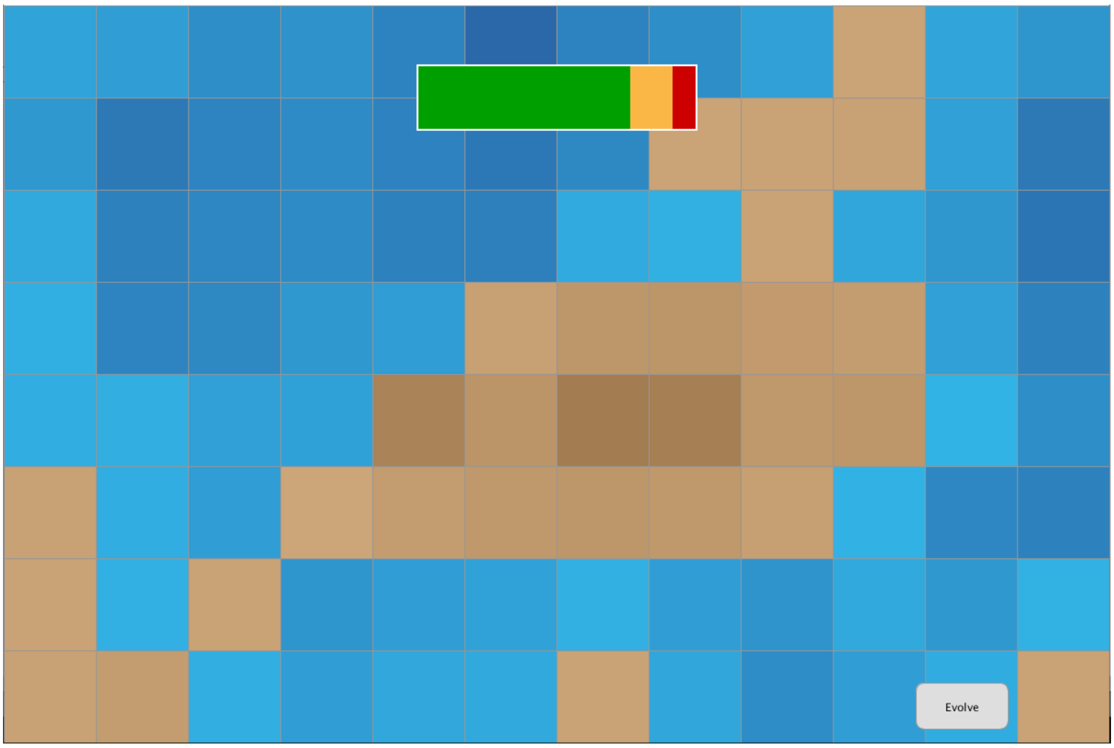

Fig. 5.11 - Screenshot of the Map View in the prototype.

In addition, this general view provides the player with important information regarding the stability of the game's ecosystem by displaying a meter at the top of the screen which represents the ratio of creatures, regarding their place in the food chain, that currently exists in the gameworld. Thus, this meter updates each turn following the changes in populations of plants, herbivores and carnivores. The meter is composed of three bars, one for each of these types of creatures, whose width is mapped to reflect their percentage in relation to the total number of creatures alive. Also, when the player hovers over the meter, additional information is provided in the form of a graph depicting the populations of plants, herbivores and carnivores over time, as well as their current exact numbers of individuals alive (Fig. 5.12). Lastly, there is also a button labeled "Evolve" in the bottom right of the screen that takes the player to the evolution interface. This button is also present in the Tile View.

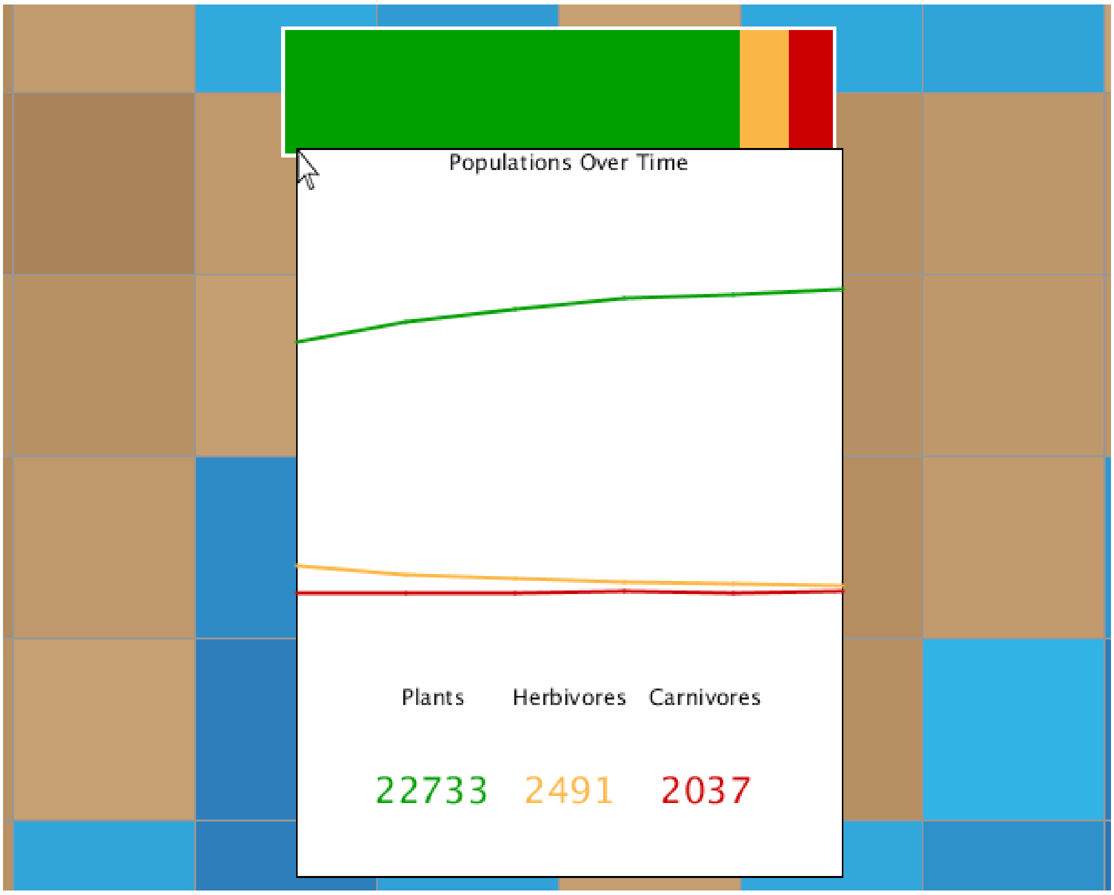

Fig. 5.12 - Screenshot of the information provided when the player hovers over the meter.

5.4.2 Tile View

As stated before, this view provides more details of an area of the gameworld, by showing a specific tile chosen by the player. Within this view, the creatures currently in the tile are represented in their respective location and, as the turns pass, their position is changed based on their movement. It is also possible to see the creatures disappear if they die or are eaten and to see them appear when reproductions occur. Another aspect of this view is the current values of the abiotics elements being displayed in the top corners, along with their respective icons. In the top left corner the temperature and the water values are represented, while the oxygen and carbon dioxide values sit in the top right corner. These values are also constantly updating as the game's turns pass. Finally, alongside the "Evolve" button there is also a "Back" button that is used to return to the Map View.

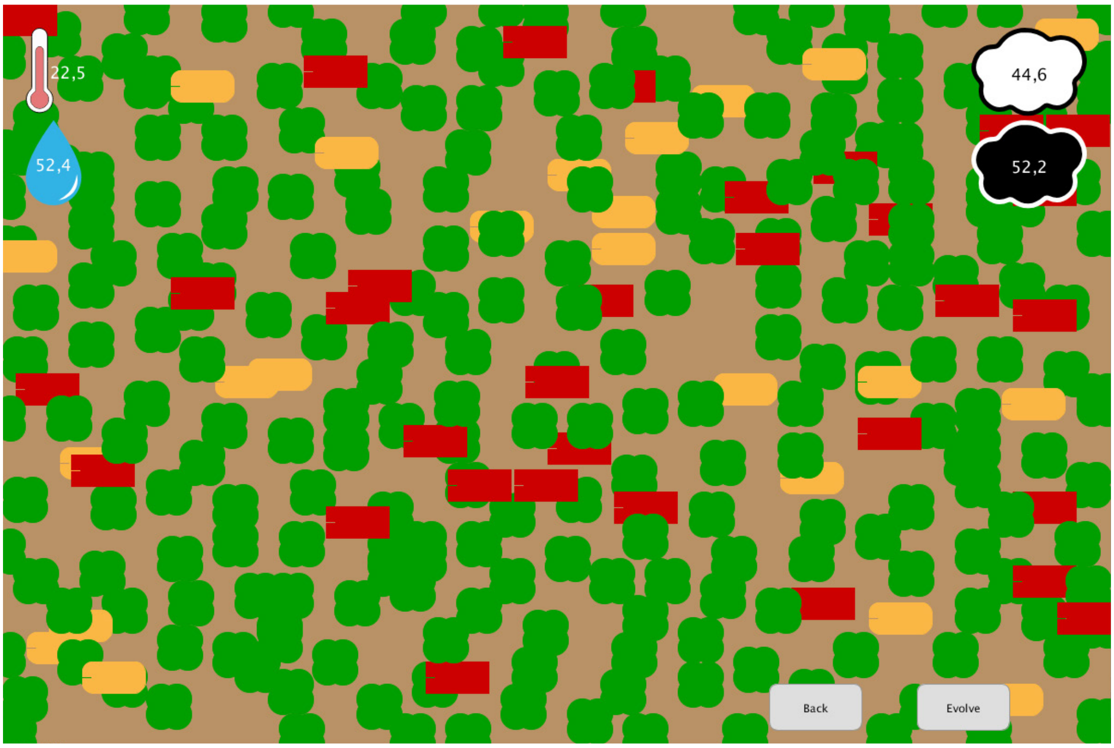

Fig. 5.13 - Screenshot of the Tile View in the prototype.

5.4.3 Evolution Interface

This interface is used by the player to evolve the creatures by selecting a species and adding/removing one or more traits to/from it, resulting in a new evolved species that appears in the gameworld. To do this, the player first has to choose one of the 6 classes of species, from a set of tabs displayed in a line at the top right of the screen. Then, a second set of tabs, displayed vertically in the middle of the screen and representing the different species of creatures in the same class, allows the player to choose the desired species to evolve. After this choice the player is presented with a list of traits, each one displayed as a button in the right side of the screen, that is possible to add or remove from that species. This list of traits is the same for every species in the same class, although some of the traits will have their button already selected if the chosen species was previously created with said traits. In that case, the player can still choose to evolve that species by removing the selected traits and/or by adding new ones. The list of traits currently available in the game prototype, and the details of their effects, can be consulted in Appendix B.

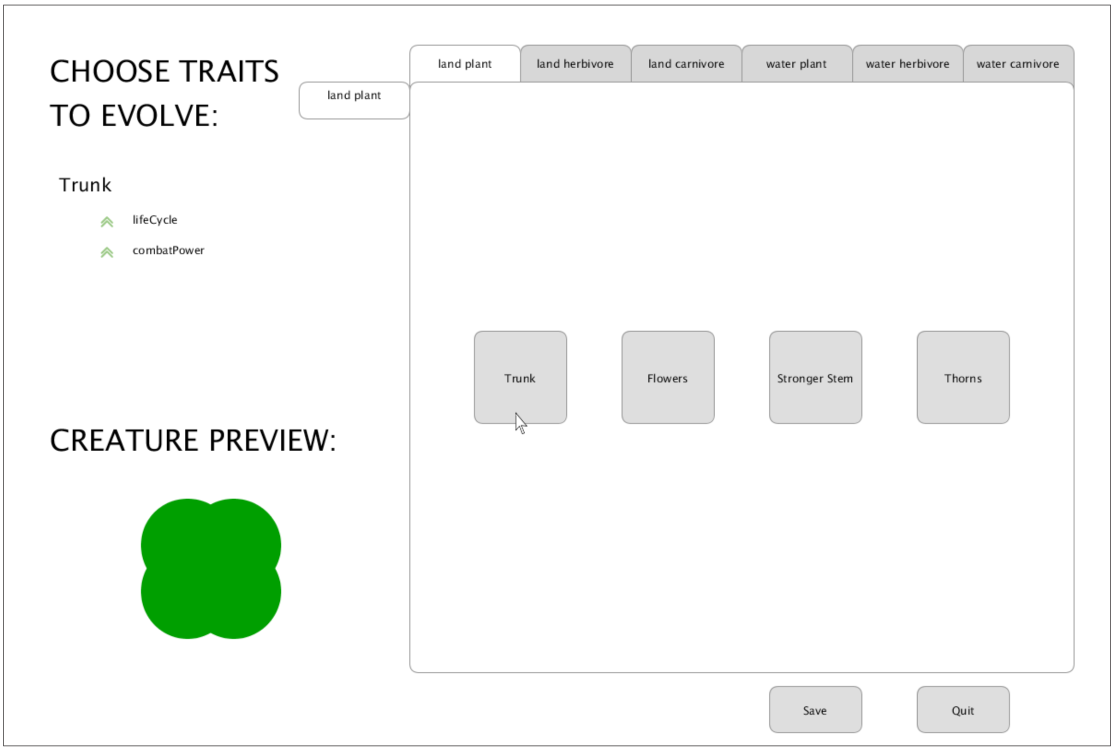

Fig. 5.14 - Screenshot of the Evolution Interface in the prototype.

As the passage of time, i.e. the game's turns, are paused when this interface is open the player is able to explore multiple possibilities to make the best decisions in regards to maintaining the ecosystem's stability. To help the player in this decision-making process, when the player hovers over a trait button, a list of advantages and disadvantages is presented, on the left side of the screen. This list shows the effects that said trait will have on the currently chosen species, with each of said effects being applied to one of the following creature's attributes: ***lifeCycle***, ***combatPower***, ***reproductionRate***, ***amountOfMovement***, ***minTemperature***, ***maxTemperature***, ***minWater***, ***minGas*** and ***minEnergy***. The values of each buff and debuff are multiplied to the current values in the case of the ***lifeCycle***, ***combatPower*** and ***reproductionRate*** attributes and summed to the current values in the case of the other attributes. Also, these values of each buff and debuff are scaled according to 6 intensity levels, 3 for buffs and 3 for debuffs. This is also displayed to the player in the form of small arrow icons next to each effect listed, as shown in Fig. 5.15.

Fig. 5.15 - Screenshot of the information provided about the effects of a trait, when its button is hovered. The arrows' direction indicates an increase or decrease in the value of the affected attribute, while its color indicates if the effect is a buff or debuff and the number of arrows indicates the intensity level of that effect.

Additionally, in the bottom left side of the interface, the player can see a preview of the species being evolved, as this preview is updated every time the player selects or deselects a trait. When the player is satisfied with the changes made, a button labeled "Save", in the bottom right corner, can be clicked to create the new evolved species and return the player to the Map View. If the player wants to return without creating the new species, there is also a button labeled "Quit" that will do so. When the player exits the evolution interface, the passage of time in the game is resumed and a few creatures of the new evolved species appear in the tiles of their respective habitat. Then, the player can watch closely as the new species influences the ecosystem stability and decide how the resulting consequences should be addressed.

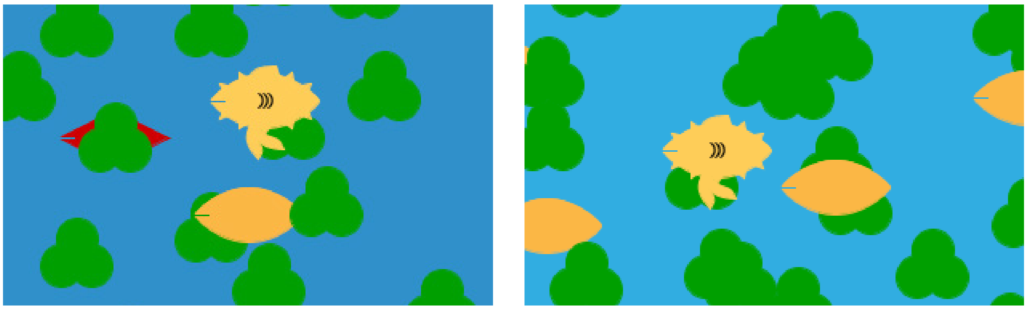

Fig. 5.16 - Screenshots of creatures, belonging to a new species created by the player, appearing in two different tiles of the gameworld.

Chapter 6

Usability Tests

6.1 Setup and Protocol

In this phase, the first prototype of the game was tested in order to evaluate how users responded in regards to its concept, interface, usability and gameplay. This prototype was stripped of the currency system feature, so that the players could freely choose any traits that they wanted as they were exploring the game. In total, 10 tests were conducted in a span of two weeks, some of them in person and others remotely through videocall.

Every test consisted of two playthroughs, from 5 to 10 minutes each, by each user: before the first playthrough, users were only given a brief explanation of the game concept and their player role in it; before the second playthrough, users were given a little more information to answer their most significant and persisting doubts, if any, regarding the game concept. The goal was to compare the player's response to the prototype with almost no information and their response when they were already more acquainted with the game. During both playthroughs the users were asked to comment on their thought process and decision-making, as well as their doubts and concerns. For the entire duration of each test notes were taken about the significant steps the users would follow, their difficulties and their comments.

After the test, the users were asked to respond to a set of post-game questions, consisting of 3 open-ended and 3 multiple choice questions, the latter on a Likert scale from 1 to 6. These questions aimed at providing users with an opportunity to elaborate on their experience with the game and comment further on difficulties with the prototype. The questions included were the following:

1. How do you interpret the game experience?
2. How confused did you feel as soon as you started the game for the first time? (1 - Not at all; 6 - Very confused)
3. How hard was it to learn what to do in the game? (1 - Very easy; 6 - Very hard)
4. Do you think there was enough available information in order to make the best gameplay decisions? (1 - Definitely not enough; 6 - I had all the info I needed)
5. What difficulties did you feel?
6. If you could change something in the game, what would it be?

6.2 Results Analysis

The responses to the post-game questionnaire, as well as the notes taken during the tests, were compiled, analysed and grouped regarding the main points and themes brought up by the users. The complete data of this analysis can be consulted in Appendix C. Despite the users displaying considerable differences regarding their understanding of the game, as evidenced by the responses to the questions 2 (Fig. 6.1), 3 (Fig. 6.2) and 4 (Fig. 6.3), some of these concepts could be commonly distinguished across multiple tests, noted observations, user comments and responses.

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5. What difficulties did you feel?
6. If you could change something in the game, what would it be?

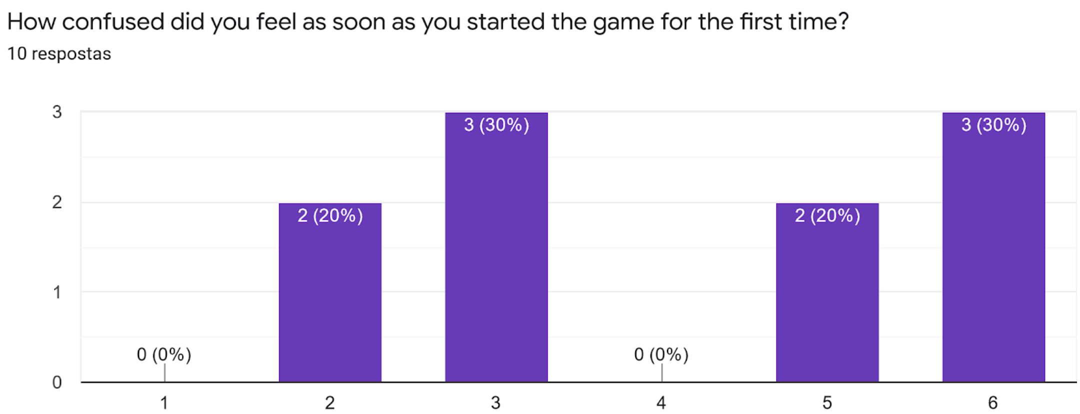

Fig. 6.1 - Answers to question 2 of the post-game questionnaire (0: "Not at all"; 6: "Very confused").

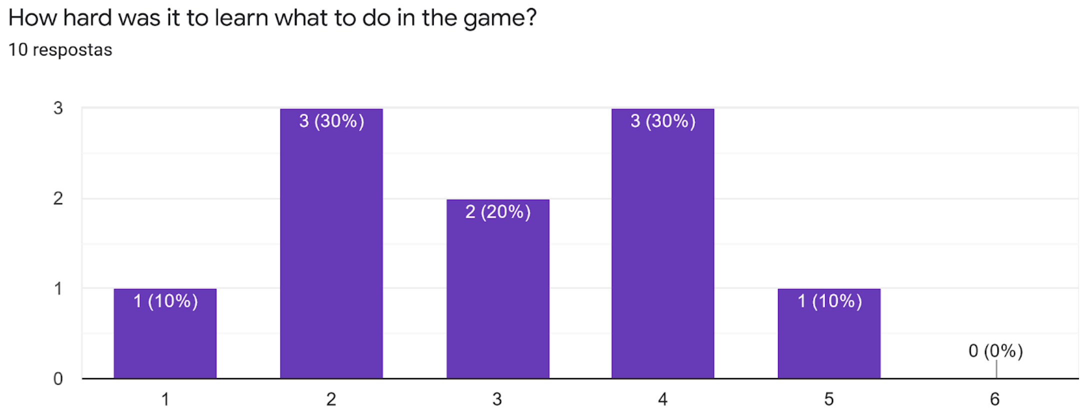

Fig. 6.2 - Answers to question 3 of the post-game questionnaire (0: "Very easy"; 6: "Very hard").

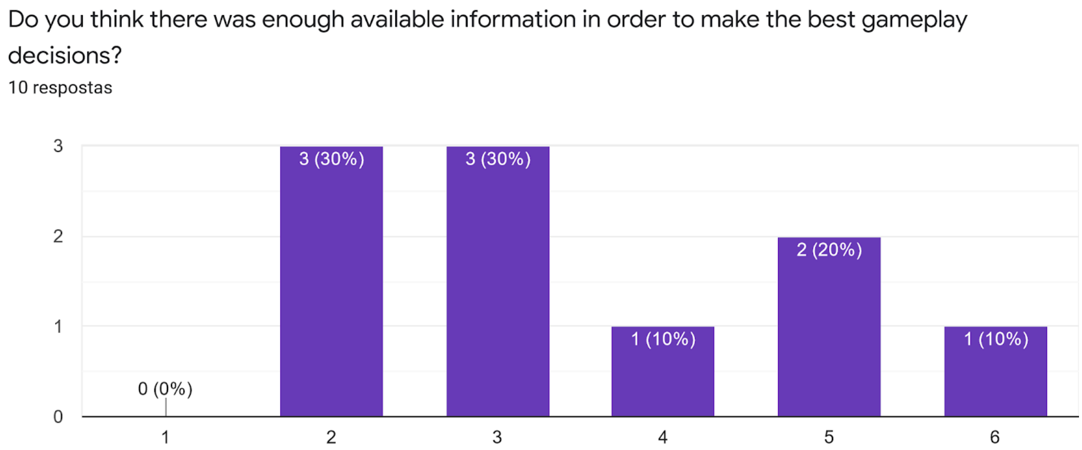

Fig. 6.3 - Answers to question 4 of the post-game questionnaire (0: "Definitely not enough"; 6: "I had all the info I needed").

Likewise, in each of these artifacts it was often possible to identify multiple of these themes. We adopted a qualitative content analysis method for processing audiovisual observation notes and answers. For classification purposes, these were grouped according to the main theme they referred to. Thus, all the notes and questionaire's responses were classified according to 8 main themes:

- Map View
- Tile View
- Evolve Interface/Functionality
- Evolve/Back/Quit Buttons
- Populations/Abiotic Meters
- Visual and Textual References
- Gameplay/Decision-Making
- Feedback

The first theme relates to comments and difficulties **regarding the initial map view**. One significant problem brought up was that this view had little information regarding what is happening with the simulation and as such it "...hides de facto all the activity of the simulation until you open each cell space" (User 3), as one user mentioned in one of the post-game answers. This lack of information would also be a problem most prominently affecting the gameplay decisions of the user, which will be another theme detailed further below. Also, three of the users had trouble understanding the map displayed and that each square represented a clickable zone which opened the more detailed tile view. On the other hand, most users understood the difference between land and sea tiles and two of the users even expressed, during the tests, that they understood the lighter and darker tones of each square represented the differences in altitude of each tile of the map.

In the tile view, it was noticeable that most users would try to click the creatures to check if they could interact with any of them directly. One of the users was also confused about the tile view in general, due to an accidental click in a square of the map view, and it took a considerable amount of time in order to understand the purpose of this view and the elements in it. In spite of these issues, most users quickly understood the relationship between both views and were engaged in the tile view, in order to understand the creatures' behavior and the oscillation of the abiotic values.

Regarding the evolution interface and its functionality, users generally understood how to use it and its purpose, with many expressing enthusiasm to explore various possibilities when customizing creatures. Despite this, there were some concerns brought up. For example, multiple users questioned whether the evolutions they made in a species were applied to individual tiles or to the entire map, as evidenced by the quotes "When I click evolve in a tile, am I just evolving species in that tile?" (User 2) and "Can I change tiles individually or just in general?" (User 4). Some users also addressed the fact that, when they exited the interface, they were always forwarded to the map view even when, before entering the interface, they were in a tile. As one user explained: "It's weird that when I go back I always go to the main map" (User 5). Another problem identified was the lack of labels regarding the classes' tabs and species' tabs, which made several of the users confused about the difference between the two during their playthroughs.

The buttons were also briefly mentioned by multiple users concerning mainly about the order of the 'Evolve' and 'Quit' buttons in the interface and the use of the word 'Quit' instead of 'Back', as explained by one user: "The word 'Quit' is making me concerned, I would like to have 'Back' instead" (User 1). It was also noted that some users were eager to press the 'Evolve' button quite early in the playthrough, for example as said by one user: "I don't know what this evolve button is but I want to try it" (User 8).

In regards to the theme of the populations and abiotic meters, the users expressed they noticed the importance of the population meter and its respective graph, as exemplified by some of their quotes: "I think I should be more focused on the population meter" (User 1), "Population graph reacts to changes I make to the creatures" (User 1) and "The objective is to balance the bar" (User 8). However, half of them demonstrated confusion about how the values displayed in the abiotic meters were changing and why they were relevant, for example one user stated: "I felt confused about the meaning of the temperature/water/oxygen/carbon dioxide levels at first since the numbers are constantly moving" (User 5).

Regarding visual and textual references, half of the users felt that the affected characteristics displayed when the mouse hovered over a trait were unclear about what exactly those characteristics meant, as evidenced by the statements like "What are these values when I hover?" (User 2). Also, 7 of the users either mentioned that they needed more displayed information to help them in their decisions or said that they felt the need for a tutorial in the beginning of the game, as exemplified by the phrases “I feel that I need a tutorial” (User 4), “A tutorial would help a lot for people to understand right away what they should do” (User 8) and “Give a menu at the beginning, probably with a mini-tutorial on how to play the game or just some information that can help you acknowledge what you have to do when you start the game” (User 5).

This topic was strongly related to **the next theme of gameplay and decision-making**, as several users expressed concerns about not knowing how to make better judgements on what they should change in the creatures. Some of their statements included: “I did not understand which information were more relevant and on which I had more impact” (User 1), “I feel like I don’t understand much” (User 10) and “Just the fact that I didn’t instantly know what kind of changes were going to happen when I did something” (User 4). However, users also stated that this was an issue that improved as the game progressed and the players managed to explore it further, as stated in quotes such as “A bit confusing at first without any explanations but then, as I was experimenting with the game, I began to realize its functions.” (User 5) and “At first it was a little confusing but there were a lot of things I started to learn along the way.…” (User 4).

In regards to the theme of feedback there were some comments made by the users expressing satisfaction with seeing the changes in creatures and in population numbers as a result of their actions: “It’s nice to see the traits I added, I feel empathy almost, it’s my creature, I evolved it” (User 1) and “It’s working they’re spreading” (User 8). Nevertheless, there were also concerns associated again with exiting the interface to the main map and thus being unable to immediately see a newly created species: “Where is my creation?” (User 3).

Finally it is worth noting that, **regarding the game overall**, a majority of users conveyed that, despite the issues mentioned above, the game presented an enjoyable experience, with answers to question 1 of the post-game questionnaire such as: “It’s very interesting, and it makes you think about what each new species brings to the ecosystem and how it affects it. Once you get into it, it starts making sense.” (User 7), “Quite curious, as it translates quite well how the ecosystems around us work. There has to be a healthy and almost perfect balance for all of us to survive and the game clarifies this issue a lot” (User 8) and “Very Good! It’s fun and you can combine fun with awareness of the environment around us.” (User 10).

In short, **players felt that they needed some time to understand the concept of the game**, mainly due to the information being presented unclearly or due to a lack of it. This led to decision-making issues that affected their gameplay. The lack of a tutorial was also a big concern, due to its presence potentially being an element that could considerably speed up the understanding of the game. Alongside this, there were also some usability issues that created difficulties in the familiarization and learning process of the game, the most critical of which were the unclear textual references in the evolution interface and the fact that when leaving this interface the player would always be directed to the general screen. Nevertheless, users expressed that, once they were more used to the game, they praised its concept and found its experience enjoyable.

6.3 Implemented Corrections and Evaluation

With the information gathered from the usability tests, some improvements were made to the prototype:

- **Tutorial:** before the start of the game, a simple tutorial was added to display the most crucial aspects of the game that the players need to know to explore it, especially in regards to first-time users (Fig. 6.4).

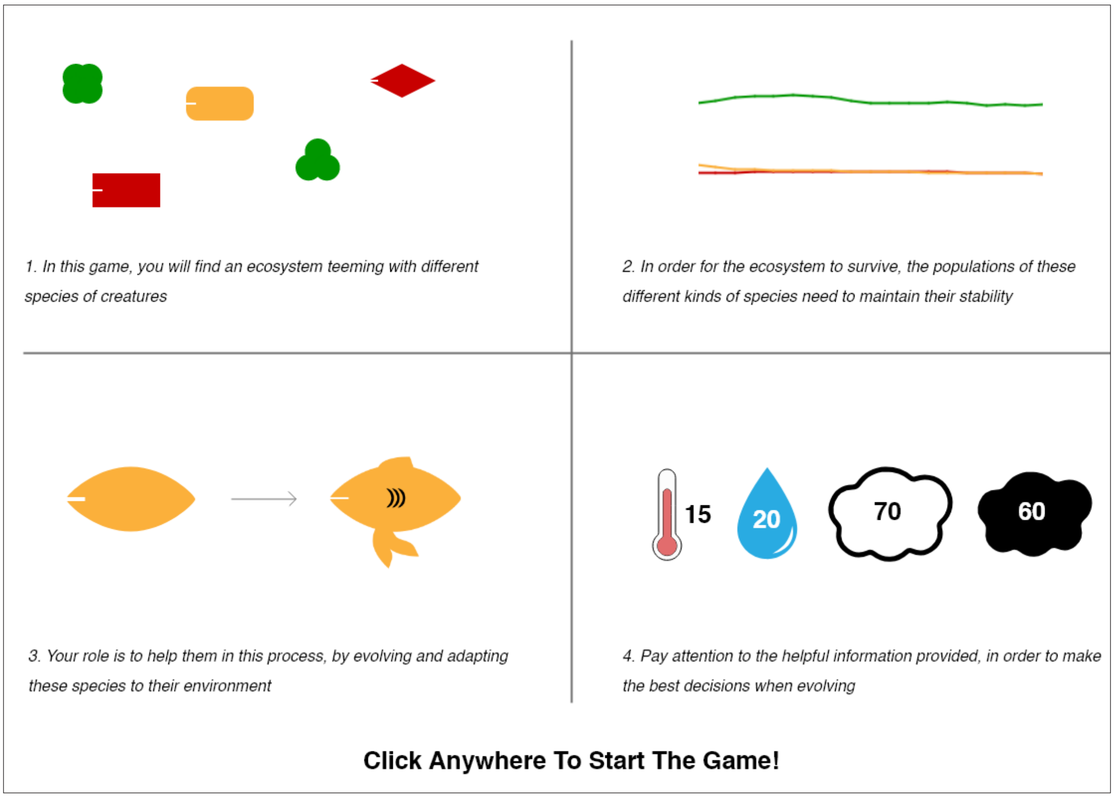

Fig. 6.4 - Screenshot of the tutorial displayed to players.

- **Improved visual indicators for the abiotic elements:** in each tile's square in the map view, as well as next to the abiotic elements' meters in the tile view, new visual indicators were added to better display the abiotics' values and their oscillation. Also, more details about a tile, regarding its abiotics and its creatures' populations, are displayed when its square is hovered in the map view (Fig. 6.5).

Fig. 6.5 - Screenshot of the improved visual indicators displayed in the Map View.

- **Population graph differentiated by habitat:** the creatures populations' graph was divided into two graphs, one for land and another for sea creatures, in order to provide a clearer picture of each separate habitat at any given moment (Fig. 6.6).

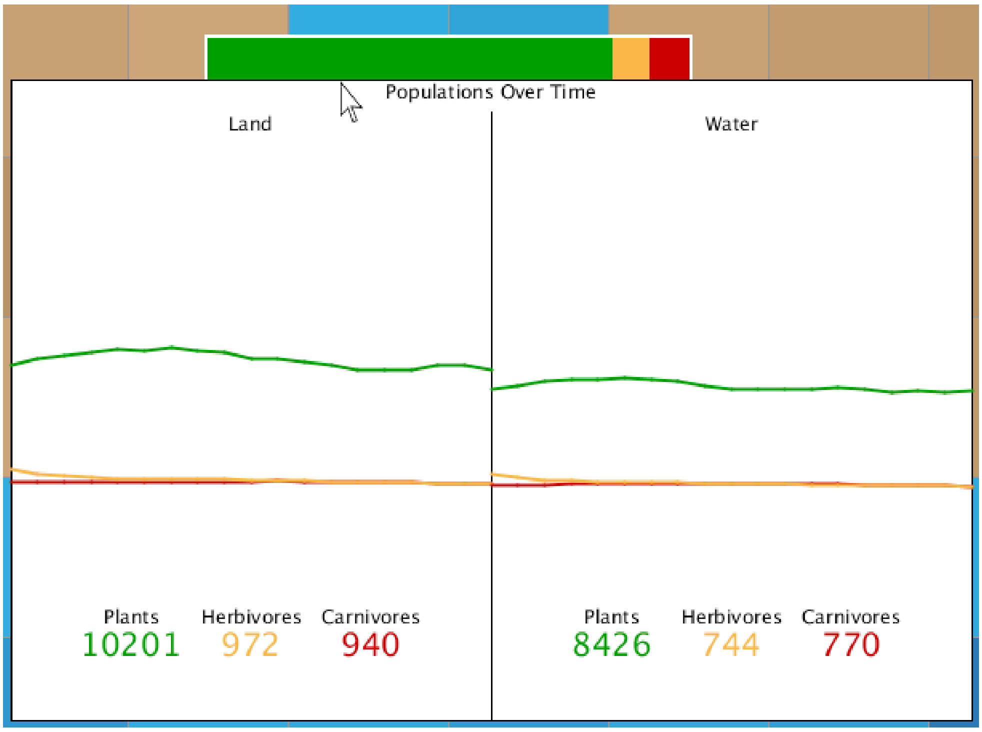

Fig. 6.6 - Screenshot of the new and divided populations' graphs.

- **Faster pace:** in order to provide an increased sense of urgency and a more thrilling and challenging experience, the simulation's parameters were adjusted to create more drastic and faster changes in the numbers of creatures, before and after the player's actions.

- **Currency system:** to balance player's actions, the currency system was added to the evolution interface (Fig. 6.7), causing the players to better deliberate and manage what traits to add to the creatures and at which point in time.

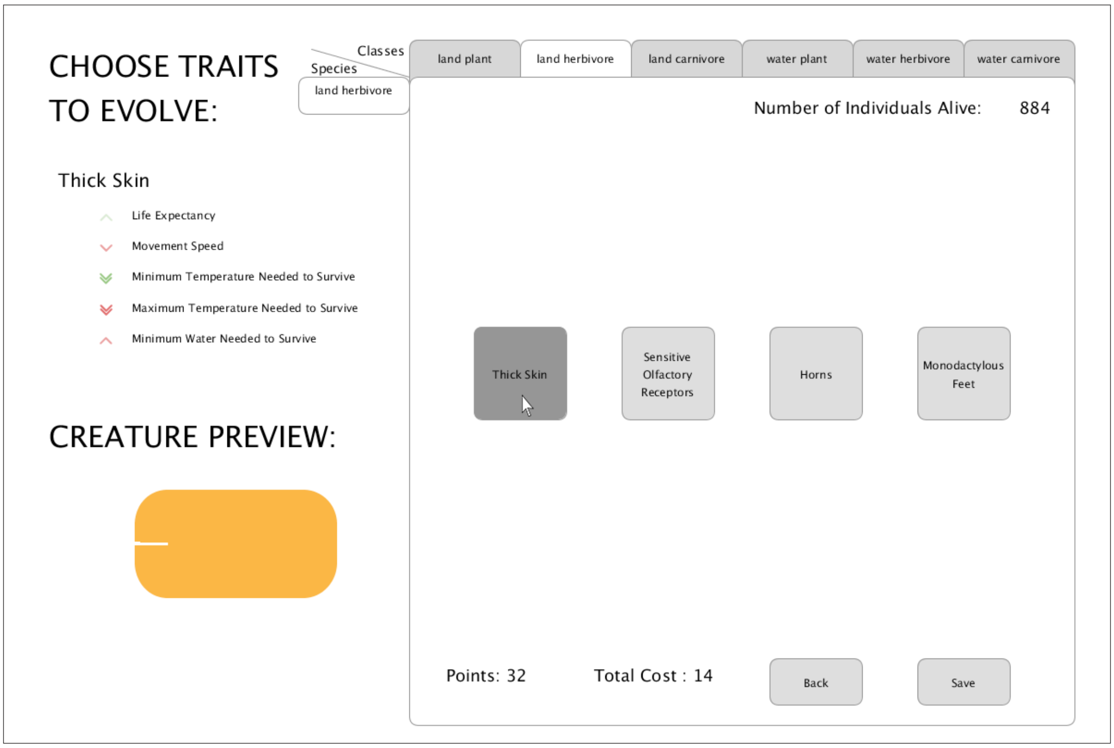

Fig. 6.7 - Screenshot of the improved evolution interface.

- **Characteristics names:** the text references displayed when hovering through traits in the evolution interface were improved to better illustrate the affected characteristics of the evolved creature (Fig. 6.8).

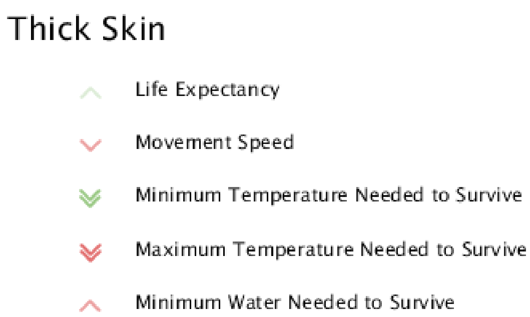

Fig. 6.8 - Detail of the new evolution interface, showing the improved text references regarding the effects of a trait.

- **Return to previous view*:*** when exiting the evolution interface, the user will now return to the view that was active before entering the interface, be it the map view or a tile view, instead of always being redirected to the map view.

- **Individual species counters*:*** in the evolution interface (Fig. 6.7), the number of creatures alive in the game world, of each species, is now displayed when a species' tab is selected.

- **Species/classes tabs label*:*** in order to better highlight and identify the classes and species tabs in the user interface, a label was added next to the interface's main area (Fig. 6.7).

All of these changes aim to improve the prototype's usability and gameplay by addressing the issues found during the tests and expressed by the users. Subsequently, in order to contextualize the overall efficiency of the prototype, the game was examined by considering a set of design guidelines, detailed by Pereira & Roque (2009), that help contextualize if the game model and the player's mental model converge. As it is explained by the authors:

> *"The game designer starts to conceive the game model and through the implementing it will lead to a system model. The player builds his mental model, through the interaction with the system model resulting in a gameplay experience and with enough experimentation, it is expected that the player's mental model will converge with the game model inscribed by the game designer." Pereira & Roque (2009)*

As such, in the topics below, the game will be framed within each of these guidelines individually.

- **The game model should be representative of the real phenomena.**
  Although the game gives the role of evolution to the player, therefore making its process based on conscious and logical decisions, the other natural processes in the game are built to represent, in a loosely accurate way, those same processes that happen in the real world. As evidenced by some of the users' statements already mentioned above, this concept of real world representation and similarities was transposed to the players during the prototype testing phase: "Complex, challenging, but following real life principles" (User 1).

- **The challenge in the game will be influenced by the complexity of the model.**
  Despite the game's challenge being increased by the changes in its pace and the addition of the currency system, the game model's inherent complexity was maintained after the testing phase. There were some ideas to enhance the game's complexity by introducing new features to the game model but ultimately the current level of challenge in the game was considered adequate to the concept detailed in the design proposal.

- **The game model should be balanced in view of the target audience and scenario of use.**
  In the prototype used for testing, the pace of the game was very slow to allow for every type of user to freely explore many possible combinations of traits and new creatures without making the ecosystem collapse rapidly. However, the game balance was then tuned to be faster and the player's actions to be more impactful. This can certainly lead to a more limited target audience but it also increases the game's challenge and learning curve, which are elements that were desired in the model.

- **The representations in the interface should be kept consistent with the simulated model and preferably all representations should have a purpose coherent with the interpretation of the game state.**
  As mentioned before, the creatures' representations are designed to be somewhat abstract but easily identifiable and distinguishable by the players. Likewise, the map representation was also made to be easily recognizable by the players so that, as the individual player becomes more familiarized and experienced with the game, both of these elements are effortlessly interpreted during gameplay.

- **The feedback to the player should be appropriate, guiding and significant.**
  The main feedback elements in the game, being the visual representation of the creatures and the populations' meter and graph, provide the means for the players to see the result of their customizations and provide them with the info needed for the subsequent decisions in the gameplay, respectively. As mentioned above, a few users expressed they were glad to see these elements represent the actions they performed in the game.

- **To strengthen the intentionality in the game, next actions should depend on the interpretation of the resulting feedback from the previous actions.**
  As stated in the previous point, the populations' meter and graph was a main focus during the tests for a majority of the users as they correctly assumed that they represented an important way to monitor their actions and help them decide what to do next.

- **The actions modeled in the game should be significant in the modeled context.**
  Given that the player's actions are a direct intervention in the creatures' adaptation process in the game world, these constitute a vital element of the game model and are a representation of the process of evolution which is also a crucial aspect of real world ecosystems.

- **The incorporation of learning goals in a serious game can be achieved by designing a context consisting of activities whose performance requires those knowledge goals to be met, while providing opportunities for the player to build that knowledge through gameplay.**
  As the players progress in the game, they are able to explore different possibilities and combinations of creatures in order to shape the ecosystem, and in doing so they can see the results of the interactions between species and between them and their habitat. As mentioned before, some users stated that through seeing these interactions in game, they could also learn and apply the same concepts when thinking about real life interactions and consequences.

6.4 Future Work

In regards to future developments of the project, it is worth noting that most of the game balancing is a subject of constant improvement, whether it's in regards to the generative algorithms' parameters, the species' and tiles' starting values or the traits' specifications. Although adjustments were made throughout the development of the prototype and after the tests were performed, these components would require additional volumes of testing and continuous tuning over time in order to try to reach the most balanced gameplay options possible.

Regarding new or improved functionalities, the main issue that could see improvement in future work is the traits visual representation. As mentioned before, the limited rendering capabilities regarding SVG files in Processing led to many constraints in the development of the traits' shapes. Possible solutions to this include the implementation of a non-SVG-based visual representation of the traits or the porting of the game to other platform(s) with a more powerful renderer.

Another feature to be added is the presence of sound and the development of a sound design system merged with the rest of the gameplay elements. This feature was an idea present early in the development of the game concept but was ultimately not realized, mainly due to its complexity and a lack of time.

Finally, the game could also contain an additional variety of traits, habitats and classes of creatures, which would significantly increase the game's complexity but also the range of possibilities available for the players to explore.

Chapter 7

Conclusion

During the development of this project, we explored ways of using generative techniques in the production of an original game, by specifically applying them to the game systems in order to create meaningful and dynamic experiences for players. Additionally, it was also important that these systems were modeled after systems present in the real world and, therefore, could provide an opportunity for players to learn about them through the interaction with the game context. This led to the creation of a game concept about ecosystems in nature and the evolution of living organisms to adapt to their environment. The subsequently developed prototype was tested in regards to its usability and the resulting data was subject to an analysis that highlighted the strengths and points of improvement for the game model.

As such, at the end of the dissertation, we can conclude that the concept responded successfully to the previously stated goals, by providing experiences that converge with the intended vision for the project. Moreover, the developed prototype constitutes an artifact that can be further improved, specifically regarding the game's functionalities, and in this way provide an opportunity to increase the effectiveness of the game model in giving complete and meaningful experiences to the players. Finally, on a personal note, working on this project has been of enormous benefit, not only because of the acquired knowledge through the research of previously unexplored topics, but also due to the skills of design, implementation and analysis that I was able to acquire and improve upon.

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Appendix A

Initial Species Starting Values

	lifeCycle	combatPower	reproductionRate	movement	minTemperature	maxTemperature	minGas	minWater	minEnergy
Land Plant	100	10	50	0	-5	25	25	30	0
Land Herbivore	200	10	5	5	-5	25	45	30	0
Land Carnivore	200	10	5	5	-5	25	45	30	0
Water Plant	100	10	50	0	5	15	40	70	0
Water Herbivore	200	10	5	5	5	15	20	70	0
Water Carnivore	200	10	5	5	5	15	20	70	0

Appendix B

List of Available Traits and their Affected Attributes

		lifeCycle	combatPower	reproductionRate	movement	minTemperature	maxTemperature	minGas	minWater	minEnergy
Land Plant	Flowers			*1,50		+5	-5			+5
	Thorns		*2,00						-10	
	Trunk	*1,50	*2,00					+10	+5	
	Stronger Stem	*1,2							+5	
Land Herbivore	Monodactylous Feet				+15			+10	+10	+5
	Horns	/1,2	*2,00	/1,2					-5	
	Thick Skin	*1,2			-5	-10	-10		+5	
	Sensitive Olfactory Receptors			*1,2				-10		
Land Carnivore	Strong Jaws	/1,2	*1,5							+5
	Long Fangs	*1,2	*1,5	/1,3					+5	
	Acute Hearing			*1,2						+5
	Pack Hunt		*2	*1,3	-10			-10	-10	-15
Water Plant	Aromatic Acid Glands		*2	*1,2				+5	+5	+10
	Light Stem	/1,2	/2							-5
	Larger Leafs	*1,2		/1,3				-5		
	Bigger Roots	*1,5		/1,3					-5	
Water Herbivore	Dorsal Fin				+5					-10
	Wide Gills		/2			+1	-1	-10		
	Strong Flippers			*1,2	+10			+10		+5
	Spiked Scales		*2	/1,3	-10					+5
Water Carnivore	Second Layer of Teeth	/1,5	*1,5							
	Blubber	*1,2			-10	-2	+2	-5		+5
	Echolocation		/2	*1,3				+5		-5
	Large Caudal Fin				+5				-5	-10

Appendix C

Tables of Observations Gathered during the Usability Tests

	Map View	Tile View	Evolve Interface/Functionality	Evolve/Back/Quit Buttons
User 1	Understood the distinction between land and sea tiles quickly	Figured quickly how to choose a tile on the map and go back and forth between the map and tile display	"I can evolve but I also can devolve, that's interesting"	"The word 'quit' is making me concerned, I would like to have 'back' instead"
			"The button 'Evolve' in or out of the tile does the same"	
User 2	"I didn't understand what the initial squares were"	"Here in green we have some bushes right?"	Understood the customization of the creatures provided in the evolve interface	Saw the 'Evolve' button and clicked it as soon as the game started
		"If I'm always evolving in the entire map I just need to check the graph right? Because the tile display is just representative?"	Had doubts if the changes made in one creature were mantained when switching tabs	Confused about the order of 'Save' and 'Quit' buttons, was used to their positions being switched
			"When I click evolve in a tile, am I just evolving species in that tile?"	Save' and 'Quit' buttons on the outside of the interface square made her think that changes across tabs were mantained

User 3	It would be interesting to be able to have a broader more continuous view across what is going on behind the cells; the main screen hides de facto all the activity of the simulation until you open each cell space		Understood the species and classes tabs but said they should be clearer	
User 4	Understood the relation between the squares displayed in the map and the tiles displayed when clicked		"Here I can understand much better the creatures that exist" (when the evolution interface was opened)	
	"The color of each square represents the altitude right?"		Felt that some sort of currency should exist to spend when choosing new traits	
			"Can I change tiles individually or just in general?"	
			"I expected to open a tile and click evolve and then the new creature would only be in that tile"	
User 5			"It's weird that when I go back I always go to the main map"	
			Thought that the creatures evolved would only appear in the selected tile	
			Noticed the species tabs very late in the playthrough	
User 6		Confused about some creatures disappearing	Became confused about returning to the main map after evolving a creature	
			Noticed the species tabs at the end of the playthrough	

User 7	Evolved first and only after that went to tile view	Noticed differences in the values of abiotics is related to the colors of the tiles	Selected new traits randomly without checking the affected values	
			"It would be interesting to have the number of each species"	
User 8	Didn't understand the relationship between the map and tile views	Was confused about what happened when accidentally changed to a tile view		"I don't know what this evolve button is but I want to try it"
			"Oh this is creating new species"	
User 9	"The darker squares must be deeper in the sea"	"I just entered an aquatic ambient where there's some characteristics like temperature and oxygen"	Confused about the various species tabs	
			Tried many times to add species with the same change	
User 10	"This in blue is the sea right?"	"I can't move the creatures"	Tried to add many varied species	
			"I'm trying many different combinations to see what works"	

	Populations/ Abiotic meters	Visual and textual references	Gameplay/ Decision-making	Feedback
User 1	Understood the populations meter and the info provided when hovering with the mouse in it	Felt the need for visual references in the evolve screen in order to understand what he was doing (didn't test creature preview yet)	Relation between abiotics and creatures not clear	"It's nice to see the traits I added, I feel empathy almost, it's my creature, I evolved it"
	"I think I should be more focused on the population meter"	Then realized the visual reference of the creature preview when attempted to add a trait	Wasn't sure if the oscillations of the abiotic values is related to player's actions	"Most of the time I have no idea what's going on, the goal is to survive but how do I know if I'm not surviving?"
	"Population graph reacts to changes I make to the creatures"	Hard to understand the listed changes when hovering through the evolve traits	Started to wonder how to have more impact	"Other games give you a clearer indication on what's good and bad at a certain moment"
	Tried to see and balance changes in both the population meter and the abiotics meters			
User 2	Thought it was hard to see the water abiotic meter due to lack of a colored border in the shape	"What are these values when I hover?"	Wasn't sure about her role as a player, in order to keep the ecosystem stable	
			"To check if the system is ok, do I need to check all the tiles in the map or is it enough to check the graph?"	
User 3				Doubts about what happened to a plant after evolving it
				"Where is my creation?"

User 4	Felt that the quantity of plants represented in the graph didn't match the quantity of plants in one tile	"I feel that I need a tutorial"	"The choices are easy because I will choose the trait that has better amount of good repercussions	
			"If I do significant changes suddenly, the whole thing will collapse"	
			"Aquatic life affects life in land?"	
			"There's some sort of plant dominance and I don't know why"	
			"I can't create the desert world that I want"	
User 5	Confused about how the values change in the abiotic elements		Tried every interaction on screen very fast	
User 6	Thought that was mantaining balance in the game by mantaining the levels of abiotics	Noticed the hover effects at the end of the playthrough	"The first time I made overly aggressive changes it all went bad"	
	Didn't check population graph until late in the playthrough		"Felt that I needed a way to control the flow of time"	
	Felt that an expected value of creatures was needed in the graph			

User 7	"This graph represents both land and sea?"	"I'm going to compensate a decrease in lifecycle with an increase in reproduction rate"	Tried everything too fast without thinking about each action	
			"I have to many plants, I will evolve the herbivores"	
			"The ones in the sea seem balanced, I will not mess with them"	
			"I have few carnivores, I'm going to evolve them"	
			"I don't want to give too many buffs to plants because then the herbivores will suffer, I'm going to evolve the herbivores first"	
			"If the temperature is low I can add the 'Thick Skin" trait so that it's more resistant to cold"	
User 8	Noticed the graph was somewhat important right away	Was aware and interested in the stats that were changing with each trait	"I have few carnivores, I need to improve them"	"It's working they're spreading"
	"The objective is to balance the bar"			
	Confused about the role of the abiotics			
User 9			"I'm going to improve the carnivores because they are dying"	
			Focused on evolving just the land creatures, especially the carnivores	
			"Every herbivore died! I had too many carnivores"	
User 10		Didn't notice the differences between the land and water creatures until later	"I feel like I don't understand much"	
			"I'm trying to evolve the animals because there are too many plants"	
			"I will try to increase the number of carnivores, I think I have few"	