Towards a Comprehensive Model for Analysis and Definition of Game Mechanics

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ABSTRACT

Since the ancient human past, people create ways to entertain themselves and express their cultural traits, such as literature and cinema. These traditional forms of entertainment possess three elements in common: a *technology* to support them; an *aesthetics* to stimulate the senses of those who appreciate it; and a *story* to give them context. However, games are a new form of entertainment and culture that possess an outstanding element, absent in the other forms: the game mechanics. This extra element allows the user to continually interact with the game and to become responsible for the conduction of a process, thus being the causative agent of the final outcome instead of a mere spectator. Therefore, in order to design and implement mechanics that are effective in making the experience of playing the best possible, it is important to research what are the game mechanics, which are their constituents and how these mechanics relate to each other. This paper presents a comparative survey about game mechanics with emphasis on digital games. Starting from this study, definitions and a methodology that stand out for their simplicity are proposed and subsequently applied in the analysis of existing game mechanics.

Keywords: Digital games, game design, game mechanics.

1 INTRODUCTION

Games are a form of entertainment that have accompanied the human being through practically all history of mankind. It can be said that the mechanics of a game are its central component, as they are what differs a game from other forms of entertainment [21]. Also, Fabricatore [9] states that a badly designed gameplay cannot be compensated by non-functional elements like story or graphics . Different authors have their own definitions of what game mechanics are and, for this reason, there is no universally accepted taxonomy about game mechanics [21]. Some individuals, mainly scholars, believe that the lack of standardized definitions in the field of game design is a crisis or barrier to game development [23] [22]. However, to Schell [21], the problem is not the lack of definitions, but the absence of a clearer thought about what these terms really mean.

Currently, it is common that a video game development team is composed by many professionals with different formation backgrounds [22]. Some researchers in the field of game design say that, many times, the game designers and the programmers in a development team have communication problems when it refers to the workings of the mechanics [23] [21]. This probably occurs because each professional has a different background, what creates a difficulty to find terms that are well understood by both parts. Because of this, it is useful, if not necessary, to identify definitions about game mechanics that are broad, intuitive and that allow the members of a multidisciplinary team to interact in an effective way during the process of development of a video game.

These are the contributions that this paper has to offer:

- The analysis of the definitions of different authors related to digital games and their mechanics.
- A new definition of game mechanics centered on the players perception instead of the actual form that the game works.
- A form to conceive, decompose and analyse the mechanics of a game, divided into a detailed textual description and a visual description.

The rest of this paper is organized in the following manner: chapter 2 talks about the features of digital games and of game mechanics, as well as the comparative analysis about how scholars define and categorize them; chapter 3 presents the proposed methodology, which includes the definition elaborated here; chapter 4 is dedicated to the analysis, under the perspective of the proposed methodology, of the mechanics present in three popular games; and chapter 5 will hold results, conclusions and future work.

2 BACKGROUND: GAME DEFINITIONS

This section is aimed to present the definitions of games found in the literature since those definitions are fundamental building blocks to define game mechanics in comprehensive manner. It is important to punctuate that some authors have a more formal definition [1] [4] [20], while others have a more flexible one [21], give only a classification [19] or define instead what play is [14]. In addition, we intend to develop a comparative study of these definitions.

2.1 What are Games?

Parlett [19] creates a classification of games into two types: informal games and formal games. Informal games are simply the act of playing freely without worrying about rules. Formal games are a competition with objectives, and also rules governing how players can try to achieve the objectives.

Abt [1] defines a game as an activity among two or more independent decision makers seeking to achieve their objectives in some limiting context. There are four concepts that are central to this definition: a game is an activity, games require that the players actively make decisions, games have objectives, and there are rules that limit and structure the activity of the game.

According to Huizinga [14], play is a free activity standing quite consciously outside ordinary life as being not serious, but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by

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it. It proceeds with its own proper boundaries of time and space according to fixed rules and in an orderly manner.

Caillois [5] builds a definition of play upon the one proposed by Huizinga. According to the author, such interaction is not obligatory, is circumscribed within limits of space and time, has uncertain course and result, creates neither goods, nor wealth, is governed by rules and is accompanied by a special awareness of a second reality or fantasy setting.

Suits [24] defends that to play a game is to engage in an activity directed towards bringing about a specific state of affairs, using only means permitted by rules, where the rules prohibit more efficient in favour of less efficient means, and where such rules are accepted just because they make possible such activity. A shorter version of this definition would be: playing a game is the voluntary effort to overcome unnecessary obstacles.

Crawford [8] does not offer a succinct definition of games, but he does list four primary qualities of things that can be considered games: they are a simplified representation of a subset of reality, they allow interaction to players so they can generate causes and observe effects, they have conflicts that manifest in the form of obstacles that make achieving an objective harder, and they offer security by presenting punishments that are less harsh than they would be if experienced in real life.

For Costikyan [7], a game is a form of art in which participants, termed players, make decisions in order to manage resources through game tokens in the pursuit of a goal. The differential in this definition is the association of games with culture and their representation as a system. Also, the notion of the existence of an internal economy is implicit to this definition.

Avedon and Sutton-Smith [4] propose that games are an exercise of voluntary control systems, in which there is a contest between powers, confined by rules in order to produce a disequilibrial outcome. It is important to note that this definition is very broad, as it introduces the notions of system, voluntary activity, limitation by rules, control and conflict.

Adams [3] [2] says that a game is a type of play activity, conducted in the context of a pretended reality, in which the participants try to achieve at least one arbitrary, nontrivial goal by acting in accordance with rules. This definition presents elements similar to those found in the definitions proposed by Huizinga [14] and Caillois [5].

Salen and Zimmerman [20] define a game as a system in which players engage in artificial conflict, defined by rules, that results in a quantifiable outcome. The rules construct the structure from which the act of playing emerges, delimiting what the player can and cannot do. A quantifiable outcome is what generally differs a game from a less formal play activity.

For Juul [17], a game is a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels emotionally attached to the outcome, and the consequences of the activity are negotiable.

Schell [21] utilizes the following characteristics of games from other authors to base his own definition: games are entered willfully, have goals, have conflict, have rules, can be won and lost, are interactive, have challenge, can create their own internal value, engage players, and are closed, formal systems. From these characteristics, he arrives to the following definition: a game is a problem-solving activity, approached with a playful attitude. It is important to note that the author tried to reach a definition that is broad but does not lose its essence.

2.2 Comparative Analysis of Game Definitions

After reviewing the definitions found in the literature we conducted a crossing between the characteristics used by the authors for building up each of these definitions. This process resulted in twenty different terms considering the subtle interpretations by each of the authors cited in this work (Figure 1).

Moreover, we accessed how comprehensive is the definition proposed by each author in a simplistic fashion by counting the characteristics used per definition (Figure 2). It may be pointed out that Parlett [19], Adams [2] and Abt [1] propose definitions that strive for simplicity whereas the number of characteristics used are kept to a minimum. On the other hand, Caillois [5], Crawford [8], Huizinga [14], plus Avedon and Smith came up with fairly complex definitions given the handful of characteristics used in their formulation.

On the other hand, this investigation also allowed to analyse which characteristics are frequently used by authors (Figure 3). This provides insights for estimating how important each characteristic is for defining what a game is. As a result, the following characteristics were obtained considering a decreasing order of estimated importance: *Rules*, *Objectives*, *Activity* and *System*.

Characteristics of a game	Parlett	Abt	Huizinga	Caillois	Suits	Crawford	Costikyan	Avedon & Smith	Salen & Zimmerman	Adams	Juul	Schell
Rules	X	X	X	X	X	X		X	X	X	X	X
Activity		X	X	X	X			X		X		X
Objectives	X	X			X	X	X			X		X
Decisions		X				X	X					
Voluntary			X	X	X			X				X
Artificial			X	X		X			X			
Captivating			X								X	
No material interest			X	X								
Space and time limits			X	X								
Uncertain				X								
Alternate reality				X						X		
Inefficient					X							
System						X	X	X	X		X	X
Connected parts						X	X					
Representational				X		X						
Conflict	X					X		X	X			X
Effort								X			X	
Negotiable consequences											X	
Result								X	X		X	
Art							X					

Figure 1: Characteristics found in the literature for describing what is a game and their respective use by the authors.

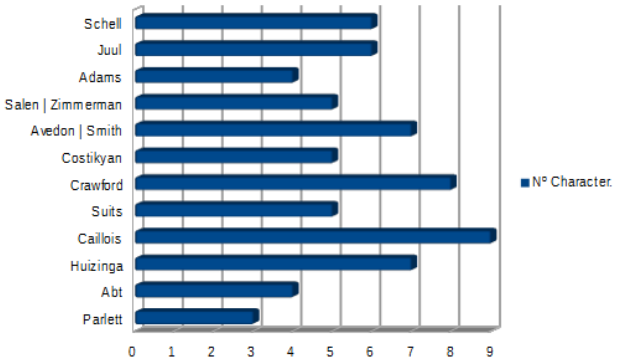

Figure 2: The number of characteristics used by each author in their respective game definitions.

3 Background: Game Mechanics Definitions

Once game definitions were presented and scrutinized in the latter section, we intend to analyse the definitions of game mechanics proposed by different authors throughout this section. Some authors offer a formal definition [6] [9] [22] while others show a more flexible one [2] [21]. In addition, we also present a comparative study of these definitions.

3.1 What are Game Mechanics?

Salen and Zimmerman [20] state that every game has a core mechanic, that is, the essential play activity players perform again and again in a game. Sometimes, the core mechanic is a single action. However, in many games, the core mechanic is a compound activity composed of a suite of actions. The core mechanic of a game contains the experiential building blocks of the player interactivity.

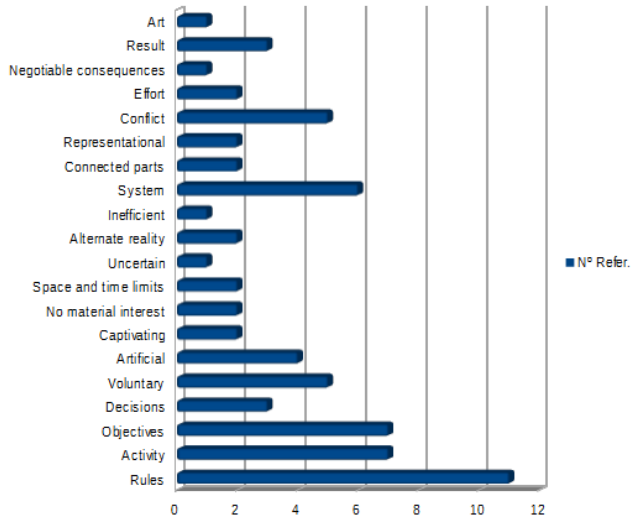

Figure 3: The number of authors that resort to each of the characteristics previously enumerated when building their definitions for games.

It represents the essential moment-to-moment activity of players, something that is repeated over and over throughout a game.

Hunicke et al. [15] propose a framework called MDA (Mechanics, Dynamics and Aesthetics) for game analysis. According to this framework, mechanics describe the particular components of the game, at the level of data representation and algorithms, dynamics describe the run-time behaviour of the mechanics acting on players inputs and on each others outputs over time, and aesthetics describe the desirable emotional responses evoked in the player, when she interacts with the game system. The mechanics are the various actions, behaviours and control mechanisms afforded to the player within a game context.

According to Cook [6], Game mechanics are rule based systems or simulations that facilitate and encourage a user to explore and learn the properties of their possibility space through the use of feedback mechanisms. In this definition, the feedback loops that encourage learning are a central concept. The feedback loop is the following chain of events that occurs constantly while a game is being played: the player performs an action, the action causes an effect within the simulated game world, the player receives feedback, and with new tools and information in hand, the player performs another action. Game mechanics should not only alter the game world while receiving input from the player, but also make this process explicit. Taking for example a black box with a button that, when pressed a thousand times, will release coins. To this apparatus be considered a game, it must first

- Encourage Discovery: First, make it obvious that the button in meant to be pushed. We need to explicitly direct them to take certain actions.
- Encourage Exploration: Second, we would put a counter on the front of the machines that lets the user know that their actions are having some impact on the system.
- Provide Tool Mastery: Third, the designer would post a note Payout: 1,000, coins! Not all games need explicit winning conditions, but hinting at future utility is a highly useful technique for encouraging the player to begin interacting with a particular game mechanic.

Under the analysis of Fabricatore [9], gameplay can be defined as the set of activities that can be performed by the player during play and by other entities belonging to the virtual world. However, to perform any activity, it is necessary to interact with concrete or abstract objects. When analysing games, players cite the mechanics, as they focus on the elements with which they must interact for events to occur in the virtual world. Because of the way players see the game mechanics, the author defines them as tools for gameplay, atomic rule-based interactive subsystems capable of receiving an input and producing an output, just like a black box. The author presents a complex way to divide the game mechanics.

- Core game mechanics: the core gameplay are the set of activities that the player will undertake more frequently during the game experience, and which are indispensable to win the game. The game mechanics which allow carrying out the core gameplay activities are called core game mechanics, and are, consequently, the most important in the game, since players will have to deal with them during most of their play experience.
- Satellite game mechanics: they enrich the core gameplay without increasing its complexity, by introducing special kinds of mechanics, aimed at enhancing already existing activities. There are three different kinds.
- Enhancement mechanics: have the purpose of enhancing already-existing core game mechanics. This can be done in two ways: by adding new features to an existing mechanics (add-on), or by modifying an existing feature (power-up).
- Alternate mechanics: offer to the player alternatives to existing core mechanics (or related features). Thus, true alternate mechanics require new learning, a price that many players are willing to pay if that allows tackling activities in new ways.
- Opposition mechanics: are a powerful means of enhancing the challenge in a game. Their main purpose is hindering the players progress. Thus, they are a very peculiar type of gameplay tools, since players' learning is not aimed at understanding their working in order to use them, but rather in order to avoid or circumvent them.

According to Jrvinen [16], the essence of games is how they work, that is, how they show behaviour while a system and how they permit behaviour to the player. The game mechanics convey to the players forms to access the game system and create combinations of two or more elements in the hope of accomplishing a well succeeded plan in relation to an objective. In terms of design, game mechanics are means to guide the player and the game to particular behaviours by restricting the space of possible plans to achieve objectives. The authors divides the game mechanics intro three different kinds.

- Primary mechanics: are available globally, in other terms, at any moment, but generally only one at a time. This means that the use of a primary mechanic makes another one unavailable for that particular game state.
- Submechanics: serve a supportive role for the primary mechanics. Alone, the submechanics cannot allow the player to achieve their goal, but make it possible for the primary mechanic to be properly executed, to this end.
- Modifier mechanics: are available locally, that is, under a certain condition. This condition can be a duration or specific attributes of the player. Examples of modifier mechanics are a power-up or the strength applied to a blow.

Sicart [22] can be noted for analysing several other definitions of game mechanics before proposing his own, including the definitions created by Hunicke et al. [15], Cook [6] and Jrvinen [16]. He states that Game mechanics are methods invoked by agents, designed for interaction with the game state. Object orientation provides a set of metaphors that describe the elements of systems and

their interrelations. It is useful because it provides a formalistic approach to actions taken within information systems like games, which may lead to the application of modeling languages like UML to the description of game systems. Following this approach, it is possible to consider game mechanics as being available to both humans and artificial agents. He also offers a categorization of mechanics.

- Core mechanics: these are the game mechanics repeatedly used by agents to achieve a systemically rewarded end-game state.
- Primary mechanics: They are core mechanics that can be directly applied to solving challenges that lead to the desired end state. Primary mechanics are readily available, explained in the early stages of the game, and consistent throughout the game experience.
- Secondary mechanics: They are core mechanics that ease the player's interaction with the game towards reaching the end state. Secondary mechanics are either available occasionally or require their combination with a primary mechanic in order to be functional.

Sigman [23] presents a way to analyse the anatomy of a game mechanic through a graphical representation. According to him, programmers generally have a very mathematical formation in university, making that attempts to explain to them a certain mechanic with inadequate terms can possibly result in a loss of the contents of the message. Because of this, the author proposes a mathematical approach to describe game mechanics. According to him, a game mechanic is a function, that is, a black box that, when receives a certain input value, generates an appropriate output value. Graphically, the function is represented by a line or curve in the cartesian plane.

A division of game mechanics types is presented by the author. They can be linear, that is, they have a constant slope, or non-linear, that is, the slope is not constant. There are several kinds of non-linear mechanics.

- Asymptotic to a value: these mechanics tend to "flatten out" as they approach a certain result (y value). After a point, huge changes in X result in very small (insignificant) changes in Y. In other words, slope approaches zero after a certain point.
- Asymptotic to infinity: these mechanics tend to approach infinity (Y) as X increase or decreases.
- Non-asymptotic: these mechanics don't fall under any other categorization.
- Segmented linear: a segmented linear mechanic is technically non-linear overall, but it can be seen as just a linear mechanic that is made up of two or more sections with different slopes.

According to Adams [3] [2], game mechanics are the rules, processes and data that are at the heart of a game. They define how the game progresses, what happens and when, and what are the conditions that determine victory or defeat. The author states that the mechanics of a digital game are hidden from the player, implemented in software with no direct access. Because of this, the players do not need to know the rules when they start playing, as the game teaches them during play. To the author, mechanics and rules are related concepts, but mechanics are more detailed and concrete, and sometimes associated with code. Adams categorizes the game mechanics into five different kinds.

- Physics: involves mainly computing the position of dynamic objects in the game, the direction in which they move, and eventual collisions.
- Internal economy: are the mechanics that involve quantifiable resources that are collected, consumed and traded in a game. Some of these resources are abstract, such as health points.
- Progression mechanisms: elements that block or unlock progress the progress of the player, such as gates, keys and levers.
- Tactical maneuvering: fundamental to strategy games, as they revolve around the positioning of units in a strategic map and the relations of advantage and disadvantage they infer.
- Social interaction: these mechanics stimulate social interaction among players. For example, players can be rewarded for forming alliances.

Schell [21] points out a way to explain the elements that compose a game. They are: aesthetic, mechanics, story and technology. The mechanics are the procedures and rules of a game. The describe the games objective, how the players may or may not try to achieve it, and what happens when they try. Game mechanics are the core of what a game really is. They are the interactions and relations that remain when all that is related to aesthetics, story and technology is removed. The author makes a very broad categorization of mechanics, creating his own taxonomy.

- Space: disregarding its appearance, a space is a mathematical and abstract concept. It can be discrete or continuous, a number of dimensions and has bounded areas that may or may not be connected.
- Time: every game has a measure of time. It can be discrete, continous or hybrid. Also, digital games allow otherwise impossible operations with time, such as rewind, pause and accelerate.
- Objects: they are the characters, accessories and tokens that occupy the game space, and can be seen or manipulated.
- Actions: represent what the players are capable of doing.
- Rules: the fundamental kind of game mechanic. They make the other mechanics possible. They also add what makes a game in fact a game, which are the objectives.
- Skill: what is necessary from the player to win the game. True capacity from the player is real skill, while power coming from his avatar is virtual skill.
- Chance: Evokes uncertainty, which creates surprises in a game. It is a common mechanic but, unlike the other ones, it is not mandatory.

3.2 Comparative Analysis of Game Mechanics Definitions

Similarly to the previous analysis of game definitions, we enumerated the different characteristics employed by authors to define game mechanics. A crossing between the characteristics of the definitions of the authors was performed, allowing to analyse which characteristics are used by which authors (Figure 4).

We also analyzed how many characteristics are used by each author (Figure 5) and how frequently each characteristic is chosen by authors to come up with their definitions (Figure 6).

As a result, Fabricatore [9], Cook [6], Sicart [22] and Jrvinen [16] present complex constructions to explain what are game mechanics. These definitions resort to a formal perspective. On the other hand, it is reasonable to assume that most authors agree that Formal Definition, Distinct from Rules and Focus on Player are the outstanding characteristics defining game mechanics. Therefore, concerning the scope of this investigation, we adopt our own definition of game mechanics which is built using these characteristics.

4 Our Approach: MINIGAME

After analysing the definitions of game mechanics we propose our own definition which we consider minimal as it is built on top of that analysis. Moreover, we also propose a simplistic game mechanics modeling approach for transmitting ideas behind the design of games.

Characteristics of a mechanic	Sigman	Cook	Sicart	Fabricatore	Hunicke et al	Schell	Adams	Zimmerman	Järvinen
It is a black box	X	X		X					
Has a formal definition	X	X	X	X	X			X	X
Mathematical function	X			X					
Definition focused on the developer	X		X		X				
Definition focused on the player		X		X		X	X	X	X
Applied only to the player		X				X			X
Distinct from the rules		X	X	X				X	X
Are actions (limited to actions)			X		X			X	X
Associated to the feedback loop		X		X		X			
Related to programming			X		X		X		

Figure 4: Characteristics found in the literature and their respective use by the authors when defining *game mechanics*.

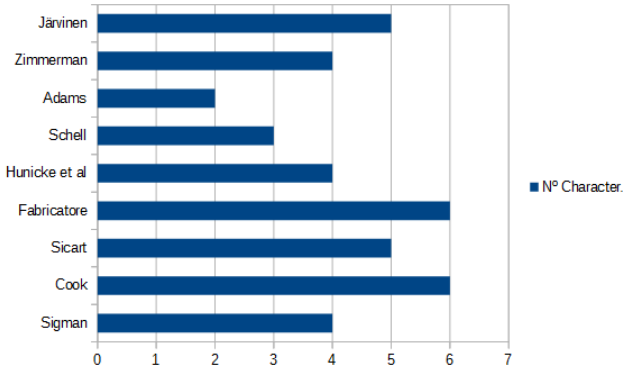

Figure 5: The number of characteristics used by each author in their respective game mechanics definitions.

4.1 Defining Game Mechanics

The game mechanics are mechanisms based on rule sets that compose the logical functioning of a game. They become *perceptible* to the player when a set of rules has a unique and meaningful interaction: they are the form that a player perceives the inner workings of the game world.

In digital games, the computer is capable of managing the enforcement of the rules of the game. Because of this, the player does not have to memorize the rules when playing, as he can learn how they work as he plays. In this way, players generally do not perceive the rules as they are, but instead the mechanics that are generated from their interaction with the game itself. The game mechanics can be seen as an abstracted and simplified form of understanding the games rules, mainly of digital games.

More complex game mechanics are composed of more elemental ones. In this way, it is necessary to decompose a certain mechanic m in all the lesser mechanics that compose it to be able to determine what are the rules that define the working of m. When a mechanic can no longer be decomposed, we have arrived to the

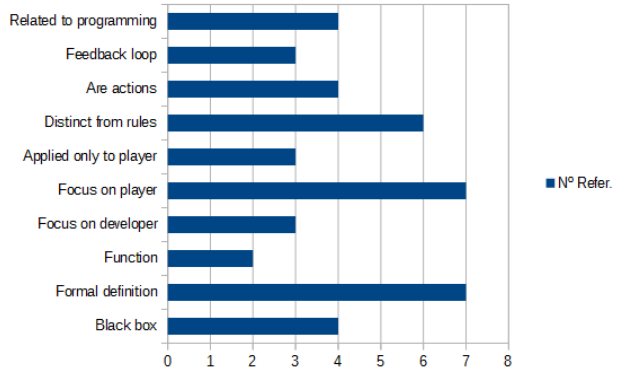

Figure 6: The number of authors that resort to each of the characteristics previously enumerated.

rule. For example, lets consider the mechanic of the player avatar in a hypothetical game. This mechanic can be decomposed in the following elements: health, damage, position and speed. Analysing the health, it can be decomposed in the following characteristics: it can be restored with health potions, it regenerates over time, it is reduced when receiving damage, and, upon reaching the value of zero, the player dies.

4.2 DTD - Detailed Textual Description

In textual form, it can be represented in the following manner:

- Players avatar
  - The player has position, speed, damage and health.
- Health
  - Health can be restored with health potions.
  - Health regenerates slowly over time.
  - Health is reduced upon receiving damage.
  - If health reaches the value of zero, the player dies.

Note that in this example, not all values have been specified, like how much health is restored with a health potion, for the sake of simplicity.

4.3 Visual Description (VD)

These same mechanics and rules in the latter example can also be represented in a visual form, depicted by Figure 7.

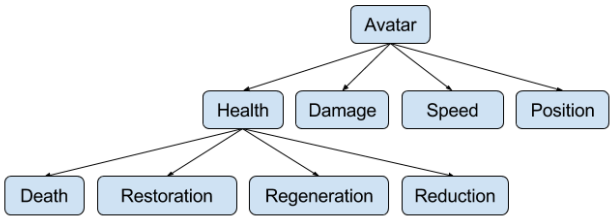

Figure 7: Visual Description of game mechanics on a hypothetical game. Note that the hierarchical structure of mechanics is clear and arguably easy to understand.

All these elements describe the most intrinsic behaviour of health. As these lower elements, like death and restoration, cannot be further decomposed, they are rules. Generally, when describing the mechanics and rules of a game through text, the mechanics are nouns and verbs, as they represent objects and actions, and the rules are sentences, as they describe the inner workings of the mechanics. So, it is a useful way to differentiate mechanics and rules.

4.4 DTD versus VD

It is important to make a distinction here between the textual description and the visual description. While the textual description allows to explicit each individual rule in more detail, allowing one to study the working of each rule deeper, the visual description allows to have a better understanding of the relationships between the different mechanics, and the hierarchy that exists among them. That is why these two descriptions have been proposed to complement each other in the analysis of game mechanics.

In order to do the modelling of the mechanics of a game, it is necessary first to identify fundamental features of the game, like its space and time. After this step, it is needed to delimit the world in which the game occurs. As all of the elements of a game exist within its world, a decomposition will be done from the highest mechanic, which is the world itself, to the rules. This approach is called Top-Down, and is the most advised to be followed. The

Bottom-Up approach can also be used, but it is generally better to be applied after the Top-Down, to identify unusual and distinct mechanics.

5 EVALUATION

In this section, the proposed methodology will be applied to existing games. PONG, Quake and Starcraft are the games chosen for analysis due to their simplicity, popularity and gameplay complexity, respectively.

Insights about the challenges faced and the respective solutions found during these analyses are also discussed since they provided feed back necessary to obtain a refined analysis method.

5.1 PONG

In this section, the proposed methodology will be applied to the simple but extremely successful game PONG (Figure 8).

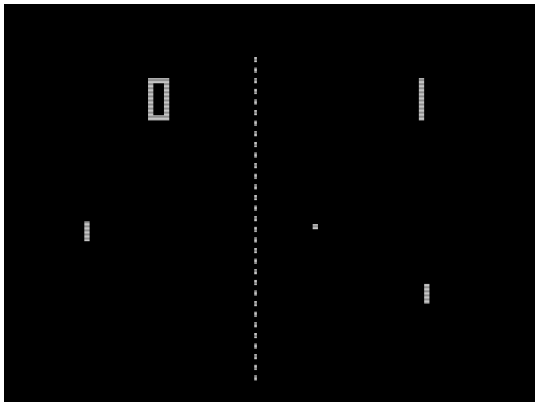

Figure 8: Image of the game PONG.

This structutre was broken into main structure, paddles, ball, score and delimitation line.

5.1.1 DTD for PONG

Main structure:

- The game is structured in an arena that contains the other mechanics.
- The time is continuous.
- The space is continuous and two-dimensional, however limited by the dimensions of the exhibited image.
- The arena of the game contains two paddles, a ball, score and a delimitation line.

Paddles:

- Each paddle is controlled by a player or AI.
- Each paddle has a position
- The paddles start, each one, at the left and right sides of the arena
- The paddles have a movement system:
  - The paddles can move vertically
  - The movement is limited by a maximum speed
  - The movement can only occur until the limits of the arena

Ball:

- The ball has position, direction and speed
- The ball starts at the center of the arena
- The ball has a movement system:
  - The ball starts with a random movement.
  - The ball can move in any direction.
  - The balls movement can only occur until the limits of the arena.
- The ball has a collision system with the paddles:
  - On contact with the paddle, the ball is redirected to the opposite horizontal direction that it was before.
  - The ball increases in speed each time it is hit.
  - The closer the ball is to the edge of the paddle in the moment of collision, the more vertical will be its movement.

Score:

- Every time the ball gets past a paddle, the player controlling the opposite paddle will gain a point.
- The first player to score 10 points wins the game.

Delimitation Line:

- The ends of the delimitation line indicate the limits of the arena.
- The ball and the bars cannot get past the vertical limit imposed by the ends of the line.

5.1.2 VD for PONG

The visual diagram allows to easier identify the level of hierarchy of each game mechanic and their interactions and relations, at the cost of more detailed information. This is shown in Figure 9.

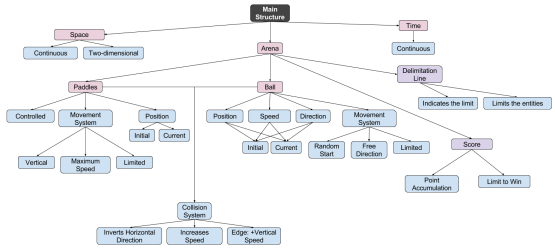

Figure 9: Diagram of the game mechanics of the game PONG.

5.2 Quake

In this section, the proposed methodology will be applied to the iconic game Quake, shown in Figure 10.

Figure 10: Image of the game Quake.

Quake presented a much higher level of complexity and numerous mechanics in contrast to PONG. Hence, this structure was broken into main structure, player avatar, health, armor, weapons, ammunition, runes, monsters, collectibles, fixed scenario elements and emergent mechanics.

5.2.1 DTD for Quake

Main structure:

- The game is structured in a campaign compound by 4 episodes.
- Each episode contains a specific number of missions.
- The game starts at the mission "Introduction" from which the player may choose a difficulty and an episode to be played.
- The player must find the exit of each mission to finish it and progress to the next mission.
- The player must collect the rune of an episode, which is located at its last mission, to conclude it.
- The space is three-dimensional and continuous.
- The time is continuous.
- The physics includes gravity.
- It is inside the missions that the other game mechanics are present.

Player avatar:

- The player has position, direction, speed, weapons, ammunition, health, armor and runes.
- The player can execute the following actions: move, look, jump and shoot.

Health:

- The health limit is 100.
- Health is deduced when receiving damage.
- When health reaches 0, the player dies.
- Health can be restored with health packs.

Armor:

- There are 3 different kinds of armor.
- Upon collecting armor, the player gets 100 points of armor of that specific kind.
- The armor deteriorates with each received attack, reducing the amount of health lost.
- The better the armor, the more damage it absorbs.

Weapons:

- There are 8 different weapons.
- The weapons allow the player to shoot, which main function is to kill monsters.
- Each weapon has a damage value, a damage type and a fire rate.
- Collecting a weapon adds it to the inventory. If the weapon is already possessed, it then counts as ammunition for it.

Ammunition:

- There are 4 different kinds of ammunition.
- Ammunition is used to shoot with the weapons, except the axe.
- Ammunition is spent for each weapon shot, except the axe.
- Ammunition can be obtained by collecting ammunition boxes.

Runes:

- There are 4 runes in the game, each one at the end of each episode.
- Upon collecting all the 4 runes, the player gains access to the final mission.

Monsters:

- There are 13 kinds of monsters and 2 bosses in the game.
- Monsters are killed when they receive a certain amount of damage.
- Each monsters possesses one or more different attacks.
- The bosses can only be defeat through special ways, as they are immune to normal damage.
- Each monsters has two different behaviors: patrol and chase.
- Patrol is the behavior when the monster has not yet detected the player. He stays still or follows a predefined route.
- Chase is the behavior when the monster has detected the player. He will try to approach the player so he can damage him.

Collectibles:

- They are items that the player can add to his inventory temporarily or permanently. There are three kinds of collectibles.
- Common collectibles: ordinary, they exist with higher frequency in the game world.
  - Weapons: allow the player to damage the enemies.
  - Ammunition boxes: add ammunition to the player's inventory.
  - Health packs: restore the player's health.
  - Armor: offer protection to the player.
- Special collectibles: exist with lower frequency in the game world. Their effects are temporary.
  - Biosuit: allows to breathe underwater and gives immunity to radioactivity.
  - Quad damage: increases the player's damage by four times.
  - Pentagram of protection: renders the player invulnerable to all damage.
  - Ring of shadows: makes the player invisible.
  - Megahealth: adds 100 health to the player, above the maximum limit. The exceeding health will slowly degenerate.
- Progression collectibles: they are necessary to progress in the missions.
  - Keys: allow the player to open locked doors.
  - Runes: allow the player to conclude an episode. All 4 together allow to conclude the campaign.

Fixed scenario elements:

- They are fixed, and so they cannot be collected or destroyed. There are 5 kinds of fixed scenario elements.
- Doors: block the access between two areas, unless opened.
  - Common doors: open upon getting close to them.
  - Locked doors: open upon being touched while possessing their key or pressing buttons.
- Buttons: do different things when pressed, such as calling elevators and opening doors.
  - Pushable buttons: are pressed by pushing them.
  - Shootable buttons: are pressed by shooting them.
- Traps: there are different traps in the game. They damage or instantly kill the player when hitting him.
- Pools: regions that allow the player to swim in all directions.
  - Water pool: damages the player only if he stays submerged for too long.

  - Radioactive pool: causes moderate damage over time, unless using the biosuit.
  - Lava pool: causes gigantic damage over time.
- Secret areas: require attention to be discovered, but contain great rewards.

Emergent mechanic: rocket jump

- Compound by the junction of the following rules:
  - Explosions create impulse in what is inside their radius.
  - Jump creates impulse upward.
- Shooting a rocket to his feet after a jump, the player can reach a higher height.
- Damage is taken, so this mechanic requires strategic use.

5.2.2 VD for Quake

As the game grows in complexity, a single diagram as shown in Figure 11 is not sufficient to represent all the game mechanics. In this case, it was split in five diagrams, being two shown here. Attributes that are common to practically all games, such as position, direction and velocity, have been abbreviated in Figure 12. Also, some connections have been used so everything can fit the image.

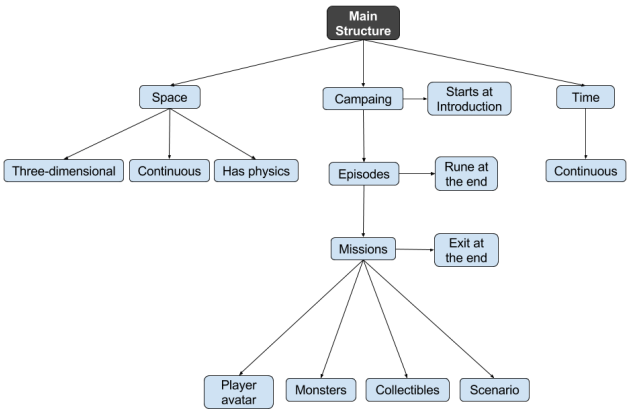

Figure 11: Diagram of the general mechanics of the game Quake.

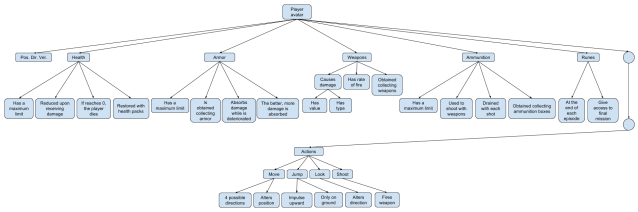

Figure 12: Diagram of the specific mechanics of the player avatar of the game Quake.

5.3 Starcraft

In this section, the proposed methodology will be applied to the game Starcraft, depicted in Figure 13.

This strucutre was broken into main structure, player controls, races, units, buildings, technologies, scenario, map and emergent mechanics.

Figure 13: Image of the game Starcraft.

5.3.1 DTD for Starcraft

Main structure:

- The game is structured in system of campaigns, having 3 campaigns.
- Each campaign is specific of a race.
- Each campaign has 10 missions.
- The space is continuous and three-dimensional.
- The time is continuous.
- It is inside the missions that the other game mechanics are present.

Player controls:

- The player controls a set of units and buildings.
- The player can move a pointer to the sides of the screen to scroll it and see other objects to interact or analyse.
- The player can left click a unit of building to select it.
- The player can click and drag a box to select all the units inside it.
- The player can right click while having a unit selected to do a contextual action.
- The player can click in an option in the command card to do specific actions, like building or using a special ability.

Races:

- There are 3 races in the game.
- Each race has specific units, buildings and technologies.

Units:

- Each unit has a production cost in resources.
- The units possess health, damage, attack rate, armor, speed, line of sight and energy.
- Each unit has a set of available actions.
  - Move: The unit moves to the desired spot.
  - Stop: The unit will stop the current action it was doing, but will still chase enemies.
  - Hold: The unit will stand ground and will only attack enemies if they are within range.
  - Patrol: The unit will move between two points indefinitely, attacking enemies that are found.
  - Attack: The unit will attack a specific enemy or will move to a certain spot, attacking enemies found on the way.

  - Harvest: collects resources from the selected deposit. Only workers can harvest.
  - Build: Constructs the selected building on the desired spot. Only workers can build.
  - Special ability: Executes a special action at the cost of energy. Exclusive to some units.

Buildings:

- Each building has a production cost in resources.
- The buildings possess health, armor, line of sight and, if they are defensive structures, damage.
- Each building has a set of available actions.
  - Produce unit: consumes resources to produce a unit after a certain amount of time, which will spawn at its front.
  - Research technology: consumes resources to research a technology after a certain amount of time, which will be applied instantly after then.

Technologies:

- Each technology has a production cost in resources.
- The technologies upgrade the player's units in some way.
  - Passive bonus: the bonus is permanent and does not require activation.
  - Active bonus: the bonus is only given when activated, consuming energy and having a duration.

Scenario:

- The scenario is where the races interact with each other and with the world. Some mechanics are specific of the scenario and are not controlled by any player or AI.
- Terrain: the terrain in the game can have different heights.
  - Units can only see what is at the same or lower height of theirs.
  - Units attacking enemies at a higher height may miss their attacks.
  - Buildings can only be built on flat and clear terrain.
- Fog of war: the scenario is covered by a fog that hides the enemy units and buildings.
  - The fog is temporarily removed from a spot while a unit is near it.
  - The fog is removed until the line of sight of the unit.
- Resources: There are 3 resources in the game: minerals, vespene gas and populational limit.
  - The scenario has these resources scattered in groupings of 8 minerals and 2 vespene gases.
  - The resources can be harvested by workers and delivered to the main building.
  - To increase the populational limit it is necessary to produce the building or unit that increases it.

Map:

- Each player has access to a map to facilitate the acknowledgment of the scenario.
- The map represents the entire scenario in a simplified manner, including terrain, units, buildings and resources.
- The map has a data representation system.
  - Units and buildings are represented as colored squares.
  - Resources are represented as white squares.

Emergent mechanic: block

- Compound by the junction of the following rules:
  - Units can move to a desired spot
  - Units cannot traverse through each other.
- Positioning your own units in a certain manner it is possible to disturb the movement of enemy units.
- As blocking the enemy can lead them to devastate your forces, it is a very risky and uncommon strategy.

5.3.2 VD for Starcraft

In this game the player is not represented by a single avatar unlike the other examples, so it was agreed to consider the player controls to be a mechanic on their own. What the player can attempt to do with his controller will not always achieve the same outcome, so the actions of the player and the actions of the units and buildings themselves have been separated, as can be seen in Figures 14 and 15.

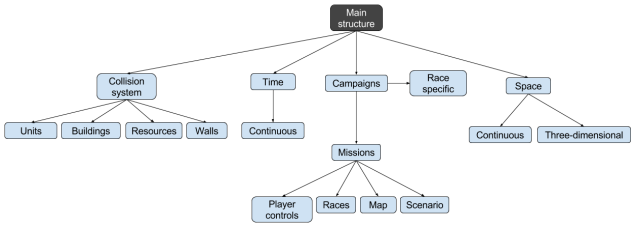

Figure 14: Diagram of the general mechanics of the game Starcraft.

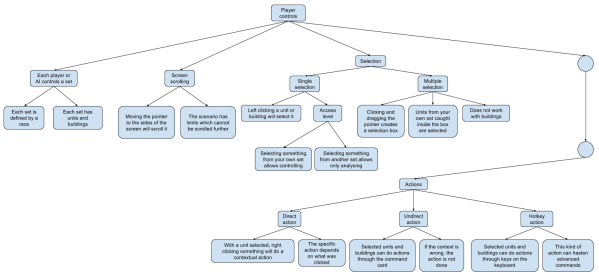

Figure 15: Diagram of the specific mechanics of the player controls of the game Starcraft.

6 CONCLUSION

Defining game mechanics is a challenging task considering the audience composed by professionals with different education: game designers, artists and programmers must understand each other and collaborate to refine their ideas when they work together building a game. Figueiredo and Ramalho [11], for example, studied the application of software design patterns to cope only with programmers. In this paper we describe the first investigation steps to achieve comprehensive model that can possibly fit the task of game mechanics analysis and definition.

An extensive literature survey was conducted, culminating in the construction of a comparative table on game and mechanics definitions. An analysis was developed over these definitions, adopting a minimalist perspective. A definition of game mechanics that excels in simplicity was proposed, so it can be used more effectively by designers, developers and, possibly, even players. This paradigm was applied to evaluate different popular games. Pong is a simple example that only demanded a single diagram. Several lessons were

learned from this analysis, including the possibility of using stereotypes for game mechanics, when a certain mechanic has features that are common for many games.

This document is a first step towards the establishment of a line of research that aims to provide the game mechanics with formal tools for their specification, including domain-specific languages [12] [18] [13]. Even inclusive programming interfaces and APIs can benefit from such studies [10].

As such, there are several work fronts to be undertaken for the implementation of the present proposal. Future work includes: Proposal of a formal model that centralizes the game, requiring revision of the current proposal; Construction of catalogs with game mechanics stereotypes; and a Manual with best practices.

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