Analyzing Space Dimensions in Video Games

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***Abstract*—The objective of this work is to analyze the role of space in video games, in order to understand how game space affects the player in achieving game goals. Game spaces have evolved from a single two-dimensional screen to huge, detailed and complex three-dimensional environments. Those changes transformed the player's experience and have encouraged the exploration and manipulation of the space. Our studies review the functions that space plays, describe the possibilities that it offers to the player and explore its characteristics. We also analyze location-based games where the player's position in game space is relative to his position in physical world. We saw in previous studies that there are more than one way to discuss space in games. Our understanding goes further and analyzes the game space in four aspects: gameworld, gameplay, player perspective and game view. Finally, we also propose an ontology to define the space characteristics**

Keywords-game space, gameworld, gameplay, game dimensions, location-based games;

I. INTRODUCTION

The objective of this work is to analyze the role of space in video games in order to understand the impact of the space on gameplay, that is, how the space affects the player in achieving the game goals. We present the functions that space plays, describe the possibilities that space offers the player and explore space characteristics like organization, possibility of manipulation, player's perspective and space dimensions. We also analyze the location-based games where the player's position in game space is relative to his position in physical world and the use of augmented reality to add a virtual layer over the world.

Game spaces have evolved from a single two-dimensional screen to detailed and complex three-dimensional environments. This transformed the player's experience and has encouraged the exploration and manipulation of space. As game technology improves, the potential for creating complex and compelling spaces seems unlimited [1].

The player identifies and recognizes the space through narrative and vision. As it becomes familiar to the player, it deepens the immersion in the fictional world. According to Huizinga, the game space is a part of a magic circle [2], which keeps the game world apart from real world [3] [4].

Our interest in studying space in video games started some years ago, while discussing, in a game design course, how interactive fiction allows the description of multiple types of game space without any visualization other than textual. However, in 2018, Matsuoka et al. presented a paper on SBGames that analyzes the meaning of the game space for the player, explaining how space commonly has significance in video games, being bound to the fictional world and, consequently, to its rules and narrative [5]. This led us to search for a better understanding of what is game space.

This paper is divided in seven parts. Section II presents the functions that the space performs for the gameplay. Section III is a review of game space characteristics. Section IV describes the emergence of location-based games and their characteristics. Section V analyzes space dimensions in previous studies. Section VI describes our understanding of space dimensions and proposes a ontology to define the space characteristics. Finally, section VII presents the conclusions of our studies.

II. THE FUNCTION OF SPACE IN GAMES

Video games invite players to explore and experience virtual worlds [6]. Almost all video games use space and spatial representations [7], which are virtual, navigable and interactive [3]. The possibility of navigation differentiates game spaces from other virtual spaces, described in movies or literature. Games also allow the player to manipulate the space and interact with objects in it.

Exploration helps players to understand the shape of the topological space they are moving through [3] [8]. Exploration may be linked closely to the pursuit of goals or missions structured into the core gameplay activities, or in order to advance the player through game levels. The greatest scope for exploration is usually found in role-playing games, where avatars are considerably free to roam at will [9]. King and Krzywinska propose degrees of freedom to classify games in relation to the ability of exploring the game space [9].

First, we will explain where space is inserted in the context of games. There are some theories that aim to classify the elements that form a game. Schell proposed four elements that define a game: mechanics, story, technology and aesthetics [4]. The mechanics are the core of the game design. Schell also represents game mechanics in six categories: objects, actions, rules, skills, chance and space [4]. Games take place in worlds that contain spaces.

Games can also be seen as narratives, and the storytelling must take place somewhere [10]. The narrative encourages the player's engagement [3]. Fernandez-Vara [11] proposes ways in which game design can encourage

narrative gameplay through the design of the space. She explains that the narrative can shape the space. The player constructs the sequence of the narrative as it navigates through space. Thus, the player must piece the story together and must understand the objects and events in the space. It is interesting to note that, through this perspective, game space also creates the time notion in games, since different navigations could generate different timelines for the narrative.

Action adventure games use backstory, interactivity, puzzles and atmosphere, to make rich game spaces [1]. Even in interactive fiction - games like Adventure (Crowther and Woods, 1977) or Zork (Infocom, 1977) - we assume there is a virtual game space, since the player enters text commands to interact with the game and progress in space [3] .

A. Game spaces as architecture

Since gameplay always occurs somewhere, McGregor [12] suggests to investigating spatiality in games looking at game space as architecture. Also, Adams [8] explains that the virtual spaces of the games are built from architecture, like in the real world. Squire and Jenkins [1] argue that game worlds are totally constructed environments. Everything is must be put on the game space for some purpose, whether to shape the game play or encourage performance, playfulness, competition, or collaboration. Players learn to scan their environments for competitive advantages [1]. Including something in a game with no purpose may confuse or distract the player.

Adams also defines a primary function for architecture and therefore for the game space, that is to support the gameplay [8]. Game space provides challenges and actions to the player in four major ways: **constraint**, **concealment**, **obstacles or tests of skill**, and **exploration**.

Game space guides the player and establishes boundaries and constraints that limit the player's freedom of movement, conceals valuable objects, offers protection and even surprises the player. Game space has obstacles that test player's skill. First person shooters games like Doom (id Software, 1993), Quake (id Software, GT Interactive, 1996) and Battlefield 3 (EA Dice, Electronic Arts, 2013) pit players in struggles over more localized spaces, such as warehouses, rooms or corridors [1]. Skilled players learn to use the space strategically. The scenery and objects are embedded in the space for the players to protect themselves, hide and fire. Game space can also take a maze form to mislead the player.

Movement availability is required for the player to appreciate the experience of the space. It acquires notion of depth and dimension. Matsuoka et al. [5] suggest the movement as a space exploration resource, to overcome the lack of the perception of the other senses in video games. They also suggest the freedom of movement in the Z axis to better explore and harness the space resources in three-dimensional video games.

Adams further proposes that space has a secondary function to the gameplay: to inform and entertain in its own right [8]. This is provided in many ways: **familiarity**, **allusion**, **novelty**, **surrealism**, **atmosphere**, **comedic effect** and **clichés**. Games favor visions that are easily mapped by people in the real world. Thus, the architecture usually creates familiar locations and an atmosphere to inspire emotion through objects and sceneries. Sometimes architecture even makes references to real places or buildings. On the other hand, if the game requires a new world, the architecture can create a sense of unfamiliarity. Architecture can also create a surreal landscape or a happy and funny environment, or relies on stereotypes.

Video games continuously reuse spatial patterns from reality and apply them in the game space structure. McGregor [12] proposes prevalent patterns of spatial use: **challenge**, **contested**, **codified**, **creation** and **backdrops**.

Challenge spaces and its puzzles are physical challenges. This pattern is primary used in adventure games like Rise of the Tomb Raider (Crystal Dynamics, Square Enix, 2015) (Fig 1a), Super Mario Bros (Nintendo, 1985) and Myst (Cyan, Brøderbund, 1993). In Tony Hawk Pro Skater 5 (Robomodo, Disruptive Games, Activision, 2015) (Fig 1b), ramps, handrails and other obstacles are the challenges to be overcome in the runway. In contested space, the landscape is object of contest, which often includes competition for resources. This pattern is primary used in strategic games like Starcraft (Blizzard Entertainment, 1998), Civilization VI (Firaxis Games, 2K Games, 2016) (Fig 2a) and Battlefield. The nodal space acts as a container, both concentrating activity and defining the area of activity. This pattern is primary used in MMORPG like World of Warcraft (Blizzard Entertainment, 2004). Codified spaces are containers that explicitly represent something other than itself. This pattern is used in Civilization VI and Lord of the Rings: Battle of Middle Earth (EA Los Angeles, EA Games, 2004) (Fig 2b). Codified spaces usually contain information and valuable objects used in gameplay.

Figure 1. Games that use challenge pattern to build the game space. Sources: images.nvidia.com and bhgames.com.br.

Figure 2. Games that use contested and codified patterns to build the game space. Sources store.steampowered.com and pinterest.com.

The mechanics and objectives of the game may sometimes involve building the game's own space. This pattern is used in Sim City 2000 (Maxis, 1993) (Fig 3a), Minecraft (Mojang, 2011) and strategic games like Civilization VI. In addition, the game space can contain backdrops that are non-interactive sceneries and are not

part of the gameplay. This pattern is used at the edges of the game space. In racing games, like F1 2016 (Codemasters, 2016) (Fig 3b), the circuit buildings and the bleachers are backdrops that cannot be entered.

(a) (b)

Figure 3. Games that use construct and backdrop patterns to build the game space. Sources: alchetron.com and comboinfinito.com.br.

III. REVIEW OF GAME SPACE CHARACTERISTICS

This section looks at game space characteristics, which includes space organization, possibility of space manipulation and player's presence in space.

A. Organization

Squire and Jenkins point out that the game space is organized so that paths through the gameworld guide or constrain the actions, making sure we encounter characters or situations critical to the narrative [1].

Schell lists five common ways to organize game spaces that are also applied in video games: **linear**, **grid**, **web**, **divided space** and **points in space** [4]. The player can only move forward and (sometimes) backward in a linear game space in Super Mario Bros and Guitar Hero (Harmonix, RedOctane, 2005). Wargames commonly arrange the game space on a square or hex grid. A web arrangement marks several points on a map and connects them with paths as a graph. Interactive fiction games define a web game space. Games may divide the space to try to replicate a map in some strategic games. Space is seldom represented in points, but Final Fantasy (Square, Nintendo, 1987-2018) uses this arrangement.

Game space can be classified according to its topology in **discrete** or **continuous** [13]. In games with discrete topology, the actions of the avatar or player-token occur in certain positions in space. The elements cannot be overlapped in some of these games [7]. The space is discrete in Chess and Candy Crush (King, 2012). Otherwise, in games with continuous topology, the actions occur in any position in space. The avatar or player-token has a continuous freedom of movement. Aarseth use Quake as an example of a game with continuous topology, since the player's movements are in all directions, with million possible alternative positions [7].

Game designers discern between games with **hard rails**, which tightly structure the player's movements, and games with **soft rails**, which are multidirectional and multi-linear. Game spaces with soft rails may have multiple entry and exit points; and there may be multiple paths around obstacles [1].

Gameworld may have hidden treasures and secret areas that are not initially obvious to casual players. These game spaces usually reward players with many coins, extra lives, or rare and precious items. Game designers have often used this feature in action adventure games to encourage exploration from players with this profile - Explorers [4] - and to please players who want to achieve all the goals of the game - Achievers [4]. In Super Mario Bros, pipes give access to secret paths that are often a shortcut to reach the end of the stage. In Super Mario World (Nintendo, 1990), Star Road (Fig 4a) is a famous secret world where the player can find rare colored Yoshis. Another secret space appears with more eight special stages, after the player accomplishes the five stages of Star Road. Donkey Kong Country: Tropical Freeze (Retro Studios, Nintendo, 2014) (Fig 4b) and Rayman Legends (Ubisoft Montpellier, Ubisoft, 2013) stages also have secrets spaces where the player gets the required items to complete all the goals of the game.

(a) (b)

Figure 4. Secret or hidden game spaces. Sources: nintendoblast.com.br and ign.com.

B. Possibility of Manipulation

Aarseth differs **static** from **dynamic** spaces, since some game spaces remain unchanged for the duration of the game, while others may be modified by the player [7]. The field and the board cannot be modified in Football, Chess (Fig 5a) and jewel games. On the other hand, the player manipulates the environment strategically in games like Lemmings (DMA Design, 1991) (Fig 5b), Minecraft, Battlefield, and Heroes of Might and Magic IX (New World Computing, 3D0, 2002). In Battlefield, the player must destroy or blow walls, fences, gates and other elements of the game space to progress strategically on the combat zone. Minecraft has become an emblematic construction game. The game does not have clear goals. The player just mines and collects resources (building blocks) to craft anything he imagines (Fig 6).

(a) (b)

Figure 5. A static game space (a) and a dynamic game space (b). Sources: youtube.com and greenmangaming.com.

Some 3D action games like 007 Golden Eye (Rare, Nintendo, 1997) and Duke Nuken 3D (3DRealms, FormGen, 1996) allow players to break windows, smash computers and blow other objects to make the gameplay more real and to please the players which enjoy themselves through a mix of competition and destruction - Killers [4].

However, this free destruction does not affect the gameplay and does not help to achieve the game objectives, so these game spaces are considered static too [14]. Actions of locking and unlocking doors are not considered space manipulation either. These actions only change the object status; they do not change the object's function.

Figure 6. Landscape and constructions built in Minecraft. Source: wallpapers-house.com.

Elverdam and Aarseth propose a slightly different classification for the manipulation of the game space, which they called environment dynamics [15]. A game has **none dynamics** if no changes to the game space are possible. Football, Chess and Tetris (Pajitnov, 1984) are games with none dynamics. A game has **free dynamics** if the player is allowed to make additions or alterations to the game space almost everywhere. Strategic games like Ultima IX: Ascension (Origin Systems, Electronic Arts, 1999) and Age of Empires (Ensemble Studios, Microsoft, 1997) have free dynamics. If such alterations only alter predetermined locations, then the games have **fixed dynamics**. Actions games like Half-Life (Valve, Sierra, 1998-2007) and Resident Evil series (Capcom, 1996-2019) have fixed dynamics.

The player's ability to manipulate space can be correlated to the boundaries of space exploration. The limits to exploration can be characterized as **hard boundaries**, that is, these boundaries offer absolute restrictions in the gameplay. Otherwise, **soft boundaries** are obstacles or barriers that can be traversed under certain conditions [9], such as if they are opened or destroyed.

Fernandez-Vara [11] expands the analysis of space manipulation in games where the player affects the space and leaves traces on it. Thus, she says that a game has a **persistent gameworld** when the state of the objects and characters must be consistent throughout the gameplay, and changes cannot be undone after the player leaves an area. First person shooter games like Doom, Far Cry 3 (Ubisoft Montreal, Ubisoft, 2013) and Battlefield usually have persistent gameworld. On the other hand, a game has a **non-persistent gameworld** when a segment of the space is restored after the player had passed through it and had overcome all the obstacles and enemies. Thus, if the player went back to a segment, the space and its obstacles would be restored and the same enemies would be revived. Restoring the space is an interesting feature to make gameplay more difficult, but the narrative becomes incoherent. Adventure games like Super Mario World have non-persistent gameworld.

C. Player's Presence

Aarseth still suggests another classification for space in games according to the player's perspective [7]. He defined an **omni-present perspective**, which occurs in Chess and Football. In these games, the player has a complete overall view of the game space [15]. He also defines a **vagrant perspective** in games like Doom and Everquest (Daybreak Game Company, 989 Studios, 1999-2018), where the player's perspective follows an avatar. The player uses strategic movements to explore the game space [7].

The view may be partially blocked in some games, but the player is able to examine the game space. Designers have used features called fog of war and black canvas to hide the game space [7]. Fog of war is the hiding of specific and often dynamic spatial information of the game, such as the enemy units' position, when none of the player's own units are in vision range of that part of the terrain. A player may only see parts of the game space where he has units in terrain [16]. Black canvas uses the same concept of fog of war. The avatar must traverse the game space, in order for the player to have more knowledge of the terrain [16]. X-Men Legends (Raven Software, Barking Lizards, Activision, 2004) uses black canvas to reveal the contours of the game space and use fog of war to display the position of the enemies according to the progress of the avatars through the facilities.

Player's position is clearly distanced and separate from the gameworld in some games. The player is given an illusion of presence inside the game space [9] in others. This visual perspective typically classifies the games in **first-person**, **third-person** or **isomorphic**.

First-person games usually provide the greatest sense of presence in the game space. Players feel immersed within the fictional gameworld. Chess (Fig 5a), Battlefield, Half Life, Far Cry 3 (Fig 7a) and F1 2016 (Fig 7b) use this visual perspective.

(a) (b)

Figure 7. First-person games. Sources: ubisoft.com and livemint.com.

In third-person games, the player sees his own avatar in game space. Third-person games give the player a representative clearly located inside the gameworld. The avatar acts as the player's agent in game [9]. God of War (SCE Santa Monica Studio,2005), World of Warcraft, Assassin's Creed: Brotherhood (Ubisoft Montreal, Ubisoft, 2010) (Fig 8a) and Need for Speed: Most Wanted (Criterion Games, Electronic Arts, 2012) (Fig 8b) use this perspective. However, many newer games allow the player to switch between first and third perspective.

(a) (b)

Figure 8. Third-person games. Sources: wsgf.org and gotogames.net.

Finally, isomorphic is an isometric perspective, which represents the 3D space as a projection in a 2D plane. Zaxxon (Sega, 1982), Marble Madness (Atari, 1984), Sim City 2000, The Sims (Maxis, Edge of Reality, Electronic Arts, 2000) (Fig 9a) and Diablo II (Blizzard North, Blizzard Entertainment, 2000) (Fig 9b) use this perspective.

(a) (b)

Figure 9. Isomorphic games. Sources: ign.com and gameranx.com.

Günzel expands the visual perspective classification including a **first-person plural** view [17]. This visual perspective considers that the player is a member of a group. An artificial intelligence controls the other members in game. In Call of Duty (Infinity Ward, Activision, 2003), the group does not separate and the player's perspective is vagrant. In Tom Clancy's Ghost Recon (Red Storm Entertainment, Ubisoft, 2001), the player can control any member in the group and switch the perspective to that member. Player's view of game space extends according to the position of the avatar used. Grand Thief Auto V (Rockstar Games, 2013) allows the player to switch his perspective too, since in some missions the player can choose a character in gameworld who will take the mission.

IV. THE EMERGENCE OF LOCATION-BASED GAMES

This section presents the emergence of location-based games, which we consider it has been the latest innovation in the use of space in video games. The previous studies cited in Section III did not mention located-based games.

In location-based games, the player's position in game space is relative to his position in physical world. Botfighters (It's Alive, 2001), CodeRunner (RocketChicken Interactive, 2012), Uncle Roy All Around You (Blast Theory, 2003), Can You See Me Now? (Blast Theory, 2003) and The Journey (A. Jakl, 2004) are some of the first popular location-based games.

Kiefer defines location-based game as a game which is supported by localization technology and integrates the position of (one or several) players as main game element into its rules [18].

Equipped with wireless technologies and GPS capabilities, video games have abandoned their original home – the video game console or the computer – and made their way into physical space as mobile and pervasive applications [10].

In location-based games, the rules guide the player movement to a certain location in a real-world environment. These locations may be an absolute position defined by GPS coordinate or a relative position that may be relative to the current location of the player himself or another player [18]

The spatially of location-based games can be classified in discrete or continuous. The actions relevant for the game happen at certain predefined locations in discrete games. On the other hand, actions can take place anywhere on the game space in continuous games [18].

Location-based games encourage the mobility of players through urban spaces [19] In addition, the integration of position and movement into the game concept offers a variety of new possibilities to the gameplay [18]

Location-based games use different features to add a virtual layer over the real world. Some location-based games use a mixed reality to map the virtual layer to the physical world through reasoning and imagination. Botfighters, GeoTicTacToe (C. Schlieder, P. Kiefer, S. Matyas, 2006) and CityPoker (Geogames Team, 2014) use this feature. In Zombies, Run! (Six to Start, 2012) (Fig 11a), the player must escape the zombies and collect supplies on runs to build up his shelter base. Parallel Kingdom (PerBlue, 2008) (Fig 11b) was the first location-based RPG. Players gathered items around the gameworld and could choose to duel against other players or non-player characters (NPC) in controlled city arenas or anywhere outside in gameworld.

(a) (b)

Figure 10. Location-based games. Sources: vulcanpost.com and xda-developers.com.

Otherwise, other location-based games use augmented reality provided by a mobile device to map the virtual layer to the virtual world, so the player does not need to use his imagination. Virtual objects are displayed on the screen of mobile devices, but it is necessary to move in the physical world to acquire them [20]. Ingress (Niantic, 2013) and Pokémon Go (Niantic, The Pokémon Company, 2016) (Fig 11a) are augmented reality location-based games.

We consider that Pokémon Go has been the most emblematic location-based game. Pokémon Go design was based on a location-based treasure hunt game called Mogi (Newt Games, 2003), which was only available in Japan [21]. Pokémon Go addresses mobility, spatial, social and surveillance [20] [22]. However, unlike other location-

based games, players do not see themselves on the screen in Pokémon Go. The game does not allow meetings [20], but it encourages players to look for other players around [22].

The augmented reality used in Pokémon Go allows players to see Pokémon characters through the mobile device, when it is superposed to the physical environment [20]. The gamespace is attached to the device camera. Thus, the players must photograph the Pokémon characters to capture them [21], as shown in Fig 11b.

Games that are played with gestural controllers may also help integrating the space of the player in the fictional world [11], but they are not considered location-based games. In Kinect Sports (Rare, Microsoft, 2010), the player's physical gestures and body movements are mapped and turned into gameplay.

Figure 11. Pokémon Go - an augmented reality location-based game. Sources: blog.socialminer.com and digitaltrends.com.

V. PREVIOUS STUDIES OF SPACE DIMENSIONS

A. *Introduction*

This section describes the representations of space found in video games. Most games are mapped in two or three dimensions, since it creates a sense of familiarity and make it easier for the player to understand the game world.

The first video games have presented abstract or open spaces to their players. However, games soon began to simulate bounded or indoor spaces as well, usually depicting them via top-down, map-like views of a character moving through a maze or walled area[8].

Günzel [17] defends that most games have at least a 1.5-dimensional space of interaction, as one find in racing games, where topologically speaking the road provides only one direction (forward), but the possible deviation from the path is what the gaming principle hinges on.

Zagal [23] proposes that there are levels of spatiality in games. First, he says the player perceives the representation of the space from a particular point of view. This representation is related to the rendering of game elements and is limited to technology [13]. Zagal also differentiates cardinality of the space in relation to gameworld and gameplay. He defines the cardinality of the gameworld as the options of navigation or movement the player has within the gameworld and defines the cardinality of gameplay as the space the player can effectively act in.

In the next subsections, we will discuss the spaces most commonly found in current games: 2D and 3D game spaces.

B. *2D Spaces*

The space is represented in a two-dimensional plane in 2D games [13]. In this article, we consider that a 2D-game refers to a game that has a two-dimensional gameworld. The most used camera perspectives are **top-down** or **back and forth** [7]. The gameworld covers a single screen or extends the boundaries of the screen.

In the first digital games, like Pong (Atari, 1972), the gameworld was contained in a single screen. This setting is the most basic graphic representation of space in a game, which dimensions of the gameworld match the size of the screen [13]. The player has a complete view of the game space, that is, the player perspective is omni-present. Galaxian (Namco, 1979), Donkey Kong (Nintendo, 1981) (Fig 12a) and Frogger (Konami, Sega, 1981) (Fig 12b) are some early single screen games. Nowadays, single screen games are commonly released for mobile devices. Jewels games like Candy Crush are examples of these games.

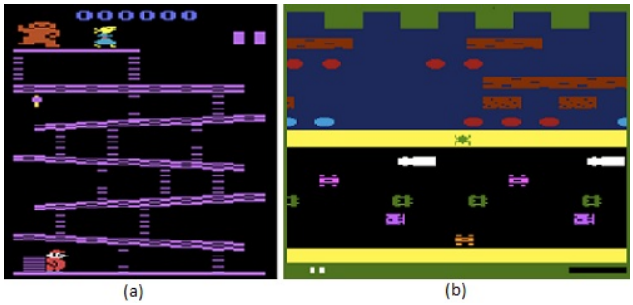

Figure 12. Early single screen games. Sources: atarimania.com and atariage.com.

Some early single screen games used a technique called wraparound to extend the 2D spaces [13]. Thus, when a game element reached a gameworld boundary, it reappeared on the opposite side. Wraparound enriched the gameworld, but player's orientation had become a bit more complicated. This effect is only allowed in some cracks in the boundaries of the maze in Pac-Man (Namco, 1980) (Fig 13a). Otherwise, the gameworld boundaries have no limits in Time Pilot (Konami, 1982) (Fig 13b). The arrows outside the screens in the Fig 13 show the limitless boundaries.

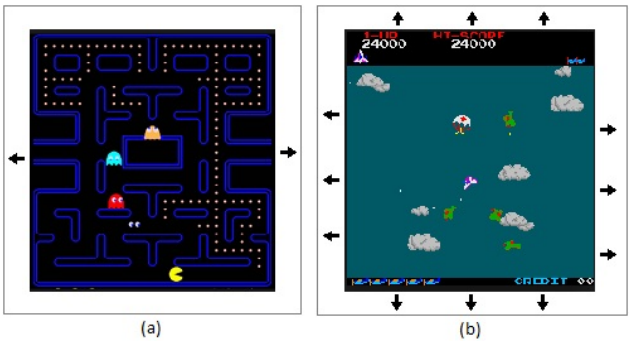

Figure 13. Single screen games that use wraparound technique. Sources: veja.abril.com.br and retrogames.cc.

The space is segmented in games whose gameworld extends the screen boundaries [13]. The avatar cannot go back to the previous scenario in some games with segmented space [7].

The gameplay can be one-dimensional or two-dimensional in 2D games. The player can only move in one direction in games with one-dimensional gameplay. Thus, the allowed movement is back and forth or up and down. The avatar can jump to skip or defeat the enemies in some games where movement is back and forth, but this feature does not mean that the up and down movement is allowed. So, gameplay is not two-dimensional in these games.

The segmentation of the game space can be either discrete or continuous for each dimension of the gameplay.

In 2D games with discrete segmentation, the space is usually represented in adjacent screens. Each one portrays a fragment of the gameworld and contains a challenge to be overcome to reach the next screen [13]. The segmentation is discrete in Pitfall (Activision, 1982), Smurf: Rescue in Gargamel's Castle (Coleco, 1982) (Fig 14a), Prince of Persia (Brøderbund, Ubisoft, 1989) (Fig 14b) and The Legend of Zelda (Nintendo, 1986). But the gameplay is one-dimensional in Smurf whilst the gameplay is two-dimensional in the other ones.

(a) (b)

Figure 14. 2D games with discrete gameplay. Sources: atari2600.com.br and techtudo.com.br.

On the other hand, the screen is displayed with a scroll in games with a continuous segmentation [13]. The space is represented continuously. The player has a sense of gameplay progression. River Raid (Activision, 1982), Spy Hunter (Bally Midway, 1983), Super Mario Bros and Jetpack Joyride (Halfbrick Studios, 2011) (Fig 15a) have a one-dimensional and continuous gameplay.

Gameplay is continuous and two-dimensional in many other games which the player controls an aircraft or spacecraft. In R-Type (Irem, 1987) or Gradius III (Konami, 1989) (Fig 15b), the avatar moves in all four directions within the screen, trying to follow the scroll.

(a) (b)

Figure 15. 2D games with continuous gameplay. Sources: halfbrick.com and retrogamer.net.

C. *3D Spaces*

The introduction of 3D graphics to games has literally added a new dimension to video games that calls for a reorientation of games research and design, and asks us to adjust our thinking about video games [3].

Gameworlds have become more detailed and complex. 3D game spaces have transformed the player's experience, encouraged navigation, exploration and manipulation of space. The graphical representation of the environment is redrawn constantly to the screen, creating an impression of continuous movement through navigable space [9].

We will keep the same notation used in 2D games, so 3D games means that the game has a three-dimensional gameworld. 3D games allow avatars to crawl, jump, run, fly, climb and other actions [3]. Players' imagination and emotional engagement were stimulated. 3D games can better immerse the player in a virtual and affective world [6].

Gameplay can be one-dimensional, two-dimensional or three-dimensional in 3D games. The segmentation of the game space can be discrete or continuous as well for each dimension of the gameplay.

Other studies have not come across any examples of discrete representations of one-dimensional gameplay in 3D games [13] [14], so this setting is continuous by defect. They cited the 3D racing games, such as Gran Turismo (Polyphony Digital, Sony, 1997), which have the same controls and therefore the same cardinality of their 2D counterparts [13].

Gameworld in 3D games with two-dimensional and discrete gameplay is displayed on images that are replaced by other images as the player moves [14]. This setting of the game space slows down the pace of navigation and is more suitable for puzzle games like Myst [13] (Fig 16a). The gameworld in two-dimensional and continuous 3D games allows the player to navigate in a 3D real time environment [13]. This setting is seen in early first-person shooter games like Wolfenstein 3D (id Software, Apogee Software, FormGen, 1992) (Fig 16b), Doom and Battlezone (Actvision, 1998).

(a) (b)

Figure 16. 3D games with two-dimensional gameplay. Sources: cyan.com and gamespot.com.

Gameworld provides a large freedom of movement in 3D games with three-dimensional and discrete gameplay. This setting requires a better sense of orientation from the player [13]. The 3D representation of the game space is segmented using different camera views in the discrete configuration. Time Crisis (Namco, 1995) and the stalker game Metal Gear Solid V: The Phantom Pain (Kojima Productions, Koname, 2015) (Fig 17a) portray a discrete configuration. The continuous configuration of the 3D spaces seems to be appropriate for action games, where the player can move around doing any actions needed. Far Cry 3 and Unreal Tournament (Epic Games, Digital Extremes, 1999) (Fig 17b) has continuous gameplay. Red Dead Redemption II (Rockstar Games, 2018) is a 3D action-adventure game played from a third-person perspective that had a great success lately. The player may freely roam

a North American western open world (Fig 18). Player can explore and interact with this huge gameworld while witnessing events or performing missions.

Figure 17. 3D games with three-dimensional gameplay. Sources: g1.globo.com/tecnologia/games/ and variety.com.

Figure 18. Huge and open 3D gameworld of Red Dead Redemption II. Sources: techcrunch.com and ign.com.

VI. PROPOSAL TO UNDERSTAND THE GAME SPACE

As we saw in the previous studies, there are more than one way to discuss space in games. It is our understanding that one can go further and analyze the game space in four aspects:

1. **gameworld** - the space where the game happens as imagined and watched by the designer and by the player. Interactive fiction, such as The Hitchhiker's Guide to the Galaxy (Infocom, 1984), often show good examples of a large gameworld with an zero-dimensional visualization.
2. **gameplay** - the space where the player-tokens move. This space is usually the same as the gameworld space, but it can be actually smaller or bigger. In Kaboom! (Activision, 1981), the player sees a 2D space but can only move in one dimension, while in Betrayal at Krondor (Dynamix, Sierra, 1993), the player has portals to move between disconnected parts of the map (counting as one, at least partial, additional dimension).
3. **player perspective** - the visual perspective that the player has of the space. In Wolfstein 3D the game space is 2D, but the player has a 3D perspective.
4. **game view** - the space as projected by the interface, as in 2D screens or 3D goggles. Both views can use augmented reality (AR).

Every game happens in a space: the gameworld. While we will mostly discuss games that have some similarity with the concept of world, there are games that are zero-dimensional, since the space is not important, such as a trivia game. Game designers like to create spaces even for abstract games. One example of this is Myst. The real gameworld in this game is just a sequence of puzzles, very abstract, but the designers made it look like a real world.

Video games mainly take place in 2D and 3D gameworlds. However, we thought how one could design a game in a 1D gameworld. So, this world would be a straight line that contains different positions, but without width. The token moves backward or forward until it reaches the finish point. Each position would be depicted by a color and its length. The color could change after a while. The token could only remain in the position or exceed it in a certain color.

We also wondered if it would be possible to design and develop a game in a higher dimension than 3D. Thus, we found the impressive Miegakure (Marc ten Bosch, in development), which calls itself as the first 4D game. Miegakure takes a 3D slice of a 4D world. The 3D gameplay focuses on exploring a 4D world in a 3D perspective viewed in a 2D screen. In each level, the player can perform miraculous feats to move through the fourth dimension.

Topologically, gameworld's dimensions can be discrete or continuous. A game may have a discrete dimension and a continuous one. Although in Math we usually think in integer dimensions, game jargon also acknowledge partial dimensions. Our proposal intends to include two modifiers to qualify the gameplay dimensions.

First, we propose a '-' modifier. This signal would indicate that the player's freedom of movement is limited in some dimension or the gameplay dimension is not fully.

We also propose a '+' modifier. This signal would indicate the possibility to teleport throughout the gameworld. In Super Mario World, the player can teleport to five distinct points on the gameworld through the secret world of Star Road. The game design can use tricks to expand the gameworld dimension sometimes. So, the player perceives gameworld in a higher dimension. The puzzle game Fez has a 2D gameplay, but the player can rotate between views of the 3D gameworld.

The application of these modifiers may be better explored in future works.

It is common, but not mandatory, that player-tokens move or use the complete gameworld, that is: gameworld and gameplay have the same dimensions. Space Invaders (Taito, 1978), is a 2D game where the spaceship moves in one dimension, but its bullets travel in the complete 2D gameworld.

The perspective is how the player perceives the game. Some games have a perspective that has more dimensions than the game. We already pointed to Wolfenstein 3D, which is actually a 2D game, since it has no idea of vertical space. However, the game appears to the public as a 3D game. GameMaker Studio 2 (YoYo Games, 1999-2019), for example, has a special mode for implementing games of this kind.

Player's perspective can also be higher than the dimension of the gameplay in some games. Guitar Hero represents the game space continuously as an extended guitar neck in 2D gameworld and 1D gameplay, but player perspective is 3D.

We have included the '.5' modifier to player perspective. We limited the use of 2.5D for isometric projection. However, in game industry, it is common to talk about 2.5D in some games with 2D gameplay and 3D

representation like Super Smash Bros. (HAL Laboratory, Nintendo, 1999-2018) series and Street Fighter IV (Capcom, 2008), or in games which combines 2D sprites and 3D scenarios like Breath of Fire IV (Capcom, 2000).

In our proposal, gameplay and gameworld represent these game space characteristics. Starcraft, for example, has a 3D gameworld, but the 3D gameplay is limited since has two continuous dimensions and a discrete one (z-axis). Thus, we rated Startcraft with 3D- gameplay and 2.5D perspective.

When we extend the game space analysis to location-based games, anyone can easily think that their gameworlds are 3D. However, we conclude that especially Pokémon Go has a 2D gameworld that maps our 3D physical world. Gameplay is 2D, but the player perspective is 3D. Game view uses AR.

We have listed some examples in Table I that will show how these characteristics of game space can be mixed:

TABLE I. GAME SPACE DIMENSION CHARACTERISTICS

Game	World	Play	Perspective	View
Guitar Hero	2D	1D	3D	2D
Pitfall	2D	2D–	2D	2D
Donkey Kong	2D	2D	2D	2D
Wolfestein 3D	2D	2D	3D	2D
Super Smash Bros.	2D	2D	3D	2D
Pokemon Go	2D	2D	3D	2D AR
Super Mario World	2D	2D+	2D	2D
Fez	3D	2D+	2D	2D
Diablo II	3D	2D	2.5D	2D
StarCraft	3D	3D–	2.5D	2D
Doom II	3D	3D	3D	2D
Minecraft	3D	3D+	3D	2D
Minecraft VR	3D	3D+	3D	3D
Miegakure	4D	3D	3D	2D

In addition to this analysis, we also created an ontology, shown in the Fig 19, to fund this understanding and to stand for a comprehensive overview of the game spaces. The ontology was created using the OntoUML specification [24].

The game space can be analyzed in relation to spatiality and perspective. Spatiality examines gameworld and gameplay. Perspective involves player perspective and game view.

We have also joined the concepts of possibility of manipulation of game spaces from the other studies and we incorporated them into the ontology. However, we must point out that manipulation of game space should not be confused with manipulation of objects in game space.

VII. CONCLUSION

This study presented the evolution of the representation of game spaces. We cited classic games from Pac-Man and Super Mario Bros up to present games as Pokémon Go and Red Dead Redemption II. We proposed to deepen the analysis of the dimensions of game spaces in four aspects: gameworld, gameplay, player perspective and game view.

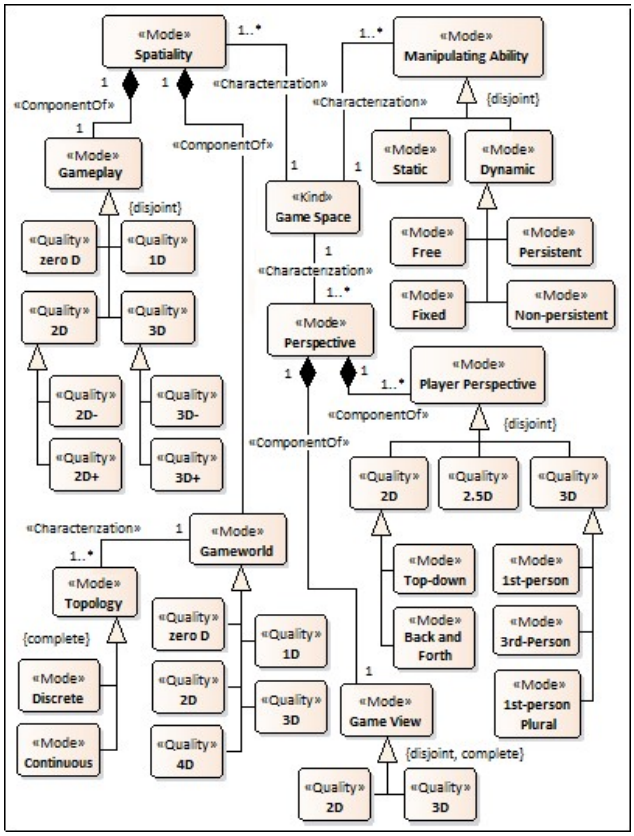

Figure 19. Game Space Taxonomy.

Architecture patterns for representing game spaces are recurrent and inspired by reality. These standards are built and modified according to the demands of the gameplay [12].

In 2007, Aarset argued that there have been no significant changes in games regarding playability, themes, tasks, sub-genres, and dramatic structure over the last two decades [14]. After our analysis, we agree that this situation has been held to this day.

Aarset explained that what had changed at that time were the sceneries, landscapes and (3D) visual effects. The innovation had taken place in increasing the complexity of the spatial representation [14]. However, we consider that location-based games and the use of augmented reality are the main innovations in relation to the representation and use of space in games in recent years.

The game space representation of the gameworld and gameplay has evolved in many game franchises. The Legend of Zelda series illustrated in Fig 20 clearly evidence this evolution since its first release in 1986.

The first game - The Legend of Zelda (Fig 20a) had a 2D gameworld, a discrete gameplay and a top-down view. The gameworld was segmented in rooms connected by doors and secret passages. The Adventure of Link (Nintendo, 1987) had a top-down player view in the gameworld, but Link - the avatar - had to enter in some nested spaces to face stages with a back and forth view. In A Link to the Past (Nintendo, 1991) (Fig 20b), the game

returned to a unique top-down view. The game had a larger and more detailed gameworld.

Ocarina of Time (Nintendo, 1998) (Fig 20c) introduced the 3D gameworld and 3D gameplay into the series. The player view is 3rd-person. Link performs basic actions such as walking, running, attacking and jumping. Throughout the game, Link learns melodies that allow him to teleport to previously visited locations in the game. The next games had the same controls and mechanics for a 3D gameplay.

In Skyward Sword (Nintendo, 2011) (Fig 20d), the representation of the gameworld became richer due to the console's better graphical rendering capabilities. Link has performed more actions such as climbing, swimming and gliding. Table II summarizes the game space in Zelda series.

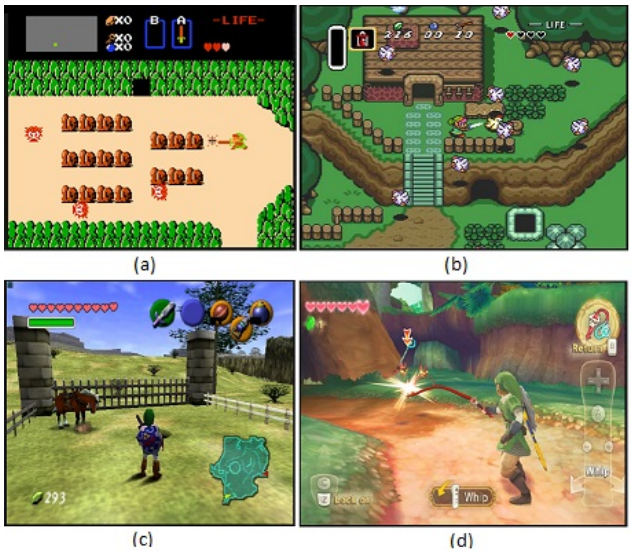

Figure 20. Game spaces in The Legend of Zelda series. Sources: en.wikipedia.org, gonintendo.com, resetera.com and jogorama.com.br.

TABLE II. GAME SPACE CHARACTERISTICS IN THE LEGEND OF ZELDA SERIES

Game	World	Play	Perspective
The Legend of Zelda	2D	2D discrete	top-down
The Adventure of Link	2D	2D continuous	top-down, back and forth
A Link to the Past	2D	2D continuous	top-down
Ocarina of Time	3D	3D+ continuous	3rd-person
Skyward Sword	3D	3D continuous	3rd-person

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