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Architecture and Videogame, The Spatial Connectivity and Digital Twinning

Prin Meesupya[1]* and Likit Kittisakdinan[2]

[1,2] Faculty of Architecture, Silpakorn University, Bangkok, Thailand

* Corresponding author e-mail: prin.mees@gmail.com

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Abstract

This research examines the evolving relationship between advanced computerization in video games and architectural design. It traces gaming development from arcade systems to 2D and 3D perspectives, each representing different visual experience models of their eras. By analyzing technological advances in gaming, the study explores how evolving equipment has transformed players' perceptual experiences, fostering innovative reading approaches. The investigation emphasizes the role of advanced computer systems in upgrading game visuals to achieve heightened realism or hyperrealism. The digitalization of architectural spaces, developed through virtual experiences, challenges traditional boundaries and promotes new perspectives. This transformation emphasizes the interplay between architectural design and the video game industry. Designing virtual spaces and interiors in video games resembles architectural spatial realization. The theoretical framework used in generating virtual spaces in video games could serve as a basis in design of actual spaces. This research explores architectural projects through the lens of video game media, emphasizing how mechanisms and concepts from gaming technology connect with and enhance architectural creativity. It investigates how the dynamics of spatial perception in virtual reality could enrich real-world architectural design. Supported by case studies of three completed public projects, the study focuses on human sensory experiences through the theoretical emphasis between designing architectural spaces in relation to designing videogame spaces.

Keywords

Video game media; Architectural perception; Virtual-sensory experience; Advance in computer 3D-software.

1. Introduction

At present, video games constitute a paramount facet of contemporary global entertainment. Forecasts indicate a continuous surge in market value, projected to escalate by an annual increment of US$130 billion. (Mestre et al., 2006) Consequently, the landscape of video game media has undergone exponential expansion over the past four decades. This evolution is tied to heightened economic growth, propelling video game media towards an aspiration to emulate reality within the digital realm. This pursuit has driven video game media to replicate real-world environments within the virtual realm. The architectural configuration within video game media plays a pivotal role in achieving this objective, endeavoring to engender a sense of immersion among

players. (Mestre et al., 2006) Conceptually akin to architectural design, the purpose underlying the design of virtual spaces in video games aligns with the historical objectives of architectural design, emphasizing the utilization of space and navigating the constraints of material resources inherent to construction. (Totten, 2014)

The architectural elements influencing interaction and communication within video games parallel and connect with those of architectural representation and design. According to Eric Zimmerman, video games constitute a voluntary interactive engagement wherein one or more participant(s) adhere to predefined rules, constraining their actions to simulate artificial conflict with quantifiable resolutions (Zimmerman, 2004). The evolution of advanced computer systems has visually enhanced the communication of architectural concepts within video games since their inception. Consequently, video game platforms possess the capability to regulate player behavior, gameplay dynamics, and spatial utilization within their confines. Technological advances in computer systems have not only influenced but also altered the visual presentations associated with video game media.

The architectural presentation methods utilized in video game media employ a variety of perspectives, including elevations, cross sections, panoramic sceneries, and axonometric visions, mirroring the spatial manifestation techniques explored in architectural design. This evolution is intertwined with advances in computer technology, notably the choice of software profoundly impacts the dynamics of architectural presentation, with various programs like Computer-Aided Design (CAD), Digital Art Programs, and 3D modeling tools being pivotal in crafting virtual environments (Totten, 2014). These software tools adapt to the evolving video game platforms, thereby influencing architectural spatial perception in conjunction with device specifications and visual aspects. Consequently, the sensory experience of players is heightened, and architectural spatial constructs undergo transformation in alignment with the constraints imposed by the gaming equipment. Facilitated by advances in computer graphics technology, the leap of evolution is the very transition from a 2D to a 3D perspective. The depth in video game media impacts the spatial representation techniques, transcending traditional boundaries to offer immersive experiences.

The architecture of virtual environments represents a realm of information and experiences as an alternative or parallel to tangible reality. Recent technological advances advocate and affirm the spatial constructs within video games as entities capable of occupying physical dimensions akin to real-world spaces. These virtual realms, fluid and three-dimensional, allow players' uninterrupted transition between spaces, navigating, manipulating, and rendering them as tangible as physical environments (Tiemersma, 2014). Consequently, the dichotomy between design space in video games and actual architectural space becomes increasingly blurred, fostering mutual comprehension and integration between the two domains, much like digital twinning. This research endeavors to scrutinize the convergent and divergent connectivity between the reality of architectural spaces and their portrayal within video games, leveraging comparison to inspire design innovation.

This research article examines the historical evolution of media representations of video games, tracing their development from past to present while raising awareness of the phenomenon. It analyzes architectural design concepts and methods, focusing on their role in connecting video game aesthetics with real-world architecture. Relevant case studies are explored to clarify the interaction between virtual environments and physical architectural structures.

2. Methods

This research article explores the evolution of video game design, tracing its development from architectural drawings to contemporary gaming views. It highlights technological advances in gaming equipment and spatial design concepts. A thorough study was conducted to synthesize insights into how architecture and spatial perception are represented within virtual game environments. By employing a spatial and typological approach, architectural designs that share notable similarities (and differences) with those found in video games were systematically analyzed and synthesized. These designs were examined through detailed case studies, providing an in-depth comparison of virtual and physical spaces. The conclusion in this study is summarized into the convergences and implications that emerge between these two realms, offering new perspectives on how virtual environments can influence or reflect real-world architectural paradigms in a form a digital twinning. Ultimately, this analysis will deepen the understanding of how video game design and architecture interact, providing a comprehensive look at their converging aesthetics and functional elements.

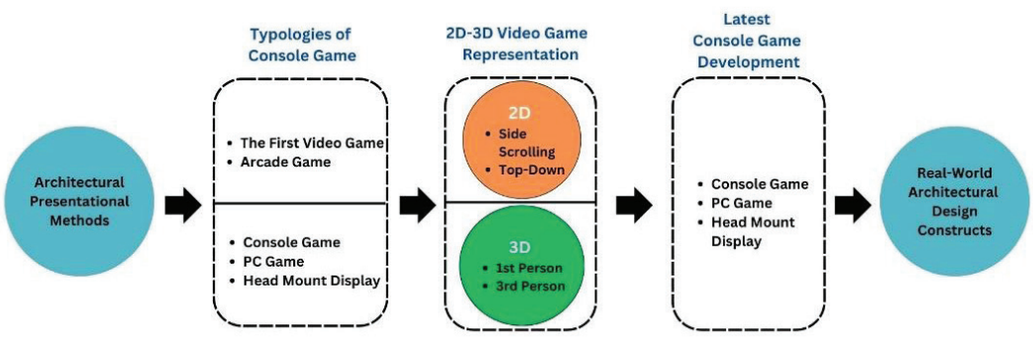


Figure 1. Conceptual Framework: Summarizing the study workflow to investigate spatial parallels and connectivity between architecture and videogames.

Source: Generated by the authors

3. Evolution of the Spatial Representation of Architectural Space through 2D and 3D Perspectives in Video Games

The inception of video games coincided with the rise of computer technology, marking a pivotal moment in entertainment media. Rapid digital advances propelled video games into mainstream culture, evolving alongside computer graphics technology tailored to advancing operating systems. In 1947, Thomas Goldsmith Jr. and Estle Ray Mann introduced The Cathode Ray Tube Amusement Device, featuring a 2D digital display resembling a radar screen where players used lasers to eliminate targets depicted by dots and lines (Büyükbaykal, 2020). This laid the groundwork for interactive digital entertainment. The integration of visual imagery into digital interfaces established dynamics between players and displays. Alexander Douglas pioneered the use of CRT displays, creating the Tic Tac Toe game in 1952 alongside the Electronic Delay Storage Automatic Calculator (EDSAC), enhancing human-computer interaction (Winter, 1996). This enabled players to engage in strategic competition against AI, revolutionizing gaming experiences.

In 1958, William Higinbotham revolutionized gaming with Tennis for Two, a pioneering 2D tennis simulation. It featured a side-by-side view that enhanced vertical ball trajectory depiction and incorporated distance calculations for ball intensity, improving players' spatial perception, making the virtual experience more realistic. In 1961, MIT students Martin Graetz, Steve Russell, and Wayne Wiitanen advanced gaming with Spacewar!,

the first multiplayer game across computer networks (Büyükbaykal, 2020). This game simulated spaceflight realistically, challenging players with gravitational fields akin to outer space. Despite these innovations, video game media continued to rely on 2D displays. Ken Thompson's Space Travel in 1969, using the Unix OS, shaped both gaming and major operating systems like Linux, Apple, and Microsoft (Ritchie, 1984).

The development of space design in video games traces its roots to Spacewar!, where players devised strategies within a 2D interface. This concept gained traction with subsequent titles like Asteroid and Pac-Man in 1979 and 1981 (Totten, 2014). Video game depictions of space mirrored real-world events such as the Apollo 11 mission in 1969, emphasizing space battle genres. However, early computer system limitations from 1960 to 1980, primarily serving military purposes, hindered aesthetic depth in video game imagery (Büyükbaykal, 2020). Despite hardware advances, these constraints persisted, limiting visual sophistication in video game displays and delaying broader aesthetic and perceptual enhancements.

Figure 2. Spacewar!, the game with the simulation of fights between spaceships presented in a 2D perspective dimension.
Source: https://www.thoughtco.com/history-of-spacewar-1992412

In 1981, games such as Defender and Adventure on the Atari console demonstrated notable advances in spatial awareness (Mcgonigal, 2011). These console games allowed players to navigate dynamic 2D environments, moving seamlessly between scenes triggered by re aching the edges of areas. Despite hardware constraints limiting visuals to images (Totten, 2014), textual narration complemented gameplay, aiding player understanding across levels. This system of contextual areas enhanced visual perception, engagement, and strategic diversity, offering immersive gaming experiences.

Figure 3. Defender, the game with the simulation of spaceship combat, maneuvered within the 2D perspective, whose spatial and contextual environments could be changed in different areas and conditions.

Source: https://forum.defold.com/t/planetoid-defender-fan-game/71769

Following the advent of the Unix Operating System (OS), for computer, essential components like CPU, RAM, ROM, and GPU improved, thereby enhancing video game visuals with better resolution, intricate patterns, and detailed object rendering (Büyükbaykal, 2020). Dynamic adjustments in lighting, shadows, and colors further augmented realism and aesthetic appeal. Games like Super Mario Bros. utilized these enhancements to change architectural styles, scenery, and terrain across levels. Transitions between outdoor and indoor environments and ascensions expanded player engagement by enhancing curiosity and perception of level details, resembling architectural drawings, enriching the gaming experience.

The evolution of 3D graphics in video games began with the integration of computer operating systems into OS systems, enhancing rendering clarity and efficiency (Konzack, 2006). This advance allowed games to depict realistic architectural designs. Battlezone (1981) pioneered 3D tank driving simulation using vector graphics (Totten, 2014), enabling free exploration of virtual environments. Subsequent arcade systems introduced polygonal images with textures and surface mapping (Wardyga, 2023), enriching architectural spaces aesthetically. Games like Wolfenstein 3D and Doom (1993) expanded 3D capabilities with first-person shooter perspectives, enhancing player immersion and spatial realization akin to architectural views. Level designers utilized these advances for dynamic environmental changes and realistic scenarios.

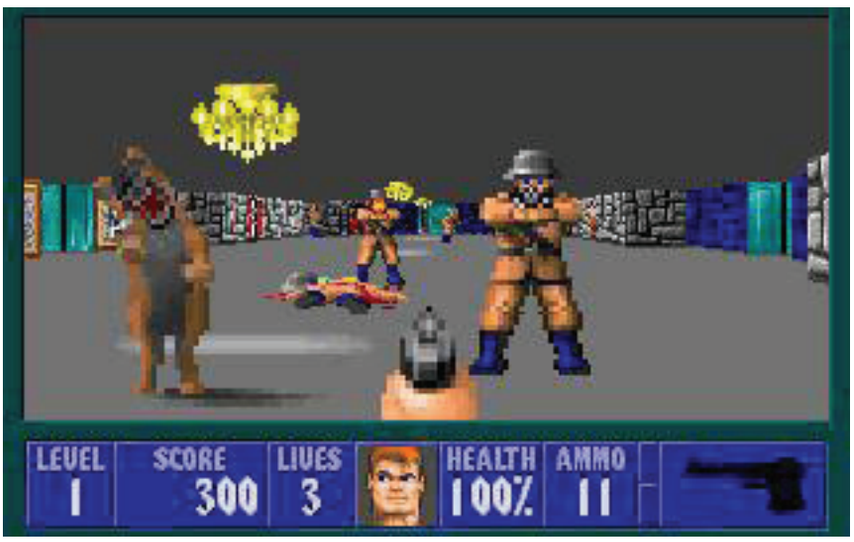


Figure 4. Wolfenstein 3D, the game is presented with a 3D moving images from the first-person shooter's perspective where the depth of space can be sensed.

Source: https://store.steampowered.com/app/2270/Wolfenstein_3D/

The principles governing the presentation of perspective in both 2D, and 3D video games draw inspiration from architectural renderings. This alignment is rooted in the recognition that varying perspectives afford distinct awareness and comprehension at different levels. Within the realm of video game design, practitioners manipulate spatial arrangements to optimize a player's interaction and engagement. Christopher Totten's work, An Architectural Approach to Level Design, serves as a foundational framework, encompassing various architectural models, including (Totten, 2014):

1. Floor plan: Floor plans are crucial in both architectural and video game design, offering a top-down perspective that defines spatial relationships and design elements. Positioned approximately 140 centimeters above floor level, elements above this threshold are depicted distinctly, often in solid black or with specific colors according to architectural conventions. Le Corbusier emphasized the floor plan's role in creative processes, noting its essential function as a generator of spatial conception (Corbusier, 1931). In game design, starting with a sketch of a floor plan helps designers shape spatial configurations and organize functional elements within the game environment. Players often interact with these floor plans presented as maps, aiding navigation and orientation.

2. Section: for the presentation and communication of views through sectional images, parallels can be drawn to the utilization of floor plans to define spatial characteristics and perceptible boundaries. A cross-sectional view describes vertical dimensions, offering insights into spatial volume and height within the depicted area (Totten, 2014). Movement through the section in the horizontal plane provides perspective on spatial arrangements. Additionally, the implication of space in the vertical plane articulates the perception of height and enveloping spaces adjacent to the player's viewpoint.

3. Elevation: within the scope of architectural design, an elevation serves as a vital component of vertical articulation, associated to sectional representations. Its role extends to formalizing the exterior architecture, elevating players' enhanced perception and emotional engagement with the depicted space or atmosphere. In video game design, elevational planes are employed not solely for spatial awareness but primarily to conceptualize and articulate the atmosphere and architectural elements. Through the portrayal of atmosphere, environment, and architecture, elevations act as a canvas for experimentation and encourage observation, fostering a deeper engagement with the constructed world (Pauwels et al., 2011).

4. Axonometry: The axonometric view offers a comprehensive portrayal of 3D spatial constructs, encompassing height, depth, and communicable essence of effective architectural visualization. This technique delivers a series of viewpoints across various representations, including Plans, Sections, and Elevations. Its application is particularly important within the presentations of games, wherein it serves as a fundamental tool for transposing spatial configurations from 2D architectural drawings into immersive 3D environments. By inclining the field of view at an angle ranging between 30 to 45 degrees, these representations transcend the confines of two-dimensionality, imbuing spaces with a sense of three-dimensionality (Christenson, 2019). Consequently, the utilization of axonometric views in conjunction with intricate spatial designs engenders a heightened sense of immersion, surpassing the capabilities of traditional 2D depictions.

5. Perspective View: a fundamental aspect of landscape representation offers an engaging depiction of 3D environments. Diverging from axonometric perspectives, which rely on geometric principles of parallel lines and angles, perspective views utilize Vanishing Points (VP) to deliver images with depth and realism. This technique orchestrates the illusion of depth within the image, referenced to the observer's vantage point. Within the realm of environmental design in gaming contexts, landscape perspectives serve as tools for visualizing a game's conceptual designs and transcribing spatial configurations (Zimmerman, 2009). Whether executed through traditional hand-drawing techniques or simulated via digital 3D software, architectural compositions realized through a 3D perspective enable immersive and detailed depictions of virtual environments.

In modern digital video game systems, architectural presentation is vital for designing and showcasing virtual environments. These visuals, akin to architectural models, depict landscapes, interiors, and entire worlds (Pearson, 2019). However, the medium of video games facilitates a heightened level of interaction between players and the game system, fostering immersive experiences that engross players within virtual realms (Mestre et al., 2006). Christopher Totten (2014) explains that 2D and 3D graphics serve as crucial means of communication between game systems and player perception, fulfilling designers' intentions. Mastering game mechanics and controls is essential for effective navigation and understanding of virtual spaces (Zimmerman, 2009). By embracing the landscapes offered within the gaming experience, players gain insights into the spatial perceptions, limitations, and advantages inherent to each game's environment.

In defining the classification of viewed imageries within video games, scholars Christopher Totten (2014) and Brian J. Wardyga (2023) assert the utilization of two primary camera angles: the 2D view and the 3D view. Each perspective embodies a system delineated by varying styles of gameplay communication. This includes the portrayal of environments, scenery, and architectural elements within video games, each engrained with objectives contingent upon how each view is employed. These perspectives are characterized by the following components:

1. 2D view: the emergence of digital video games in the 1960s introduced the industry's initial adoption of the 2D view as a primary means of spatial representation, offering players a visual insight into game environments. However, this choice suggests a potential disparity between the capabilities of 3D presentation technology and the conceptual aspirations of designers. Notably, the familiarity with 3D perspective views since the Renaissance era implies that limitations in designers' creative processes may not be solely attributed to conceptual constraints (Millon, 1994). Rather, technological limitations of the time may have hindered the execution of realistic communications, thereby necessitating the utilization of the 2D perspective view in various games with actions such as jumping, shooting, and exploration. This reliance on the 2D depiction persists as it enables players to perceive and navigate through spatial challenges within the constraints of physical space (Totten, 2014).

1.1 Presentation of Side View (Side-Scrolling Space): The side-scrolling perspective entails a gameplay experience wherein the player navigates various environments through lateral movements, resembling a traverse between architectural cross-sections and forms. Consequently, the character's actions, such as jumping, climbing, flying, or shooting, demand an acute awareness of spatial dimensions beyond the immediate field of viewpoint. When areas wider than the screen's presentation are concealed from the player's sight, a sense of risk emerges, requiring players to undertake leaps of faith. This side view promotes players' understanding of spatial dimensions within the scene, enabling them to grasp both height and width and determine the permissible range of movement or usable space based on their spatial perception.

Figure 5. Super Smash Bros., the game is depicted with Side-Scrolling Space that uses sectional representation used in architectural design.

Source: https://www.newgamenetwork.com/article/2055/super-smash-bros-ultimate-review/

1.2 Presentation of Top View (Top-Down Space): The top view perspective simulates an architectural presentation of a building's floor plan. Through this perspective, lines of sight extend from the player character into the displayed field, providing a clear boundary, scope, and definition of playable area. Character's movement within this framework resembles traversing within a two-dimensional architectural floor plan. Encountering areas beyond the character's immediate awareness instills curiosity in players, prompting exploration beyond the confines of the initial space. This pursuit of uncharted territory presents players with fresh spatial perspectives, thereby enriching their gaming experience.

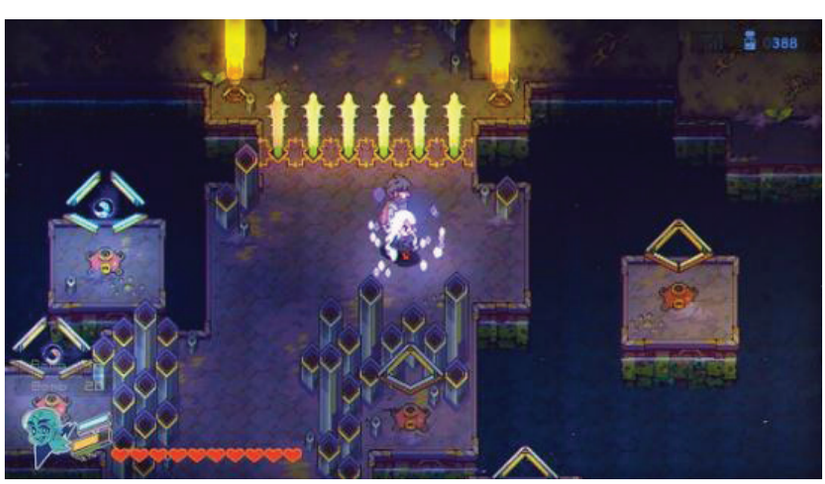


Figure 6. Eastward, the game is presented with Top-Down Space utilizing the techniques of architectural plan.

Source: https://store.steampowered.com/app/977880/Eastward/

2. 3D View: the presentation of a 3D view represents a continuous evolution driven by advances in computer technology. Its primary objective lies in empowering players with a heightened sense of realism during character role-playing experiences. By striving to replicate real-world environments, the 3D perspective in video games encompasses two primary viewpoints: the first-person perspective and the third-person perspective.

2.1 First Person View (First Person Perspective): The first-person view situates the player's perspective near the head of the in-game character they control. Communication within this viewpoint mirrors the character's vision, encouraging a direct sense of embodiment for the player. This perspective closely mirrors the natural human visual experience of perceiving the physical world. Consequently, players gain a comprehensive understanding of virtual environments, allowing for clear spatial perception and cognitive mapping. As players become acquainted with the virtual landscape, the first-person perspective enhances emotional engagement with the environment, aligning with Mestre's theory of immersion, culminating in an elevated sense of presence and reality within the virtual realm (Mestre et al. 2006).

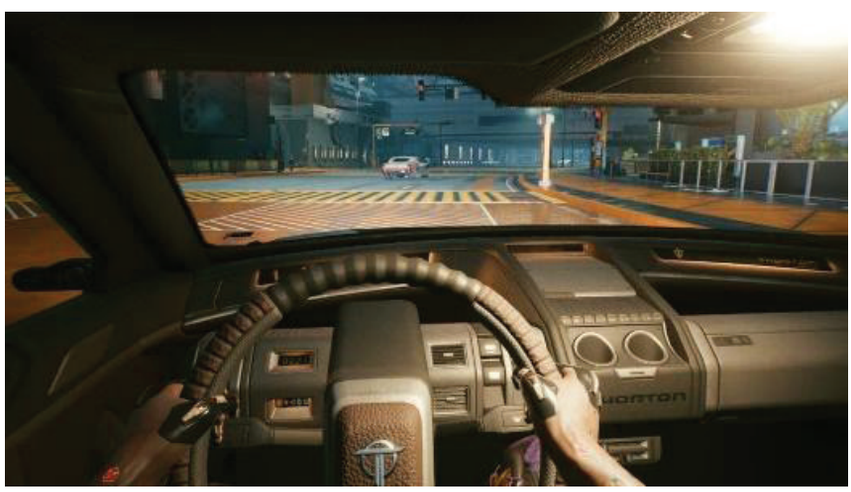


Figure 7. Cyberpunk 2077, the game is presented with First Person View, simulating driving with a perspective similar to the real world.
Source: https://www.dexerto.com/cyberpunk-2077/players-are-struggling-with-the-games-first-person-driving-2328213/

2.2 Third Person View: the third-person perspective situates the viewpoint behind the character, offering a comprehensive depiction of the character's physical attributes, including body shape, height, clothing, and gender. This perspective tracks the direction in which the character's face is oriented, aligning the player's viewpoint with the character's actions and interactions. This third-person perspective emulates a human's visual experience within the physical world, albeit from a distinct vantage point. However, the third-person perspective surpasses the first-person view of spaces due to its broader field of vision, enabling players to gain spatial awareness within the gaming environment.

Figure 8. Control, the game is presented with the Third Person View, simulating control of a designated character.
Source: https://gamerant.com/control-story-summary-recap/

Both the first-person and third-person perspectives have been integral to video game design, facilitating immersive player experiences across various environments from the inception of gaming to the present day. Contemporary video gaming design transcends the constraints of hardware limitations, as advances in technology drive game consoles to approximate real-world environments. This evolution extends to the symbolic communication of generating virtual worlds beyond the bounds of reality. Notably, the advent of Head-Mounted Display (HMD) gaming machines represents a paradigm shift in perspective vision. While comparable to the first-person view, the perceptual experience engendered by HMDs diverges, granting players a temporary sensation of elevated consciousness. The heightened visual presentation uplifts elements of the storytelling narrative, topological-view considerations, and operational view and path to boost player's interaction with the virtual environment (Wei & Wang, 2017). Such techniques, in line with Mestre's theory, allow players to dive into virtuality and evoke a sense of presence, thereby upgrading emotional engagement and spatial perception (Mestre et al., 2006).

The potential of architectural concepts in video games extends beyond visual realization by integrating complex spatial perspectives. Game consoles, evolving with digital technologies in both 2D and 3D, have shaped video game experiences over time. Each console generation introduces unique media developments, revolutionizing gaming narratives to adapt dynamically to visual trends. Despite limitations in perspective tools and computer resolutions, the progress of gaming consoles reflects continuous technological refinement. Scholars like Brian J. Wardyga (Wardyga, 2023) and Omri Wallach (Wallach, 2020), categorize this evolution into five distinct typologies of console games across different eras.

1. The first video game
2. Arcade Game (The 8-bit and 16-bit Arcade Game)
3. The PC Game (Personal Computer)
4. The Console Game
5. The Head Mount Display

The evolution of gaming consoles, categorized into five types, mirrors advances in computer science that have progressively improved visual and auditory presentation. These developments have enabled more realistic graphics and enriched multimedia experiences through ambient sound and narrative elements. Each console generation has enhanced spatial awareness and environmental perception. Devices like Head-Mounted Displays, used in architectural design for 3D spatial simulations (Zaini & Embi, 2017), parallel 3D space modeling

in video games. This simulation approach allows digital walkthroughs of architectural plans, akin to character navigation through game environments, with control mechanisms driving both storyline and player engagement.

The 3D-perspective visualization portrayed in video games and their accompanying consoles as a measure for experiencing environments and architectural structures constitutes an integral facet of Level Design (Totten, 2014). This includes the direct integration of environment and architectural elements to cultivate environmental awareness within video game media, i.e. the comprehensive inclusion of perspectives within both video games and consoles, ensuring the immersive portrayal of game environments (Konzack, 2006). The evolution of digital video game media has paralleled advances in computer technology, enabling players to more precisely interpret visual cues presented on screen. Realistic imagery processed through console games allows players to discern vivid architectural spaces, complete with colors, details, shapes, and map symbols. Features such as the player's health bar serve as aids in understanding the game's environment and objectives, while gameplay perspectives, whether first-person or third-person, offer distinct immersive experiences (Aroni, 2022). In the former, players are connected in the character's world, directly experiencing missions, while the latter emphasizes exploration of the game world to gain advantages and overcome challenges. In various types of gaming consoles, the ability to process realistic graphics enables the transmission of architectural spatial perceptions to players, offering experiences closely resembling the real, as a form of digital twin. This is achieved by navigation space perception systems in Sandbox games. Essentially, the visual perception of space within video games allows for an understanding of environments and architecture akin to Kevin Lynch's theory (Lynch, 1960). Lynch defined how perceptions of paths and patterns in architecture vary according to the roles of different spaces. Effective portrayal of environments and architecture within video games essentializes the creation of realistic imagery to allow players to simulate real-life experiences and develop an understanding of spatial dynamics. Christopher Totten's typology of space design in video games, as outlined in his book *An Architectural Approach to Level Design*, (Totten, 2014) formalized ten distinct categories to explain complex characteristics of catalytical concepts, underlining architectural representation and perception within this medium. Subsequently, for further clarification categorization is made into three distinct types based on their virtual modes of manipulation toward spatial realization:

1. *Figure-ground* delineates Positive-Negative Space in Environmental Design, highlighting the interplay between foreground elements and their surrounding environment.
2. *Form-void* leverages architectural mass to carve out or sculpt solid structures, shaping the environment through strategic constructs.
3. *Arrivals* orchestrates multiple routes to introduce players to the architectural and environmental intricacies of a video game setting, propelling a dramatic initial experience.
4. *Genius Loci* infuses spaces with a distinct spirit of place, evoking a unique atmosphere that distinguishes them from others in the game world.
5. *Labyrinth* crafts intricate spatial configurations with challenging objectives and dead ends, prompting players to navigate within complex environments.
6. *Maze* intricately conceals dead ends throughout varied spaces, gradually revealing the area's drama as players progress toward the goal.
7. *Rhizome* facilitates swift shortcuts between spaces, offering alternative modes of transportation beyond conventional means.
8. *Narrow Space* creates tension through confined passageways, heightening players' anticipation of future events within the game.

9. *Intimate Space* clusters areas closely together, enabling vertical interaction and heightened environmental awareness, which players can exploit for strategic advantage.
10. *Prospect Space*, characterized by vast emptiness, serves as a backdrop for dramatic storytelling, often utilized in Boss's encounters to increase tension and challenge players both vertically and horizontally.

Due to overlapping descriptions and presentations of spatial environments within Christopher Totten's original 10 types of space design in video games, our research team has reorganized them into 3 groups to provide a clearer understanding of spatial design within video games:

1. Spatial Characteristics of 3D Perception & Navigation: This group focuses on architectural experiences that impact players' sensations, serving as navigational tools within spaces of video game environments.

1.1 Form-void: The form-void representation in video games is similar to architectural design. It includes aesthetic elements like balconies, doorways, windows, and private rooms, as well as functional aspects. This concept highlights accessible areas and strategic locations for gaining advantages over competitors. Thus, it not only enhances beauty and functionality but also improves player awareness and cognitive processing for tactical advantages and discovering new gameplay strategies to achieve game objectives.

1.2 Arrivals: Arrivals denotes the initial path a player takes upon entering a new game space, designed with dramatic scenery and intentional ambiguity to guide players and align with the game's narrative objectives. These spaces evoke curiosity and elicit emotional responses crucial to narrative progression. For example, a narrow, dark corridor may induce fear, while a large, enclosed area leading to an open space suggests hidden elements. Camera angles further influence spatial communication and player perception of these environments.

1.3 Genius Loci: refers to the expression of a space's spiritual essence, creating a unique and immersive atmosphere for the player. This concept aims to provide a memorable experience unparalleled by any other area in the video game. Achieving Genius Loci involves manipulating lighting, shadows, spatial organization, and scale. For example, in a horror game, developers evoke fear through art style, environment, enclosed space size, lighting, and sound effects. These elements enhance the player's emotional connection to the space, aligning their feelings with the intended atmosphere.

2. Puzzle and Maze Design: This group focuses on the complexity of spatial design in video games, which can affect the clarity and ambiguity of those spaces. Additionally, Puzzle or Maze can create challenges within these spaces for players.

2.1 Labyrinth: Labyrinth presents a model of linear space in video games, incorporating twists, turns, and physical challenges that affect player navigation. The core concept is to create pathways that impede progress, extending the journey. This design includes obstacles and diversions to delay reaching the endpoint, often rewarding players with treasures or storyline advancements.

2.2 Maze bears similarities to labyrinth spaces, but its design introduces complexity through intricate walls and pathways, featuring multiple dead ends that challenge players to find new routes. Maze Space is characterized by its diverse array of pathways, with its branching nature presenting various risks and rewards. Players may encounter uncertain elements such as powerful monsters or bosses. However, experiences within Maze Space are not solely negative; they also can include rewards such as treasure chests or panoramic views.

2.3 Rhizome: represents a spatial principle focused on connecting various points for efficient navigation, similar to real-world elevators. In video game design, rhizome allows instant travel from one place to another.

Large-scale adventure games often use this mechanism, enabling players to traverse distances quickly through "warp points" or "warp portals."

3. Spatial Typology: This group focuses on creating spatial experiences and dimensions that impact gameplay spatiality of systems, planning, and utilization.

3.1 Narrow Space: Narrow Space refers to an environment where users feel confined, designed to be equal to or smaller than the player-controlled character. Common in games requiring tension and problem-solving, narrow spaces create stress by limiting movement and restricting actions. This design heightens awareness and anticipation, often seen in horror games, evoking claustrophobia and impending danger. In stealth games, narrow spaces like lockers or air ducts enhance strategic gameplay, allowing players to evade opponents and reinforcing the stealth element through careful planning and movement.

3.2 Intimate Space: Intimate Space is appropriately sized for the player's character, comfortably supporting their movements. It facilitates interactions between players and also can promote interactions with NPCs on different vertical planes and horizontal planes. This spatial design enhances strategic planning.

3.3 Prospect Space: Prospect Spaces, like Narrow Spaces, evoke strong emotions but do so by creating feelings of desolation in large open areas. These emotions can be intensified with fog, music, shadows, and atmospheric effects to create a distinct Genius Loci. Often used in boss rooms, prospect spaces enhance AI movement capabilities, prompting players to use strategic problem-solving. Incorporating Intimate Spaces within these environments can provide tactical advantages, such as allowing players to inflict greater damage on bosses by using varied spatial types for more engaging gameplay scenarios.

3.4 Figure-ground: Figure-ground management in video games uses positive and negative space to indicate player-controlled characters and delineate spatial boundaries. Positive space represents accessible areas or pathways, while negative space denotes restricted or enclosed areas. This representation helps players perceive spatial boundaries, territorial extents, and navigational routes. Typically combined with a 3D perspective view, figure-ground representation aids in navigation and reduces disorientation, clearly defining accessible areas and enhancing gameplay.

Contemporary video game media plays a critical role in shaping spatial awareness through architectural design, bridging the virtual and the real. Architectural structures serve as the physical backbone within the video game medium, guiding players through immersive environments. Ultimately, the visual stimuli presented in video games are transmitted to the players' eyes, triggering nerve impulses that convey perceptions to the brain (Aroni, 2022). This process involves calculating movement and physical understanding, blurring the boundaries between players and the virtual environments while enriching their comprehension of real-world space, in essence, acting as a digital twin. The physics governing the virtual realms of video games often surpass human physical limits, projecting surreal or hyperreal environments that challenge players' perceptions. By designing landscapes, sceneries, and architectural marvels within the game world, developers transport players into fantastical realms that may exceed the confines of everyday reality, offering an unparalleled journey through uncharted territories of imagination.

Based on the study of spatial presentation and environmental design in 2D and 3D video games, it is evident that video game media can elicit perception and experience analogous to real-world architectural presentations. By leveraging the visual perspective of the player, video games facilitate the control of in-game characters along pathways engineered by game developers. The physical and graphical representations of 2D and 3D space, in relation to storytelling elements such as light, color, sound, and motion, engage players'

cognitive processes. This engagement influences their decision-making and emotional responses, thereby portraying psychological reactions to the game environment. Our research team has reviewed the literature and selected architectural case studies that illustrate the connections and relationships between spatial elements in video games:

1. **2D and 3D Visualization of Architectural Spaces:** The graphical and physical form of architecture shares similarities with the spatial and environmental design between 2D and 3D video games, analogous to a digital twinning. This parallel allows architecture to depict spatial concepts that align with Christopher Totten's theoretical framework for categorizing videogame spaces, which our team has restructured into new groupings.
2. **Circulatory Design of Users' Movements:** Architectural designs should incorporate pathways that guide users to their destinations, choreographed by the architect. Similarly, videogame pathways direct players toward primary objectives defined by the gaming design narrative.
3. **Influential Cognitive and Emotional Processing:** The design of 2D and 3D spaces, along with goal-oriented passages, should evoke spatial awareness and emotional responses. Architectural designs should influence users' cognitive processing and emotional perception in the same way as videogame environments affect players' psyches. These perceptions are realized both during the journey and at the destination, providing a comprehensive sensory experience.

By adopting these three points for selecting case studies, we underscore the intricate relationship between architectural design and video game environments, focusing on how each medium enhances user experience through crafted spatial dynamics.

4. Case Study Analysis: Architectural Design through Spatial Analysis within Video Games

Architecture and spaces in video games share similarities with real-world architectural designs in terms of spatial aesthetic and functionality. However, architectural usage within video game worlds does not adhere to real-world functional standards; rather, it serves the game's objectives, storyline, and stimulates player curiosity and perception. The case studies selected by our team feature architectural elements that are not functionally explicit but rather spaces designed to evoke human curiosity and enhance their circulatory experience. This case-study analysis undertakes a selection process, identifying three architectural projects whose spatial characteristics resonate with those portrayed in videogame environments. Drawing upon Christopher Totten's seminal work on spatial design within the scope of video games, as articulated in An Architectural Approach to Level Design, the analysis translates the original types of spatial configurations prevalent within gaming landscapes: *Figure-ground, Form-void, Arrivals, Genius Loci, Labyrinth, Maze, Rhizome, Narrow Space, Intimate Space, and Prospect Space* (Totten, 2014) into Spatial Characteristics of 3D Perception & Navigation, Puzzle and Maze Design, and Spatial Typology—the three groupings that were synthesized above by the study team. This study delves into nuanced spatial typologies within virtual environments in relation to real-world architectural projects. It explores how video games mediate perceptions of architectural space and its physical counterparts by examining their convergences and divergences.

1. Lusatian Lakeland Landmark: Designed by Stefan Giers

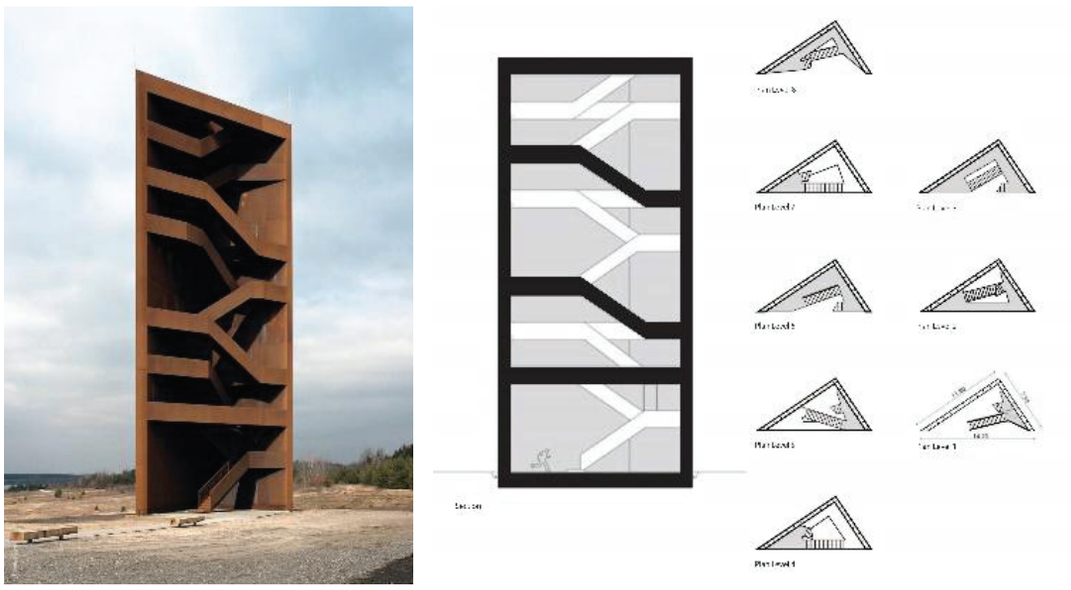


Figure 9. Lusatian Lakeland Landmark
Source: https://www.area-arch.it/en/lusatian-lakeland/

The Lusatian Lakeland Landmark Project emerges as an attempt to establish a panoramic vantage point within the scenic expanse of the Lusatian Lake region in Germany. Conceived as a structure solely for the purpose of lake observation, its spatial configuration is characterized by a soaring staircase, serving as the conduit to its summit. This deliberate architectural digital twin choice emphasizes a narrative of ascension, wherein visitors are compelled to embark on a journey packed with physical exertion—a trip that culminates in the revelation of a sublime vista, offering respite and satisfaction for the effort endured. The intricacy of the staircase, with its alternating steps, prolongs the ascent, providing a choreographed deceleration in pace. This design tactic not only serves to heighten the sensorial immersion but also functions as a mechanism for gradual revelation, unveiling the scenic grandeur of the surrounding environment in an incremental fashion.

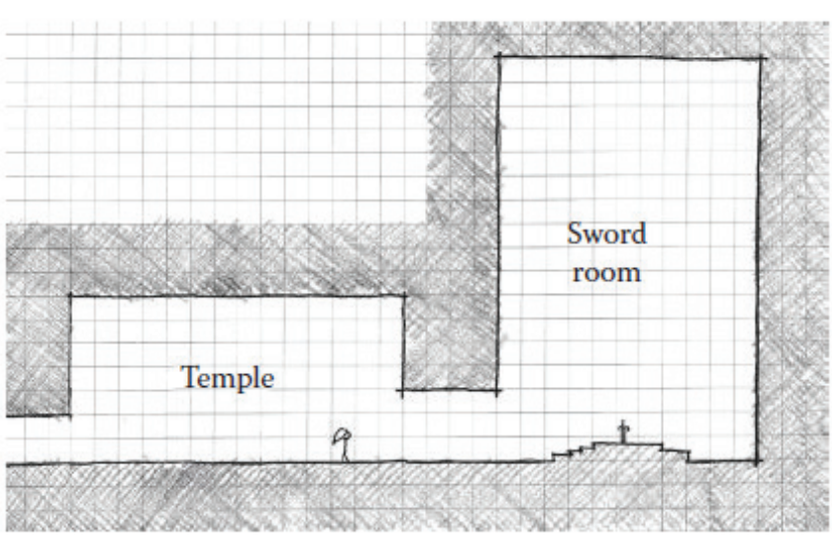


Figure 10. The Legend of Zelda: Ocarina of Time, sword room represents the arrival space to enhance the player's cognitive emotion to the game storyline.
Source: Totten (2014). An Architectural Approach to Level Design. CRC Plance Taylor & Francis Group.

Figure 11. Lusatian Lakeland Landmark provides 360 degrees sublime view for visitors who reach the top of the project, having a convergence connection with arrival space experiences in videogaming.
Source: https://worldarchitecture.org/architecture-news/pnnep/project-lusatian-lakeland-landmark.html

Figure 12. The Elder's Scroll: Skyrim, the underworld dungeon represents the arrival space encountering uncharted areas where narratives or events unfold.
Source: Totten (2014). An Architectural Approach to Level Design. CRC Plance Taylor & Francis Group.

Spatial Design interplay with architecture & video game

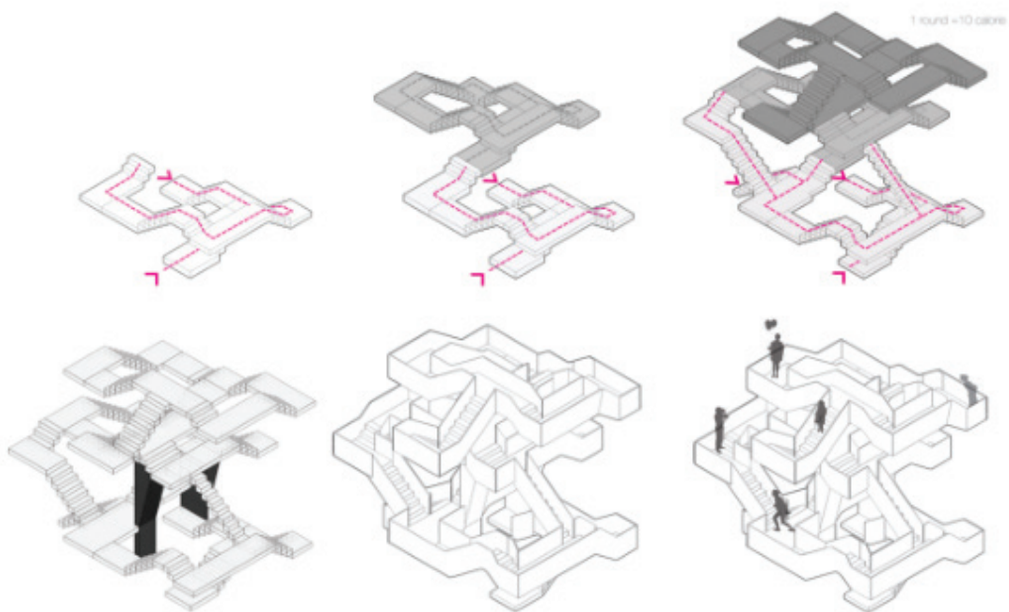
The design of the Lusatian Lakeland Landmark project bears resemblance to the Spatial Characteristics of 3D Perception & Navigation grouping, which includes the concept of "Arrivals" within the realm of video game environmental design. The project's space is characterized by elements that provoke curiosity and uncertainty about the destination. This is achieved through a unique architectural feature that stimulates users' goals to reach the topmost area of the building. Along the way, the building's design incorporates complex pathways that do not immediately reveal the destination. The space not only serves to stimulate exploration but also culminates in reaching the highest point to reveal a panoramic 360-degree vista, akin to encountering uncharted areas in video games like The Elder's Scroll: Skyrim, where hidden narratives or events unfold. This design encourages player curiosity and motivates them to overcome challenges to reach the spatial goal.

2. 10Cal Tower: Designed by Supermachine Studio

Figure 13. 10Cal Tower circulation diagram

Source: https://www.creativemove.com/architecture/10cal-tower/

10Cal Tower, a project initiative in Thailand, presents itself as an educational endeavor catering to children, reimagining traditional playground dynamics into exercises such as stair climbing. This architectural endeavor, reminiscent of a maze with its intricate staircases and vertically interconnected pathways, induces a deliberate sense of subtle disorientation among users. Entrants find themselves traversing the interior passages without clear endpoints, compelled to navigate until ascending to the highest elevation.



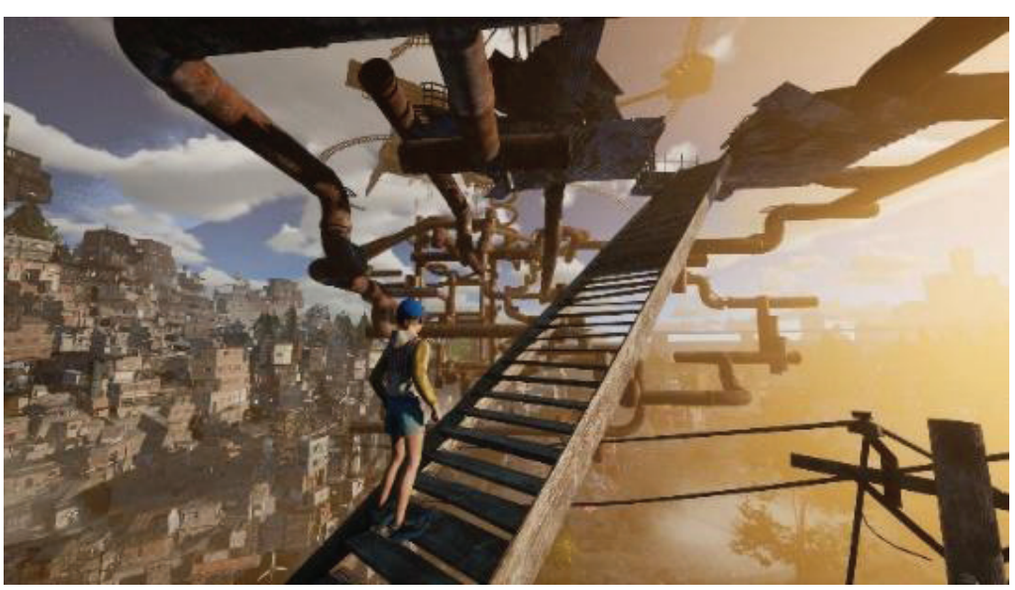


Figure 14. Only Up game, the character encounters a maze circulation scenery. 10Cal Tower circulation representing the Maze Space allows the visitor to enhance perception and decision=making to process through the top, which represents a convergent digital twin connection between architecture and videogame.

Source: https://gbatemp.net/review/transistor.142/

Source: https://www.creativemove.com/architecture/10cal-tower/

Figure 15. The Elder's Scroll: Skyrim, Shalidor's maze represent maze environment circulation in level design.
Source: https://elderscrolls.fandom.com/wiki/Shalidor%27s_Maze

Figure 16. Resident Evil game, narrow space passageway that increases players' awareness and anticipation.
Source: https://www.gamesradar.com/best-resident-evil-games/

Spatial Design interplay with architecture & video game

The design of the 10Cal Tower project bears a convergent resemblance to the "Spatial Typology" and "Puzzle and Maze Design" grouping, which includes the concept of "Maze" and "Narrow Space" within the realm of video game environmental design. The Maze challenges users' perceptions and decision-making, fostering an environment weighed with uncertainty. Analogous to the emotional landscapes crafted within Maze videogame typologies, the 10Cal Tower's design diverges somewhat because it lacks explicit Maze definitions but seeks to evoke emotive responses through the coastal vistas of Bang Saen, heightening users' experiences as they ascend. The intertwining network of paths within the tower introduces an element of uncertainty akin to that found in Narrow Spaces within videogaming contexts (Totten, 2014). Just as narrow passages in typical horror games evoke anticipation and dread before unveiling expansive vistas, the confined spaces within the

tower amplify the eventual reveal of the expansive seascape. This intentional manipulation of spatial dynamics prompts users to journey through confined pockets of spaces, intensifying the eventual revelation of the vast ocean vista upon reaching the pinnacle, thereby enriching their sensory encounter with the local coastal and cultural ambiance. This space not only challenges users to achieve its objectives but also aims to redefine its use as a primary exercise area, with the reward of reaching the beautiful viewpoint of Bang Saen Beach. Comparatively, this space resembles gameplay in The Elder Scrolls: Skyrim, specifically Shalidor's Maze, where players bravely enter the maze's complex paths, and upon achieving its objectives, receive rewards while exploring the maze's beautiful environments.

3. The Vessel: Designed by Heatherwick Studio

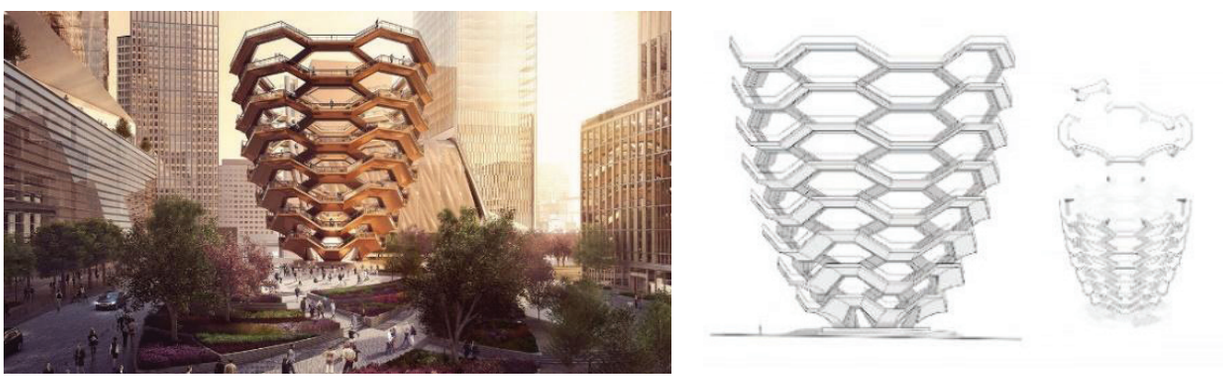


Figure 17. The Vessel: Designed by Heatherwick Studio
Source: https://www.elevatorscenestudio.com/blog/2019/3/17/heatherwicks-vessel-brings

The Vessel of Heatherwick Studio's creation, nestled in the vibrant heart of New York City, stands as a monumental edifice soaring 46 meters in height amidst the burgeoning property development, the Hudson Yard. Surrounded by a tapestry of commercial complexes, residential enclaves, and dense green parks, it beckons tourists and commuters alike. As inhabitants navigate the High Line, an abundance of architectural marvels unfolds before them, punctuating the urban landscape. This architectural masterpiece, characterized by its semi-sculptural design, defies conventional notions of functional usage, opting instead for a bold expression of creative ingenuity, evoking a palpable sense of drama and evocative allure (Kozlowski, 2013). In comparison with the 10Cal Tower project's endeavor, which prioritizes the ascent towards a climaxing goal, both teams of architects envisioned a journey of ascent and exploration, akin to wandering outlandish terrains, thereby enriching the visitor's sensory odyssey. The Vessel's distinctive staircase, on the contrary fashioned in a continuous spiral, affords users panoramic vistas from myriad vantage points, drawing inspiration from the geometric intricacies of Indian stepwells, fostering interactions among users across levels and spaces. Upon reaching the summit, users are gifted with an unparalleled panoramic view of New York City, an encounter of transformative experience surpassing the ordinary urban mise-en-scène.

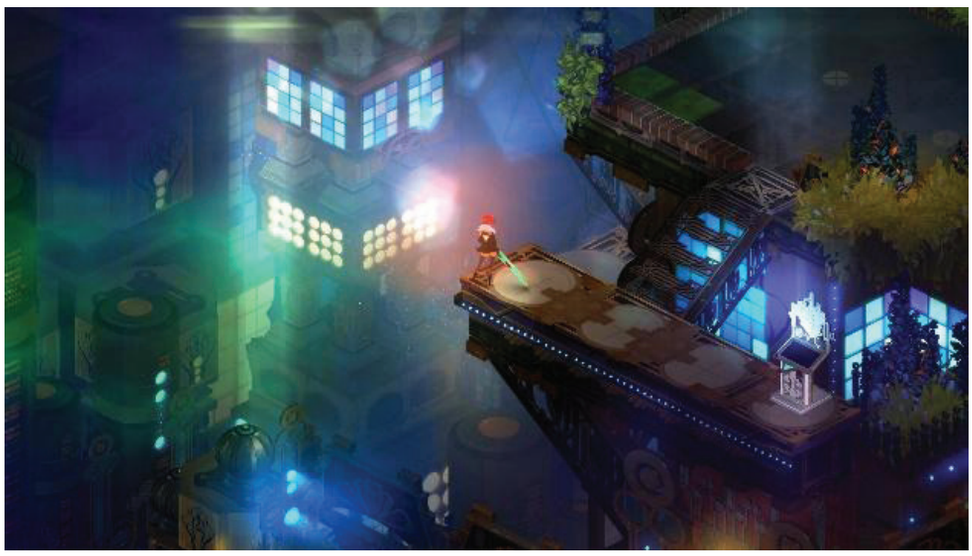


Figure 18. Transistor, the character navigates through Form-Void spaces to advance through levels, while also showcasing the diverse cityscapes within the game's virtual environment.

Source: https://gbatemp.net/review/transistor.142/

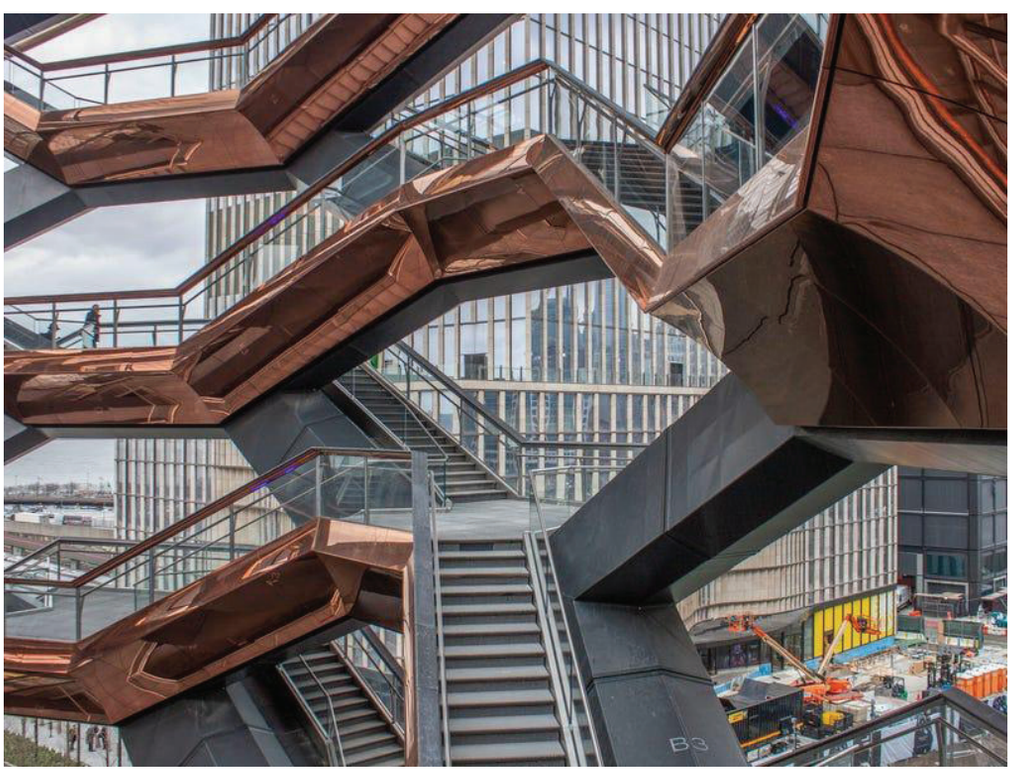


Figure 19. The form-void spaces in The Vessel provide visitors with opportunities to engage with the surrounding New York City skyline, enhancing their interaction with the urban environment.

Source: https://www.businessinsider.com/new-york-city-vessel-sculpture-hudson-yards-views-photos-2019-3#-and-nearly-2500-steps-10

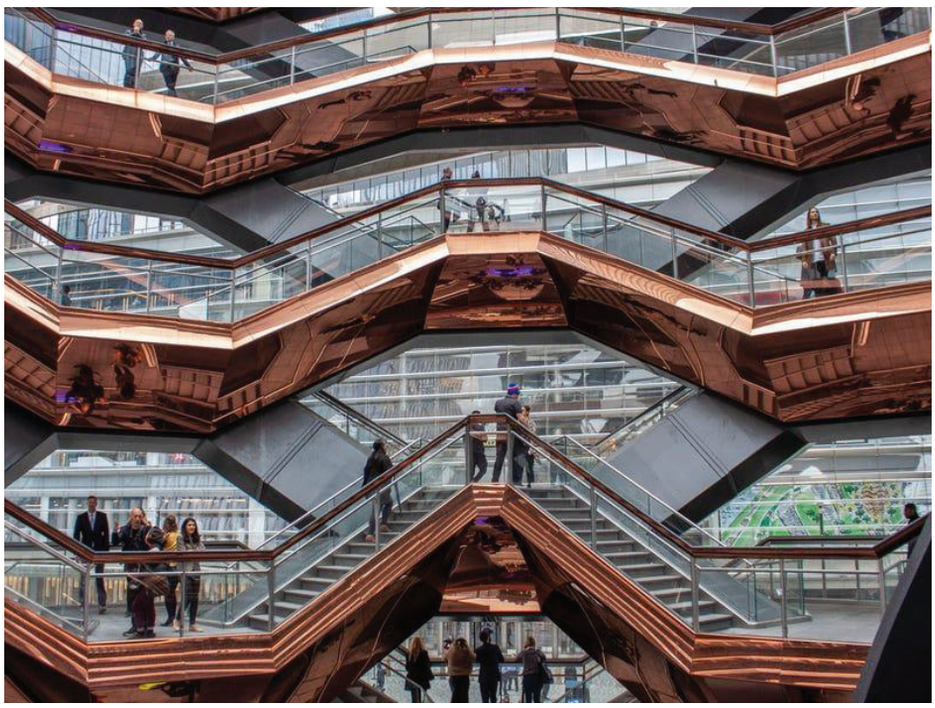


Figure 20. Intimate spaces within The Vessel allow people to interact across multiple levels, fostering engagement with the verticality of the architecture.

Source: https://www.businessinsider.com/new-york-city-vessel-sculpture-hudson-yards-views-photos-2019-3#-and-nearly-2500-steps-10

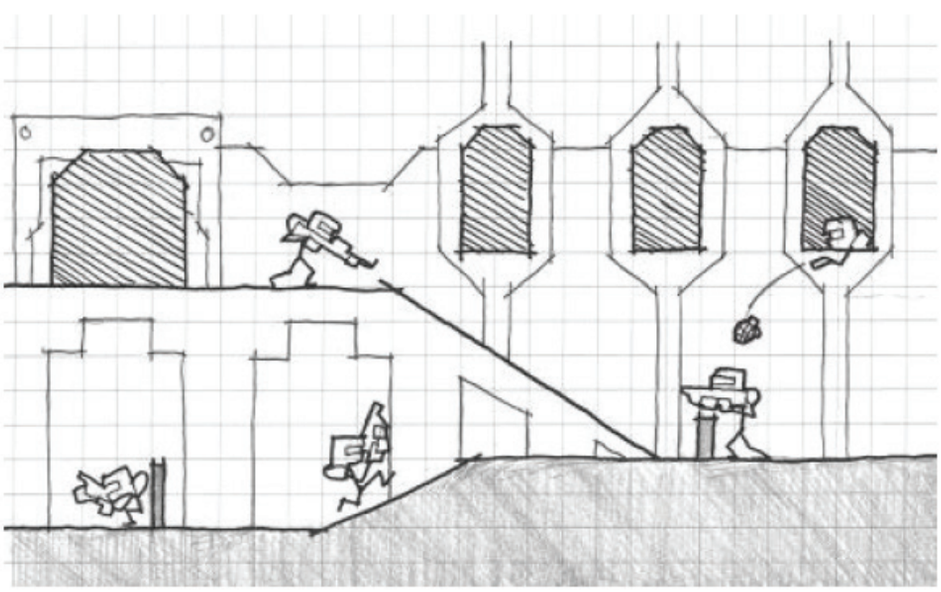


Figure 21. Sectional diagram shows characters battling within an intimate space.

Source: Totten (2014). An Architectural Approach to Level Design. CRC Plance Taylor & Francis Group.

Spatial Design interplay with architecture & video game

In the realm of video game spatial design, the construct of the Vessel converges as a digital twin with the concept of Arrivals, Form-Void within the Spatial Characteristics of 3D Perception & Navigation grouping and intimate space under Spatial Typology grouping, where the initial engagement shapes players' emotional entanglement, paving the way for subsequent explorations. Similarly, The Vessel orchestrates an immersive experience, offering diverse perspectives of the cityscape, contingent upon the user's constantly shifting senses against endlessly interconnected elevations within the singular structure. Embodying the architectural paradigm

of Form-Void, The Vessel prompts an interactive dialogue between occupants across the simultaneity of vertical and horizontal planes, accentuating the city's kaleidoscopic diversity. This architectural intervention mirrors the interactive settings observed in videogaming environments, where spatial configurations serve as conduits for strategic engagement and narrative progression. The convergent interplay between Arrivals Space, Intimate Space, and Form-Void generates a spatial ambiance flooded with emotive resonance, experiential depth, and monumental dynamism, inviting users to engross themselves fully in the cityscape's multifaceted appeal (Mestre et al., 2006). Comparing the architectural reflection of The Vessel in video games to accessing spaces within Control, the game's concept of bending reality to create new spatial components aligns with mission objectives. This necessitates players to adjust their 3D perception, navigation, and spatial typology using formats like Form-Void, Arrival Space, and Intimate Space. However, Control diverges in that it lacks a cityscape view that impresses players with space, making The Vessel's project similar in spatial perception to video game concepts of path layout and architectural forms. Thus, building users may be stimulated to curiosity and sight to accomplish space goals with perception in visioning the Cityscape.

Table 1. Comparison between Real-world Architectural Projects and Videogaming Perception of Architectural Space

Case Study Analysis of 3 Architectural Projects	Spatial Perception in Videogaming	Videogaming Modes of Representation of Spatial Perception	Console Game Types for the Advancement of Spatial Perception
1. Lusatian Lakeland Landmark **Designed by Stefan Giers** **Area:** 1400 sq.m. **Location:** Lusatian Lake District, Senftenberg, Germany **Completion:** 2008	**Spatial Characteristics of 3D Perception & Navigation** - Arrivals Space	- 2D View - Side Scrolling Space - 3D View - First Person View - Third Person View	- Arcade Game: 8,16 Bits - Console Game - PC Game - Head Mount Display
2. 10Cal Tower **Designed by Supermachine Studio** **Area:** 72.70 sq.m. **Location:** Chonburi, Thailand **Completion:** 2014	**Puzzle and Maze Design** - Maze Space **Spatial Typology** - Narrow Space	- 2D View - Top-Down Space - Side Scrolling View - 3D View - First Person View - Third Person View	- Console Game - PC Game - Head Mount Display
3. The Vessel **Designed by Heatherwick Studio** **Area:** 2210 sq.m. **Location:** New York, United States **Completion:** 2019	**Spatial Characteristics of 3D Perception & Navigation** - Arrivals Space - Form-Void **Spatial Typology** - Intimate Space	- 2D View - Top-Down Space - Side Scrolling View - 3D View - First Person View - Third Person View	- Console Game - PC Game - Head Mount Display

Source: Generated by the authors

Through a probing of three distinct case studies, it becomes evident that real-world architectural design manifests adaptive characteristics. Analogous to the methodology employed in crafting architectural spaces and environments within video games, a nuanced approach utilizing Arrival Space, Maze Space, Intimate Space, and Form-Void constructs the perceptual landscape for players. Remarkably, this set of design principles extends seamlessly to real-world architectural design practices as a digital twinning. While none of the three examined projects explicitly adhered to these videogaming design concepts, it is the spatial composition specifically corresponding to video game environments that brings about expressive responses towards the scenery and the perspective of the visual and virtual fields. The environmental design's capacity to evoke emotions in architecture can be grouped into two categories: the subjective perception of individuals directly engaging with the architecture and the recognition of distinct scenarios within architectural spaces. This approach mirrors the architecture of videogame design, which aims to boost exhilaration from players through emotional and psychological engagement tied to narrative progression. Interweaving personal identity and emotional experiences (Ojeda, 2007), this synergistic, convergent, relationship between architectural space and users cultivates experiential connections, exceeding conventional boundaries and encouraging exploration beyond the confines of architectural understanding.

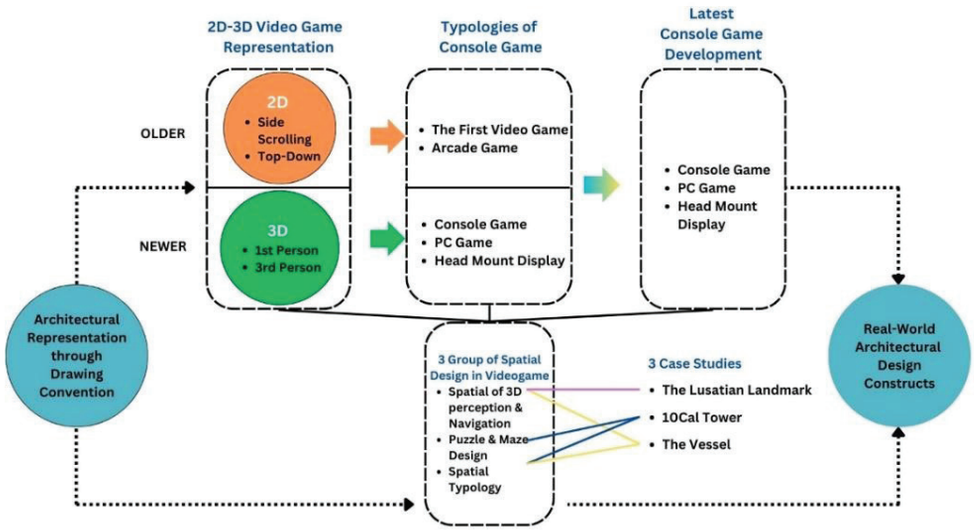


Figure 22. Diagrammatic Summary: how videogaming perception of architectural space connects with spatial perception of real-world architectural constructs.

Source: Generated by the authors

5. Conclusion

The evolutionary path of the video game medium reflects the advance of computer science, transitioning from mere imagery presentation to an intricate manipulation of player awareness within digital realms. The utilization of various perspectives, including elevations, sectional images, and axonometric angles, underlines an attempt to infuse video game architecture with spatial comprehension which connects to real-world architectural design. This symbiosis between digital and physical realms is enhanced by the relentless evolution of gaming tools, from basic creations to modern masterpieces capable of evoking realistic and immersive perceptual experiences. Coincidently, real-world architectural undertakings strive to craft spaces that transcend mere functionality, seeking to embed profound perceptual encounters connecting to those in video games. The emotional appeal evoked by both mediums is inevitable, entwining personal identity and emotional experiences to foster deeper connections between users or gamers and spatiality. Moreover, the integration of cutting-edge computer software in architectural design augments creative possibilities, enabling the realization of complex forms that continue to defy conventional limitations. The prospect of synergizing architectural design principles with the immersive potential of videogaming aesthetics presents an intriguing frontier, promising to redefine user's perceptions and expand the boundaries of architectural imagination. Architecture in video games continues to reflect real-world architectural concepts in a form of digital twinning, but with the freedom of unlimited design possibilities. This allows video game architecture to serve as a model for simulating new spatial environments where architects can adapt ideas for real-world design in the future. The overlap in design philosophies between video game architecture and real-world architecture demonstrates how video game architecture can function as a prototype, distorting reality to create opportunities in "realistic" and "hyper-realistic" design experiences. This transformation enriches the architectural design industry, paving the way for innovative spatial experiences beyond conventional limits.

Author Contributions

Conceptualization, P.M. and L.K.; Methodology, P.M. and L.K.; Analysis, P.M. and L.K.; Data Curation, P.M. and L.K.; Validation, L.K.; Writing-Original draft preparation, P.M. and L.K.; Writing-review and editing, P.M. and L.K.; Visualization, P.M. and L.K.; Supervision, L.K.; Project administration, P.M. and L.K.; All authors have read and agreed to the published version of the manuscript.

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