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XR Application Design for Amusement Park Environments

An Exploration of XR Applications for Amusement Parks and Spatial Environments

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Abstract

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This thesis explores the design of Extended Reality (XR) applications tailored for outdoor environments, with a particular focus on amusement park fairgrounds. The study defines the concept and characteristics of amusement parks and researches how amusement parks benefit from immersive technologies such as XR. The thesis examines how XRs lesser utilized medium of Mixed Reality (MR) can offer an interactive, immersive real-life experience now, as the technology has advanced to a point where developing these types of experiences is more viable.

The research includes an analysis of existing XR implementations in amusement parks, focusing on their integration within controlled environments. This thesis also investigates outdoor-based XR applications beyond amusement parks, providing insight into the design and functionality of immersive experiences in public spaces. To contextualize these findings, the study presents a concept design for an MR application intended for the amusement park fairground environment. This design showcases how interactive markers can trigger digital content in outdoor settings, creating immersive, story-driven experiences in a controlled environment. The concept further explores challenges such as environmental factors, hardware limitations and user interaction, and proposes solutions to address these issues.

Keywords: Extended Reality, XR Design, Spatial Design, Amusement Park, Theme Park, Mixed Reality, Augmented Reality

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1 Introduction

This thesis explores the integration of Extended Reality (XR) technologies including Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) in the amusement park industry, particularly focusing on how MR could revolutionize the way visitors could explore and interact with the amusement park environment.

This thesis delves deeper into two key case studies which use MR as the foundation for an attraction. The first case study explores the development and implementation of the first amusement park MR attraction in the world, *Hysteria in Boothill*. The second case study investigates how *Relive 1770,* a spatial historical MR experience was designed and developed. These case studies were conducted through online interviews.

In addition to analyzing these cases, this thesis offers insight on how to design and conceptualize XR, particularly MR applications for an amusement park's spatial environment. A guide for designing XR applications suitable for amusement park requirements, particularly by optimizing user engagement in large-scale spatial environments, is presented in the fourth section of this thesis, *XR Application Design for Spatial Fairgrounds Environment*, and through the findings of this study, an MR application design for amusement park fairgrounds is presented.

Ultimately, this thesis aims to address these key questions: How has XR been utilized in amusement parks and their fairgrounds and how to design XR applications that effectively leverage the spatial scale of amusement parks?

2 Defining the Research Topic

This thesis focuses primarily on the research surrounding XR uses in amusement parks. These topics have been researched in theses and research

papers quite extensively, from a game design standpoint in AR (1) (2) to the impact of the technologies in the amusement park setting. (3) This thesis takes a deeper look into MR, as it remains a relatively under-researched topic due to the limited use of MR in amusement parks and within tourism industry generally.

New XR focused amusement spaces have been established in recent years, as there is a growing demand for immersive experiences. (4) These establishments are typically called VR parks. However, these types of entertainment spaces may integrate various experiences beyond VR, such as traditional arcade games in their game selection. The primary focus of VR parks is to provide attractions that are fully virtual, or partially virtual by combining VR with real-world elements like haptic elements from a mechanical ride. VR parks are generally established entirely indoor, most likely because the VR hardware is not designed to withstand outdoor conditions extensively. (5)

However, this thesis focuses on attractions integrated within existing amusement parks rather than establishments that offer primarily entertainment in the form of XR. This thesis aims to explore how XR technologies can enhance visitor experiences in existing amusement parks, with an emphasis on the synergy between XR technologies and expansive fairground spaces to improve visitor engagement in the environment. Additionally, it explores the potential of utilizing the amusement park fairgrounds as attractions on their own right.

To clarify the distinction difference between the concept of amusement park and VR park, a comparison sheet below was made to illustrate the operational differences between the two different amusement industry concepts. (Figure 1) This figure was developed through a general comparison and analysis of these establishments and is fundamentally a summary of personally gathered information.

Category	Amusement Park 	VR Park 
Attraction	Physical rides	Virtual Experiences
Technology	Mechanical Attractions	Immersive Technology
Capacity	Thousands of visitors per day	Hundreds of visitors per day
Operation cost	High	Varied
Environment	Outdoor attractions and infrastructure	Indoor establishment, typically within another commercial space
Duration of visit	Est. 6 to 10 hours	Est. 2 to 5 hours

Figure 1. Comparison sheet of amusement parks and VR parks.

Given the limited relevance of outdoor spaces to the research scope, VR Park attractions are excluded from this thesis research. To contextualize the thesis subject matter, *Defining the Research Topic* section provides definitions of XR and amusement parks. These definitions establish a foundational understanding for the more specific topics explored in the subsequent sections, which focus on application design tailored for outdoor use.

2.1 Defining XR

This section clarifies the differences between the technologies and terms used in this thesis. The abbreviations XR, AR, MR and VR are common when discussing digitized reality but to an average technology user, many of these concepts are widely unknown.

Extended Reality (XR) is an umbrella term used to refer to various ways of blending virtual elements with reality. The term refers to extending our experience of reality with virtual, non-physical elements. XR is typically divided into three mediums that combine virtual elements with reality. These mediums are **Augmented Reality** (AR), **Mixed Reality** (MR) and **Virtual Reality** (VR). (6) To illustrate the overlapping qualities of these mediums, the following figure presents a coherent chart defining the terms. (Figure 2) To elaborate on the contents of the chart, a more detailed explanation of these terms is provided.

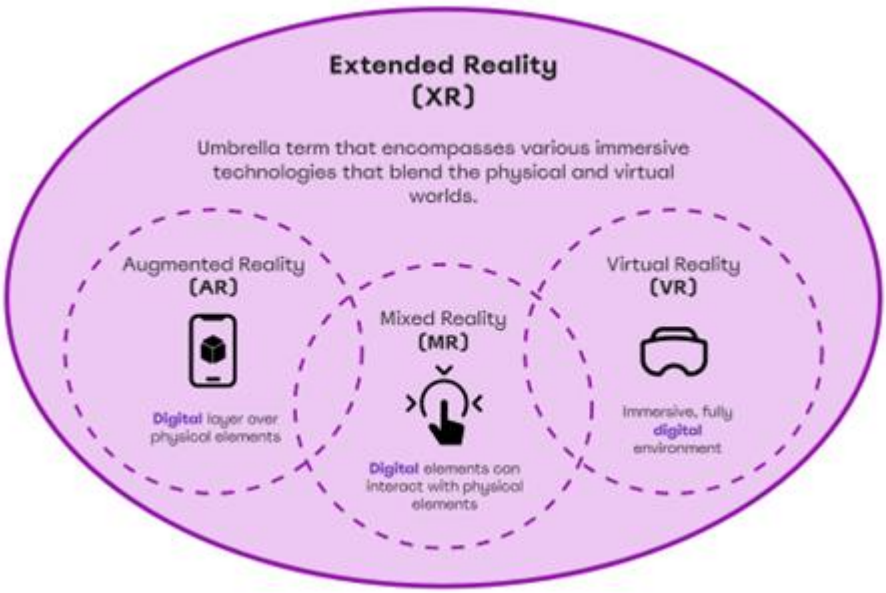


Figure 2. Chart of the definitions of XR, AR, MR and VR.

Augmented Reality is a technology focused on interactivity that allows digital images and information to be overlaid onto the physical environment. (7) AR has become a widely used technology in smartphones. The most common way to use AR on smartphones is through the phone's camera. The camera can be pointed at different spaces, showing surroundings on the phone screen. The real-time camera feed can be combined with virtual 3D elements, bringing virtual objects through the "window" of the phone into the real world. An example of the use of AR is the IKEA Place application available on smartphone app stores. This application allows the user to bring virtual IKEA

furniture into the user's home, arrange them to match their real home and see how the IKEA pieces could fit into their own home decor. (8)

Mixed Reality overlaps with both AR and VR technology. AR is mostly synonymous with MR due to both using actual reality as the platform for digitized content, typically through transparent digitized glasses or camera feed. The main difference between the two is that MR can typically recognize and use physical elements, e.g., hands as an interaction trigger. In MR, digitized assets can be "touched" to interact with them. MR is usually experienced with either a VR headset's passthrough function or via AR glasses, which resemble eyeglasses but have a digital display integrated into the glass.

Virtual Reality as a technology medium usually refers to a headset in which the user can immerse themselves in a fully digitized environment, separate from the actual reality. In this medium, a head-mounted VR headset is typically used to create the sensation of being fully immersed in a digital environment. (9) In most cases, commercial VR headset uses 3D near-eye displays to show a digital environment in a realistic manner, as well as positional tracking to enable the user to look and walk around in the digital environment.

2.2 Defining The Amusement Park

To accurately define an amusement park, examining its historical development is essential as it provides insight into the definition of the concept. The concept of amusement parks can be traced back to religious festivals and trade fairs. The earliest known established park that still operates today, *Dyrehavsbakken* in Denmark, was founded in 1583. The park was originally a popular gathering place due to its natural spring, which attracted entertainers and traveling salespeople to cater to the audience. As the park's reputation grew, the park started to upgrade its facilities, attracting circuses and inventing amusement rides for visitors. The resort grounds, known as pleasure gardens, sparked a trend that led to the establishment of many similar venues across Europe in the 16th to 18th centuries. These "amusement gardens" were typically holiday spots

settled on public royal gardens. They are credited for being the basis for the concept of amusement parks. (10)

As permanent, enclosed amusement park spaces began to emerge in the 18th and 19th centuries, the distinction between pleasure gardens and amusement parks started to blur. (10) However, the growing amusement park industry faced a significant decline from 1920s to 1950s due to The Great Depression and the Second World War. During the 1950s, the public opinion on amusement parks regarded them as 'tacky, down-at-heel relics of a bygone age' due to the introduction of more thrilling leisure options such as movies, television and air travel. Despite these opinions and the shift in public interest, the modern concept of a new type of amusement park, a "theme park" was in active development by Walt Disney. Although the development of Walt Disney's *Disneyland* had significant financial difficulties, the project persevered. This new type of amusement park was meant to be a whole immersive experience rather than just a collection of rides. (11) Their initial success in revolutionizing the concept of amusement parks marked the beginning of a new, modern era in the development of amusement parks.

As previously noted, theme parks represent a relatively recent innovation within the amusement park industry. Theme parks are broadly defined as amusement parks built around a specific theme, sharing many characteristics with traditional amusement parks. As of today, an amusement park is defined as a commercially operated park providing various devices for entertainment, such as a merry-go-rounds or roller coasters, and usually booths for selling food and drinks. (12) The research of the article *'What is a Theme Park? A Synthesis and Research Framework'* (13) concludes in its research that amusement parks typically have these characteristics:

1. Admission system

2. Permanent site

3. Rides/Shows/Games

4. Shopping/Food/Beverage

These characteristics are understood as the minimum requirements to categorize a space as an amusement park. However, the term ‘amusement park’ serves as an umbrella term for various types of parks sharing these foundational traits while also incorporating additional features. Thus, while all variations of amusement parks fall under the umbrella of amusement parks, not all amusement parks are theme parks. Many of the listed characteristics for amusement parks are shared by water parks, adventure parks, carnivals, funfairs, family entertainment centers and historical theme parks as they appeal to audiences similar to those of amusement parks. However, these establishments are not the primary focus of this thesis and are therefore less extensively researched.

To summarize, this thesis defines an amusement park as a commercial entertainment park which has rides, shows, games and dining possibilities in a permanent site. The decision to focus on amusement parks rather than public parks as the main research subject in this study stems from the thesis’ aim of exploring how XR applications can be designed and developed within an enclosed, permanent and typically privately owned fairground setting.

2.2.1 Types of Amusement Parks

As mentioned above, all types of amusement parks follow the main characteristics of an amusement park. Amusement parks can vary from each other in some key features that differentiate the parks. These are the *thematic focus, target audience, types of attractions*, *scale* and the *duration of the visit* in park. To convey the distinction between various types of amusement parks, a selection of diverse examples was chosen for comparative analysis. (Figure 3) The following amusement parks are included in the comparison: *Disneyland* (California, USA), *Cedar Point* (Ohio, USA), *Liseberg* (Gothenburg, Sweden) and *Efteling* (Kaatsheuvel, Netherlands).

Comparative Overview of Amusement Parks

Amusement Park	Disneyland, California USA	Cedar Point, Ohio, USA	Liseberg, Gothenburg, Sweden	Efteling, Kaatsheuvel, Netherlands
Thematic focus	Disney Franchise	Traditional Amusement Park	Traditional Amusement Park	Fantasy, Folklore
Target Audience	Families, Disney fans, tourists	Thrill-seekers, Rollercoaster enthusiasts	All ages	Small children, families
Types of Attractions	Themed rides, character experiences, parades	Classic amusement park experiences, roller coasters, thrill rides	Family-friendly attractions, live performances, seasonal event-based experiences	Family-friendly attractions, immersive atmosphere rides, story-driven experiences
Scale	500 acres	364 acres	42 acres	180 acres
Duration of the visit (Typically)	Multiple days	One day	One day	One day

Figure 3. Comparative overview of amusement parks based on preliminary research and general perception of the establishments.

Although it is hard to accurately assess how many amusement parks exist now, according to *The Global Association for the Attractions Industry's Global Theme and Amusement Park Outlook Report* predicted that in 2023 the industry would reach $32 billion dollars in customer spending in North America alone. (14) Considering the predicted gradual increase in revenue following the recent pandemic years, it is reasonable to conclude that the amusement park industry is estimated to perform well in the following years.

2.2.2 Amusement Attractions and Rides

This section begins by defining and reviewing the concept of dark rides, as the term will be frequently referenced in subsequent discussions. Following this, a historical overview of amusement rides is provided. One of the primary focuses of this thesis is dark rides, as well as experiences that share similar characteristics to dark rides, since the subsequent sections explore the potential

of XR application design in amusement parks. The synergy between dark rides and XR stems from the fact that both of these attraction mediums are designed for environments where users experience movement, in a ride of walking freely.

The early concepts of dark rides were originally scenic rides called “scenic railways” and “pleasure railways”. (15) Generally dark rides are understood to be an amusement ride or attraction that guides visitors through a specially lit area, typically containing elements like animation, sound design, music and special effects. (16) Although the origins of dark rides are tied to fixed rides like “The Tunnel of Love” or “Ghost Rides”, the concept of a dark ride has variations, such as being trackless but using automated guided vehicles or offering interaction while on the ride like shooting targets. Many characteristics of dark rides are incorporated into other attractions and rides; however, the concept of a dark ride is defined by the factor that a visitor must board a moving vehicle for the ride. As the definition of a dark ride can vary, to avoid complicating the terminology, the term ‘dark ride’ is used in this thesis to also refer to experiences that can be categorized as ‘semi-dark rides’ which would exclude the use of transportation systems moving throughout a building.

The aforementioned precursor to amusement parks, pleasure gardens were the first place where different types of amusement attractions and rides were invented and experienced. These early attractions provided a pleasant environment for visitors to stroll through, along with music shows for entertainment, somewhat similar to modern dark rides.

The beginning of thrill rides can be traced back to the 19th century, in the form of Russes Montagnes (Russian Mountains), a carriage that wheeled down a track with high speeds. It offered an experience similar to roller coasters. During the mid-1800s industrial revolution, a set of more mechanical rides were invented. The first mechanical rides introduced to the parks were carousels, electric roller coasters and the Ferris wheel. These rides heralded the beginning of the amusement park era that followed. (17)

Identifying and categorizing amusement park attractions is complex, as almost anything within an amusement park can be considered an attraction on its own right. To simplify this, the following analysis organizes attractions into three overarching categories: *Mechanical*, *Scenic* and *Interactive*. These categories were selected to highlight the primary purpose of each attraction, whether its focus lies in creating an immersive atmosphere, giving a sense of thrill or excitement through an experience, or offering visitors an activity-based interaction. The following graph illustrates the categories mentioned and provides examples of rides that fall within each section. (Figure 4)

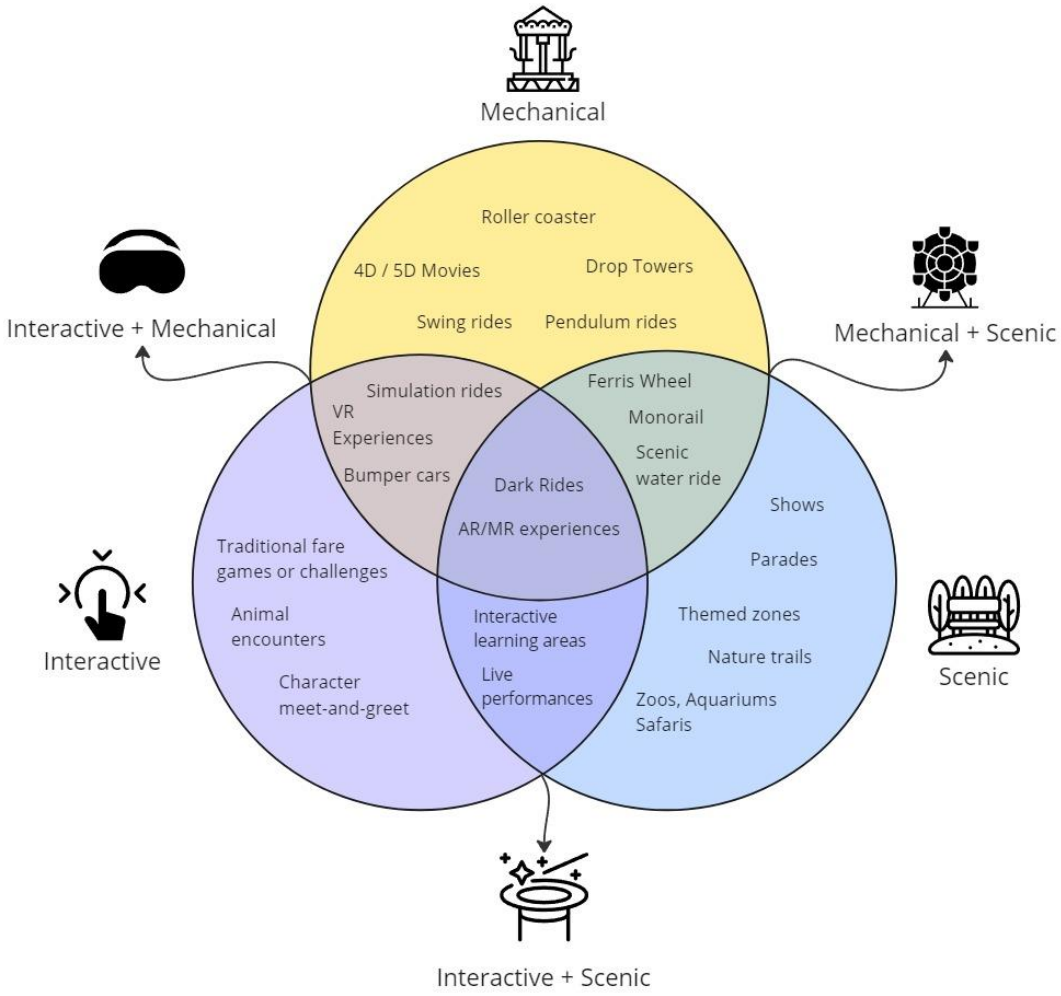


Figure 4. Venn graph categorization of amusement park attractions and rides based on their characteristics.

The Venn graph includes the primary categories of Mechanical, Interactive, Scenic along with their intersecting combinations: Interactive-Mechanical, Mechanical-Scenic and Scenic-Interactive, and the overlap of all three core categories. To better understand the distinction, the following list explains each primary and overlapping category, highlighting their key characteristics:

1. Mechanical: An attraction that utilizes engineering to deliver rides or entertainment experiences, emphasizing mechanical and technical functionality. E.g., Fast thrill rides, in which the experience comes from the intense motions and speed of the experience.

2. Scenic: An attraction focused on showcasing the scenery and theming that the amusement park offers. E.g., Heavily themed areas or special events which can be explored freely.

3. Interactive: An attraction designed to prioritize visitor engagement by allowing them to interact directly with the attraction. E.g., Character interactions, where you can interact with a performer or perform an action in a game to win prizes.

Combining these primary categories creates new classifications that merge their defining characteristics in synergy. They are as follows:

1. Interactive-Mechanical: An attraction that is heavily engineered and mechanical, which also provides direct interaction with the attraction. E.g., Simulation rides, where mechanical motion is augmented by the user steering the ride or fully immersive VR games.

2. Mechanical-Scenic: An attraction which uses mechanical engineering to allow visitors to enjoy the provided scenery from a new perspective or along a guided route. E.g., A Ferris wheel ride, where the slowly moving ride offers the possibility to view the park scenery from heights.

3. Scenic-Interactive: An attraction that immerses the visitor in a scenery and offers a chance to interact with the environment or the subject of attraction which is placed with the scenery in mind. E.g., A water pump that can be cranked, shooting water in a themed environment or a magic show, where the performer may interact with visitors.

Combining these three elements together has been a subject of new development in amusement parks, offering visitors a unique, mechanically engineered, interactive and scenic experience. These experiences were initially developed as variations of dark rides or semi-dark rides. However, the recent wave of technological advancements in XR has expanded the possibilities for creating digitally engineered experiences for visitors.

Many VR rides leverage the synergy between mechanical elements and advanced technology, allowing visitors to interact directly with the experience. However, fully virtual experiences do not incorporate the existing scenery found in amusement parks. Instead, they create entirely immersive environments that rely solely on digital scenery in a virtual setting. To fully utilize the synergy of these key characteristics like mechanical elements and the incorporation of existing scenery found in amusement parks, the ideal medium could be offered through AR and MR technologies. These mediums allow for a seamless integration of digital content with the physical environment, including interactivity within the experience.

The *Venn graph of categorization of amusement park attractions and rides based on their characteristics* (Figure 4) does not represent a definitive or flawless categorization of amusement park attractions and rides, as these can be analyzed from various perspectives. Exhaustive lists of existing attractions and their functions are challenging to create due to their vast diversity and overlapping nature. However, this framework broadly categorizes attractions by the nature of their core appeal, focusing on what serves as the primary draw or purpose of the attraction. The graph intends to conceptualize how a specific type of attraction might fit within this categorization framework. Alternatively,

amusement park attractions and rides can be classified through other aspects such as the demographics they aim to attract, the primary function it serves, the degree of technological complexity it offers, or the emotional appeal the attraction has.

3 XR Methods in Amusement Parks

This chapter of the study explores the various ways VR, AR and MR have been used in the amusement parks around the world so far. This chapter also reviews history and the current trends in the uses of these technologies and looks into some more recent attractions as a case study. The purpose is to review the differences between the uses of AR, MR and VR technologies in amusement parks or similar settings and identify how to best leverage the individual strengths of each technology medium.

To better differentiate the possibilities within various experiences under the XR umbrella term, research has found that all extended reality experiences can be categorized into a Punnett square. Although the primary source for this categorization of interactivity is the Punnet square concept presented in the article *'Redefining The Axiom Of Story The VR And 360 Video Complex'* (18), which primarily focuses on movie-like experiences, the same principles can be applied to categorize XR experiences.

Examining the categorization can provide a better understanding of the spectrum of interactivity within virtual experiences. To demonstrate this categorization within the context of this thesis, a detailed examination of these aspects is reviewed from the perspective of amusement park attractions.

The Punnet square categorizes all virtual experiences to be either "participant/active", "participant/passive", "observant/active" or "observant/passive". (18) To clarify the concept of the categorization, a definition of used terminology is provided by defining the characteristics of the role taken by the user in each category.

The **Observant** role refers to an experience in which the user maintains a detached perspective to the experience, lacking an identity within it. This is typically the case with experiences that are not story driven, or that are portrayed stories in which the user might not be able to affect the outcome directly.

The **Participant** role guides users to identify themselves within the story and become immersed as a participant in the experienced world. This is particularly seen in story-focused experiences in which the experience proceeds by the participation of the user.

The **Active** role enables the user to affect the progress or outcome of the experience by action. The outcome of the action can yield different outcomes for the experience, granting the content a sense of causality.

In the **Passive** role, the experience is designed to be self-contained and unaffected by outside influences, meaning that the user is neither given nor expected to have control over the course of the experience.

The following figure illustrates how these categories are presented in the Punnet square, providing examples of cases that are explored in more detail. (Figure 5)

Figure 5. Punnet square figure highlighting four different types of XR experiences.

To enhance the understanding of the differences in the Punnet square's categories, this analysis examines the four highlighted example experiences and compares them at a holistic level. These examples were chosen by their feasibility for amusement park use and they can all be considered types of attractions.

Passive/Participant: *The Ghostbusters: Dimensions* experience falls into the categories of Passive influence and Participant existence. The so-called "hyper-real" world of *Ghostbusters: Dimensions* was developed by the company *The VOID.* It was one of the world's most expensive and immersive VR experience in 2016, featured at the *Madam Tussauds Wax Museum* as a larger exhibit and was based on the 2016 *Ghostbusters* movie. (19) The *Dimensions* is intended to be experienced as a team of three. The users enter a stage where the real world is mapped to the experience's virtual one. This experience's hardware consists of VR glasses, VR blaster guns, a haptic vest and a backpack computer running the experience. The gameplay consists of exploring the

virtual world and shooting ghost targets in a VR shooting gallery. What makes *The Ghostbusters: Dimensions* Passive in influence is that the experience itself does not have narrative changes depending on the users' actions within the virtual world. However, the experience is interactive due to its gameplay of shooting ghost targets, making the user exist as a Participant within the experience. The typical uses for Passive/Participant XR experiences are either interactive simulations or games without player agency over story.

Active/Participant: *Star Wars: Secrets of the Empire* falls into the categories of Active influence and Participant existence. *Star Wars: Secrets of the Empire* was developed by the same company as *The Ghostbuster: Dimensions*, *The VOID*, in collaboration with *Lucasfilm* and *ILMxLAB*, released first in 2017 in *Disney Springs, Walt Disney World*. (20) The experience is set up similarly to the *Ghostbusters: Dimensions*, having a similar player hardware setup. The core gameplay of the *Secrets of the Empire* consists of exploring the VR world, shooting enemies and solving a puzzle. (21) What categorizes the *Star Wars: Secrets of the Empire* as Participant existence is the possibility to shoot targets and interact with the world, similar to the *Ghostbusters: Dimensions* experience. The key difference between *Secrets to the Empire* and *Ghostbusters: Dimensions* is the way they progress forward in a narrative sense. In *Secrets of the Empire*, the storyline progresses as participants complete certain tasks, such as solving puzzles, making it an active experience in terms of user influence.

Passive/Observant: *Marvel Super Heroes 4D* falls into the categories of Passive influence and Observant existence. *Marvel Super Heros 4D* is a 4D movie shown in the *Madam Tussauds* wax figure museums. There have been various versions of the movie set in the different cities where the *Madam Tussauds* museums are located. The 4D movie is presented in a domed auditorium, utilizing a 360° display for an immersive experience. The movie is a nine minutes long animated 4D cinema attraction, complete with high impact special effects such as splashing water effects and smoke effects. Although the dome display and the movie graphics are displayed in 3D, the experience is marketed

as 4D because it incorporates additional sensory stimuli, adding an ‘extra-sensory fourth dimension’ to the experience. (22) The *Marvel Super Heros 4D* experience is Passive in influence, as it does not offer interactive elements for the viewers to influence the outcome of the experience. The experience is also Observant in existence, as viewers are not an active part of the narrative.

Active/Observant: *Kim Possible: World Showcase Adventure* falls into the categories of Active influence and Observant existence. *Kim Possible: World Showcase Adventure* is a scavenger hunt attraction where the visitor is recruited to help the Kim Possible franchise characters solve puzzles and defeat the villains. (23) The experience is Active in influence, as the story within the experience progresses only if the given puzzles and tasks are completed. Although the progress is linear, active participation is required to complete the experience. However, the experience is Observant in existence as the user does not operate within the cartoon world the story is set in. The interaction between cartoon characters and the real-world environment lacks full immersion, as the user is not intended to be immersed in the cartoon world despite the story taking place in the Kim Possible fictive universe.

Experiences can be very diverse, especially in an amusement park environment, and pinpointing them to a specific category can be challenging; however, the value of this examination lies in the insight it offers for application design. The examined categories help determine whether the experience would be immersive, transporting a visitor into a new world or enhancing the existing scenery digitally, and whether it should give the visitor the possibility to engage with the experience at their own pace and on their own terms.

3.1 VR in Amusement Parks

The history of XR in amusement parks begins with VR. Prior to incorporating VR into amusement parks, early concepts for a virtually enhanced experience were experimented on from 1970s to early 1990s by mixing synchronized visuals and motion to create immersive experiences. An early and successful

example incorporating this new technology is *Disneyland's Star Tours*, opened in 1987. (24)

The first VR ride featured as a theme park attraction, *Galaxie Express*, was developed as a test concept for a "VR" coaster. It operated for 9 months in total during the years 2003 and 2004 at the *Space Center* in Bremen, Germany. (25) VR was still in its infancy at the time, marking this experience as one of a kind. In the ride, visitors sit on a rollercoaster with an additional screen display in front of them. The scenery and contents on the screen are synchronized to match the ride, flickering imagery of space to the viewer. Following the brief period of *Galaxie Express* as a test concept, it took an additional 11 years for this technology to be utilized for amusement purposes again. The first VR ride that used head mounted VR glasses as a hardware piece is *Alpenexpress Coastiality*, opened in 2015 in Europa-Park, Germany. (26) Between 2015 and 2016, several VR-enhanced rollercoasters debuted in amusement parks worldwide. These years marked the beginning of XR use in amusement parks as we know it today.

3.1.1 VR Uses in Amusement Parks

VR typically acts as an attraction in itself due to its nature of being completely virtual. As the guest is immersed with a completely virtual world, real-life aspects are almost entirely obsolete. In this setting, real-life sensory aspects can enhance the virtual experiences rather than the other way around. An example of this is the incorporation of movement, smells and haptics into the virtual experience. Some examples of these attractions or uses seen in the context of amusement parks are:

1. VR roller coaster – Roller coaster ride enhanced virtually by head-mounted VR glasses. The rides typically require the user to put on the hardware and they only show virtual elements during the ride.

2. VR free-roam experience – An experience where the visitor can move freely and explore the virtual world in a controlled environment. This type of attraction can be interactive, a game or a type of simulation.

3. VR theatre – Typically a VR movie, enhanced by other sensory elements such as movement. These types of attractions can be an addition to existing 4D or 5D theatres. (27)

4. VR dark rides – Indoor attraction where the VR experience is synchronized with digital visuals and/or movement of a physical ride.

5. VR 360 tours – A virtual tour, typically on a website, showcasing the surroundings of an amusement park.

VR is also used for mapping and planning new attractions, where it helps visualize design concepts; however, these applications are less documented in research as they focus more on construction and planning rather than on attractions for guests.

3.1.2 VR Dark Rides and The Future in Interactive Design

Amusement park trends have shifted from enhancing physical rides with virtual elements to creating fully immersive environments and fully interactive digital worlds, where every aspect of the experience is driven by VR.

The aforementioned company, *The VOID* has pioneered the uses of VR in amusement parks, introducing the concept of “hyper-reality”. The idea is to blend physical spaces with virtual environments seamlessly to experience a highly immersive, realistic digital amusement attraction. The addition of interactive elements to virtual experiences has proven highly successful in amusement parks, with *The VOID*’s attractions driving a surge of innovation throughout the industry. Parks created by companies such as Disney and Universal Studios are continually incorporating new VR elements into their attractions. The use of fully realized virtual worlds is fitting, as Disney and

Universal Studios' parks are themed around well-known stories and narratives. VR can enhance storytelling and interactive aspects of said world seamlessly, which explains why it is used for this purpose by these companies. (28)

To create highly immersive, fully virtual attractions, it is stated that 'the heart of every VR theme park experience is the ability to create visually stunning worlds that feel real to the user', according to the article 'The Future of Virtual Reality Theme Parks: Immersive Attractions and Interactive Rides'. (28) As VR hardware has developed further in recent years, high-resolution OLED displays are offering an even more life-like visual experience that immerses the users better than before. Initially, maintaining a high frame rate to prevent motion sickness was a significant challenge. This has been addressed through foveated rendering, a technique that renders only the user's focal area in full detail. This reduces overall computational load, which allows for smoother performance. In addition to utilizing new rendering techniques, the development and use of 5G technology has made streaming heavier applications run smoothly without significant latency. Recent improvements in VR hardware have made the headsets wireless as well, which has marked a new era of expansive virtual environments being experienced without the constraints of being physically confined by cables, further enhancing the sense of immersion.

To increase immersion towards a realistic VR experience aside from the visuals, it is good to take into consideration the integration of haptic elements. Although still somewhat rarely used today, haptic suits and gloves could potentially simulate complex sensations further. Additionally, spatial audio can play a crucial role in creating a convincing sense of presence within the experienced attraction. (28)

The popularity of interactive experiences is evident, especially in an amusement park setting. However, VR's most promising feature lies in its ability to allow the user to become an active participant. As previously mentioned, this feature is primarily utilized in dark rides, where guests can influence the narrative by

making choices, interacting with virtual characters and manipulating objects within the environment.

In addition to interactivity within the narrative of a story, another trend with VR attractions in amusement parks is the development of multiplayer attractions that allow guests to collaborate or compete with one another in a shared virtual environment. These can be arena-style VR shooting ranges such as the attraction in *Knott's Berry Farm* (California, USA), called the *Showdown in Ghost Town*, in which guests compete against one another for the highest score within the experience. (29)

VR has been the go-to method of highly immersive entertainment for amusement parks for a longer time compared to AR or MR. This is partially due to the earlier accessibility of VR and AR technology, which has left MR relatively unexplored as an attraction medium. The future of VR in the amusement park industry seems evidently significant, as new XR focused establishments such as VR Parks are being opened. The VR Park Franchise *Warpoint* alone is planning to open 24 more locations soon, according to their main website. (30) However, despite the demand for VR experiences, VR hardware still falls short of fulfilling many people's expectations. (31)

For now, the challenges and expected progress towards deeper immersion within VR lies in accessibility, cost and sustainability. VR use in theme parks is not just a novelty at this point, it is continuing its evolution towards better experiences and storytelling. The key factor to the excitement in integrating VR into amusement park attractions lies within the limitless possibilities to create environments unreachable or unreproducible as real environments, meaning that only the human imagination itself is the limit. (28)

3.2 AR in Amusement Parks

AR has been a key feature in embodying fictional elements for immersion in amusement parks. The earlier augmentation techniques used in the amusement park setting were mainly for visual flair, giving personality to otherwise static

displays. Projection-based augmented reality is defined by the AR community as augmenting and enhancing 3D objects and space in the real world by projecting images onto their visible surfaces. A known example of this were the augmented reality projection-based heads in *Haunted Mansion*, featured in Disney Parks. (32) (Picture 1)

Picture 1. Quintet of singing busts with the projection-based AR in use. (33)

Projection-based AR served as a starting point before AR evolved into a medium for standalone attractions. More interactive AR experiences were introduced to amusement parks as tracker-based and mobile-based augmentation technologies were introduced to the market.

This thesis categorizes AR use in amusement parks in two ways: first, as an amusement attraction where AR serves as the main focus for a complete attraction experience; second, as a tool to enhance visitor engagement and immersion beyond primary attractions. These categories are covered in the *'Augmented Reality as an Attraction Experience'* and *'Augmented Reality for*

Enriching Visitor Engagement' sections. The *Augmented Reality as an Attraction Experience* section examines the origins of standalone AR experiences, the unique aspects they bring to an attraction, and how AR as a standalone experience has evolved to the present day. The *Augmented Reality as an Attraction Experience* section explores how AR has been used to elevate immersion in existing attractions, how AR can offer entertainment in the amusement park fairgrounds outside the actual attractions, and how AR can help guide the amusement park experience.

3.2.1 Augmented Reality as an Attraction Experience

One of the earliest standalone AR experiences developed for an amusement park was *Kim Possible: World Showcase Adventure.* It was opened in *EPCOT Theme Park* during January 2009. In this scavenger hunt game, guests were recruited as secret agents alongside Team Possible, with the main task of saving the world from super-villains with the help of a "Kimmunicator". (34) (Picture 2)

Picture 2. "Kimmunicator", a customized cell phone for the game. (35)

The phone used for the game, the “Kimmunicator” is a Motorola i870 videophone with a GPS attached. This device was used to drive the story and activate some of the clues during the scavenger hunt by utilizing the Kimmunicators GPS location and completing tasks such as taking photos. (23)

Ultimately, what made *Kim Possible: World Showcase Adventure* a pioneer in AR was its use of digital storytelling and interactive elements which seamlessly merged with real-world settings. Although mentioned earlier, the experience does not necessarily fully immerse the user in the cartoon world of the Kim Possible franchise. However, the tasks and puzzles integrated into the real-world environment seamlessly, allowing the visitors to interact with both the virtual communication with the cartoon world and their physical surroundings in a cohesive way. An example of this is the communicative synergy, where the visitor receives a teabag from a real-life shop vendor as a puzzle piece and writes the correct answer using the Kimmunicator device to solve the puzzle and advance the storyline. (36)

Kim Possible: World Showcase Adventure and its antecedent versions augment reality by enhancing the physical environment with digital elements. The phone devices used trigger special effects that appear integrated with real-world locations. For instance, when visitors approach certain areas, an action might trigger due to the tracked GPS location. These triggered actions could be characters speaking through the phone, objects moving or water-elements turning on. These are key features of AR, as the real-world scenery is “augmented” by these digitally triggered actions, creating the illusion that the story of the attraction is interacting with the real environment. In essence, the attraction experience augments reality by combining live-action environments with digital media, allowing visitors to interact with the story in a dynamic way.

In 2012, the scavenger hunt changed its theme franchise from Kim Possible to Phineas and Ferb, going with a new name of *Agent P’s World Showcase Adventure,* which used nearly the same gameplay and premises. (37) During the operation of *Agent P’s World Showcase Adventure*, the attraction updated

its gameplay from using cell phones to personal smartphones, eliminating the need to borrow hardware for the game. (38) In 2019, the attraction was announced to undergo thematic rebranding to *DuckTales World Showcase Adventures* by 2020. However, the COVID-19 pandemic caused delays with many projects including the switch from *Agent P's World Showcase Adventure* to *DuckTales World Showcase Adventure.* The official launch of the updated scavenger hunt game finally happened on December 16th, 2022. (39)

Considering that the *World Showcase Adventure* concept has been rebranded twice and maintained operation for most of the last 15 years with only a brief hiatus from 2020 to 2022, it stands as a remarkably enduring attraction at *EPCOT*. Though it was initially introduced as an experimental, interactive experience, the concept has had notable longevity. The longevity of the project suggests that the concept has been both successful and well-received by visitors, as it continues to remain in operation to this day.

Another example of Disney's AR use as an attraction can be found at the *Magic Kingdom Park* with the interactive AR game experience *Sorcerers of the Magic Kingdom.* The premise of this AR game is that the wizard Merlin is recruiting park visitors as new apprentices to prevent Hades from taking over the Magic Kingdom. This is done by defeating Disney villains through various "portals" throughout the park. (40) The game is played by casting spells utilizing special AR cards at various portal locations found in the Magic Kingdom. This game employs AR by using physical AR markers, which activate the digital interactions when presented to a designed sensors, embedded with the attraction. (41) (Picture 3)

Picture 3. AR Spell cards being used in front of a pirates clocktower portal. (42)

The attraction operated from the year 2012 to 2021, closing due to changes in how visitors use mobile technology, decreasing the demand for *Sorcerers of the Magic Kingdom,* according to Disney. (41) According to Disney's description of the closing of *Sorcerers of the Magic Kingdom*, the initial goal of the experience was to provide a free, interactive activity for visitors to enjoy while in the park, offering a break from long lines at traditional attractions. It also featured a card-collecting aspect, possibly designed to encourage repeat visits to the parks to continue the progress within the game or try harder levels of the game. The decreased demand for these types of experiences could be caused by the widespread availability of entertainment and activities on modern smartphones, which can offer an alternative form of engagement during visits.

3.2.2 Augmented Reality for Enriching Visitor Engagement

As AR has become more widely known and used, especially on mobile phones, new ways have been presented as to how AR can be used in amusement parks

as an attraction itself or as an enhancer of an existing attraction. This section focuses on the different ways AR has been used to enhance existing attractions or scenery, improving visitor engagement during park visits. It also examines possibilities for the future of AR use.

As previously mentioned, projection-based AR presented an initial example of how AR can offer digital augmentation for real-life environments. This concept has evolved together with the introduction of smartphones, as the AR function capabilities of these devices have improved. Instead of projecting digital augmentation with lamps directly to a real-life physical surface, the visitors can now augment their park visit in various ways on their own smartphone devices. For example, localized AR filters in Snapchat, where visitors can take pictures with digital characters or become lookalikes of characters. (43) Along with becoming characters themselves, visitors can also engage with the augmented environment itself through their personal smartphones, fostering a deeper connection with the physical surroundings of the park. This technique has been utilized by the *LEGO MYTHICA* experience, which offers a modern AR-enhanced walkthrough of The Magic Forest located in *LEGOLAND Windsor*. (44) (Picture 4)

Picture 4. *LEGO MYTHICA* exhibit piece on a stone stand with instructions on how to scan the AR marker. (45)

The attraction is designed to be local and has the possibility to be installed directly on a smartphone for use in the park or to try the technology out in home environments. (44) This application exemplifies how AR is used to enhance experiences in parks, transforming static exhibits and scenery into a dynamic and engaging experience.

The use of AR to enhance visitor engagement, beyond adding visually expressive elements to the park scenery, has been researched, particularly how AR can help to reduce perceived waiting times when queuing for attractions in theme parks. This research suggests that offering interactive activities, in this case games, to a queuer can help reduce the perceived waiting times. (2) While AR games designed for queues have been researched and developed, as of today, there is little evidence to suggest that the concept has been widely implemented in amusement parks. Development and operation costs, along with hesitancy to design experiences heavily reliant on mobile phone usage, may explain the slow adoption of AR technologies in amusement parks. (46) Despite the hesitancy, it is evident that AR has the potential to deliver highly interactive and personalized experiences in amusement parks, enhancing visitor engagement both within attractions and in other areas of the park.

3.3 MR in Amusement Parks and Tourism

This thesis defines MR applications as requiring virtual elements to integrate seamlessly with the physical world. The key difference between an AR experience and an MR experience is that AR digital elements are overlaid onto the real-world environment. The digital elements in AR are not typically interactable by touch directly and do not respond to physical surroundings, whereas in MR virtual elements are not only overlaid onto the real world, but also often anchored to the physical surroundings and can be aware of the environment, allowing the user to interact with its elements. In essence MR takes AR a step further. (47) (48)

Earlier uses of MR in amusement parks typically included most of its defining characteristics but lacked interactivity. For example, the attraction *Harry Potter and the Forbidden Journey,* located in *Universal Studio Orlando Resort* stands out as one of the earlier attractions that effectively combines virtual elements with real-world special effects. The *Harry Potter and the Forbidden Journey* attraction is a dark ride in which the visitor is taken to an immersive, movie-like adventure through the world of Hogwarts alongside Harry Potter. The ride

synchronizes motion-based seating with digital movie screens and real-world props, including animatronics and special effects like smoke machines. The system moves the ride vehicle between these physical and virtual elements, creating a sense of flight within the experience. (49) (50)

Notably, MR is only now beginning to be utilized in amusement parks fully with its defining characteristics. Upon the release of Meta Quest 3 and Apple Vision Pro's cutting-edge passthrough capabilities, the XR industry has finally received hardware capable of making MR experiences that feel natural for the user. (51) With this in mind, the featured case studies showcase two notably distinct applications that explore the capabilities of the hardware. The first case study, *Hysteria in Boothill* is the first MR experience developed for an amusement park. (52) As of the release date of this thesis, no other MR experiences have been released for amusement parks, making *Hysteria in Boothill* the only amusement park attraction of its kind.

The second case study *Relive 1770* was chosen to illustrate the potential of interactive MR experiences in the tourism industry, an industry which is similar to the amusement park industry in terms of being experience-, destination and entertainment-based. Although *Relive 1770* is not directly developed for an amusement park, it is an example of an application that supports the ideas and possibilities of what the future of MR in amusement parks could look like.

These case studies were conducted by reaching out to the creators of the applications and interviewing them about their projects. The interviews took place online on the Google Meet platform and in preparation for the interview, a list of interview questions was written to aid the interview flow.

3.3.1 Case Study of Hysteria in Boothill

The case study of *Hysteria in Boothill* contains online research including articles and an interview with Eduardo Herranz, COO and co-founder of Spatial Voyagers, the company that developed the experience. Spatial Voyagers is associated with a pre-established company, Virtual Voyagers, which is also co-

founded by Eduardo Herranz. In a sense, Spatial Voyagers is a branch of Virtual Voyagers that focuses on spatial XR development as opposed to exclusively working on virtual or metaverse projects. (53)

A series of questions was asked in the interview to establish a better understanding of the company, the concept, the development, and the reception of the project. Due to the inability to physically visit the location of the experience personally, the interview heavily emphasized questions on what the experience is like. The interview was conducted during 14th of October 2024 on a Google Meet call.

This case study will present the findings in the same order as the interview questions, which are as follows:

- Could you tell me briefly about yourself, Virtual Voyagers and your role at Virtual Voyagers?
- What kind of projects has Virtual Voyagers (Spatial Voyagers) done previously? (More specifically, Amusement park related or Mixed Reality related?)
- What is the origin of the project “Hysteria in Boothill”?
- What is “Hysteria in Boothill” like as an MR experience? How is used? What hardware is it developed for? What is the “Gameplay” like in the application?
- What was the development process like of the application “Hysteria in Boothill”? What challenges were there?
- What has the feedback been like so far from this project?
- How do you see MR transforming the future of amusement parks?
- What advancements in MR technology are you most excited about, and how do you envision these shaping the future of the amusement park industry?

Eduardo Herranz introduces himself as a co-founder and COO in both Virtual- and Spatial Voyagers and he oversees the Voyagers Academy, an additional education academy with a focus on the XR industry and development.

Before the Spatial Voyagers branch started its operation, Virtual Voyagers was established. Virtual Voyagers’ operation in the XR industry began mainly with

marketing projects, which were developed for various customers including Ferrari and Disney. In addition to marketing, Virtual Voyagers has developed XR projects for training purposes, media and entertainment in the form of videogames as well as creating content for Vodafone's metaverse. (53) As of today, Virtual Voyagers has completed 230 projects with 90 different brands and won over 20 awards as a company. (54)

Spatial Voyagers started its operation in January 2024 and before the project *Hysteria in Boothill*, they had created their first spatial game, *Spatial Assault*. (55) PortAventura World, an entertainment resort company, approached Spatial Voyagers to develop an MR experience as a new attraction for *PortAventura Park*. Spatial Voyagers and PortAventura World collaborated to explore the possibilities of MR, testing various hardware to determine development potential. The utilization of recently launched technologies such as Meta Quest 3 and Apple Vision Pro were explored in the beginning stages of the development. The project faced a significant challenge from the outset, as PortAventura World requested its completion within a strict four-month timeline. The project was completed successfully within this timeframe, celebrating the opening of the attraction in August 2024. (53)

Hysteria in Boothill is an MR experience specifically designed as a horror attraction. Based on its premise, the experience can be categorized as a trackless semi-dark ride which runs on Meta Quest 3 hardware. The hardware and software are regularly operated and calibrated by the PortAventura staff to ensure the application functions as intended. Upon arriving at the location of the experience, set within a Far West-themed house, visitors are immersed in a horror-themed environment with eerie music and atmosphere. Prior to being equipped with the hardware, the visitors are shown a video which tells the premise of the experience and the role they are expected to take as a participant. Once the visitors have familiarized themselves with the premise, they are guided to put on the hardware and the experience begins as visitors gather for a digital spiritism session.

The experience is in a themed house, which is laid out to be maze, similar to many haunted-house dark rides. The visitor explores and walks through the experience, which lasts approx. 9-10 minutes. To elevate the feeling of terror and further blur the lines between virtual and reality, the maze incorporates various sensory triggers throughout the experience. These include fans, pressure air systems and items such as ties, disguised as spiders to evoke disgust. During *PortAventura Park's* Halloween event, an actor roamed around the experience, giving the visitors additional startles outside the application itself. The atmosphere of the blended realities can be observed through a screenshot from the experience. (Picture 5)

Picture 5. Screenshot from the *Hysteria in Boothill* MR experience. Real life and virtual props blending in the environment using Meta Quest 3's passthrough capabilities. Picture provided by Eduardo Herranz.

Prior to the official launch of the attraction experience in 19th of August 2024, the application was soft launched, tested as a concept and tested for bugs. Upon release, Spatial Voyagers and PortAventura surveyed the visitors with a questionnaire containing 7-8 questions. The questionnaire contained questions including what the visitors thought was good and bad about the experience, if they got value for their money, how much they would pay for said experience

and asked for a general satisfaction rating on a 1 to 10 scale. The questionnaire was answered by approx. 1000 visitors, with an average rating of 8.5 – 8.7. The feedback and reception of *Hysteria in Boothill* has been exceptionally positive, making it a massive hit despite having an additional cost to visitors who want to visit the attraction. By 26th of September, more than 10 thousand parkgoers have visited the *Hysteria in Boothill* experience in addition to their visit to the *PortAventura Park*. Since the launch of *Hysteria in Boothill*, the experience has continually sold out for days, highlighting the interest and demand for MR experiences among the public.

As stated above, the development was executed at a fast pace of four months. The development team consisted of approx. 15 people from Spatial Voyagers and their collaboration partners. The tasks in the project varied between programming, music composing, 3D artistry, motion capture and animation. From the four-month development period, three months were spent on full-time development before the user testing phase. Given the notably short timeline to develop the experience, the project was especially demanding for the team to execute. A significant time-consuming factor was the need to troubleshoot on-site. This process was particularly time-consuming due to the challenges associated with commuting.

The biggest challenge of developing the experience aside from the demand for on-site troubleshooting was executing the MR anchoring to work correctly with the experience infrastructure. Spatial anchoring is a key feature in MR, binding virtual props to real-life infrastructure or surfaces. The on-site troubleshooting included measuring the drift of the anchors and adjusting them accordingly in the development platform. As anchoring was introduced to the development process, reverse-engineering was conducted to learn how Meta’s anchoring technology fundamentally worked, especially regarding illumination requirements. High brightness and contrast of the real-life spatial space was found to cause less drift in the application. To create a lurid and dark experience for the users, the application itself was set to look dimmer for the user as opposed to lowering the lights in the real-life surroundings, risking drift

in the spatial anchors. Other development aspects included planning the experience layout and its flow, measuring the real-life environment to match the measurements in Unity.

Initially, the development took inspiration from the MR game *Hauntify*. *Hauntify Mixed Reality* game turns the players house into a horror game, where evil spirits hunt you down. It uses physical environment in its gameplay and includes interactive aspects, such as a flashlight. (56) As the concept of *Hysteria in Boothill* was developed, interaction possibilities were explored. Using a virtual flashlight in dark surroundings was eventually scrapped as an idea, when concerns regarding the limited accessibility to see the surroundings arose. Ultimately, interactive aspects were not developed for the experience because of limitations in Meta's software, which at the time did not support disabling the software's hand menu. Having users accidentally take themselves out of the application was a significant concern, which is why the experience relies mainly on the visual aspects of MR.

Eduardo Herranz explains his views on the future of MR in the amusement park industry, "It is clear that MR will change the future of amusement parks." Complementary experiences in MR are clearly exciting and interesting to the customer target group. MR has great potential to enrich, enhance and renew rides and attractions, which *Hysteria in Boothill* illustrates with its popularity and success. *Hysteria in Boothill* represents a successful proof of concept on the synergy of MR and amusement park industry.

Regarding future MR development, Eduardo Herranz envisions MR to take a bigger role in the amusement park industry, as the spatial anchoring technology develops further. There is hope to bring interactivity to MR amusement park experiences once the means to develop it without the risk of user error evolves further. While it is difficult to determine whether the excitement around MR experiences stems from the initial novelty of the technology, *Hysteria in Boothill* clearly demonstrates the potential of utilizing real-life space as a foundation for virtual experiences.

3.3.2 Case Study of Relive 1770

The case study of *Relive 1770* contains online research including articles and an interview with Dylan Husted, founder of See Reality, Inc., the company that developed the experience. The case study for *Relive 1770* began with an initial search using the term 'Mixed Reality in Amusement Parks' on Google. This search led to a travel website highlighting an *'Interactive Augmented Reality Experience Along The Freedom Trail*'. Further investigation allowed the research to established contact and request an interview with the creator of the experience.

Interview with the creator of *Relive 1770*, Dylan Husted was held on Google Meet at 7th of October 2024 regarding the company behind the project and the project itself. The following is a list of questions asked during the interview:

- Could you tell me briefly about yourself, your occupation and the company that created Relive 1770 Experience?
- Have you or your company done other AR / MR applications? (More specifically, Amusement Park related or Mixed Reality related?)
- What is the origin of the project "Relive 1770"?
- What is "Relive 1770" like as an MR experience? How is used? What hardware is it developed for? What is the "Gameplay" like in the application?
- What was the development process like of the application "Hysteria in Boothill"? What challenges were there?
- What has the feedback been like so far from this project?
- How do you see MR transforming the future of tourism?
- What advancements in MR technology are you most excited about, and how do you envision these shaping the future of the amusement park industry?

Dylan Husted introduced his background as a Babson College graduate with a Bachelor of Science degree, specializing in business and entrepreneurship. He explained that his ambition was to start his own company, leading to the creation of a nonprofit gamified platform aimed at addressing climate change. The platform encouraged collage students to take climate-friendly actions in exchange for rewards. In addition to this project, he worked as a software

engineer in web-app development for six years before transitioning to a role as Lead Engineer at a video chat software company.

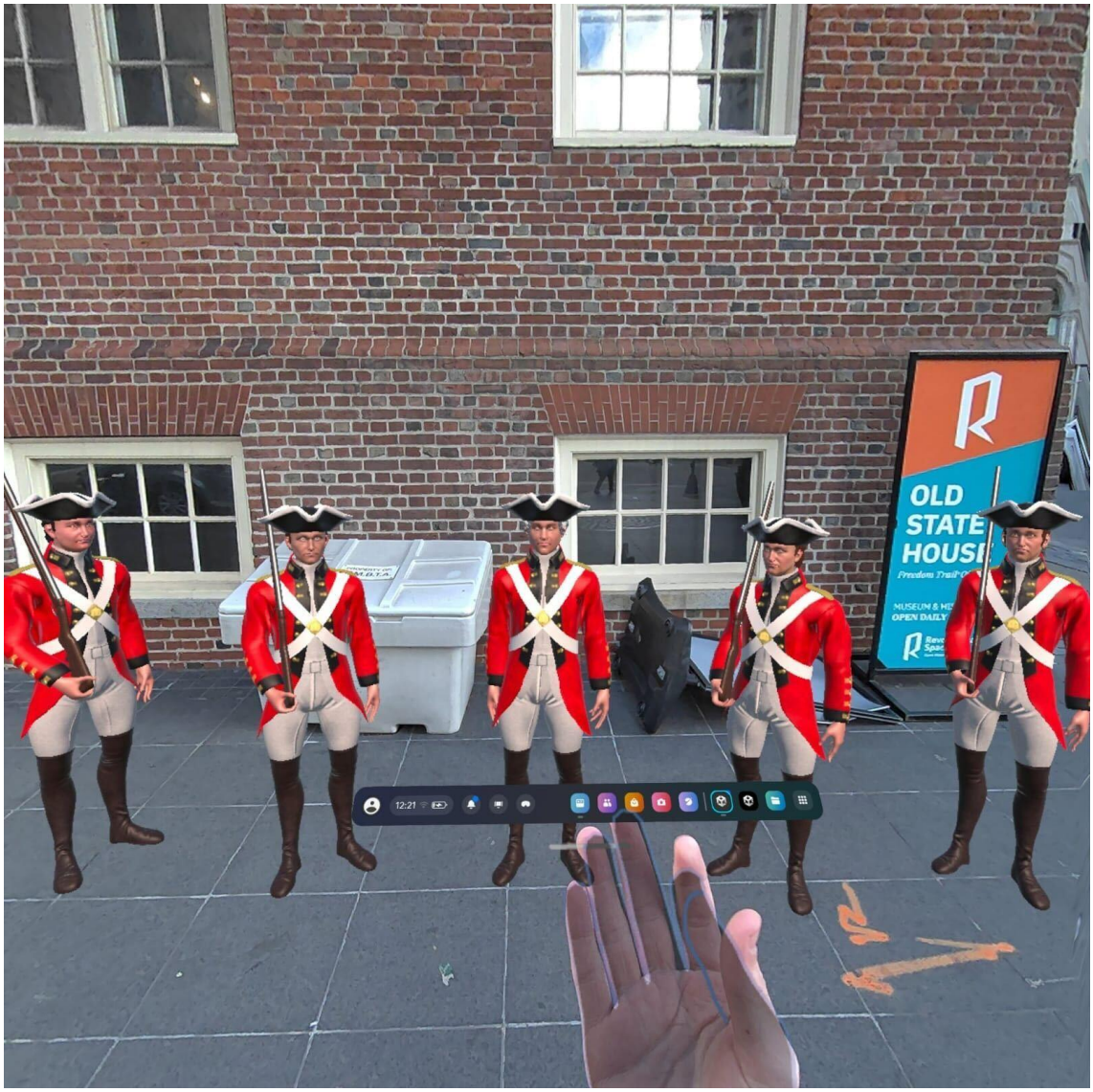
Dylan Husted recently founded a new company called See Reality, Inc. See Reality uses AR and MR technology to bring historical sights to life by illustrating what the sights used to look like in earlier time periods. As of now, there is one application set up to operate in Boston, which is the *Relive 1770* experience. See Reality, Inc. is a self-funded startup, including Dylan Husted as the founder and CEO along with a 3D artist and an XR Engineer. During summer 2024, the *Relive 1770* experience itself had a team of four employees whose task was to guide the experience for the visitors, manage the hardware and handle sales.

The *Relive 1770* experience is the first project developed by See Reality, Inc., and it initially started as a proof-of-concept project rather than a commercial endeavor. The *Relive 1770* experience allows users to see and interact with virtual props and characters during the Boston Massacre, which happened on March 5th, 1770, in Boston. This proof-of-concept project seeks to elevate the user's understanding of real-life historical sights and events by demonstrating MR's potential in bringing history back to life, offering a more insightful way to experience history and truly comprehend it. The main goal of the experience is to help visitors better remember and understand historical elements by interacting with them virtually.

As mentioned above, the *Relive 1770* project originated from the proof-of-concept research on leveraging MR to create "mind-blowing experiences with low budget". (57) In comparison to VR, MR is less costly to develop due to the absence of the need to create an entire customized virtual world. *Relive 1770* worked as a smaller-scale project to test these concepts and observe how people responded to the idea, ultimately producing positive results. The idea of bringing to life the Boston Massacre event arose from the observation of extensive foot traffic surrounding the historical memorial plaque from the massacre. It became clear that the significance and meaning of the site remains

relatively unknown to the tourist visitors and residents alike. The *Relive 1770* experience's core purpose is to educate visitors of the history behind the otherwise nondescript memorial plaque and site.

In the experience itself, users see the surroundings of the Old State House of Boston and they are familiarized with the event via virtual video, which appears in front of them in the MR setting. This graphic-novel type video establishes the context of what is going on during the events depicted by the experience as it illustrates to the user the tension between British soldiers and civilians with the narrative as it was told at the time of the events. After the video is viewed, the interactive part of the experience is enabled for the user. The characters of this event are replicated virtually for the experience, making it possible for the user to trigger reactions from the virtual characters by touching them or throwing virtual objects at them. Triggering a reaction from the virtual characters by approaching them physically was also experimented with. This experience is a type of simulation rather than a game, as it does not use aspects of games or gamification in its design despite being an interactive experience. The experience was designed to be relatively straightforward to make it comprehensible to operate for technologically inexperienced users. The experience is modelled to replicate the famous engraving of the event created by Paul Revere. The engraving depicts British soldiers firing into a crowd of unarmed colonists, highlighting the chaos and brutality of the event, which has later been described as a piece of propaganda against the British rule. Despite this setting, the experience itself does not contain significant inaccuracies regarding the historical subject matter. The following screenshot illustrates how the virtual elements blend to the city environment. (Picture 6)



Picture 6. Screenshot from the *Relive 1770* MR experience. Virtual British soldiers standing in a street blending into environment using Meta Quest 3's passthrough capabilities. Picture © See Reality, Inc.

The development began by experimenting with Unity's XR plugins. Once the project's XR foundation was established and implemented, the team proceeded to create a placeholder scene for the experience. Throughout the process, the team adapted and experimented as they went due to having no prior experience with MR, this project being their first one in this domain. Unexpected errors took a significant amount of time to solve, as XR plugins and the AR foundation are relatively new technologies within Unity engine and are still undergoing development.

A significant challenge arose from adapting the hardware to work outdoors, as Meta Quest 3 is primarily developed for indoor use. Rendering virtual elements in an environment with direct sunlight is challenging for the hardware, which required manual adjusting of the Unity engine lighting settings. To better understand the challenges of MR development for outdoor use, Dylan Husted was asked to further explain how a developer should approach creating outdoors MR content. Dylan Husted pointed out three key things to take into consideration as *Relive 1770* was developed, which are physical location and render space, floor and ground adjustments, and lighting.

Regarding feedback that was gathered from the users, it was concluded that the modern hand-tracking MR technology is intuitive and easy to use regardless of the age of the user and everyone who has tried the experience has been able to figure out how to use it without prior experience with MR. The feedback was gathered during the summer of 2024 from visitors from all around the world. The concept was perceived as exciting and using the technology was enjoyable for the users. It was also noted that some of the users were initially worried about using the Meta Quest 3 as its design is that of a full set of VR glasses. According to Dylan Husted and the feedback from the users, many users had a better experience being immersed with MR as opposed to VR. Some users have negative experiences with VR for reasons such as motion sickness and spatial awareness anxiety, which are minor or completely obsolete with the MR medium. Out of 47 online reviews, the average rating of the experience in travel website called TripAdvisor is five, on a scale of one to five, as well as placing the experience as a top 66th attraction of 360 listed Tours & Activities in Boston. (58) The profoundly positive feedback shows the success of *Relive 1770's* proof-of-concept.

When discussing the future of tourism and MR, Dylan Husted viewed the future of tourism as benefiting greatly from MR. As travelers put a significant amount of time, money and effort into visiting a travel destination, typically somewhat underwhelming real-life sights and monuments can be made significantly more engaging and captivating with the use of AR and MR technology. Since travel

destinations, especially historical sights, can often be the highlight of a visitor's trip, it is given that the tourism industry would seek to optimize these experiences. As the MR technology we have access to today remains relatively unknown to travelers, these experiences are difficult to find as they are not searched for specifically by the potential clientele. For the future, Dylan Husted hopes that mobile XR becomes more available and known to the public which could result in growth in the potential clientele that would seek out experiences like *Relive 1770*. "I think it's huge, we are just at the beginning. The challenge now is that VR has been around for so long and people have had bad experiences with it", Dylan Husted states. He further explains that fixing the narrative of what XR could potentially be is a challenge. Introducing the potential of MR to masses remains a challenge, as many potential users are unfamiliar with the technology. This might be presumably due to the lack of hands-on experiences developed using this technology, given that it has only begun to gain traction in recent years.

4 XR Application Design for Spatial Fairground Environments

The previous chapter addressed the first primary research question of this thesis: 'How has XR been utilized in amusement parks and their fairgrounds?' The contents of this section of the thesis address the second primary research question: 'How to design XR applications that effectively leverage the spatial scale in amusement parks?' By examining content relevant to these questions, a design concept can be developed based on the findings, which is the final topic of this thesis.

This chapter aims to address the second primary research question by reviewing and analyzing existing XR applications designed for spatial outdoor environments, with the goal of understanding how XR has been utilized to leverage larger spatial areas. This section also examines the challenges associated with developing for MR and outdoors environments, while providing design guidelines to consider when creating extended reality elements in such

settings. Finally, these findings form the theoretical framework for developing an application concept that aligns with the research focus of designing applications for the spatial environment of amusement parks.

4.1 XR in Spatial Outdoor Environment

The XR formats that are typically used outdoors are AR and MR. VR is seldom used or utilized at all under these conditions. The likely reason for this is that being outdoors offers little advantage in a fully immersed virtual environment. On the contrary, outdoor use of standard VR hardware systems can be impractical and unpredictable. Exposure to environmental factors, particularly changing weather conditions, poses significant challenges.

This section mainly examines XR applications like those used specifically for immersive entertainment and education. To narrow down the scope of the research topic, this section focuses solely on the use of spatial outdoor applications. This entails that, while AR and MR elements may exist in an outdoor setting, they are not considered relevant unless they are widely spatially integrated, which would most likely require the user to move through the space themselves to fully explore the application. For instance, projection-based AR placed outdoors in a confined area that does not require exploring larger spatial environments would not meet the criteria in this case.

An early example of leveraging vast outdoor spaces as a gameplay setting would be *Ingress* and *Pokémon GO,* created by Niantic, Inc. These games were initially designed to explore the possibilities of using geospatial mapping data, such as that of Google Earth, as a setting for a video game. (59) In *Ingress* and *Pokémon GO*, interactive features like *Ingress'* portal networks and *Pokémon GO's* PokéStops add a digital data layer to the physical environment. These data layers augment reality by providing gameplay interactions tied to specific locations, allowing players to engage with the game world based on their real-world positioning. This relies on the GPS data of their device. (60) The visual AR aspects were introduced in *Pokémon GO*, providing the possibility to catch

and examine Pokémons in real-world space using the smartphone camera. The spatial mapping camera picture feed technology used in *Pokémon GO* has been continuously developed and recently updated to point, position and photograph the digital Pokémon on ground, on objects or in the air naturally. (61)

Ingress and *Pokémon GO* use spatial aspects in the sense that they offer augmentation in real-world permanent sites, on top of which *Pokémon GO* offers the possibility to display digital 3D assets in the user's current location based on the camera feed. This could be described as free-roaming AR, in which contents are not directly tied to any specific location for the AR aspects to work, as the spatial data is gathered mainly from the user's current GPS data. For free-roaming AR to function, a GPS-enabled device is necessary. This is why such AR technology is typically used with smartphones rather than VR headsets, even though VR devices are capable of seamless passthrough.

Marker-based AR is another form of AR that can be used outdoors without relying on GPS data. Instead of tracking geographical data to place AR interaction points, it uses physical markers – typically QR codes or images in the environment to trigger digital content. (62) These markers can initially be placed anywhere to trigger digital content in both AR and MR settings, be it a smartphone or VR glasses with high quality passthrough capabilities.

An example of marker-based AR implemented in an outdoor environment is the AR city tour designed for the *Mikhail Chekhov Riga Russian Theatre*. This experience is a scavenger hunt, which leads participants through ten locations in Latvia's capital Riga, revealing aspects of Mikhail Chekhov's time in the city. Using AR markers placed on plaques in the outdoor setting, users can uncover educational and entertaining digital content placed in real-world locations, enhancing their understanding of the area's cultural heritage. (63)

The Mendez Monument Tribute Park (California, USA) uses AR similarly in outdoors environments. With the use of object recognition, the park provides

augmentation features throughout different parts of the park, as local wall murals can become interactive sliding puzzles and virtual characters can be found speaking to you through smartphone AR. A scavenger hunt element can also be found in this AR implementation, as the aim for the installation is to guide users to look for educational items placed in the park that would trigger content based on the application recognizing the right objects. (64)

Digital assets can also be placed into the environment through anchoring, like in the case of *Hysteria in Boothill*. Though, as mentioned above, the use of large-scale MR integration in spatial outdoor environments is still in its infancy, as no evidence or use cases demonstrating such applications could be found. However, using this type of technology is currently being researched as the European Regional Development Fund (EFRE) is aiming to bring Mixed Reality Arts into public spaces by providing artists with the means to create MR artworks. An ongoing project *Meta*^{2} + *UNREAL* focuses on creating a platform for multi-user and multi-modal art. (65) The project description itself does not specify if it employs anchoring techniques like in the case of *Hysteria in Boothill*. Nonetheless, the aim of the project suggests outcomes comparable to those achieved by a cloud-based anchoring system in this context.

4.2 MR/AR Design for Outdoor Environment

This section outlines key considerations for designing XR applications suited for outdoor use. As previously mentioned, VR is excluded due to its inherent limitations in such settings; therefore, this section considers only MR and AR as coherent platforms for XR development in outdoor environments.

To reiterate the differences between MR and AR, AR is typically used with smartphone hardware and often lacks the capability to direct interaction with digital elements, such as 3D objects. In essence, MR differs from AR by integrating virtual images directly into the user's real-world view through specialized headwear, offering broader applications and interactions with digital content. (66) However, both XR platforms – smartphone-based AR and VR

headset-based MR - share similar technological challenges when designed for outdoor use. The upcoming section addresses the design considerations for the most used XR hardware mediums, including smartphone-based AR and VR headset passthrough MR. AR glasses are excluded from this design guide, as the hardware has not achieved widespread adoption yet largely due to its high cost, limited practicality and a lack of integration into everyday user routines. (67)

The case studies and interviews of the MR applications explored earlier in this thesis provided insight into the design aspects that were especially challenging in the process of designing and executing MR with VR headset passthrough technology. The upcoming list of concerns is provided to address the main aspects to consider when designing an application that is aimed for outdoor use. This guideline is primarily based on insights gained throughout the course of this study and, as such, does not heavily rely on external sources. It serves as a summary of interpretations and recommendations for designing VR headset-based MR and smartphone-based AR applications that incorporate visual digital assets into AR.

4.2.1 Content Placement and Environmental Factors

The development for outdoor use should first and foremost determine the area in which the developed application takes place. As previously stated, an outdoor application can be “free-roaming”, tracking regionally localized areas with GPS to trigger content, or be fixed into a certain location by using anchoring technology or using marker-based triggers to trigger content. Markerless content can be used in an outdoor setting, but it is typically not strictly tied to outdoor spaces, since there is no way to restrict the use to a specific place. Due to this, it is challenging to ensure that the content is used outdoors. The used area is important to establish early in development, as the area itself frames the factors to consider when designing a very tech-heavy application. The following

graph illustrates visually the differences between free-roaming, marker-based, anchored and markerless triggers in outdoor spatial environments. (Figure 6)

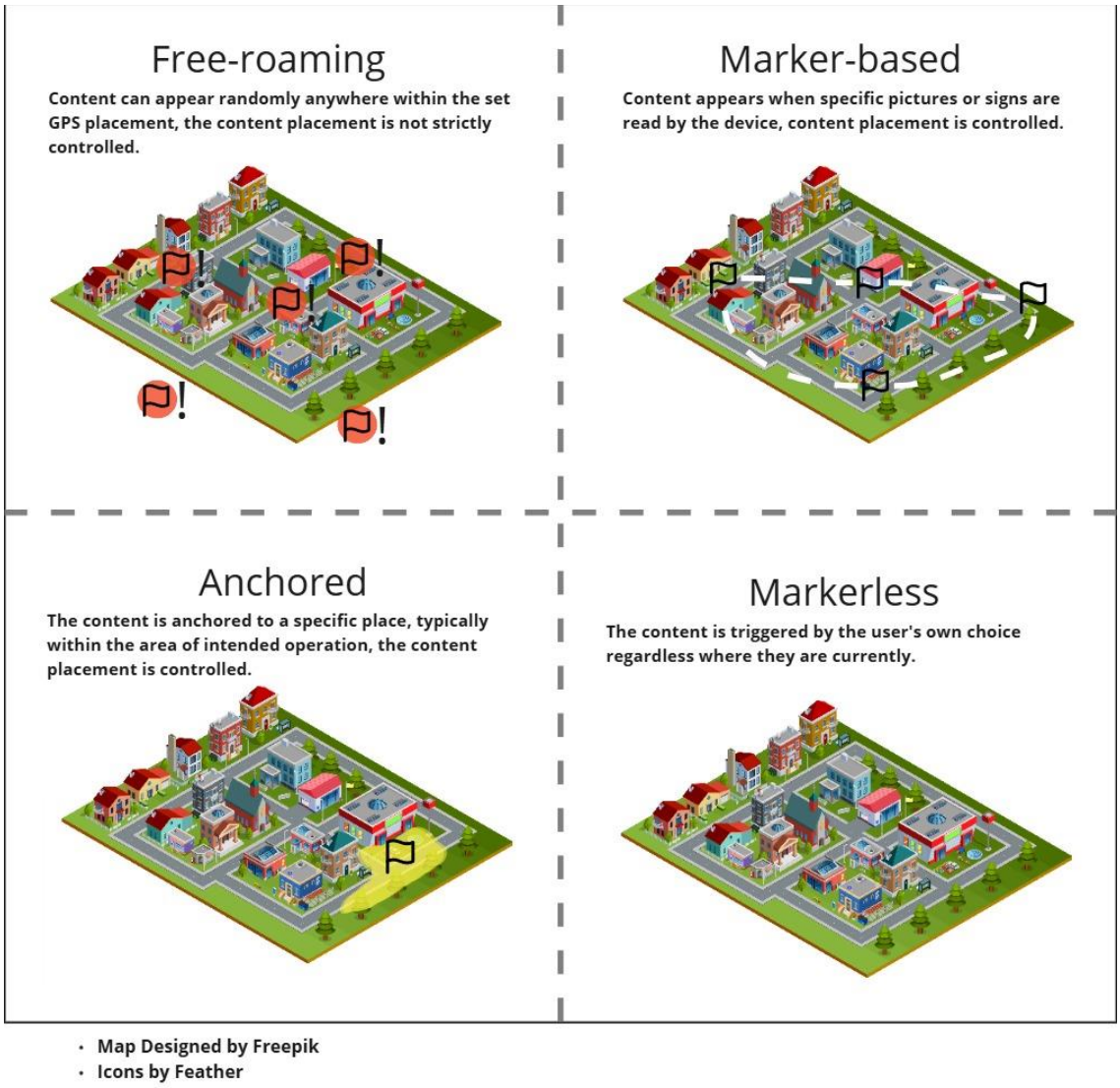


Figure 6. Illustration of various methods of placing digital content in an outdoor setting.

This graph illustrates the various methods of placing digital content in outdoor environments, explored through the gathered examples examined in this thesis. As mentioned, *Pokémon GO* uses two of these methods, “free-roaming” by having the Pokémon appear on the world map and markerless by allowing the user to place Pokémon into a location of their choosing. Marker-based triggers were used in *Sorcerers of the Magic Kingdom* and *The Mendez Monument Tribute Park*, in both cases encouraging exploration of the respective areas they

operated in. *Hysteria in Boothill* used anchoring to achieve the seamless digital content integration into a real-world setting.

Knowing the type of area used for the outdoor space can help determine which medium is best suited for the intended uses. Free-roaming and marker-based content triggering can work at scales ranging from localized scale to global scale. Anchoring; however, remains challenging to implement as noted by the case study of *Hysteria in Boothill*, which is why it has yet to be explored extensively whether it can be used on a large scale outside its initial mapped location.

The next aspect to determine would be if the idea of the application is to trigger content at different places individually, or if it is meant to be experienced simultaneously. Sparsely placed trigger points can be explored effectively through a marker-based medium, as it is not restricted to GPS-data or anchoring to determine the intended area of operation. Implementing these types of selected trigger points or anchored areas has some limitations depending on environmental factors, like the unevenness of the terrain or climate/weather suitability.

Uneven terrain can be a major challenge for implementing anchoring techniques effectively and climate factors can impose problems when using hardware. Another environmental factor to consider is that smartphone-based applications may rely heavily on strong cellular and GPS signals to operate. Similarly, this concern applies to VR hardware when the application depends on features like cloud-based anchoring to function. Lighting conditions are a crucial design factor, as both smartphones and VR glasses' passthrough functionality depend on specific lighting requirements to operate effectively, as was noted during the development of *Hysteria in Boothill.* This necessitates careful consideration of whether the application should be intended for use during daylight hours. Depending on the location and season, utilizing this technology might be highly impractical.

4.2.2 Hardware and Technical Considerations

The introduction of viable passthrough technology in VR headsets is quite recent and the use of the hardware outdoors is generally discouraged due to possible hardware damage from the sun. (5) Although the VR hardware is designed to be used indoors, pushing the capabilities to outdoor use is possible, as showcased in *Relive 1770*. Some implementation and hardware risks are still present.

Implementing outdoors MR with VR hardware requires safeguarding the headset's lenses and displays. This can be achieved with lens covers or shades attached to the hardware. Another restriction present with, for example, Meta's hardware is that it requires the user to set the boundaries of operation to prevent accidents. This limits the use to specifically mapped areas, meaning that exploring various trigger points across the outdoor spaces with this hardware is nearly impossible. This is due to the boundary mechanism, which is designed to be mapped within indoor space limits, which are smaller in area compared to, for example, standard parks.

Setting up the area should ensure that the user has enough space to explore without disturbing other outdoor goers, be that foot-traffic or automobiles. Weather is a major factor to consider when adapting hardware designed for indoor use into an outdoors setting because rain, strong winds and fast temperature changes can cause damage to the headset or hinder the experience in a major way. (68) It is evident that using this medium – VR hardware for MR applications outdoors – requires a specifically designated area of operation and the presence of an instructor to monitor the operating conditions, such as sudden weather changes, and to recalibrate the application if necessary. Unlike VR glasses, smartphones are more resilient to environmental changes, making them a safer and more practical choice for developing less complex applications.

To summarize, VR hardware passthrough MR is best suited for highly immersive, interactive applications and experiences within controlled, guided environments. These environments can be carefully mapped out, requiring a level area for accurate spatial integration. While this type of MR lacks agility in terms of moving between multiple locations to trigger content, its hardware excels in providing enhanced immersion, a broader field of view, and the ability to directly interact with digital content in the spatial environment.

On the other hand, smartphone-based AR is ideal for agile applications that involve triggering content across various areas. The hardware is more resilient to environmental conditions, often utilizing personal smartphones, which requires minimal guidance due to the familiarity users already have with the technology. This independence allows AR to be deployed practically anywhere, avoiding many of the risks associated with outdoor use of VR headsets.

4.2.3 User Experience and Safety Concerns

As mentioned, selecting the location where the application's experience takes place is one of the most crucial factors in shaping the user experience. When using the real-world outdoors as the backdrop and setting for the experience, the environment inherently defines the terms of engagement. For instance, the atmosphere of a busy street differs significantly from that of a nature trail. Factors such as noise levels in crowded areas can influence the design of the application, making it essential to account for these environmental variables when creating outdoor experiences.

In densely populated areas with heavy foot traffic, integrating digital assets into the real-world setting can present challenges. These digital assets may obstruct users' vision or spatial awareness, potentially disrupting immersion. It is essential to consider placing spatial elements on surfaces or in areas that are unlikely to be blocked by people walking through or in front of them, as such interruptions can break the immersive experience. For example, if a person

walks directly over or through a digital object, it may lessen the sense of realism.

Additionally, lighting conditions can pose challenges for outdoor applications from a user experience perspective, as certain seasons or times of the day may make the experience unusable. To address this, the application design should evaluate whether the area can be supplemented with artificial lighting or consider limiting the application's functionality to daylight hours for optimal performance. Well-lit areas of operation may also diminish the risks associated with using both VR headset-based MR or smartphone AR.

Ensuring that the area or areas chosen for the application have sufficient space to display digital elements spatially, are well-lit, and are easily accessible or clearly marked is crucial for providing the best user experience. As previously mentioned, outdoor environments introduce safety concerns. Some locations may be inaccessible or hazardous, necessitating careful planning to guide users away from potential risks, such as dangerous terrains or trespassing onto private property.

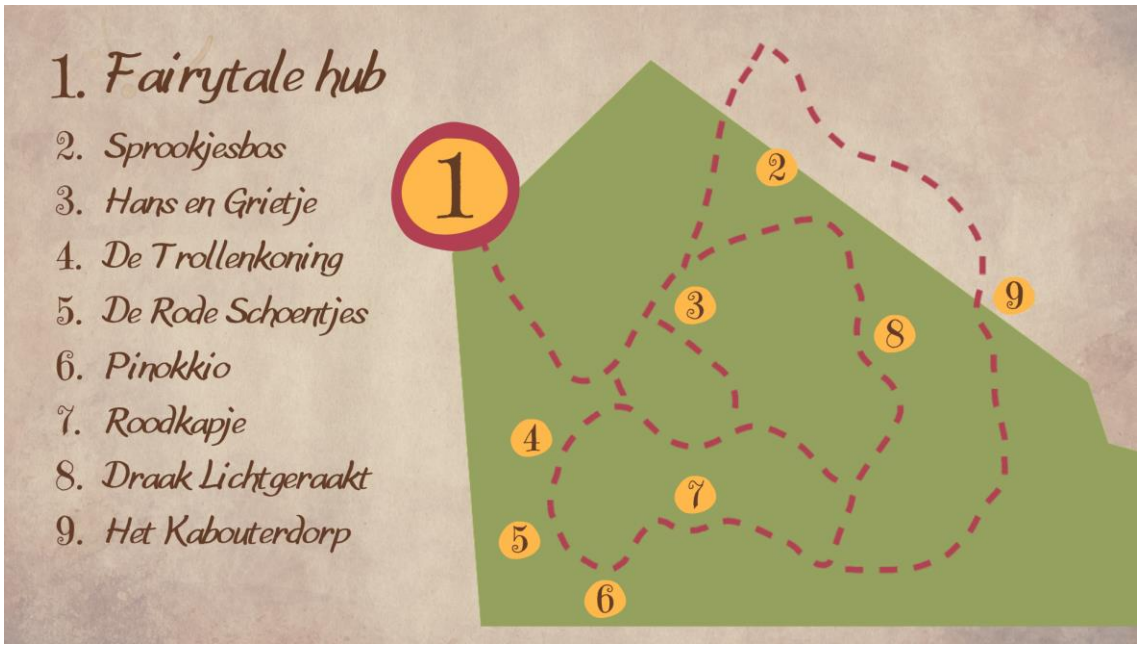
Controlled trigger points can be strategically placed in predetermined safe locations to simplify placement and lessen risks. However, if the content is designed to trigger in random locations, it is vital to exclude unpredictable terrains, weather-prone areas or private zones from the application's functionality to ensure user safety, local regulations and compliance with accessibility guidelines.

4.3 MR Application Concept for Amusement Park's Fairground

The main purpose of this thesis is to explore the possibility of using an amusement park's fairground as a setting for an experience, encouraging participants to explore the park outside traditional permanently placed attractions. Amusement parks, especially theme parks typically offer a rich, detailed, and beautiful environment with great immersion to visitors. These carefully landscaped environmental details placed in theme parks are rarely

utilized as larger attraction pieces themselves. The MR application design presented here explores the possibility to enhance amusement parks' decorative pieces as an experience and it draws inspiration from many of the applications and experiences presented in this thesis.

The concept application's placement is largely inspired by the fairytale forest trail that exists in *Efteling*. While this design can be adapted to other environments, ***Efteling's*** fairytale forest serves as a key reference point for this application. Deciding on and evaluating the areas for an outdoor application is crucial, and such planning typically requires a predetermined setting, which is why *Efteling* is used as the main premise for this design. The park's fairytale forest trail primarily functions as an illustrative setting. The design is an application meant as an interactive, themed adventure game attraction in the theme park. The area used by the application is a landscaped forest trail, which is fenced throughout most of the trail, making it easy to follow. The following map illustrates the different interaction points in the application. (Picture 7)



Picture 7. A map illustrating the different interaction points of the experience, illustrated by referencing aerial data found on Google Maps.

The fairytale hub illustrated in the map is a makeshift location for setting up the MR experience similar to the starting point of *World Showcase Adventures.* It works as a place in which one can borrow the hardware for the experience. Since the experience is meant to utilize MR, the hardware used for the experience would be developed for newer VR glasses with sufficient passthrough capability. This hardware would also have the necessary additions to help with the risks from sunlight damage. This hub has guides ensuring that it is feasible to use the hardware, regarding weather conditions and season. They are also there to help if complications arise. The other locations on the map illustrate different attraction points, which are mostly animatronics, showcase installations and props.

Although the environment is controlled, with fixed, safe trails that prevent free roaming to an extent, the experience would still possess some risks if current hardware was used all the time while walking. A user may take the hardware off while relocating from one marker-based trigger area to the next one. This, however, may break immersion with digital elements. Regardless, using markers or object-recognition to trigger content allows the user to move freely with the hardware without the need for a difficult spatial mapping process. The user experience can be guided by informing the user to take off the hardware when relocating from a trigger point to another and remapping the designated user area once a new interaction point is reached. This could be guided by information signs, which showcase the area that is intended to be mapped for the experience. This information sign is illustrated in the following picture. (Picture 8)

Picture 8. A sign mock-up guide to adjusting boundaries at a marker location.

Currently, marker-based MR has not been widely adopted, based on the research done for this thesis. As such, its feasibility for development remains largely uncharted territory. However, as this technology continues to advance, showcased by Varjo Markers technology, it is reasonable to anticipate that its implementation will become more accessible in the future. (69)

The core gameplay is interactive puzzle mystery solving, presented through MR. The setting encourages players to listen to the digitally enhanced fairytale creatures and solve puzzles given by them. The experience would be that of an active/participant in the XR spectrum of interactivity, as the experience proceeds only if puzzles are solved, and the user participates in the same world

as the fairytale characters. These aspects are illustrated by the following storyboard. (Picture 9)

Picture 9. A storyboard mock-up illustrating hand menu UI, interactions with digital content and physical places.

The application allows users to put digital assets into their digital inventory using a hand-menu. Since the premise of this interactive adventure is story-driven, emphasis is placed on dialogue and environmental storytelling. This is achieved by incorporating virtual fairytale creatures into the narrative and enhancing physical props with digital content to bring them to life. The storyboard illustrates how a physical prop character of Gretel could deliver dialogue to guide the narrative, synchronized with a fully digital fairy character near an interaction point, in this case, a real-life cake prop.

This storyboard illustrates a potential approach towards implementing interactions within the experience. As this premise is conceptual, further exploration into user interface design and narrative development has not been pursued at this stage. Such work would require delving into additional aspects of application development and story design, whereas this thesis focuses on examining how this type of technology can be applied in an outdoor setting.

In summary, the concept application is an interactive MR puzzle game with interaction points triggered at various attractions along the Fairytale Forest trail. The objective is to solve a story-driven mystery by completing puzzles using a combination of provided assets, both digital and potentially physical.

Further development of this concept would require an active development process, including testing the technology and further evaluating its capabilities. A proof-of-concept for this idea has not yet been confirmed and is not currently planned for formal conceptualization. Instead, this concept serves as an illustrative example, drawing features from various existing ideas and presenting them in a way that could help break boundaries and expand the potential of VR headset-based MR.

5 Conclusions

The goal of this thesis was to explore the potential of leveraging the amusement park fairground itself as a central attraction. As existing research literature exists on the topic of XR in amusement parks, this thesis aims to address MR, a lesser used form of XR in the amusement park context. To explore how XR has been utilized in amusement parks, an analysis of existing attractions was conducted, with a particular emphasis on recently developed MR experiences in both amusement parks and in outdoor settings. Additionally, the use of XR in outdoor spaces was examined to understand how these environments have been adapted for immersive applications. The findings from these investigations were synthesized into an outline highlighting key considerations for designing and developing immersive outdoor experiences in controlled environments. However, due to the diversity of the examples and case studies, pinpointing specific design narratives as definitive guidelines proved challenging, although many shared overlapping design considerations.

While XR has been utilized in various forms within amusement parks for a significant period, its application across outdoor fairgrounds remains relatively unexplored. The findings indicate that VR is not well-suited for an outdoor

setting, directing the focus of XR design for outdoor fairground environments towards AR and MR technologies. To fully leverage the spatial scale of amusement parks, it is crucial for the development process to account for environmental factors such as weather and seasonal conditions, which could affect hardware designed primary for indoor use. Additionally, the design must guide the outdoor experience to avoid unsafe areas or trespassing, ensuring both user safety and compliance with spatial limitations.

When designing AR to enhance visitor engagement, the primary consideration for a designer is to define the purpose of the application. This could include enriching an existing attraction (e.g., *Singing Busts*), bringing life to areas of the park outside official attractions (e.g., *LEGO Mythica*), gamifying mundane aspects of the visit (e.g., queue games), personalizing the visitor experience (e.g., adding an AR layer to merchandise), or offering an attraction that transforms the entire park into an interactive experience (e.g., a scavenger hunt). These considerations apply to the design and development of both AR and MR applications content-wise.

From a technological standpoint, it is challenging to determine whether the proposed concept of an agile, multi-location MR interactive mystery nature trail attraction is feasible with today's existing hardware and software. In conclusion, further research into the evolving capabilities of this technology is necessary to evaluate its practical implementation.

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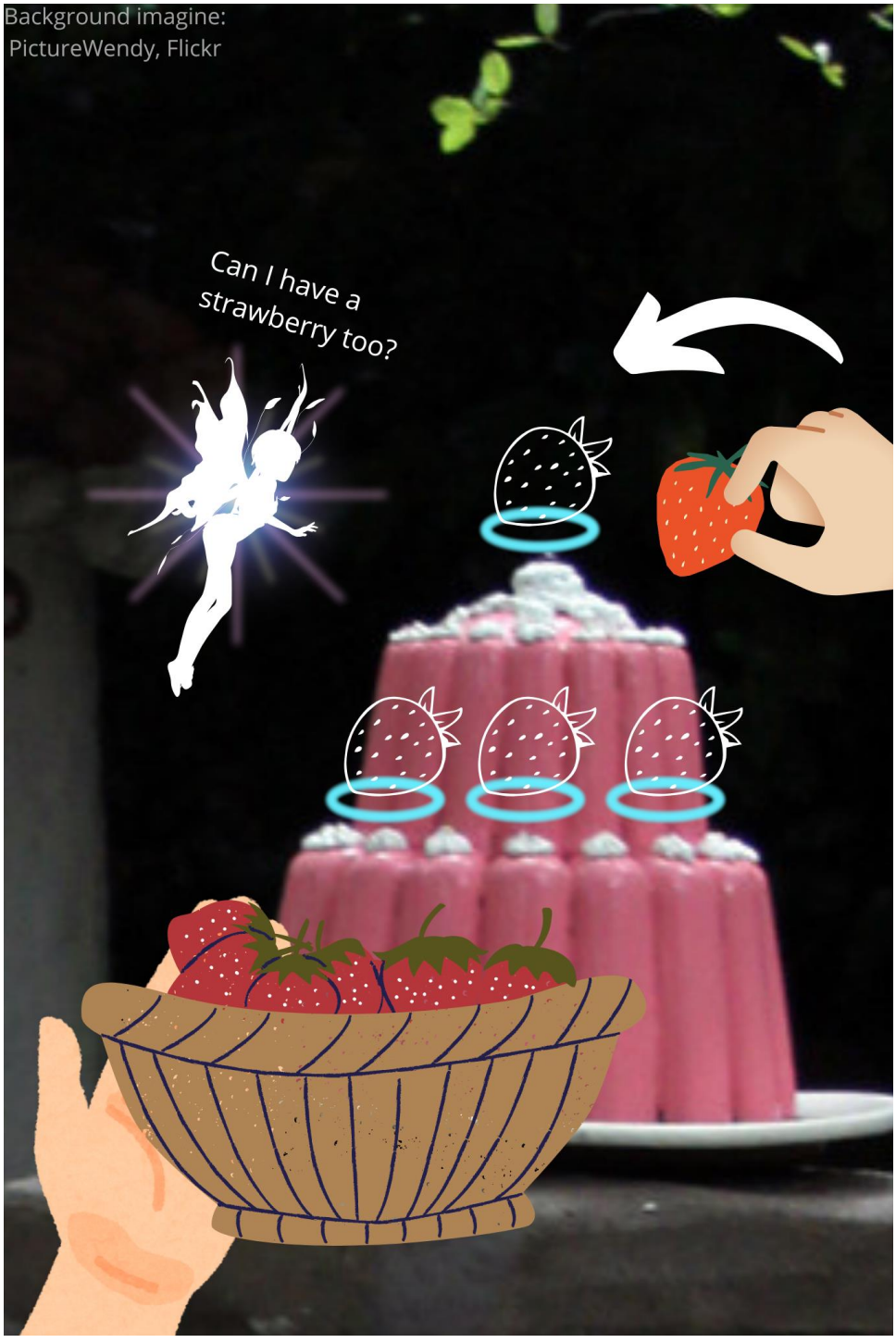
Storyboard pictures

The storyboard pictures are displayed here for better readability.

Appendix 1


Background imagine:
PictureWendy, Flickr
Are those strawberries? They would look great on the cake!

Appendix 1


Background imagine:
PictureWendy, Flickr
Can I have a strawberry too?