# LUMIEA: Enhancing User Engagement in Storytelling: Empowering Personal Narratives through AI-Generated Environments and Tactile Interaction in Mixed Reality

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## ABSTRACT


Traditional storytelling is often constrained by linear structures, limiting engagement and interactivity. This research explores how AI-generated MR environments can enhance storytelling through speech-driven interactions, real-time adaptive narratives, and Tactile feedback. Users speak to real-world objects, transforming them into AI-generated characters and 3D elements that shape the story. A GPT-4-powered LLM ensures narrative consistency, while haptic feedback enhances immersion.

Using Research Through Design (RTD) , this study develops prototypes to investigate how AI-generated storytelling elements integrate with physical space and influence user engagement. The findings contribute to MR storytelling, AI-native games, and interactive media, reimagining storytelling at the intersection of human creativity and AI-generated worlds.



### Keywords:

Mixed Reality (MR), Artificial Intelligence (AI), Interactive Storytelling, Spatial Interaction, User-Driven Narratives, Haptics, Speech-Driven Narratives, Generative AI, AI-Native Games

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# TABLE OF CONTENT

## LIST OF TABLES

## LIST OF FIGURES

# CHAPTER 1: INTRODUCTION

## 1.1 Motivation

Storytelling has long been a fundamental part of human communication, enabling individuals to share experiences and express creativity. However, traditional storytelling is often constrained by linear structures, positioning audiences as passive recipients with little control over the narrative (Green & Jenkins, 2014). This limits engagement, as users cannot shape the story according to their own perspectives (Dow, 2008).

New opportunities for participatory and adaptive storytelling have surfaced as Extended Reality (XR) and Artificial Intelligence (AI) advance. XR—including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—allows people to engage with immersive surroundings in real-time. Conversely, artificial intelligence allows narrative creation that responds to user input, therefore producing more individualized experiences.

Among these, Mixed Reality (MR) is particularly promising as it merges physical and virtual elements, allowing interaction between real-world and digital narratives. However, current MR storytelling still suffers with deep interactivity and adaptable, user-driven storylines. A major challenge is the limited integration of tangible feedback, which affects immersion and engagement.

AI-driven storytelling is already shaping games. Tools like Inworld AI (2024) help create smarter NPCs, while Jasper AI assists with content generation. But AI-powered stories have their own problems—large language models (LLMs) can reinforce biases (Helm, Bella, Koch, & Giunchiglia, 2010) and sometimes make storytelling feel predictable when they try too hard to match user expectations (Padmakumar & He, 2023). AI-native games are changing that by making AI a core part of world-building, letting players shape the game through open-ended input (Sun et al., 2024).

Yet, beyond technological advancements, storytelling is also about emotional connection. This project stems from my own experiences with both digital and physical worlds. As a child, I found comfort in the glow of fireflies—fragile, fleeting, and magical. But as I grew, I sought refuge in digital spaces, where everything felt more stable and predictable. Over time, I realized that the sense of control in virtual worlds was an illusion, shaped by hidden algorithms and predefined structures. This project is an attempt to reconcile those two realms, blending the organic and the digital to create a storytelling experience that feels both immersive and deeply human.

At its core, this work is about the tension between control and impermanence, between reality and illusion. Like fireflies in a jar, digital experiences can be mesmerizing, but true meaning lies in the fleeting, uncontained moments of the real world. By merging MR and AI, I aim to create a space where players don't just consume a story but actively shape it—engaging with technology in a way that feels dynamic, personal, and alive.

## 1.2 Research Summary

### 1.2.1 The Problem

Mixed Reality (MR) technology enables the integration of digital content and physical environments, creating opportunities for immersive storytelling. However, current MR applications often suffer from limited user interaction and insufficient narrative adaptability, making user experiences passive and disconnected. While AI-driven narratives can respond to user inputs, these typically remain isolated from real-world contexts and lack tangible interaction, weakening users' sense of immersion and presence. Existing MR experiences rarely incorporate tactile feedback or leverage users' real-time speech input, resulting in diminished engagement and interactivity. Therefore, there is a critical need for a cohesive system that integrates MR spatial interaction, adaptive AI-driven narratives generated from speech recognition, and tactile feedback from everyday objects, delivering a unified and fully interactive storytelling experience.

### 1.2.2 Hypothesis

This thesis hypothesizes that integrating AI-generated Mixed Reality (MR) environments with real-time adaptive narratives and tangible feedback from everyday objects can address the passive nature of traditional storytelling. By combining spatial mapping, speech recognition, and tactile interactions, the proposed MR system enables active audience participation and narrative co-creation, creating a more interactive storytelling experience.

### 1.2.3 Research Questions

**1) Main research question:**

How can AI-generated MR environments, incorporating real-time narratives and tangible feedback from everyday objects, potentials to overcome the limitations of passive consume of traditional storytelling by offering deeper, more personalized experiences, and bridging the gap between passive audience engagement and active narrative co-creation?

**2) Sub-questions:**

This research aims to answer the main question by the following sub-questions:

1. How can real-world spatial mapping and speech recognition establish a foundation for AI-driven interactive storytelling in MR environments?
2. How can AI-generated 3D content and character-driven responses enhance user engagement and agency in MR storytelling?
3. How does incorporating tactile feedback from real-world objects influence user immersion and engagement in MR storytelling?
4. How can adaptive AI-generated storytelling elements create a cohesive and interactive storytelling experience in MR?

### 1.2.4 Goal and Objectives

The goal of this research is to develop an AI-driven MR storytelling system that integrates spatial mapping, speech recognition, and AI-generated content to enhance user engagement and narrative co-creation. This study explores how MR environments can align virtual elements with real-world objects, how AI-generated 3D models and interactive characters can enhance user agency, and how tangible feedback can improve immersion. By combining these elements, the research aims to establish a structured framework for interactive, user-driven MR storytelling, offering insights for applications in gaming, immersive media, and digital narratives.

### 1.2.5 Approach and Method

This thesis employs a Research Through Design (RtD) approach, emphasizing iterative prototyping to explore MR storytelling enhanced by AI and tactile feedback. Prototypes will be evaluated through self-evaluation, usability heuristics, and self reflection conducted during exhibitions.

### 1.2.6 Outcome and Contributions

The outcomes of this research include a synthesis of literature on storytelling, MR, and AI-driven interactions, alongside practical insights derived from iterative prototyping. The four prototype is : 1） Establishing MR-AI Integration – Develops an interactive MR environment by integrating real-world spatial mapping and speech recognition, enabling AI-generated objects to align with physical space and establishing the foundation for AI-driven storytelling in MR. 2） AI-Driven Content Generation and Character Interaction – Implements AI-driven text generation, 3D model creation, and a responsive firefly character that provides real-time feedback, making AI-generated content more interactive within MR. 3） Enhancing Immersion through Tangibility – Ensures AI-generated 3D models are placed according to the size of real world objects, using physical space to enhance immersion and interaction. 4）AI-Driven MR Storytelling Experience – Combines all system elements to create an AI-driven MR storytelling experience, integrating AI-generated text and 3d content, spatial interactions, and animation to structure the narrative.

The final project explores interactive storytelling in MR environments, providing insights into spatial interaction design, aesthetic considerations, and narrative structures specific to MR experiences. This thesis introduces a novel interaction framework that integrates AI-driven narrative content with Mixed Reality by utilizing everyday objects as tactile feedback sources, grounding virtual content within real-world constraints. Additionally, the research offers insights into designing immersive, user-centered interactions through speech-driven AI content generation. The practical framework developed through four iterative prototypes addresses current gaps identified in the literature, contributing to more personalized and interactive storytelling experiences. These findings have potential implications across multiple domains, including entertainment, education, interactive media art, and therapy, where enhancing user engagement through immersive MR storytelling is beneficial.

### 1.2.7 Scope and Limitation

This thesis focuses on designing and prototyping an AI-driven Mixed Reality (MR) storytelling system that overlays 3D digital objects onto real-world ones. The research explores how existing MR technologies—spatial mapping, speech recognition, and basic tactile interactions—can be used to enhance storytelling by integrating AI-generated content with tangible objects in the environment.

The study does not aim to evaluate AI model performance or the visual fidelity of generated textures. Instead, the focus is on how well AI-generated elements function within MR spaces and how they interact with physical surroundings. While tactile interactions play a role, this research does not explore advanced haptic feedback; rather, it considers everyday objects as passive tactile anchors within the MR experience.

Extensive formal user testing is not included, as the project prioritizes iterative development and technical feasibility over behavioral studies. Additionally, this research does not engage deeply with storytelling theory. Instead, it examines how MR technology can make AI-driven storytelling more interactive and spatially integrated with real-world environments.

### 1.2.8 Chapter Overview

This thesis consists of seven chapters. Chapter 2 presents a literature review, examining storytelling models, MR, AI, and tactile feedback. Chapter 3 details the methodology, specifically the Research Through Design approach. Chapter 4 outlines the iterative prototyping process, presenting four core prototypes. Chapter 5 exhibition plan. Chapter 6 discusses findings, focusing on implications for interactive storytelling. Chapter 7 concludes with reflections on contributions, limitations, and future directions.

# CHAPTER 2 LITERATURE REVIEW

The selection of literature and related work in this review is driven by the aim to investigate how advancements in Mixed Reality (MR), Artificial Intelligence (AI), and tactile feedback intersect to enhance interactive storytelling experiences. Literature is chosen based on its relevance in illustrating foundational theories of storytelling, technological integration within digital narratives, and existing challenges in AI-driven storytelling environments. This selection encompasses key areas such as the historical and theoretical context of storytelling, advancements in Mixed Reality (MR) technology, the integration of AI-generated content, and tactile interaction's impact on immersive experiences.

## 2.1 What is Storytelling?

My research builds upon the foundational understanding of storytelling as an interactive meaning-making tool, exploring how emerging technologies—such as Mixed Reality (MR), Artificial Intelligence (AI), and tactile feedback—can amplify storytelling's potential for user engagement and personalized experiences.

Storytelling is an enduring and pervasive practice throughout human history, enabling the sharing of experiences, creation of meaning, and preservation of cultural heritage (Ladzekpo et al., 2024). Fundamentally, storytelling involves organizing personal or collective experiences into structured narratives that reflect and reinforce shared cultural and individual identities (Bietti et al., 2019; Ladzekpo et al., 2024). It serves as a powerful medium for self-expression, helping individuals articulate their emotions, interpret life events, and convey complex information effectively (Markova et al., 2020).

Moreover, storytelling plays a critical role beyond cultural transmission, contributing significantly to fields such as journalism, education, organizational studies, and intercultural communication. In these contexts, narratives foster empathy, clarify intricate concepts, and promote collective sense-making (Bietti et al., 2019). This versatility underscores storytelling's capacity as both a communication tool and a method for strengthening connections within diverse communities.

### 2.1.1 Traditional and Interactive Storytelling Models

Storytelling has traditionally followed a linear structure, with authors or creators exercising full control over the narrative. Audiences in these models assume passive roles, consuming the content without the ability to influence its trajectory. While such storytelling methods effectively communicate ideas, they often fail to fully engage audiences on a deeper, interactive level. (Green and Jenkins 2014)

Traditional storytelling structures, such as Freytag's Pyramid, adhere to a well-defined progression with a beginning, middle, and end (Freytag, 1894). In contrast, other cultural traditions, such as African oral storytelling, incorporate cyclical narrative patterns that emphasize communal participation and continuity (Koenitz et al., 2015). Despite these variations, most conventional storytelling frameworks remain author-driven, limiting audience participation beyond interpretation.

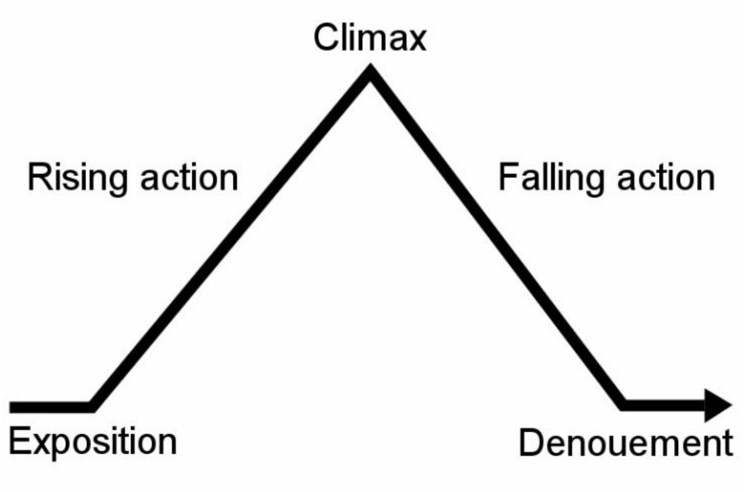


Figure 1. Freytag's Pyramid, a model of dramatic structure first proposed by Gustav Freytag in Die Technik des Dramas (1864). *Source: Gustav Freytag, Die Technik des Dramas (Leipzig: Hirzel, 1864).*

The advent of interactive digital storytelling challenges these traditional notions of narrative (Kaloi et al., 2025). Digital media platforms, particularly in video games and virtual environments, allow for nonlinear storytelling, where users actively shape the story's progression through their choices (Spierling & Ulrike, 2005). This shift introduces an important dynamic—the interaction between audience and narrative—which is a defining characteristic of digital storytelling (Thoss et al., 2018).

To bridge the gap between traditional linear storytelling and the interactive nature of digital media, researchers have explored various models. The multimedia model, for instance, seeks to explain the interplay between traditional and emerging narrative structures, highlighting the increasing complexity of storytelling in digital spaces. Additionally, formal design models have been developed to classify interactive story-based systems, helping define the principles that guide user-driven narratives (Spierling & Ulrike, 2005).

As storytelling continues to evolve in digital and immersive environments, understanding the relationship between linear, cyclical, and interactive narrative models becomes crucial for designing experiences that balance authorial intent with user agency. This study situates itself within this evolving landscape, examining how AI-driven storytelling in Mixed Reality (MR) can create new forms of audience participation and co-creation.

### 2.1.2 AI in Storytelling

Artificial Intelligence has emerged as a powerful tool for generating adaptive, real-time narratives, enabling more interactive and immersive storytelling experiences. AI systems, such as natural language processing (NLP) models and machine learning algorithms, generate content in response to user input, allowing for non-linear and emergent storytelling. In virtual role-playing games, for example, AI-driven narrative generation adapts storylines based on player decisions, generating text that reflects the consequences of their choices (Chamola et al., 2023). This shift towards AI-assisted storytelling has opened new avenues for interactive experiences, particularly within virtual environments and the metaverse.

However, automatic story generation presents several challenges. Alabdulkarim, Li, and Peng (2021) highlight key obstacles, including controllability, commonsense reasoning, and character representation. Controllability remains a major issue, as user input can unpredictably alter AI-generated content. To address this, researchers have explored techniques such as defining structured story outlines or constraining AI-generated endings. Additionally, character representation and creativity remain underexplored areas, requiring improved modeling of character emotions and behaviors to enhance plot coherence and engagement (Alabdulkarim, Li, & Peng, 2021).

A new approach to AI-driven storytelling is emerging in the form of AI-native games,((Eladhari et al., 2011)  a genre where generative AI (GenAI) is not merely an enhancement but the core mechanism driving both gameplay and aesthetics. Unlike traditional AI-based games that use AI to support pre-defined game mechanics (e.g., NPC behavior or procedural level generation), AI-native games rely on GenAI technologies, such as large language models and text-to-image generation, as the foundation of the experience. These games are characterized by real-time multimodal content generation (e.g., text-to-image transformations), highly open-ended natural language input (as opposed to pre-scripted dialogue trees), and challenges related to content consistency and controllability (Sun et al., 2024). This genre fundamentally redefines the relationship between AI and player agency, pushing the boundaries of interactive storytelling.

More broadly, AI-based game design has been described as a practice that deeply integrates the affordances of AI systems within the context of game mechanics, aesthetics, and dynamics (Eladhari et al., 2011). The key to effective AI-driven game design is ensuring that AI and game mechanics inform and shape one another, rather than functioning as isolated components. By embedding AI into the core structure of a game, developers can create novel mechanics that dynamically adapt to player actions, leading to more organic and emergent storytelling experiences. (Eladhari et al., 2011)

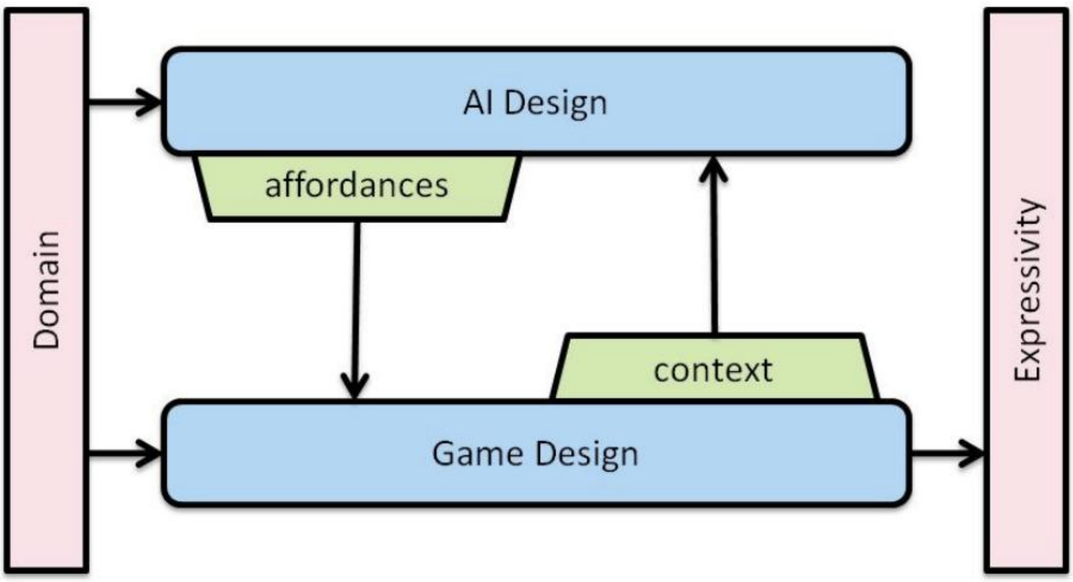


Figure 2. AI-based game design, enabling new playable experiences through AI-driven mechanics. *Source: Eladhari et al. (2011), UC Santa Cruz Baskin School of Engineering.*

This evolution in AI storytelling—from narrative adaptation to AI-native game design—raises new questions about how generative AI can meaningfully shape player-driven experiences while maintaining coherence, creativity, and engagement. This study explores how AI-generated narratives, characters can be integrated into Mixed Reality (MR) storytelling, leveraging AI's ability to enhance immersion and user agency within interactive digital spaces.

## 2.2 Mixed Reality (MR)

Mixed Reality (MR) is a technological paradigm that integrates real and virtual elements, existing as a continuum between Augmented Reality (AR) and Virtual Reality (VR).(Speicher, Hall, & Nebeling, 2019). Unlike AR, which overlays digital information onto the physical world, or VR, which immerses users entirely in a digital space, MR enables both physical and digital objects to coexist and interact dynamically within the same environment (Speicher, Hall, & Nebeling, 2019).

Egger et al. (2020) highlight how MR enhances user experience by blending the physical and digital worlds, enabling intuitive interactions that feel natural and immersive. This is achieved through advanced spatial awareness technologies, which allow MR systems to analyze the user's surroundings and integrate digital content in a way that feels contextually relevant (Tsou et al., 2022).

A key feature of MR is the introduction of "mixed objects," digital entities that are embedded into the physical world, effectively blurring the boundaries between reality and virtuality (Papadopoulos et al., 2021). Unlike static overlays in AR, mixed objects in MR are responsive to environmental factors such as lighting, surface textures, and user movement, enhancing the illusion of coexistence.

Rokhsaritalemi et al. (2020) emphasize the importance of real-time interaction in MR, noting how responsive digital environments foster a heightened sense of presence. The ability to manipulate digital elements as if they were part of the physical space contributes to a more immersive and intuitive experience.

Building on this foundation, my research explores how MR can be enhanced through AI-driven content generation and tangible feedback. By integrating AI-generated environments with real-world spatial awareness, my work seeks to push the boundaries of MR storytelling, creating experiences where users do not just observe but actively engage in co-creating their own narratives within an immersive and dynamic space.

### 2.2.2 Mixed Reality (MR) in Storytelling

Mixed Reality (MR) integrates physical and digital environments, allowing users to interact with virtual elements within real-world spaces. (Speicher, Hall, & Nebeling, 2019） This hybrid approach enables new forms of interactive storytelling by situating narratives within familiar spaces while simultaneously introducing novel, digital components. Research has highlighted MR's potential in crafting immersive storytelling experiences through spatial mapping, real-world object interaction, and dynamic narrative adaptation (Hoffman, 1998; Sra et al., 2016).

Young et al. (2022) emphasize MR's potential in pioneering "never-before-seen ways" of constructing and experiencing stories, offering audiences an unprecedented level of agency within digital narratives. Similarly, Jin et al. (2022) highlight how MR-based storytelling enhances both narrative and interactive experiences, leading to deeper emotional engagement and enjoyment.

The applications of MR-driven storytelling extend across diverse fields, including virtual museums, cultural heritage preservation, and advertising (Papagiannakis et al., 2024). By leveraging the spatial and interactive affordances of MR, these domains have demonstrated the potential of mixed reality narratives to educate, entertain, and captivate audiences in ways that traditional media cannot.

### 2.2.3 Tactile Feedback and Sensory Engagement in MR

The integration of tactile feedback and physical interactions can help connect digital and real-world elements, leading to a more immersive and engaging experience in vritual reality applications (Hoffman et al. 2023). Fang et al. (2023) explored the use of everyday objects as tactile proxies in MR, demonstrating how sensory feedback can enhance engagement by grounding virtual interactions in the physical world. Their findings suggest that the integration of real-world objects as interactive elements within MR environments fosters a deeper sense of presence, as users can physically interact with their surroundings rather than relying solely on abstract digital representations. Similarly, Wagener et al. (2022) found that passive haptic feedback—where virtual objects align with tangible physical counterparts—can significantly increase spatial presence and user involvement in VR experiences. This form of feedback allows users to experience a more coherent and believable MR environment, reinforcing the illusion that virtual and physical elements coexist.

Beyond passive haptic feedback, more complex tactile responses, such as pressure sensitivity and texture simulation, have been explored in various MR applications. Brunzini et al. (2022) highlight the importance of realistic tactile feedback in physical training simulations, where the accuracy of haptic sensations ensures the effectiveness of MR-based learning and skill development. While these approaches are widely used in training and simulation contexts, they remain largely unexplored in interactive storytelling applications.

My research builds on these findings by investigating how integrating tangible interactions with AI-driven storytelling can enhance immersion and user engagement. By aligning virtual elements with real-world objects, my work aims to deepen the connection between users and MR narratives, making storytelling experiences more interactive and physically engaging. This approach explores how everyday objects can serve as both narrative tools and interactive components, ultimately shaping a new dimension of immersive storytelling that combines AI, MR, and tangible feedback.

## 2.3. Related Works

### 2.3.1 1001 Night

The "1001 Nights" project presents an innovative approach to interactive storytelling, where language shapes virtual worlds in real time. This AI-native game allows players to co-create narratives with an AI-driven King, using spoken keywords to generate tangible in-game elements. The dynamic visualization of these evolving stories through Stable Diffusion bridges the gap between narrative creation and immersive gameplay, blurring the boundaries between player input and AI-generated content. Unlike conventional AI-assisted games that use AI for supporting mechanics like procedural generation or NPC behavior, "1001 Nights" treats Generative AI (GenAI) as the core of the game’s existence, making AI-driven storytelling an essential gameplay mechanic rather than an auxiliary feature (Sun et al., 2024).


**Tell the story to lead the king to mention a weapon.** **Click the word to receive the weapon.**

Figure 3. 1001 Nights, an AI-driven storytelling game where spoken words shape virtual worlds.
*Source: Sun et al. (2023), https://doi.org/10.1609/aiide.v19i1.27539.*

A key challenge in AI-native game design, as identified in this work, is the balance between AI-generated content and meaningful player agency. The game explores the limits of authorship in AI-generated narratives, adding control to player to shaping the story while ensuring engagement. This challenge aligns with broader discussions in narrative AI, where maintaining story logic, emotional depth, and consistency in player-driven interactions remains an open research area (Alabdulkarim et al., 2021).

Building on this concept, my research further explores how AI-generated environments and interactions in Mixed Reality (MR) can enhance narrative co-creation. While "1001 Nights" demonstrates speech-driven AI storytelling in a 2D game setting, my work extends this idea to MR spaces, where real-world objects are transformed into interactive 3D storytelling elements. By incorporating tactile feedback and spatial computing, this research investigates how AI-generated elements can become integral to the player's embodied experience in MR storytelling, ensuring that AI-driven narratives feel personal, immersive, and adaptive to user agency.

### 2.3.2 Pillow[1]

Pillow Meta is an MR application for Meta Quest 3 that allows users to experience interactive bedtime stories through AI-generated 3D depth illustrations. Users can mix different story elements to create new narratives and make interactive choices that lead to hundreds of unique endings. The application blends MR and AI-generated storytelling, offering an immersive storybook experience where users can explore dynamically generated visual narratives in their real-world space.

My research builds on this concept by exploring deeper integration between AI-generated storytelling and MR spatial computing. Instead of solely displaying AI-generated visual content in MR, my work focuses on how AI-driven 3D models can interact with real-world objects, using room scanning, spatial mapping, and tactile feedback to create a more immersive and adaptive storytelling experience.

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[1] https://www.meta.com/experiences/pillow/5655932521164368/?srsltid=AfmBOooRYpCGm0ahlIVFhd17jeJckRHAzIXdXkoi2WBIVx6INAUWu82s

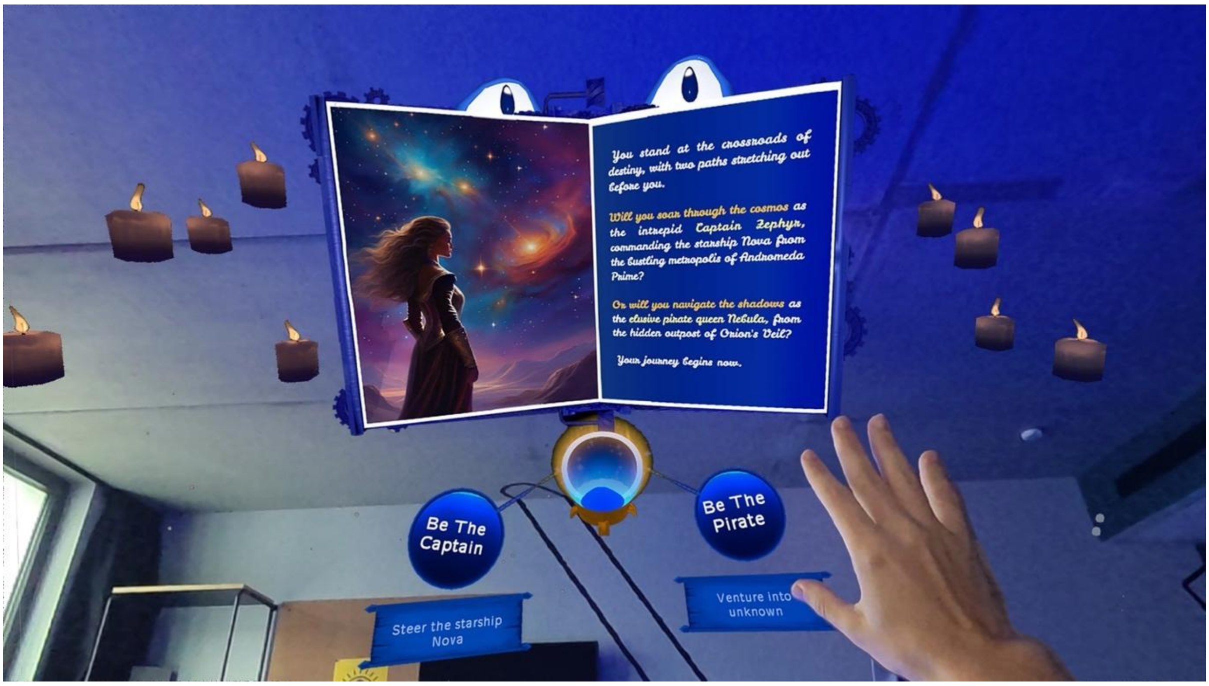


Figure 4. Pillow - Quest VR on Meta Store. *Source: Meta Store, accessed March 16, 2025, https://www.meta.com/experiences/5655932521164368/*

### 2.3.3 SCENECRAFT

SCENECRAFT is a framework that leverages large language models (LLMs) to automate the generation of interactive narrative scenes in digital games, translating high-level author descriptions into playable 3D game episodes (Kumaran et al., 2023). By integrating natural language processing (NLP) and procedural content generation, SCENECRAFT streamlines scene authoring, allowing creators to control elements such as NPC dialogue, gestures, and emotions while ensuring narrative coherence. The system employs semantic extraction techniques to generate emotionally expressive interactions, making NPC behaviors feel more immersive and responsive. Through empirical evaluation, SCENECRAFT has demonstrated its ability to align generated content with authorial intent while enhancing player engagement.

This work highlights the increasing role of AI in adaptive storytelling, where generative models assist in crafting dynamic and context-aware narratives. While SCENECRAFT primarily focuses on static authorial input, my research builds upon these advancements by shifting towards real-time user-driven storytelling in Mixed Reality (MR). Instead of relying solely on pre-defined scene descriptions, my approach enables users to shape the MR environment dynamically through speech-driven AI-generated 3D models, which adapt to real-world spatial constraints and user interactions. By integrating speech recognition, spatial computing, and AI-driven narrative co-creation, this study expands the scope of AI-assisted storytelling beyond traditional game environments, fostering a more immersive and participatory MR storytelling experience.

### 2.3.4 Luoyang VR project

The Luoyang VR project, developed by iQiyi [2], represents a significant step in immersive storytelling by integrating virtual reality, sensory simulation, and interactive theatrical elements into a cultural narrative. Set in ancient Luoyang, one of China's four great historic capitals, this location-based VR experience allows players to engage in a fully immersive multi-sensory environment, where they navigate challenges, interact with props such as boats and carriages, and experience environmental effects like wind and waterfalls. The project merges historical storytelling with interactive media, enhancing user engagement by grounding the narrative in a rich cultural context while leveraging advanced VR technology to heighten immersion.

A key contribution of the Luoyang VR project is its integration of physical and digital elements, offering an experience that transcends traditional screen-based narratives. It demonstrates how cultural heritage and virtual reality can be combined to create engaging, experiential storytelling, aligning with growing industry trends in interactive location-based entertainment. The project also reflects an increasing demand for personalized and immersive digital experiences, particularly among younger audiences who seek high-engagement, participatory narratives (PwC, 2022).

[2] https://www.cnbc.com/2023/02/20/chinas-netflix-iqiyi-launches-an-immersive-vr-ride-based-on-its-own-show.html#:~:text=Human%20players%20appear%20as%20avatars,in%20Shanghai%20in%20February%202023.&text=BEIJING%20%E2%80%94%20Chinese%20video%20streaming%20platform,city%20of%20the%20same%20name.

Figure 5. Interactive environment in the Luoyang VR Project, developed by iQiyi, demonstrating the integration of VR, sensory effects, and cultural storytelling. *Screenshot by the author, based on iQiyi's VR experience.*

While the Luoyang VR project showcases the potential of historically inspired VR storytelling, its approach remains pre-scripted, limiting real-time user agency and adaptive narrative generation. My research builds upon these advancements by exploring AI-native Mixed Reality (MR) storytelling, where AI-generated environments respond to user input. Unlike the fixed narrative structure of the Luoyang VR experience, my work focuses on real-time speech-driven AI interactions that transform real-world objects into interactive MR storytelling elements. By incorporating tactile feedback and spatial computing, this research seeks to push the boundaries of immersive storytelling, enabling users to co-create and shape the narrative in real-time rather than merely experiencing a pre-designed story.

## 2.4 Summary

The reviewed literature highlights the advancements in MR and AI for interactive storytelling while also revealing key limitations that persist in the field. Despite the growing potential of these technologies, several gaps remain unresolved. MR storytelling environments often fail to integrate tactile feedback, limiting sensory immersion and reducing user engagement.

Another challenge is the lack of clear frameworks for evaluating engagement, immersion, and personalization in MR storytelling. While MR and AI open new possibilities for narrative design, existing research does not offer comprehensive methods to assess how interactive AI-driven storytelling affects perception and interaction.

To address these gaps, this research introduces an integrated approach that combines tangible feedback, AI-generated storytelling, and spatial mapping using the Meta Quest and Meta MR Utility Kit. By leveraging real-world object recognition and environment scanning, the system aligns AI-generated content with physical surroundings. This study explores how these elements can create more immersive, user-driven storytelling experiences, offering insights into how AI and MR enhance narrative engagement and personalization.

# CHAPTER 3. METHODOLOGY

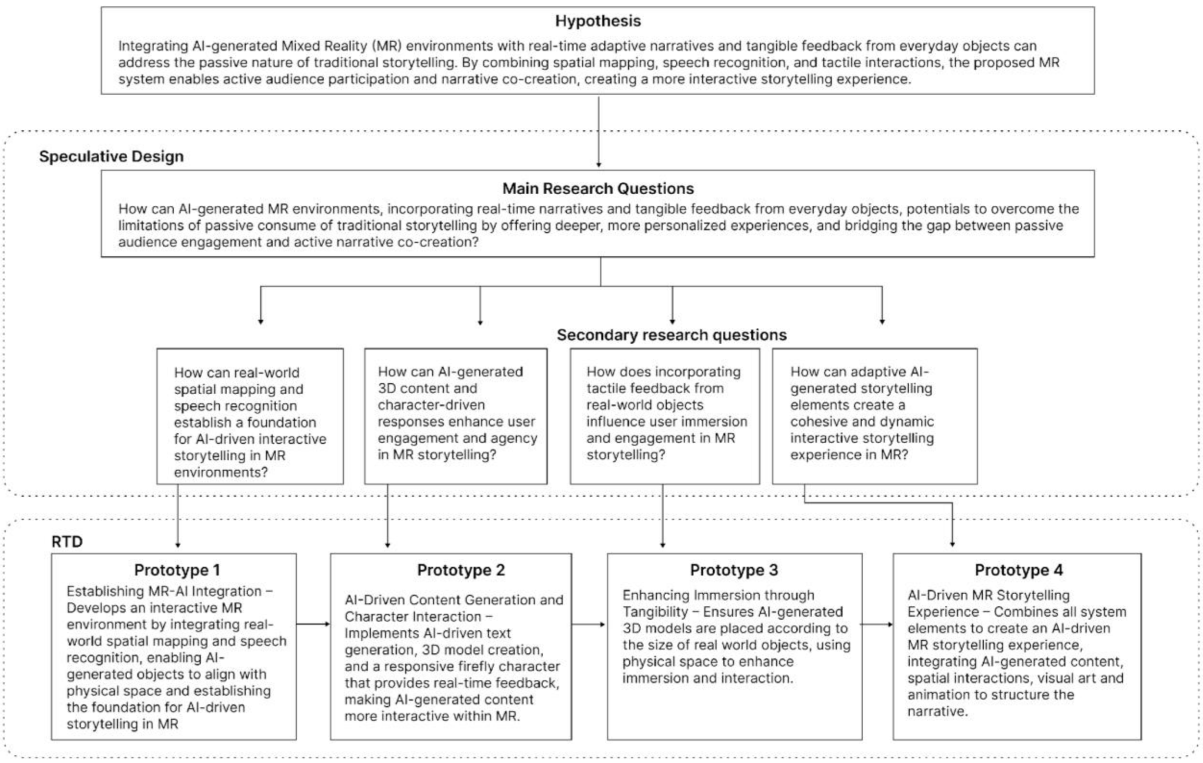


Figure 6. Diagram illustrating the research workflow,

## 3.1 Research Through Design

This study employs a Research Through Design (RTD) approach, an iterative process of prototyping, testing, and refinement to explore user-driven storytelling in Mixed Reality (MR) environments powered by Artificial Intelligence (AI). Zimmerman and Forlizzi (2014) indicate that "Research through Design (RtD) is an approach to conducting scholarly research that employs the methods, practices, and processes of design practice with the intention of generating new knowledge." It allows for prototyping and iterative design. By combining qualitative and quantitative methods, the research aims to evaluate how MR and AI can create immersive, personalized storytelling experiences.

## 3.2 Evaluation Approach

The evaluation of this project employs a multifaceted approach, integrating both structured self-evaluation and aim to reflections based on observations from the Digital Futures Graduate Exhibition. For the usability and interaction aspects, Nielsen's usability heuristics for VR (Kendrick 2021) are applied as a framework to conduct a structured self-evaluation, particularly suitable for assessing interactive systems in Mixed Reality (MR) environments. The heuristics employed include evaluating alignment between system functions and the real world, visibility of system status, user control and freedom, aesthetic minimalism, and flexibility and efficiency of use.

For storytelling quality, a narrative evaluation framework informed by literature in storytelling theory and interactive narrative design will be used. This framework emphasizes the importance of narrative coherence, character relatability, user agency, conflict and resolution structures, and multimodal engagement, thus capturing the user's experience of storytelling within an MR context.

In addition to these structured self-evaluations, observations from the Digital Futures Graduate Exhibition at OCAD University Waterfront Campus, 130 Queens Quay E., March 27th–April 2nd will further inform a reflective self-evaluation, offering insights into how actual users interact with and respond to the system in a realistic exhibition environment. This combined approach ensures a comprehensive understanding of both usability and narrative effectiveness.

### 3.2.1 Self evaluation

**Evaluation of MR Usability and Interactive User Experience**

To assess the Mixed Reality (MR) storytelling experience, I conducted a structured self-evaluation using Nielsen's Usability Heuristics for VR (Kendrick, 2021) and the User-Centered Design (UCD) framework (Interaction Design Foundation, 2019). This approach provided both a usability-focused assessment and a design-oriented reflection, helping to identify strengths and areas for improvement in system interaction and overall experience.

| Criteria | Evaluation Focus |
|---|---|
| Match Between System and the Real World | Evaluates whether AI-generated virtual content accurately aligns with and adapts to real-world furniture and spatial constraints, enhancing user perception of MR coherence. |
| Visibility of System Status | Checks if the interface clearly informs users about system states, including speech recognition, AI generation processes, and object placement through timely visual and auditory feedback. |
| User Control and Freedom | Assesses whether users can easily explore various interactions without constraints, offering flexibility in object transformation and storytelling choices. |
| Aesthetic and Minimalist Design | Evaluates whether the UI elements are minimalistic and non-intrusive, facilitating storytelling without visually or cognitively overwhelming the user. |
| Flexibility and Efficiency of Use | Reviews if the system accommodates different skill levels, offering intuitive interactions and contextual guidance through the interactive firefly character to support ease of use and learning. |
| Satisfaction and Engagement | Observes user reactions and engagement levels during interactions, assessing overall user satisfaction and perceived immersion. |

Table 1: Self-Evaluation of MR Storytelling Usability (Based on Nielsen's Usability Heuristics (Kendrick 2021) and User-Centered Design Criteria)

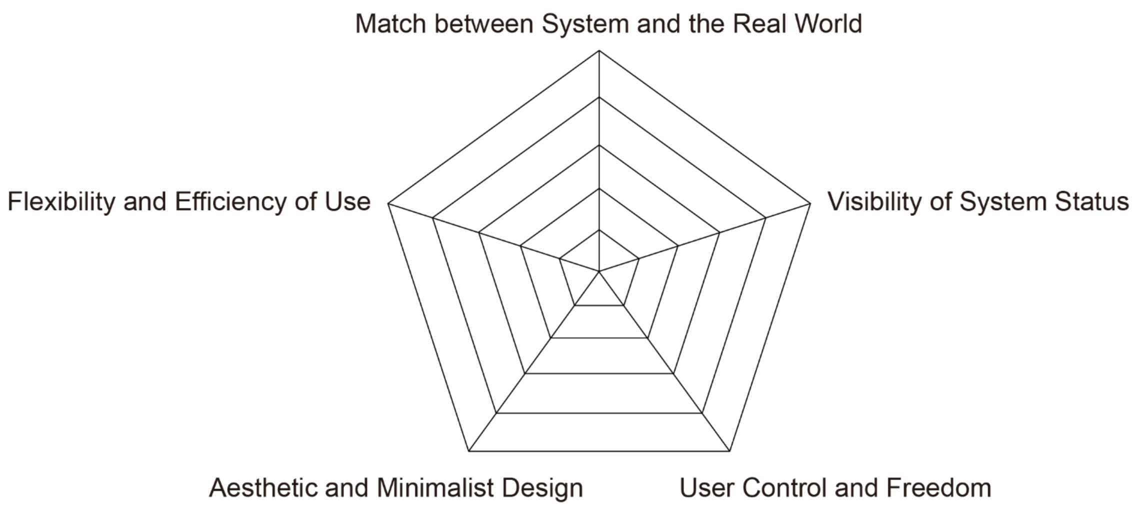


Figure 7.Prototype evaluation radar chart template.

### 3.2.2 Evaluation Criteria for Storytelling in MR Environments

To assess the quality of storytelling experiences within the MR system, a structured evaluation framework was developed based on an review of existing literature. Five key principles were identified as essential components of an engaging and immersive storytelling experience:

| Criterion | Description |
|---|---|
| **Narrative Structure and Coherence** | Evaluates if the narrative progression logically integrates user-generated content, maintaining a clear and coherent storyline structure that enhances user comprehension and interest (Francis, 2020). |
| **Character Development and Relatability** | Assesses if the virtual characters, particularly the firefly, display believable, engaging responses and emotions that resonate with users, enhancing empathy and emotional connection (Sanders & Van Krieken, 2018). |
| **User Agency and Narrative Influence** | Examines the extent to which users can meaningfully influence the narrative direction through speech-driven interactions, measuring whether their choices have significant impacts on the storyline (Nakevska et al., 2017). |
| **Meaningful Multimodal Interactions** | Evaluates how effectively multiple sensory interactions (visual, auditory, tactile) are integrated to reinforce narrative immersion and storytelling realism (Nakevska et al., 2017). |
| **Narrative Coherence and Flow** | Determines whether dynamically AI-generated narrative content maintains logical consistency, facilitating smooth storytelling experiences that align with user inputs and physical environments (Thue et al., 2016). |

Table 2: Self-Evaluation Criteria for Storytelling Experience

# CHAPTER 4. PROTOTYPE DEVELOPMENT

This section outlines the iterative prototyping process used to explore the integration of AI-generated storytelling within a Mixed Reality (MR) environment. The prototypes were developed to address the research questions and progressively refine the interaction between AI-driven content, spatial mapping, and user engagement. Each prototype builds upon the previous one, incorporating new functionalities and refining system design to create a more immersive storytelling experience.

Prototype 1 establishes the foundation by integrating real-world spatial mapping and speech recognition, enabling AI-generated elements to align with physical space. Prototype 2 expands on this by incorporating AI-generated 3D models and interactive character feedback, enhancing user agency in storytelling. Prototype 3 introduces tangible feedback through mapping Ai generated 3d models on tangible objects in the environment. strengthening the connection between virtual and physical elements.

Finally, Prototype 4 integrates all previous components into a AI-driven MR storytelling experience, featuring narrative adaptation, interaction design, and aesthetic elements such as music, animation, and environmental storytelling.

Through these prototypes, the project explores how AI and MR can be combined to create interactive, adaptive, and immersive storytelling experiences, leveraging speech input, spatial mapping, and tangible interactions. The following sections detail each prototype's objectives, implementation, evaluation, and reflections.

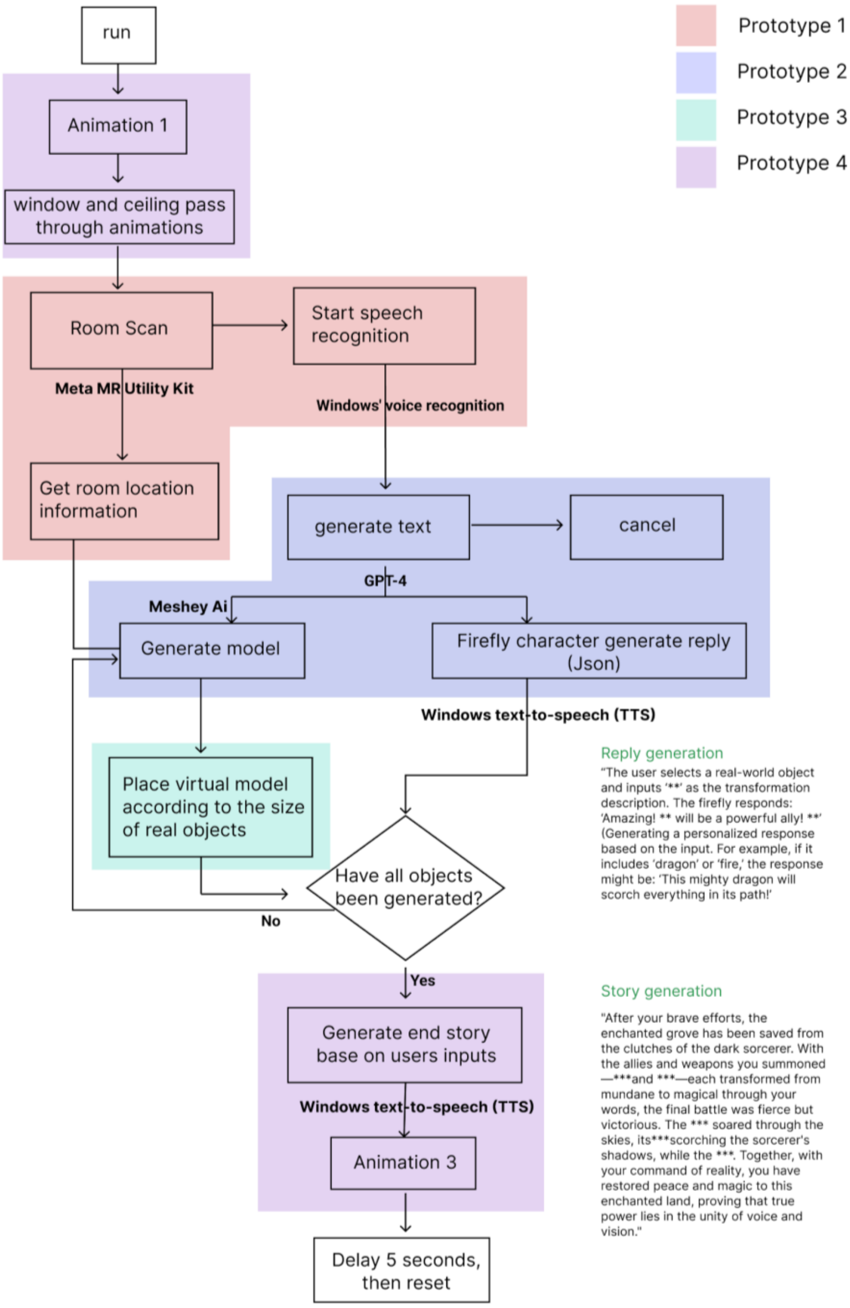


Figure 8. The flow chart of the methodology

## 4.1 Prototype 1: Establishing MR-AI Integration

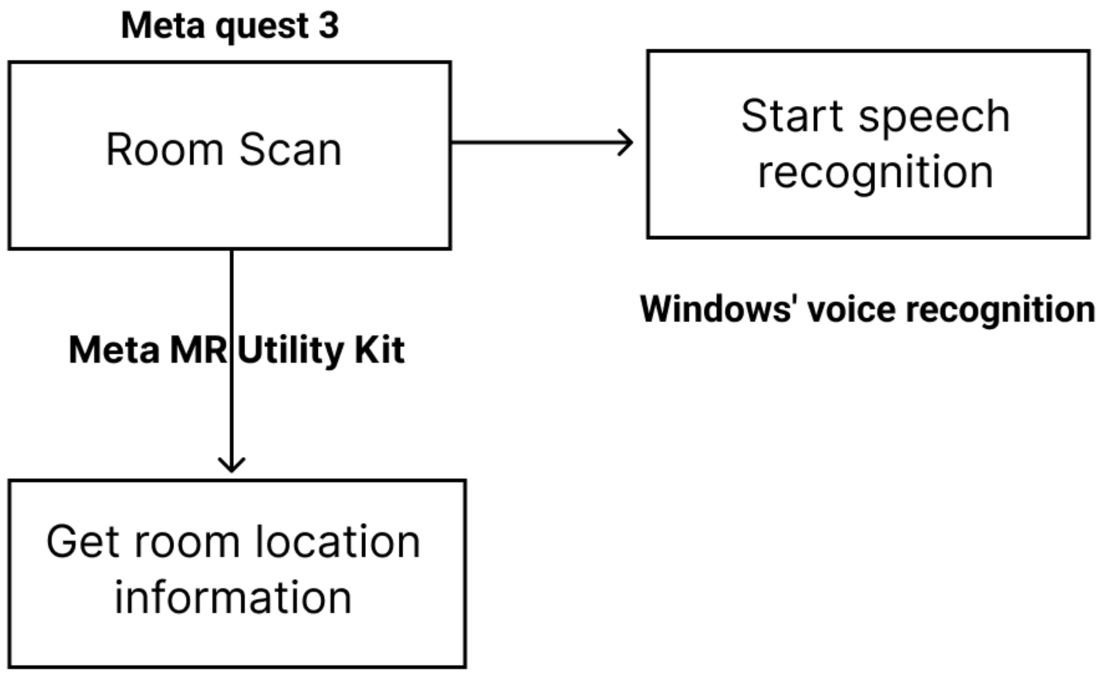


Figure 9. Flowchart of Prototype 1, illustrating the process of system.

### 4.1.1. Description

This prototype focused on developing an MR environment where digital objects, including textures, characters, and environmental elements, integrate with physical space. Using Unity's Meta MR Utility Kit[3] and Meta Quest 3[4], the system performed real-time room scanning to generate a spatial map with collision detection. This allowed virtual objects to recognize and align with real-world surfaces, creating a more immersive and interactive MR storytelling experience.

A key feature of this prototype was the transformation of ceilings into environmental backgrounds. By integrating Windows voice recognition[5], users could speak descriptive keywords (e.g., "sky"), which were processed by Chat-GPT[6] to generate AI-driven scene adaptations. The

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[3] https://developers.meta.com/horizon/documentation/unity/unity-mr-utility-kit-overview/

[4]https://www.meta.com/ca/quest/quest-3/?srsltid=AfmBOor23ap8n1Kffb8lfKRwQA-R-FzL1mzjsOe_AucNZWfH_KRyuuqU

[5] https://support.microsoft.com/en-us/windows/use-voice-recognition-in-windows-83ff75bd-63eb-0b6c-18d4-6fae94050571

[6] https://openai.com/index/hello-gpt-4o/

Meta MR Utility Kit was used to identify and mark the ceiling, allowing for dynamic modification of the environment. For instance, when a user said "blue sky," the system generated a simple sky texture, transforming the ceiling into an atmospheric background.

Additionally, Meta Building Blocks[7] was used to create the basic interaction interface, enabling users to start and stop voice recognition through a simple UI. This ensured a foundational interaction structure for future prototypes, where more complex speech-driven interactions could be built upon.

Before finalizing Meta Quest 3 for spatial scanning, I experimented with three alternative 3D scanning methods:

LiDAR scanning (iPhone/iPad Pro): High depth accuracy but lacked real-time MR integration.

Photogrammetry (RealityCapture[8], Polycam[9]): Created detailed 3D meshes but required long processing times, making it impractical for live interactions.

Depth cameras (Azure Kinect[10], Intel RealSense[11]): Provided accurate 3D spatial data but required external hardware, increasing complexity.


Figure 10. 3D scanning with Revo Scan 512, using structured light technology for high-precision model capture.

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[7] https://developers.meta.com/horizon/documentation/unity/bb-overview/
[8] https://www.capturingreality.com/
[9] https://poly.cam/
[10] https://azure.microsoft.com/en-us/products/kinect-dk
[11] https://www.intelrealsense.com/

[12]https://www.revopoint3d.com/pages/support-download?srsltid=AfmBOoqr2vUrp8_H_mWKZRIlygA-1Cx3p6Co9z2MJmNJPZXwt8IqncNg&msged=1

After testing, Meta Quest 3's built-in scene understanding API proved the most efficient for real-time MR integration, allowing AI-generated elements to interact with the physical world.

### 4.1.2.Process

The process began with room scanning and spatial mapping using Meta Quest 3's Scene Understanding[13]. This enabled the system to detect physical objects and generate a spatial mesh with collision volumes in Unity 2022.3.42f1c1[14], ensuring that AI-generated objects could respond to real-world constraints. Different spatial mesh resolutions were tested to balance accuracy and performance, with higher resolutions offering more precise mapping at the cost of increased processing demands. I used The Meta MR Utility Kit 66.0.0 (MRUK) to retrieve and utilize scanned room data from Meta Quest's Room Setup experience. The workflow involved:

1.Room Scanning: If no existing user environment data was available, the system prompted users to scan their space through Quest's Room Setup in Settings.

2.Retrieving Room Data: Using MRUK, the system retrieved scene information, including semantic surface types (e.g., walls, ceilings, floors, tables, and couches) and mesh data for collision detection and object placement.

3.Placement of Virtual Objects: MRUK's FindSpawnPositions[15] tool allowed for automatic positioning of virtual objects on surfaces, ensuring AI-generated elements were placed in contextually relevant locations (e.g., a virtual object appearing on a table rather than floating in mid-air).

[13] https://developers.meta.com/horizon/design/mr-design-scene/

[14] https://unity.com/cn/releases/editor/archive

[15] https://developers.meta.com/horizon/reference/mruk/v69/class_find_spawn_positions

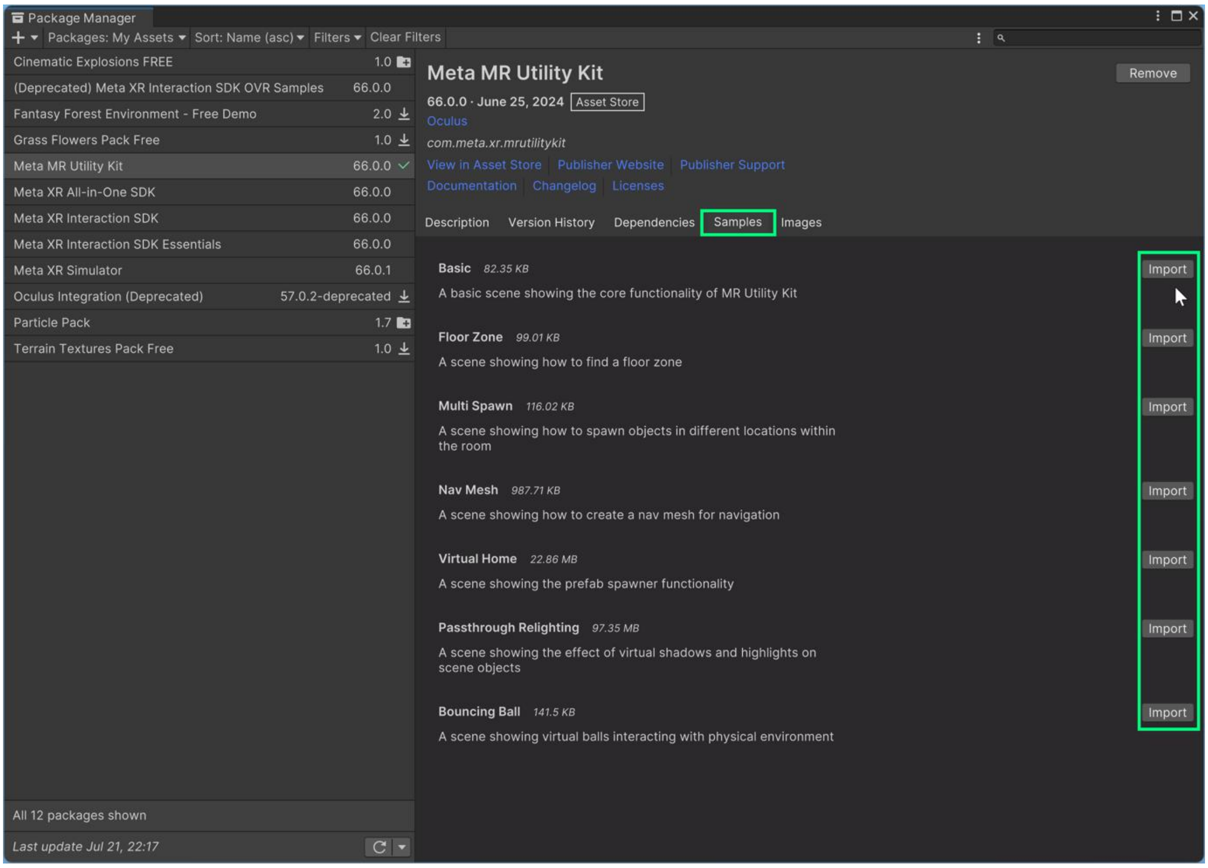


Figure 11. Meta MR Utility Kit (MRUK) 16for building mixed reality apps using physical surfaces. *Source: Mixed Reality Now, accessed March 17, 2025*

To validate interaction with AI-generated objects, I implemented a physics-based validation system using a script from Valem Tutorials[17]. This allowed users to launch virtual balls via controller input to test collision detection and environmental responsiveness. The balls responded accurately to the scanned space, demonstrating that the environment could effectively recognize and process real-world spatial constraints. AI-generated textures, such as those created with Stable Diffusion, were then mapped onto physical surfaces, including walls and ceilings. Ensuring these textures aligned correctly with the real-world environment was a key challenge in this stage.

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[16] https://mixedrealitynow.com/building-mr-apps-using-physical-surfaces-has-never-been-easier-how-to-use-meta-mixed-reality-utility-kit-mruk.

[17] https://www.youtube.com/watch?v=CcJ4yMTzXUM

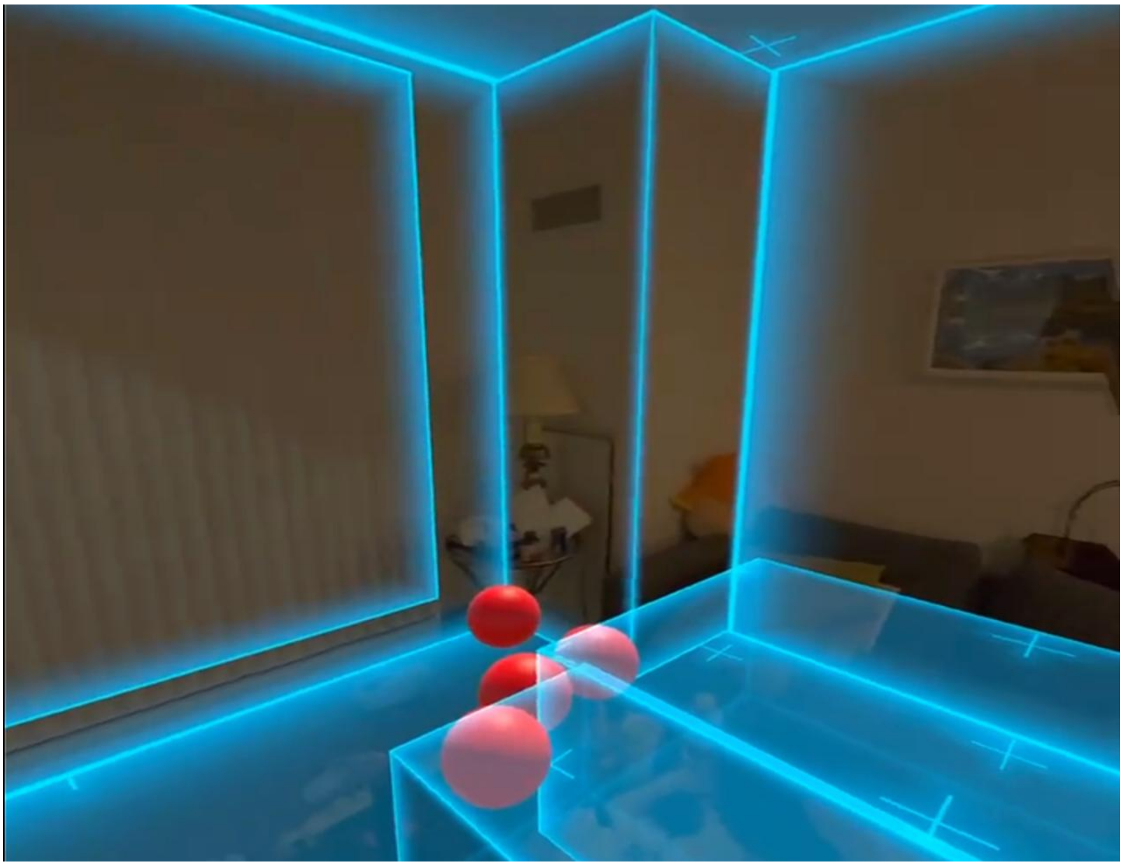


Figure 12 Physics-based validation system using Valem Tutorials' (Valem,2024) script

The integration of AI-generated object placement and interaction involved implementing real-time object recognition. The system was designed to identify physical structures such as furniture, walls, and floors as anchor points for AI-generated assets. Early tests with AI-generated textures demonstrated the potential for ai and MR combine. This step aimed to explore how MR storytelling could be enhanced by AI's ability to shape the environment based on user interactions.

I used Windows voice recognition to convert speech into text, which was sent to Chat-GPT to generate scene changes. The Meta MR Utility Kit marked structures like ceilings so that AI-generated textures were placed correctly.

Meta Building Blocks in Unity handled basic interactions, including a start/stop button for voice recognition. After scanning the room, users could say a word like *"sky."* Windows voice recognition transcribed it, Chat-GPT turned it into a text prompt, and an AI image model created a matching sky texture. The Meta MR Utility Kit then applied the texture to the ceiling.

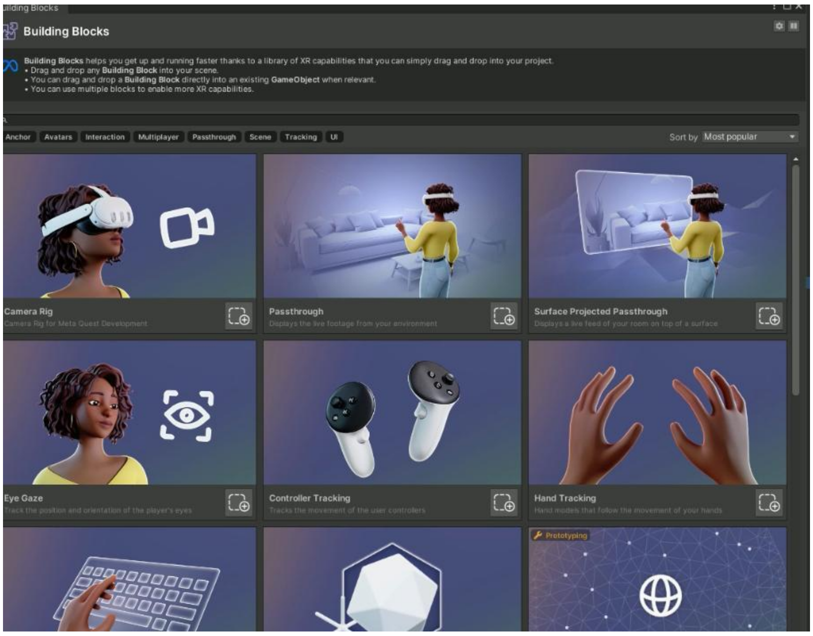



Figure 13. Building Blocks 2.3.0 in Unity[18].


Figure 14. Interaction flow of Prototype 1: users provide a spoken keyword, which is processed through AI to generate and apply corresponding textures in the environment.

[18] https://developers.meta.com/horizon/documentation/unity/bb-overview/

### 4.1.3. Reflections

This prototype successfully established an interactive MR environment where AI-generated visual elements integrated with physical space.

However, the current implementation relies primarily on AI-generated 2D textures, meaning that the interaction remains limited to visual feedback. While this enhances atmospheric immersion, it lacks physical presence or tactile engagement. The next stage of development will explore the integration of 3D-generated content that aligns with real-world objects, introducing tangible feedback and further bridging the gap between digital and physical experiences.

## Evaluation Criteria and Scores

| Criterion | Description | Score (Out of 5) |
|---|---|---|
| **Match Between System and the Real World** | The system accurately mapped AI-generated content onto physical space, allowing digital textures and objects to align with real-world surfaces. | **3** |
| **Visibility of System Status** | The interface provided clear system feedback for room scanning, speech recognition, and texture placement. However, some users were unsure when the process was complete. | **2** |
| **User Control and Freedom** | Users could trigger speech recognition and modify the MR environment, but interactions were limited to predefined spatial elements. | **1** |
| **Aesthetic and Minimalist Design** | The integration of textures and spatial mapping maintained a clean design without overwhelming visual clutter. | **1** |
| **Flexibility and Efficiency of Use** | The system allowed for basic ai combine with MR environmental, but lacked customization beyond selecting sky textures. | **2** |

Table 3. Evaluation of Prototype 1

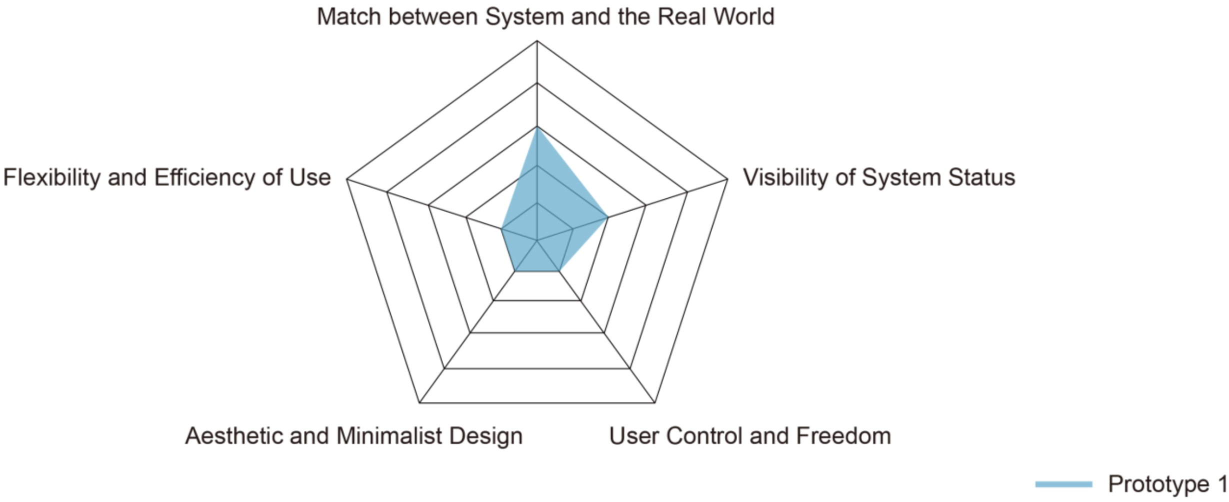



Figure 15.Radar chart for Prototype 1.

## 4.2 Prototype 2: AI-Driven Content Generation and Character Interaction

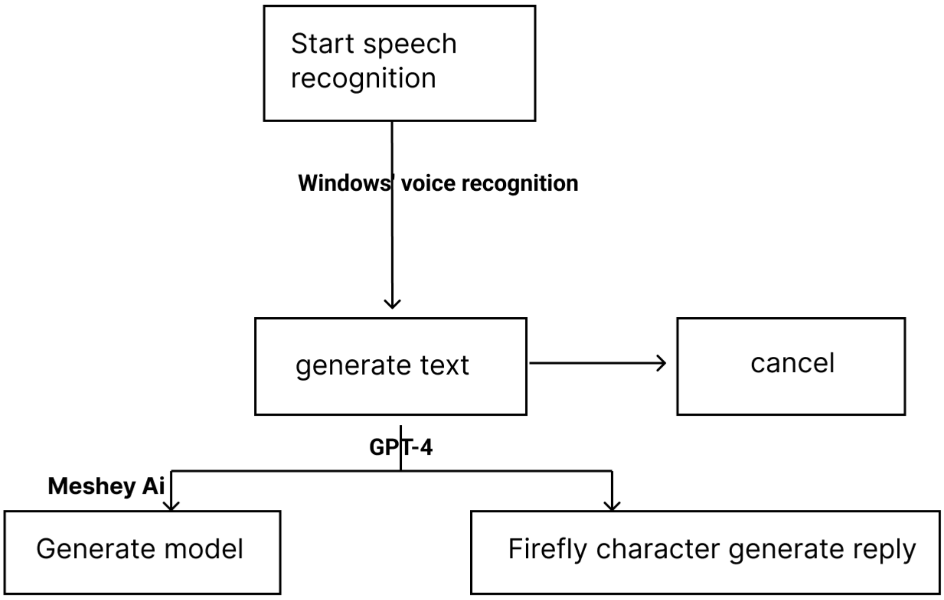



Figure 16. Flowchart of Prototype 2, illustrating the interaction and processing steps of the system. *Created by the author.*

### 4.2.1.Description

This prototype explores how AI-generated 3D content and interactive character responses enhance user agency and engagement in MR storytelling. It builds upon the speech recognition system established in Prototype 1 by incorporating AI-driven responses and interactive character feedback, transforming the content generation process into a dynamic and engaging experience.

### 4.2.2.Process

The implementation begins with voice recognition, where the system converts the user's speech into text using the speech-to-text function from Prototype 1. This text is then processed by GPT-4, which generates structured prompts that are sent to the Meshy AI [19] 0.1.2 API through its Unity integration (Meshey for Unity). This results in the real-time generation of 3D models that align with the user's descriptions.

During early testing, it became clear that waiting for a model to generate felt static and disconnected from the interactive nature of MR. To improve this, I introduced a Firefly character, which engages with the user during the process and adds a sense of continuity to the experience.

The Firefly character, powered by ChatGPT, serves two key functions:

1.Providing contextual feedback on the user's generated content – Once a 3D model is created, the Firefly dynamically responds to what the user has summoned, adding playful commentary or narrative hints.

2.Maintaining engagement during the generation process – Since generating AI-driven 3D models can take several seconds, the Firefly interacts with the user in the meantime, ensuring they remain engaged rather than passively waiting.

Example Interaction:

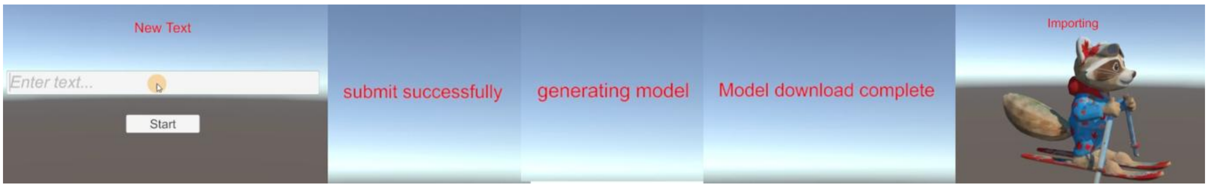



Figure 17. Example interaction in the project: user speech generates AI-driven 3D models in real time. *Screenshot by the author.*

User Speech Input: “A raccoon skiing in a maple leaf ski suit.”

Speech-to-Text Processing: The input is converted into text.

AI Processing: GPT-4 translates this into structured commands and sends them to Meshey AI for model generation.

Firefly character interaction: While the model is being generated, the Firefly comments in real time:

“The snowy slopes better watch out—this raccoon looks ready to carve through them with style! I hope it doesn't get too distracted by the fun and forget the mission!”

[19] https://docs.meshy.ai/unity-plugin/introduction

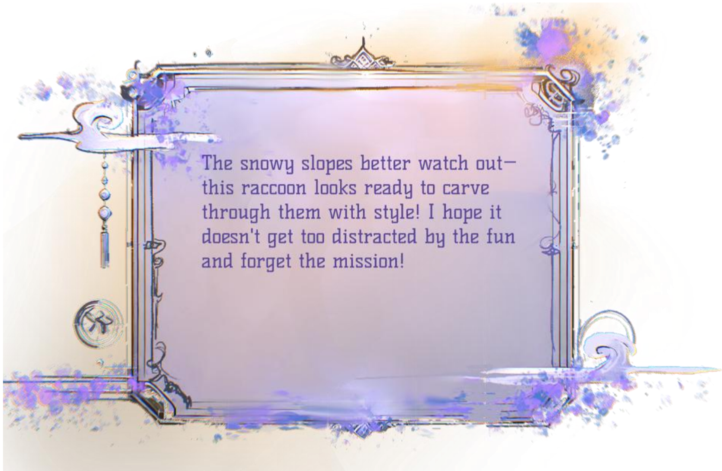



Figure 18. AI-driven generation: Firefly provides dynamic commentary.

I designed a Chinese fantasy-inspired chat interface in Procreate to further refine the aesthetic integration of AI interactions within the MR experience.

### 4.2.3.Reflections

Observations revealed that when AI-generated elements were placed arbitrarily in space, I found them disconnected from their environment. The floating objects did not feel like part of the real world, making interactions feel abstract rather than immersive. In contrast, when digital objects were mapped onto physical surfaces, users described a greater sense of presence, as if the MR elements truly coexisted with their surroundings.

However, limitations emerged. The system currently relies on passive object placement, meaning AI-generated elements do not dynamically adjust based on space characteristics such as size, position, or height. Additionally, while AI-driven voice recognition enabled object summoning, the actual object mapping was manually pre-set, limiting adaptability. Future iterations will explore object adaptation, allowing MR elements to recognize a wider range of object and respond more fluidly to the user's environment.

| Criterion | Description | Score (Out of 5) |
|---|---|---|
| Match Between System and the Real World | AI-generated 3D models were placed in the MR environment, but they did not yet adjust dynamically to real-world surfaces. | 0 |
| Visibility of System Status | Users received speech-to-text feedback and Firefly character commentary, but some model generation delays created moments of uncertainty. | 4 |
| User Control and Freedom | Users had the ability to influence content through speech, but placement was automated rather than manual. | 3 |
| Aesthetic and Minimalist Design | The introduction of the Firefly character improved engagement, keeping UI elements minimal and non-intrusive. | 2 |
| Flexibility and Efficiency of Use | The AI pipeline successfully converted text into 3D models, but users had to wait for each transformation before proceeding. | 3 |

Table 4. Evaluation of Prototype 2

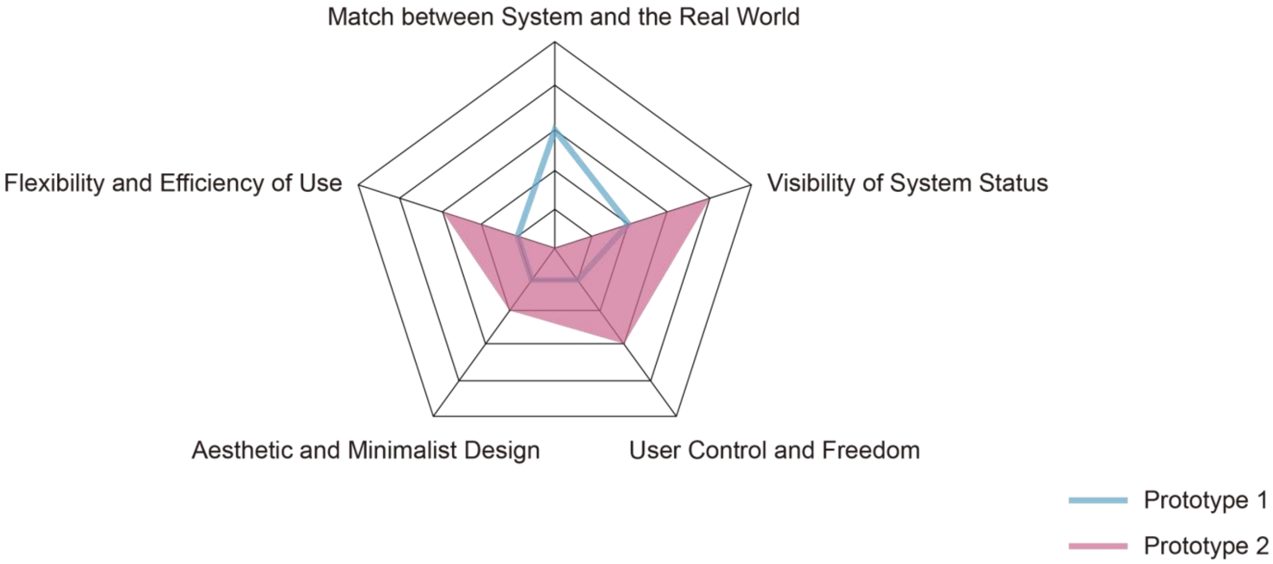



Figure 19. Radar chart for prototype 2

## 4.3 Prototype 3 Enhancing Immersion through Tangibility

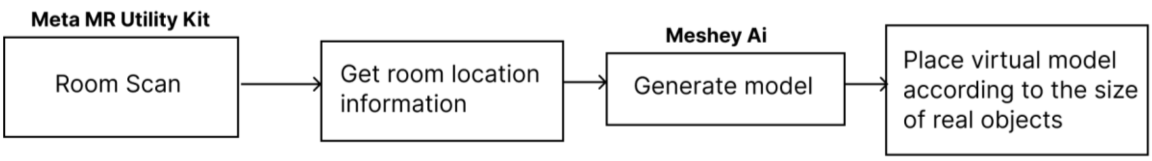



Figure 20. Flowchart of Prototype 3, depicting the interaction process and system logic.

### 4.3.1.Description

This prototype investigates how AI-generated 3D objects can adapt to real-world spatial constraints, ensuring integration between virtual content and physical environments.

I'm using the Meta headset and SDK to recognize objects in real-time, identifying their physical dimensions within the MR environment. Through AI-driven speech recognition, users provide descriptive prompts for object transformation. These descriptions are processed using Meshy AI 4.0 [20], which generates 3D models that align with the detected physical structures. The system ensures that the generated 3D object's center is precisely mapped to the real-world object's center, with its height adjusted accordingly to maintain realistic alignment.

### 4.3.2 Process

I'm using the Meta headset and SDK to scan and map the physical space, detecting the volume and placement of real-world objects. Users interact with these objects through speech, describing what they want them to transform into. A speech interaction marker is placed on each recognized object, allowing users to pinch it and "speak" directly to the object to trigger the transformation.


Figure 21. The generated object according to prompt *princess with wings* is accurately positioned at the center of the scanned model.

[20] https://www.meshy.ai/workspace

However, generating AI-driven 3D models takes 30 seconds, so the interaction is designed to remain fluid. Instead of waiting for one transformation to finish, users can continue selecting other objects. By the time they finish making multiple selections, earlier transformations will be ready, keeping the storytelling experience uninterrupted.

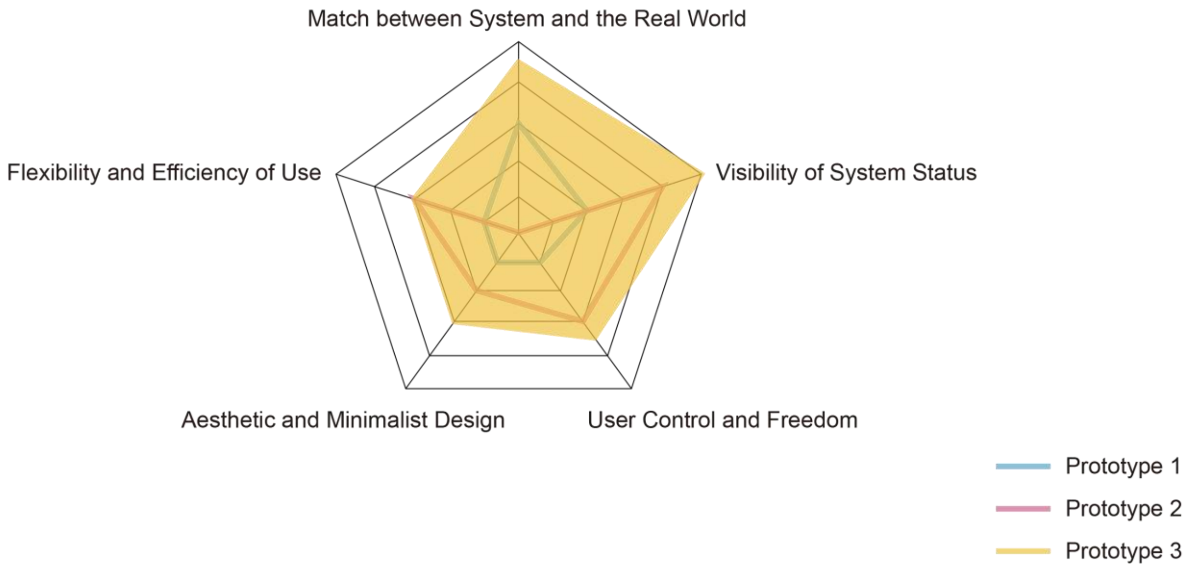
### 4.3.3 Reflections

This prototype proves that AI-generated elements can align with real-world constraints, but the next step is integrating them into narrative structures. The next prototype will further examine how dynamically generated MR spaces can drive user immersion, engagement, and co-creative storytelling experiences.

## Evaluation Criteria and Scores

| Criterion | Description | Score (Out of 5) |
|---|---|---|
| **Match Between System and the Real World** | AI-generated 3D objects were successfully mapped to real-world furniture, ensuring spatial accuracy. | **4.5** |
| **Visibility of System Status** | Interaction markers allowed users to **track object transformations**, ensuring clarity in the process. | **5** |
| **User Control and Freedom** | Users could choose which objects to transform, but the **transformation process itself was pre-scripted** rather than dynamic. | **3.5** |
| **Aesthetic and Minimalist Design** | The system maintained a **clean and cohesive MR aesthetic**, allowing virtual elements to blend naturally with the real world. | **3** |
| **Flexibility and Efficiency of Use** | Parallel object generation **reduced waiting times**, improving interaction flow. | **3** |

Table 5. Evaluation of Prototype 3




Figurer 22. Radar chart for Prototype3

## 4.4 Prototype 4 AI-Driven MR Storytelling Experience

### 4.4.1 Description

The final prototype explores how real-time AI-generated 3D model creation based on user speech can influence interactive storytelling and user agency within an MR environment. By integrating spatial interaction, narrative adaptation, and co-creative storytelling, this stage deepens user engagement and immerses them in a dynamic, evolving story world.

Beyond AI-generated content, this prototype includes interaction design elements such as UI/UX features, animations, and environmental storytelling. Visual and auditory cues guide users, making interactions smooth and intuitive. The interface features interactive prompts, gesture-based controls, and visual indicators for speech recognition and AI-generated content. Animations enhance the experience, from the firefly's movement and glow to changes in real-world objects. Dynamic skyboxes and subtle particle effects help shape the atmosphere, reinforcing the fantasy setting.

The storytelling experience follows a structured main storyline with room for user-driven co-creation. It begins with the user discovering a cursed firefly trapped in a jar, its glow flickering as it struggles against the glass. Releasing it reveals its predicament—it is powerless to change the world, but the user, blessed by a goddess, has the ability to speak to real-world objects, turning them into magical entities and tools needed to defeat the Dark Overlord.

The prototype's artistic vision draws from childhood imagination and folklore, creating a dreamlike atmosphere within the MR environment. Soft colors blend fantasy with semi-realistic elements, while stylized 3D models, UI, and a custom soundscape—featuring ambient music and spatialized effects—enhance immersion. The scene design balances realism and fantasy, blurring the line between physical and virtual spaces. By bringing together AI-driven storytelling, spatial computing, visual and interaction design, and dynamic soundscapes, this prototype serves as a demonstration of an AI-powered MR storytelling experience.

### 4.4.2 Process

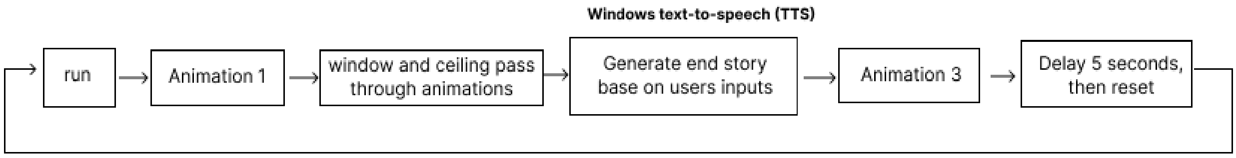



Figure 23. Workflow of Prototype 4

**1) Detailed MR Experience Flow design**

The MR system begins by detecting real-world objects within the environment, assigning interactive markers that allow users to engage with them through speech-based transformation commands. Using AI-generated models powered by Meshy AI, objects are dynamically reshaped in response to user input. For example, the user may command a table to transform into a winged raccoon companion or turn a cabinet into a fire-breathing cannon.

A key design challenge was ensuring that object transformations felt meaningful within the narrative structure. To facilitate this, the user's choices directly impact the final battle sequence, where their transformed objects will come to life and work together against the antagonist. Each decision adds new layers to the unfolding story, reinforcing a sense of player agency and co-authorship. Since 3D model generation takes time, a sequential interaction design was implemented to maintain user engagement. Users interact with real-world objects one by one, pressing the interactive markers and speaking their transformation requests. As they move on to the next object, previously commanded transformations begin rendering in the background, ensuring a fluid and uninterrupted experience.

In the final stage, the firefly, connected to ChatGPT, narrates a dynamically generated climactic battle story, weaving together the transformations and choices the user has made. The AI creates a unique resolution for each session, detailing how the transformed objects fight alongside the user and ultimately defeat the Dark Overlord. This adaptive storytelling ensures that each player's journey feels personalized and emergent, reflecting their individual creative decisions.

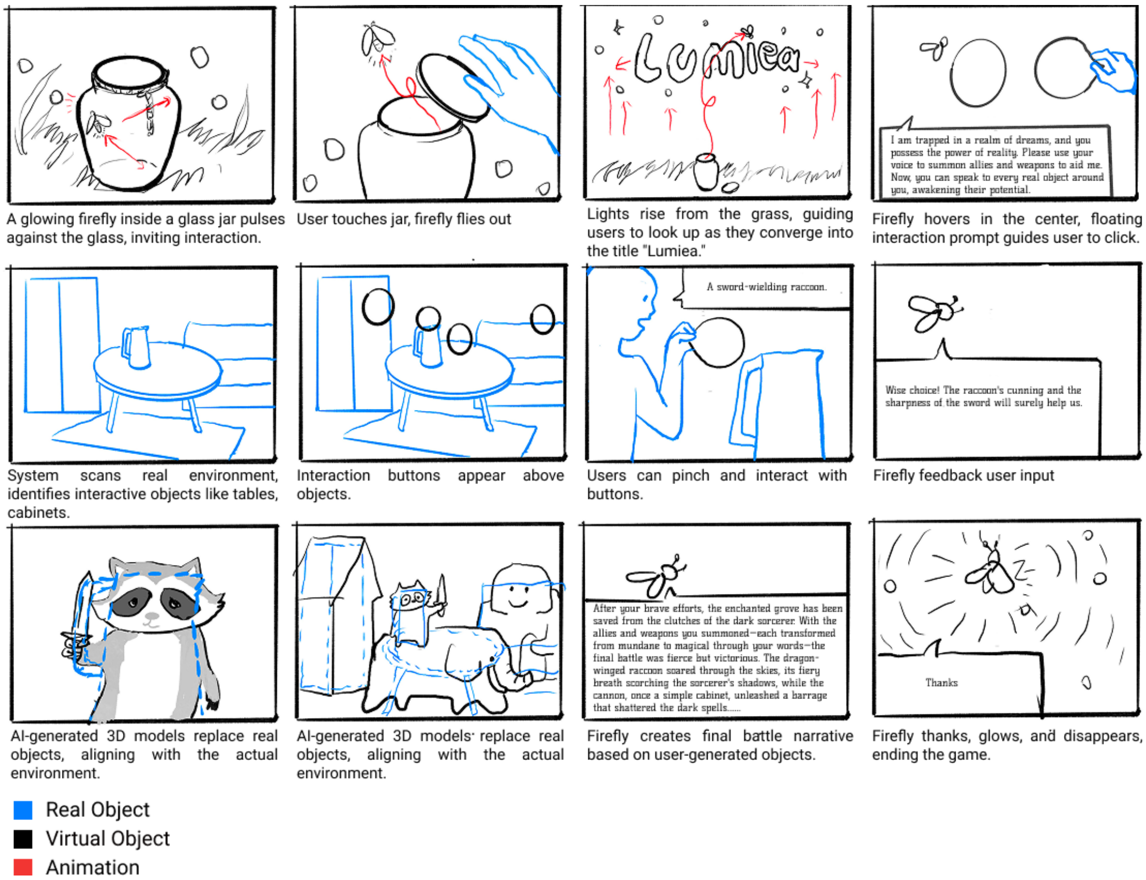



Figure 24. Detailed MR experience flow design

Upon launching the MR experience, users see their real-world environment subtly overlaid with a soft, blue starry filter, creating a dreamlike nighttime ambiance. This effect preserves the familiarity of their physical surroundings while immersing them in an altered, magical space. The filter maintains spatial awareness but introduces an atmospheric shift, setting the tone for the journey ahead.

The first scene unfolds on a virtual grass-covered ground, appearing within the physical space. In the center, an ornate jar rests on the grass, faintly illuminated. Inside the jar, a firefly repeatedly collides with the glass, emitting a gentle thud-thud sound, drawing the user's attention toward it. This subtle audiovisual cue encourages interaction.

**Interaction 1: Releasing the Firefly**

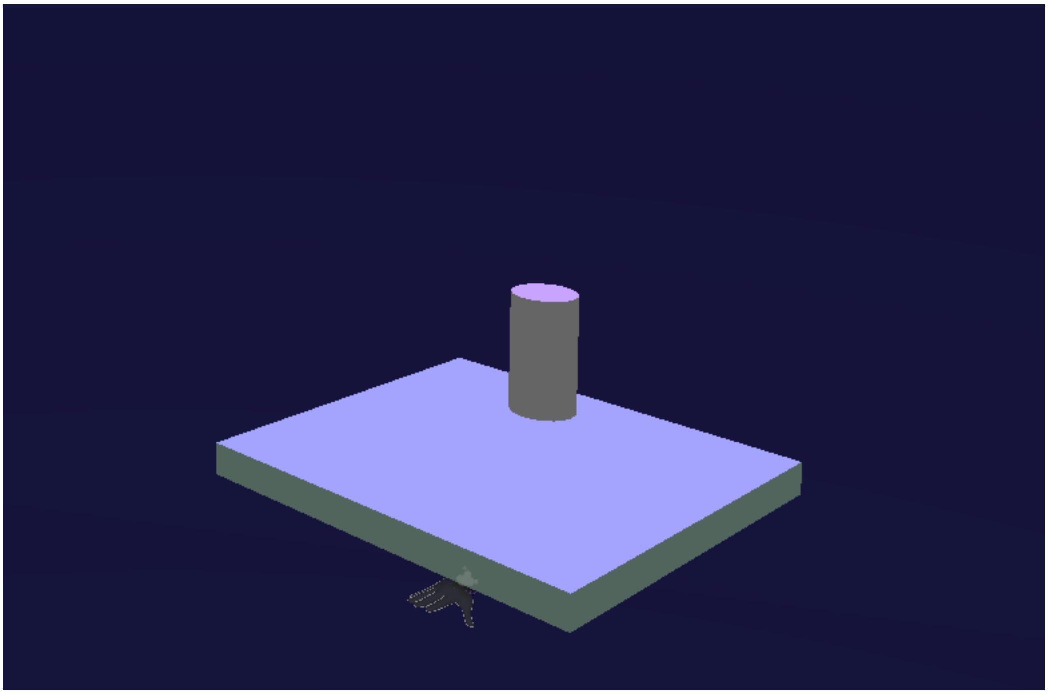


Figure 25. Testing setup: a rectangular prism represents grass, and a cylinder represents the jar, with automatic positioning and touch interaction to start the game.

For testing purposes, I used a rectangular prism to represent the grass and a cylinder to represent the jar. The rectangular prism is programmed to automatically position itself at the center of the scanned room. The cylinder includes a touch interaction, allowing the game to start when the user collides with it.

Users interact using hand gestures, reaching out to touch the glowing jar. As they do, the glass shimmers and dissolves, allowing the firefly to escape and hover into the air. At this moment, small lights begin rising from the grass, mirroring the firefly's ascent. The lights drift upwards, illuminating the darkened sky, forming a soft, ethereal glow above. The passthrough mode turns on, user can see the immersive night sky celling and fantasy forest outside the window. The celling and window is marked by unity utility MR kit.

The firefly now floats at the center, its wings gently beating, surrounded by radiant particles. A subtle interactive prompt appears nearby, indicating that users can touch it to engage in dialogue.

**Interaction 2: The Firefly's Story**

Once the user interacts with the firefly, it introduces the narrative premise:

"I have been trapped in this dream, lost and powerless. But you… you come from the real world. You carry something I do not—true power. Only through your reality can I break free from this nightmare. Help me summon my allies and forge the weapons we need to defeat the Dream Eater who holds me captive in this endless maze."

With this, the firefly guides the user's gaze downward, prompting them to look at the objects in their physical environment.

**Interaction 3: Transforming Reality**

The system identifies real-world objects, such as tables, cabinets, or chairs, and overlays glowing interactive markers on them. Users can select an object by pinching their fingers near the marker, activating a speech-based interaction prompt.

For example:

The user selects a table and says:

"Become a winged raccoon!"

The chosen object begins glowing, and an ethereal aura surrounds it as the AI starts generating a 3D model via Meshy AI.

To reduce waiting time (3-4 minutes for model generation), users can continue interacting with other objects while previous transformations are in progress.

While waiting, the firefly encourages the user, reinforcing the magical transformation:

"Your words hold power. The world reshapes itself at your command."

Once all transformations are complete, anchoring the model accurately to the physical surface, the firefly acknowledges the user's success: "Now, feel the strength of reality! Your words shape this world—carry these powers into battle and break free from this nightmare!"

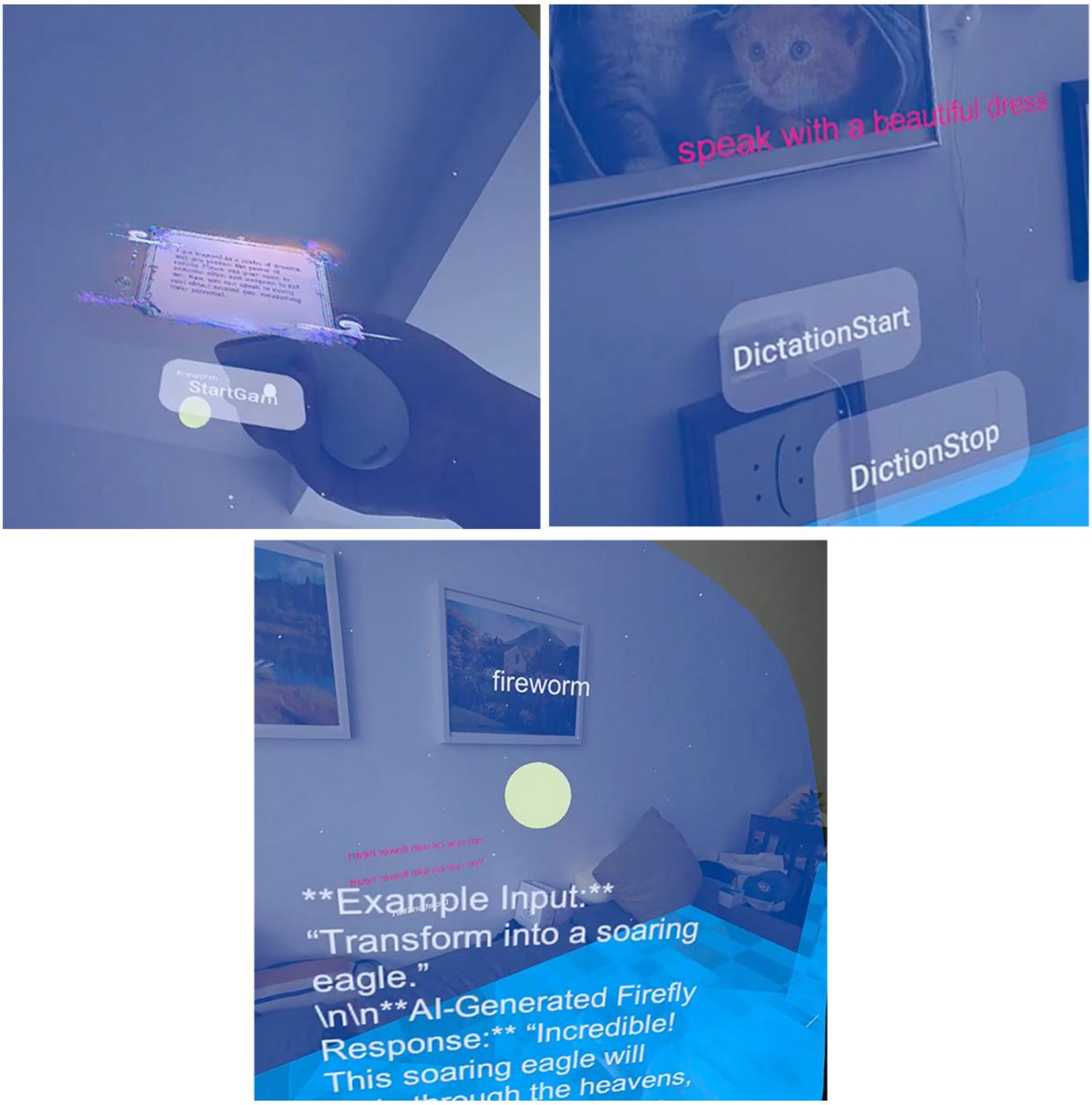



Figure 26. Game start sequence: users begain the game, select a real object, voice recognition generates a model, and the firefly reacts accordingly.

**Final Interaction: AI-Generated Storytelling**

The firefly takes its position at the center of the scene and, using ChatGPT, generates a dynamic battle story based on the user's summoned companions and weapons. The narration synchronizes with animated movements from the AI-generated models, enhancing the immersion.

Updated ChatGPT AI Prompt:

"Create an epic battle story where the protagonist, alongside their magical allies [transformed objects], fights against the Dark Overlord. The story must integrate all generated elements, maintaining a logical and engaging progression. The final confrontation should showcase each transformed object playing a decisive role in the battle's climax, ensuring their abilities contribute meaningfully to the resolution."

As the final story unfolds, the generated objects react in sync, enhancing the sense of presence and connection between the narrative and the environment.

At the story's conclusion, the firefly offers a moment of reflection:

"The dream is shifting… but the power remains with you. Every object holds a hidden story, waiting to be spoken into existence."

As the lights fade softly, the experience transitions to an outro, leaving users with the lingering sensation of a world shaped by their words.

**2) Artistic design**

The artistic design of this prototype was developed to enhance the narrative depth and immersive quality of the MR storytelling experience. A combination of 3D modeling, environment design, and audio elements was used to create a visually and atmospherically rich world that supports the interactive storytelling mechanics.

A variety of 3D assets were created using Blender 3.6 LTS and integrated into Unity to shape the MR environment. These assets were designed to establish a cohesive visual aesthetic that aligns with the project's storytelling themes. Key elements include interactive props, fantastical environmental details, and animated transitions that reinforce the magical and narrative-driven atmosphere

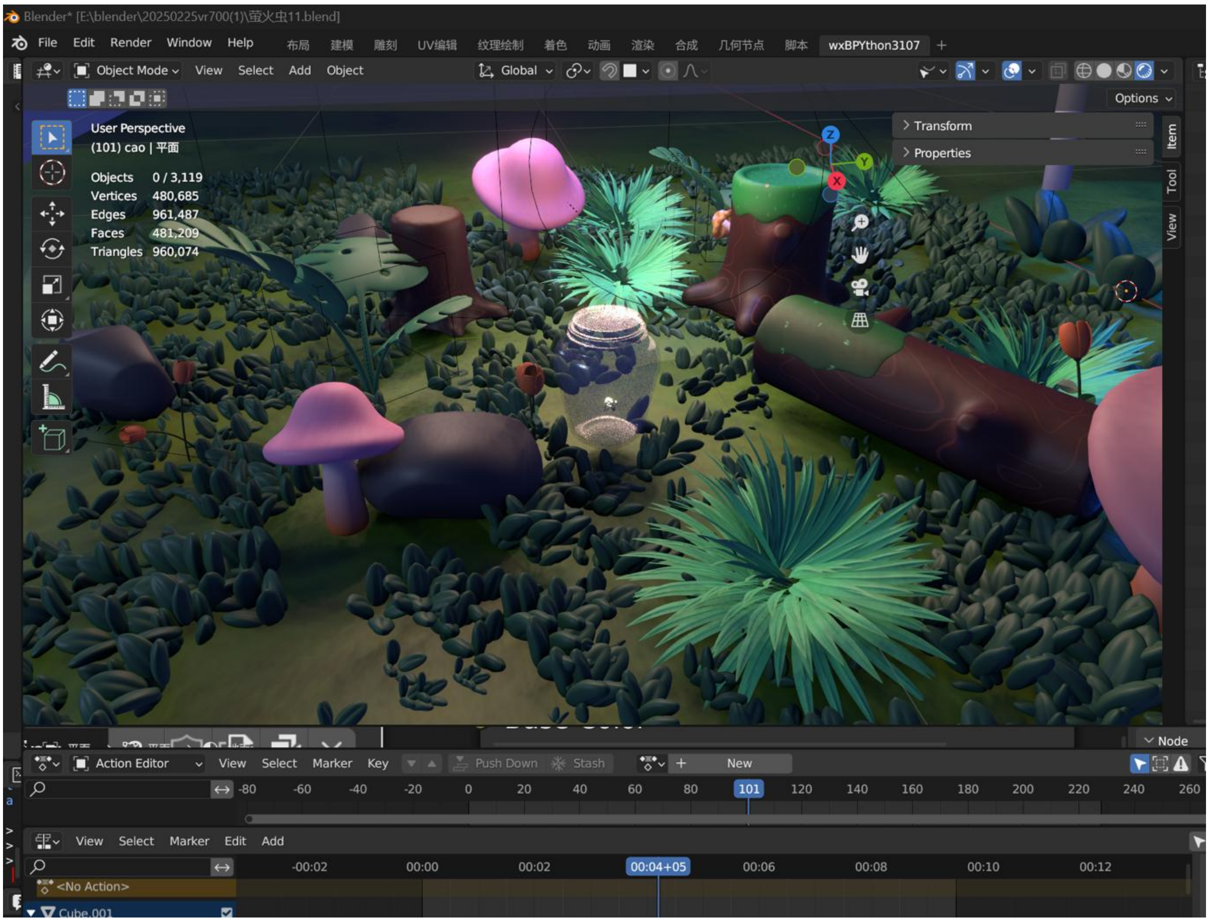



Figure 27. Firefly character scene and animation created in Blender

1.Title


Figure 28. *LUMIEA* title screen in Unity

The title LUMIEA draws from the interplay between light and ideas, symbolizing both illumination and imagination. The word evokes lumière, the French term for “light,” which historically represents enlightenment, discovery, and perception. Light has long been a metaphor for knowledge, inspiration, and the act of revealing hidden truths. In the context of this project, light is not merely a visual phenomenon but a bridge between the real and the imagined—a guiding force that transforms physical reality into an interactive storytelling space.

2. firefly

Figure 29. Firefly modeling design


Figure 30. Initial scene design upon entering the game, setting the environment and atmosphere. *Created by the author.*

Figure 31. Fantasy forest scene modeling in Unity

To guide users toward interacting with the jar, I designed a blue guiding hand gesture that visually directs attention and encourages interaction. This visual cue appears near the jar, subtly indicating that users should reach out and engage with it. This design ensures that users intuitively understand their next action without requiring explicit instructions, maintaining an immersive and storytelling experience. To further enhance user guidance and immersion, I incorporated sound design elements. A bell sound effect was spatially positioned at the jar's location using 3D audio, drawing users' attention and encouraging interaction with the trapped firefly.

For the background music, I use Udio AI V1.5[21] generation with the following prompt:

*"Create a melancholic yet beautiful instrumental track with a soft, peaceful atmosphere. The music should have a gentle, nostalgic quality with subtle retro childhood textures, evoking a dreamy and slightly psychedelic feel. The tempo should be around 70 BPM, with a flowing, immersive sound that feels intimate and emotionally resonant. Keep the arrangement delicate and ethereal, allowing the mood to be both wistful and comforting."*

[21] https://www.udio.com/home

This generated an atmospheric soundtrack that complements the visual and narrative design, reinforcing the emotional depth of the experience.

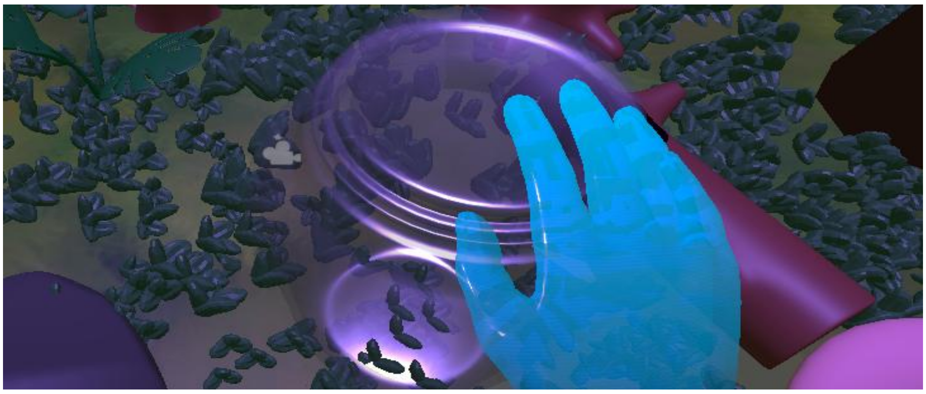


Figure 32. Guide animation featuring a blue hand, prompting users to interact

One of the core environmental features is the use of Passthrough Mode, allowing users to see real-world elements overlaid with dynamic MR visuals. The ceiling was designed to display a sky full of stars and a shifting skybox, reinforcing the dreamlike atmosphere. Additionally, the windows in the MR space reveal a surreal, otherworldly forest, contrasting reality with fantasy and immersing users in a liminal storytelling experience.

Figure 33. Fantasy forest scene modeling in Unity

Figure 34. Fantasy forest scene modeling in Unity, featuring mist and rain effects for atmospheric immersion

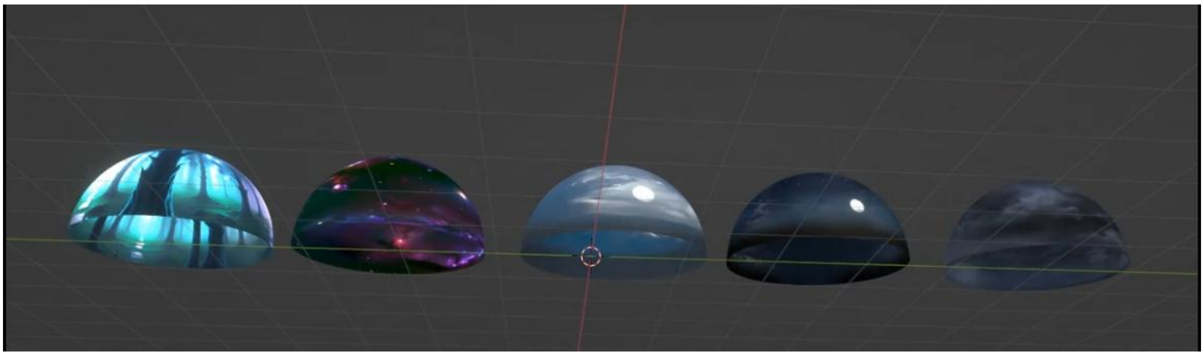


Figure 35. Selection of different skyboxes using the inverted normals method on a hemisphere in Blender.

Figure 36. Scene effect in passthrough mode, blending a fantastical forest view outside the window with the real-world environment. The blue checker box is the real objects.

Figure 37. Passthrough mode scene effect, featuring a starry sky and rain effects blending with the real-world environment.


Figure 38. The firefly provides dynamic feedback on the user's 3D object description, displaying text in a floating MR text box and playing audio via Windows TTS for enhanced accessibility.

After the user describes the desired 3D object, the firefly provides feedback on their description, offering a dynamic response. This text is displayed in a floating text box within the MR space while simultaneously being played aloud using Windows TTS. This implementation enhances accessibility by ensuring both visual and auditory feedback, making the interaction more inclusive and engaging.

After the story is generated, the firefly gradually ascends, its glow intensifying as it transforms into a radiant star. It drifts into the vast expanse of the sky, merging with the celestial backdrop, signaling the conclusion of the experience.

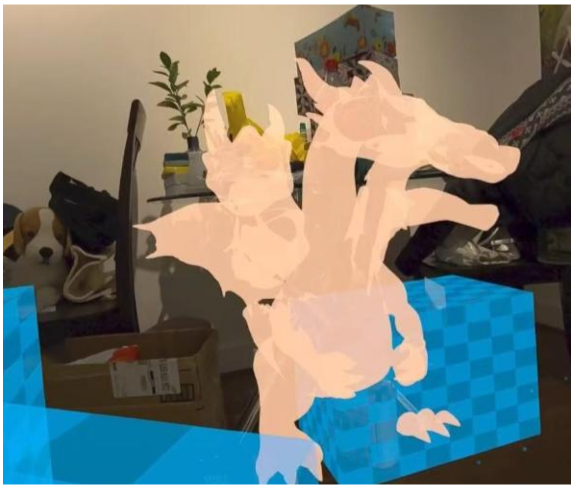


Figure 39. AI-generated three-headed dragon by Meshey AI,  placed at a real table from room scanning.

Once the AI-generated 3D model is successfully created, it is placed in the corresponding real-world location, aligning with the spatial constraints identified during the room scanning process. This ensures that the digital content  integrates with the physical environment. The previously visible blue marker, which indicated the object's placement, disappears upon model completion. The generated 3D model is now anchored to the real-world object, allowing it to provide tangible feedback through the physical properties of the underlying furniture or surface.

Figure 40. After the story is generated, the firefly transforms into a star and disappears into space, marking the end of the game.

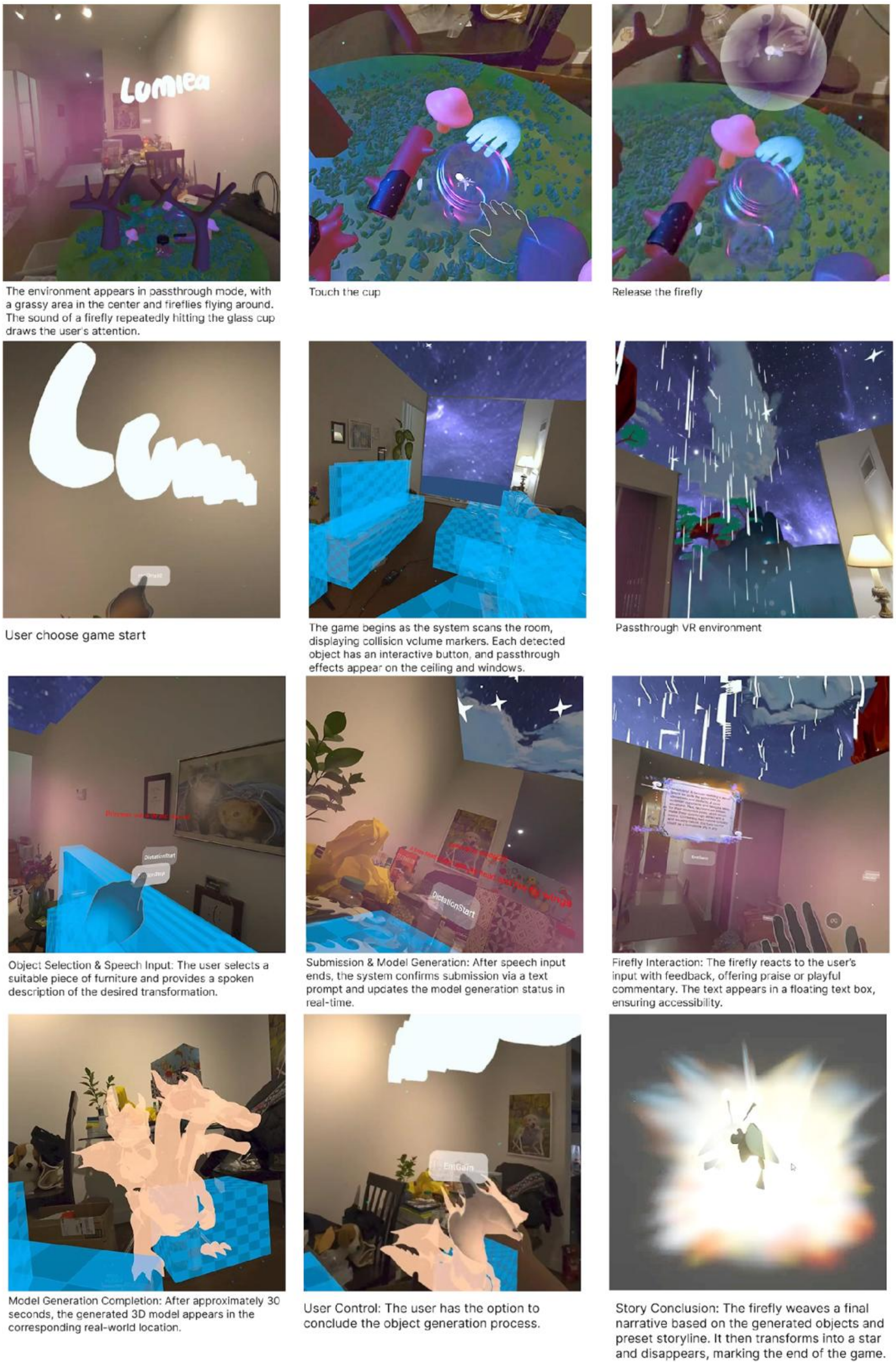



Figure 41. Screenshot from the recorded experience of Prototype 4, showcasing the complete interaction flow and system functionality.

### 4.4.3 Reflection

**1) Evaluation of MR Usability and Interactive User Experience**

| Criterion | Description | Score (Out of 5) |
|---|---|---|
| Match Between System and the Real World | The system aligned AI-generated MR content with real-world objects, allowing for spatial interaction and object transformations. | 5 |
| Visibility of System Status | Users received clear visual and auditory feedback when interacting, including speech recognition prompts, object generation progress, and story transitions. | 5 |
| User Control and Freedom | Users could experiment with different transformations and interactions, but object selection was limited to predefined furniture types. | 4.5 |
| Aesthetic and Minimalist Design | The MR interface, animations, and UI elements were designed to be unobtrusive, ensuring an immersive experience without unnecessary distractions. | 4.5 |
| Flexibility and Efficiency of Use | The system provided an interactive guide (Firefly character) to assist users, but generation delays caused slight breaks in pacing. | 4 |

Table 6. Evaluation of Prototype 4: Assessing MR Usability and Interactive User Experience.

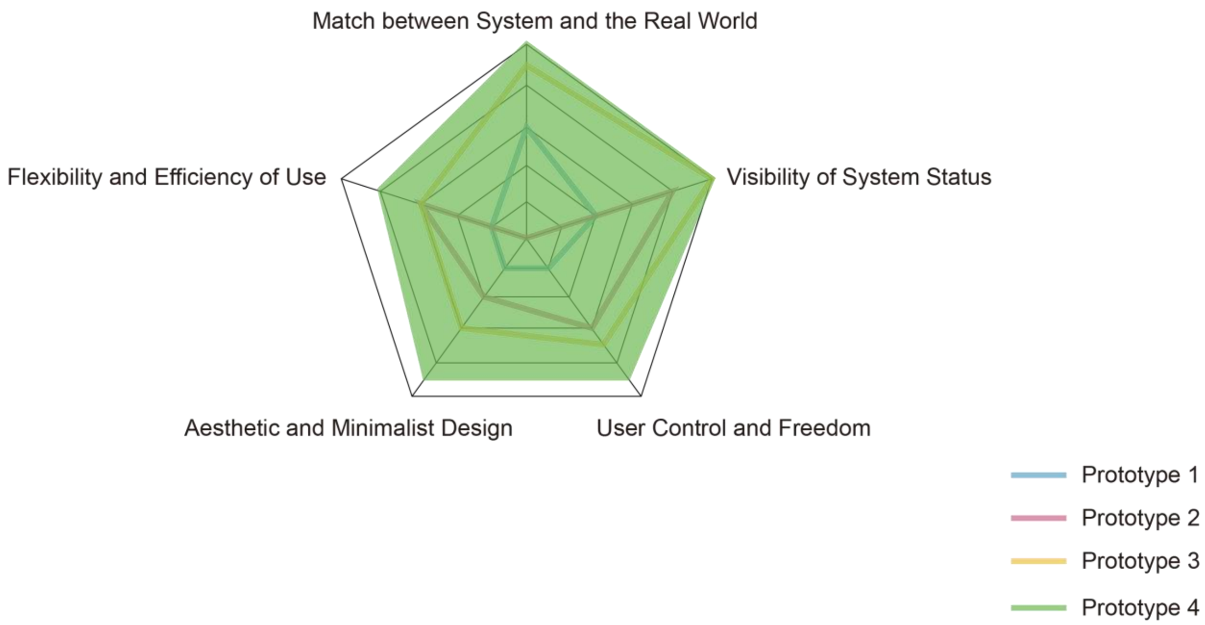



Figure 42. caption Radar chart for prototype 1

**2) Storytelling Evaluation**

| Criterion | Description | Score (Out of 5) |
|---|---|---|
| Clear and Compelling Narrative Structure | The structured storyline provided clear goals while allowing user-driven transformations to shape the experience. | **4.5** |
| Strong and Relatable Characters | The Firefly character was well-received, providing both guidance and narrative continuity. However, additional characters could enhance engagement. | **4** |
| Meaningful Conflict and Resolution | The final battle against the Dark Overlord was well integrated, but AI-generated conclusions could be more contextually tailored to user choices. | **4** |
| Audience Agency and Interaction | The ability to transform objects through speech gave users creative agency, though story branching was limited. | **4** |
| Multimodal Engagement | The system successfully combined speech, spatial interaction, and visual storytelling, but lacked direct tactile feedback. | **5** |

Table 7**.** Storytelling Evaluation for Prototype 4

# CHAPTER 5. EXHIBITION

## 5.1Exhibition Plan

The prototype is planned for presentation at the Digital Futures Graduate Exhibition 2025, held at OCAD University's waterfront campus at Artscape Daniels, Toronto. The exhibition serves as an opportunity to demonstrate the system's ability to integrate AI-generated 3D models with real-world spatial constraints and tangible interactions in a Mixed Reality (MR) environment.

Figure 43. Photograph of the exhibition space

Since a core research question examines how everyday objects can provide tactile feedback for MR-generated content, the exhibition setup includes real furniture arranged to simulate a living room environment. This setup allows visitors to interact with MR-generated objects in a familiar physical setting, assessing the impact of tangible interactions on immersion and engagement. The inclusion of physical objects provides a controlled environment for testing spatial alignment, user interaction, and AI-generated content adaptation.

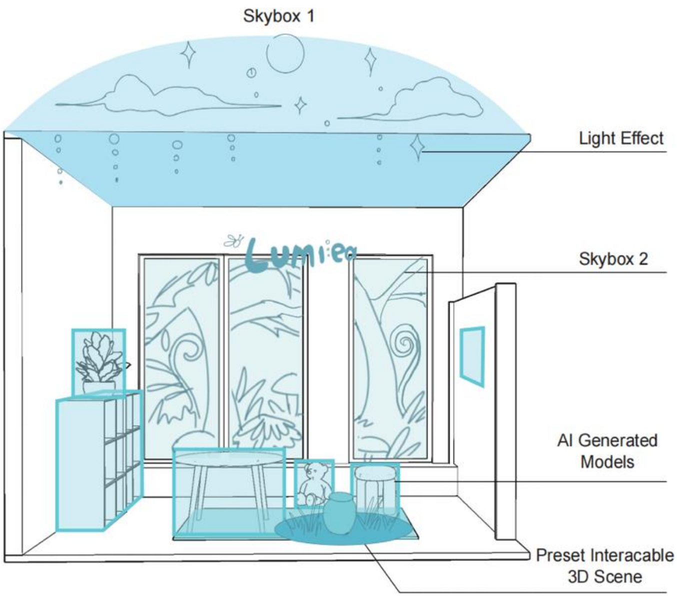



Figure 44. MR effect in the exhibition space, showcasing interactive mixed reality elements.

To explore the relationship between real and virtual space, the exhibition design incorporates a passthrough effect on the windows, displaying an AI-generated external environment that contrasts with the real-world setting. Additionally, the ceiling projection features a skybox, including animated stars, clouds, and environmental effects. These elements aim to examine how MR can balance realism with digitally generated environments to enhance user perception and interaction.

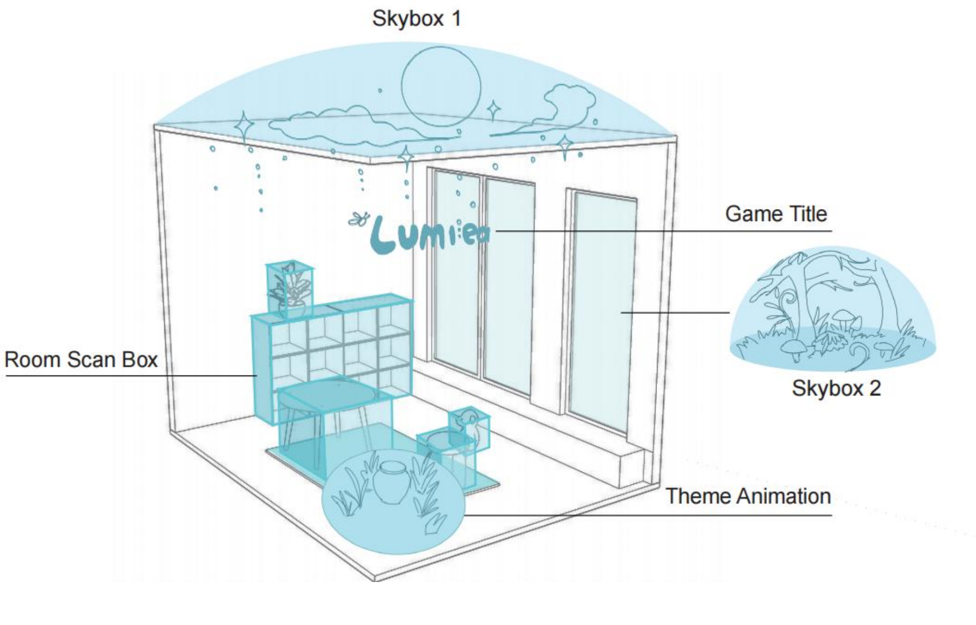



Figure 45. MR effect in the exhibition space, featuring both the sky and forest VR environment and skybox

The exhibition will give me a chance to see how people respond to and interact with AI-generated content in MR. I hope to gain insight into how these interactions shape their perception of space and narrative, helping me reflect on my own relationship with technology and storytelling.

## 5.2 Exhibition Overview


Figure 46. Picture showing the exhibition setup, featuring a living room environment filled with real furniture for interaction.

The final prototype was exhibited at the Digital Futures Graduate Exhibition, attracting considerable interest from participants with diverse backgrounds.

During the exhibition, the ceiling automatically switched to pass-through mode upon recognition, revealing a starry skybox complete with shooting star animations. Similarly, windows transitioned to pass-through mode, showcasing animated fantasy forest scenes.

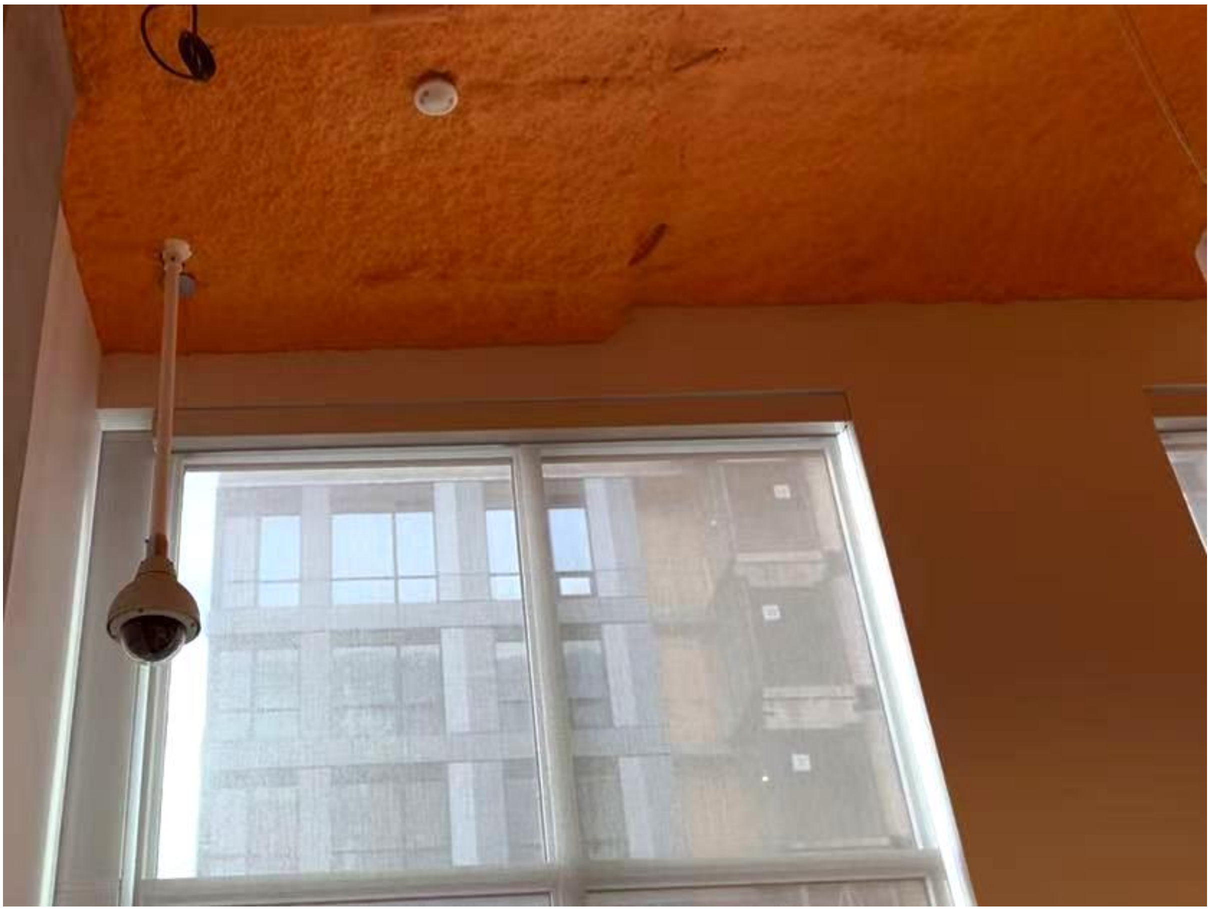


Figure 47. The real-environment ceiling and window

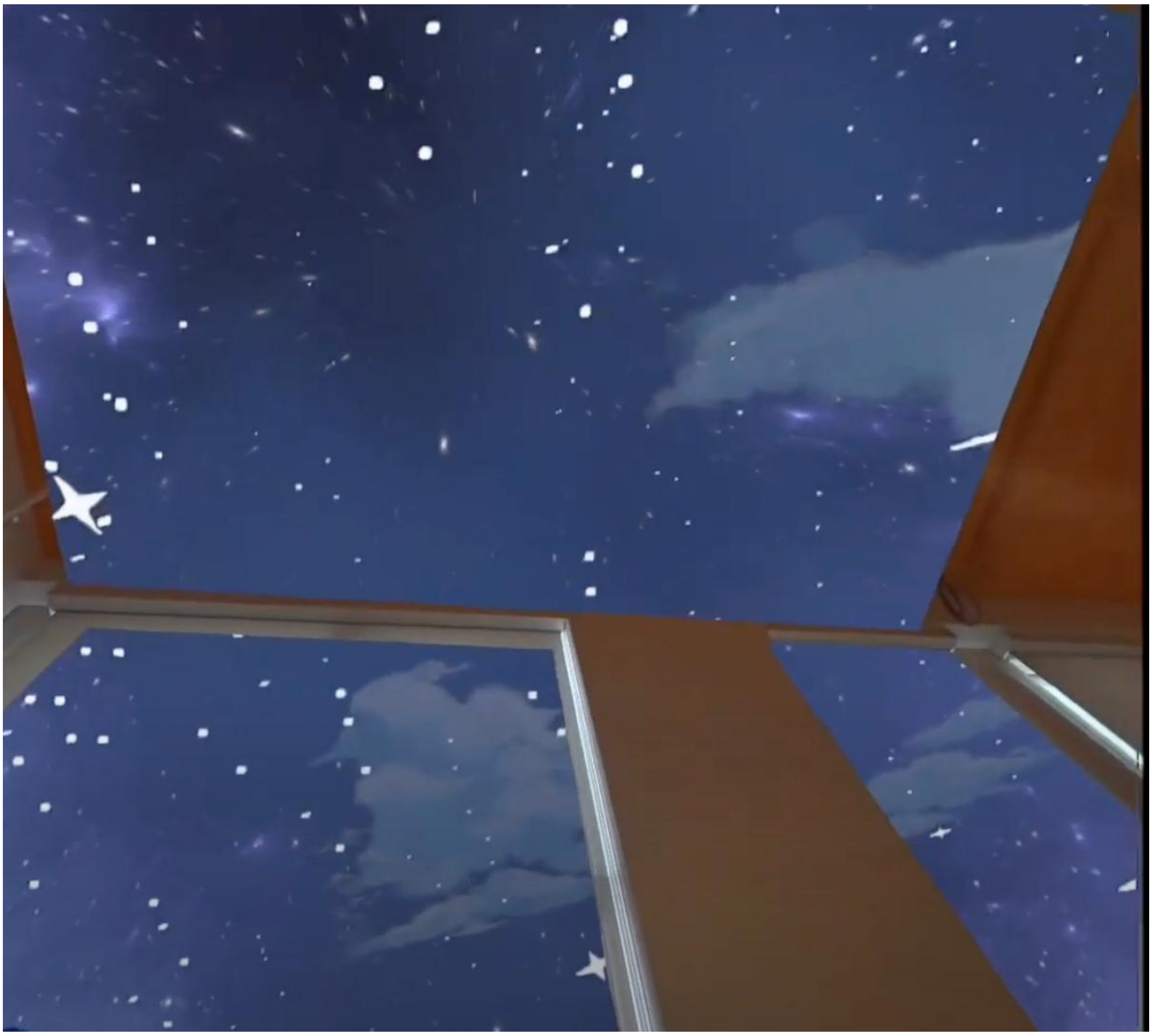


Figure 48. Screenshot showing the pass through mode ceiling and window in the MR environment.

Figure 49. Screenshot showing the animated fantasy forest scenes.

A living room setup was created in advance to simulate a typical daily-use scenario, where furniture was seamlessly identified and overlaid with blue markers and interaction buttons, inviting user engagement.

Figure 50. Screenshot showing a living room setup simulating a daily-use scenario, with furniture overlaid by blue markers and interaction buttons for user engagement.

The firefly jar initiating the game was automatically positioned at the center of the room's floor, accompanied by engaging music designed to attract user interaction.


Figure 51. Screenshot showing the firefly jar, auto-positioned at the center of the room.

Observations and feedback collected during the exhibition are summarized below:

• An interaction guide was displayed during the exhibition, providing participants basic interaction tips, such as using finger-tap gestures and voice commands to transform furniture into interactive characters, similar to a Dungeons & Dragons (DND) experience.

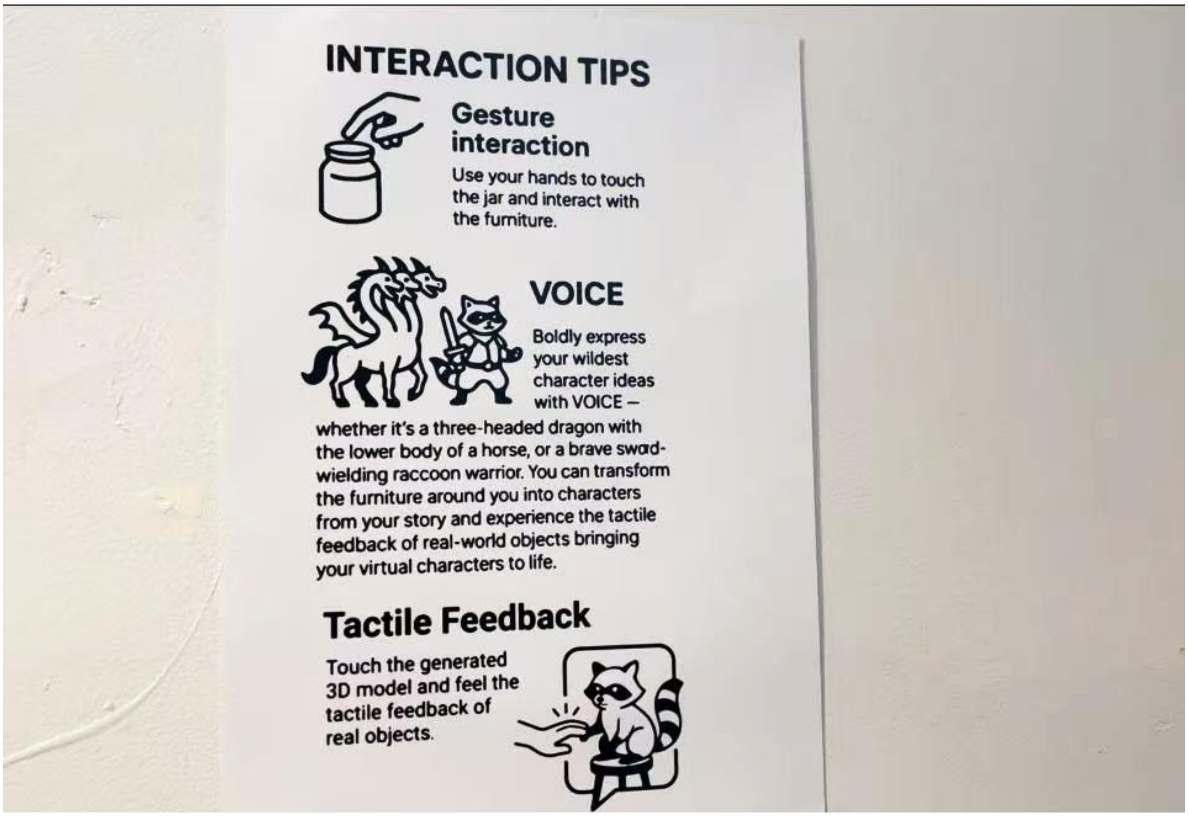



Figure 52. An interaction guide displayed at the exhibition, instructing participants on finger-tap gestures, voice commands to transform furniture into characters, and tactile feedback.

• Many participants expressed enthusiasm for the freedom to generate personalized 3D characters, which directly influenced the narrative flow. Participants demonstrated highly creative interactions and imaginative use of the MR system.


Figure 53. Image showing user interacting through hand gestures.

• Some participants attempted to physically pick up the virtual objects created during the interactions, highlighting an unmet expectation, as the prototype did not include functionality for object manipulation.

• Several participants commented on the audio volume during the exhibition. Specifically, background music occasionally overpowered the AI-generated character dialogue, making it difficult to clearly hear responses.

• Voice recognition accuracy presented challenges for certain male participants, as the recognition system was primarily trained on female voice data, resulting in occasional inaccuracies or misinterpretations during interactions.

• A few participants mentioned the VR headset's weight as a limitation, expressing a preference for a lighter, more comfortable device to enhance the overall experience.

# CHAPTER 6. DISCUSSION

## 6.1 Evaluation of Prototypes and Research Questions

This research aimed to explore how AI-generated MR environments, speech recognition, and tactile feedback could enhance interactive storytelling experiences. The four prototypes were designed to iteratively answer the research questions through experimentation and development. Below is an evaluation of each prototype's contributions to the research questions:

| Research Question | Related Prototype | Findings |
|---|---|---|
| **How can real-world spatial mapping and speech recognition establish a foundation for AI-driven interactive storytelling in MR environments?** | Prototype 1 | Integrated **speech recognition** and **real-time room scanning** to create an MR environment where AI-generated textures respond to user inputs. However, the interaction remained **purely visual**, lacking **tactile or narrative depth**. |
| **How can AI-generated 3D content and character-driven responses shape user engagement and agency in MR storytelling?** | Prototype 2 | Added **3D model generation** and an interactive **Firefly character**, improving engagement. However, real-time **object placement** and deeper user **agency in storytelling** needed further refinement. |
| **How does incorporating tactile feedback from everyday objects in MR storytelling influence user immersion and engagement?** | Prototype 3 | Introduced **tangible interaction** by mapping AI-generated 3D models onto real-world objects. This significantly improved **spatial coherence and immersion** but required **better automation in object detection**. |
| **How can AI-driven storytelling be designed to create an interactive and immersive MR narrative experience?** | Prototype 4 | Integrated **all elements—AI-driven storytelling, real-time interaction, and animations**—into a cohesive experience. The Firefly character played a central role in guiding the user. However, the system still had limitations in **real-time adaptability** and required **structured guidance** to ensure narrative flow. |

Table 8. Evaluation of all prototypes

## 6.2 Self-Reflection and Lessons Learned

Throughout this research, I focused on refining the technical and narrative aspects of MR storytelling. Spatial alignment wasn't a major issue, but accurately marking all objects during room scanning was essential. Initially, generating 3D models with textures took about four minutes, but switching to pure mesh reduced the time to just 30 seconds. Moving forward, I plan to explore local deployment for 3D generation to speed up textured model creation or find a faster online solution.

Narratively, I found the story somewhat simplistic and want to develop more complex storytelling structures in future iterations. Expanding the narrative depth will be a key focus, ensuring a more dynamic and engaging experience.

**Comparative Analysis with Related Work**:

| Feature | 1001 Nights (AI-Native Game) | Pillow Meta (AI-MR Interaction) | SCENECRAFT (LLM-driven 3D Scene Gen) | Luoyang VR Project (Cultural Immersion) | My Work |
|---|---|---|---|---|---|
| **AI-Generated Storytelling** | Speech-driven AI narrative co-creation | AI-generated bedtime stories | LLM-driven NPC interactions | Pre-scripted historical VR experiences | **Real-time AI-driven MR storytelling** |
| **Tangible Feedback** | No tangible interaction | Minimal spatial integration | AI-generated NPCs but no real-world alignment | Physical props used in location-based VR | **MR storytelling using real-world objects as interactive elements** |
| **Real-Time Adaptability** | User input influences AI-generated text | Limited real-time adaptation | Generates story scenes but not real-time | Pre-defined narrative structure | **User speech generates 3D objects & affects storytelling** |
| **Visual & Aesthetic Design** | 2D visual overlays | AI-generated 3D depth illustrations | 3D scene generation | Highly detailed VR environments | **Handcrafted MR aesthetics with AI-generated assets** |

Table 9. Comparative analysis of the prototypes with related work, evaluating key features, methodologies, and outcomes.

This comparison highlights the novelty of integrating AI-generated content with MR spatial mapping and tactile interaction, moving beyond existing MR experiences that rely primarily on pre-scripted storytelling or static AI interactions.

# CHAPTER 7. CONTRIBUTION & CONCLUSION

## 7.1 Research Contribution

This research explores the intersection of Mixed Reality (MR), AI-driven storytelling, and interactive media, proposing an innovative MR-AI framework. This framework integrates speech recognition, AI-generated 3D models, and spatial mapping to deliver interactive narratives. By transforming tangible objects within the environment from static props into dynamic storytelling elements, the project introduces a novel dimension of tactile and spatial feedback, significantly enhancing user engagement in MR experiences.

The system specifically investigates how AI-driven MR environments can support greater user agency while preserving narrative coherence. Interactive characters, exemplified by the Firefly, and adaptive scene dynamics ensure a balanced design approach, merging structured storytelling with user creativity. This contribution advances the design and implementation methodologies in interactive narrative systems, demonstrating new possibilities for immersive MR storytelling.

## 7.2 Limitations

Despite the significant contributions, this research encountered notable limitations. First, AI content generation was relatively slow, causing noticeable delays that disrupted seamless, real-time user interactions. This latency directly affected narrative flow and user immersion, highlighting the current technological constraints of real-time generative systems.

Another key limitation was the rigidity of object adaptation. The system relied heavily on predefined object recognition models, restricting its ability to spontaneously adapt narrative elements to unexpected or novel shapes in diverse home environments. The variety of real-world interiors and object arrangements posed challenges to creating universally applicable MR interactions.

Additionally, narrative coherence still depended significantly on structured guidance. Users often required explicit or implicit cues to engage meaningfully, indicating that entirely open-ended storytelling remains challenging without adequate contextual prompting or framework structures.

Finally, the absence of formal user testing was a critical limitation. Much of the project evaluation relied on self-assessment and informal feedback gathered during exhibitions and prototype demonstrations. While valuable, this approach lacked the robustness and reliability of structured user-centered studies.

## 7.3 Future Directions

Addressing these limitations, future research should prioritize comprehensive, in-depth user testing with diverse groups to better understand user interactions, narrative preferences, and participation modes in MR storytelling systems. Formal evaluations will provide deeper insights into usability, engagement, and emotional impact.

Technological improvements are another key focus area. Enhancing AI-generated content—improving model quality, increasing visual and textual detail, and significantly reducing generation time—would enable smoother and more immersive real-time interactions. Advances in AI responsiveness will be critical in achieving fluid narrative dynamics that better adapt to user inputs.

Moreover, improving spatial scanning technologies will allow for finer and more detailed mapping of physical environments. Capturing detailed object geometry and precise spatial alignment will enable AI-driven content to more naturally and realistically integrate into various real-world interiors. This capability would greatly enhance narrative believability and user immersion.

Lastly, developing more sophisticated and layered narrative structures will enable richer storytelling experiences. Expanding narrative complexity with multiple storylines, deeper character interactions, and diverse user engagement points will significantly elevate the depth and replayability of interactive MR narratives.

## 7.4 Final Thoughts

This research demonstrates the transformative potential of integrating AI and MR to move storytelling beyond passive consumption, empowering users to actively shape and co-create narratives. The fusion of voice interaction, spatial mapping, and tangible engagement presents a compelling model for interactive storytelling, redefining user roles from passive observers to active participants.

As technological capabilities continue to evolve, opportunities for immersive, user-driven storytelling experiences will expand dramatically. While technical and narrative challenges persist, particularly in real-time responsiveness and adaptability, this research lays critical groundwork for future innovation. Ultimately, the goal is not merely to leverage AI as a storytelling tool, but rather as a dynamic, responsive partner in creating meaningful narrative experiences within mixed reality environments.

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