MRCIAC: A Mixed Reality Conversational Intelligent Agent Companion in Cars for Supporting Travel Experience

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Abstract

This thesis investigates how a Mixed Reality Conversational Intelligent Agent Companion in Cars (MRCIAC) can enhance the travel experience of individuals in unfamiliar cities by addressing four main problems: difficulty finding popular locations, lack of a travel buddy, complex in-car human-machine interaction, and neglecting passenger experience. The research approach includes three methodologies: Research Through Design (RTD), Prototype Iteration, and Descriptive Design Evaluation. The study creates and evaluates three types of prototypes, including mobile applications, Virtual Reality (VR) and Mixed Reality (MR), to demonstrate the potential of mixed reality intelligent agents to revolutionize human-computer interaction in transportation and improve the travel experience. The outcomes of this research demonstrate the potential of MRCIAC to provide a companion for the owner and passengers on a trip. It is hoped that further research in this area will lead to exciting new developments and improvements in transportation.

Keywords: Companion and Intelligence, Mixed Reality, Augmented Reality, Natural Language Processing, In-vehicle Applications, Design Thinking, Prototype Iteration, Descriptive Design Evaluation, Cognitive Load, Distraction Reduction, User-vehicle Relationship, Human-computer Interaction.

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Chapter 1: Introduction

1.1 Personal Motivation: Boredom in the car

In the summer of 2022, even though I had been in Canada for 1 year, I had only been to Montreal once and stayed home. My friend suggested he drive my classmate and me to Montreal, but it was a 3-hour drive each way. I was a little worried because on the last trip, my classmate felt very drowsy driving, and it made me keep finding things to talk about with him, and I was apprehensive that she would fall asleep at any moment. Also, we spent a lot of time looking for where to go because we didn't have enough planning. However, when this friend drove my classmate and me on the trip, everything became more interesting as she talked to me about the diversity of the local culture, played popular local music in the cars, and talked to us about the food on the different streets. My friend lamented, 'I'm so glad I met you; we would have missed so many wonderful things on our drive without you.' And that's when an idea suddenly blew up in my head. Whenever I travel by car, I get exhausted and bored. Part of this is because, during the drive, I focus on getting to the destination, with little attention to the scenery along the way. And the most important thing about travel is to experience the scenery you see during the process. My car can connect me to the environment outside the car through mixed reality based on my geographic location or my behavior. Another reason is that drivers get sleepy easily during driving, especially in assisted driving. My car can remind me not to fall asleep if it detects signs that I will fall asleep.

In addition, I have designed intelligent assistants for children's video platforms in smart home scenarios in my previous work[1]. During my research and design, I found that humanized intelligent assistants can change the user's and machine's relationship through conversational interactions. So I envisioned that I could have a companion, an intelligent assistant in my travels to make me enjoy the scenery I see during my travels. It also makes me rethink the relationship between humans and cars. For example, an intelligent assistant in the cabin could be like a bumblebee that actively communicates with the user while driving instead of just passively completing tasks.

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[1] See the website link: https://jiaminliu.myportfolio.com/smart-qi-1

1.1.1 AI recommend and smart agent for cars

Breakthroughs in 5G and AI technologies have changed how we interact with machines, and the era of the Internet of Everything has defined a new relationship between machines and people.

AI has reshaped our lives; for example, TikTok's[2] personalized recommendations suggest content users like based on their preferences, behaviors, and personal information. Advances in voice interaction technology have allowed intelligence to move more towards a natural human conversational experience. Voice interaction includes intelligence with their own tones and can communicate with users by converting words into sounds. In car and travel scenarios, the intelligent body should have a clearer persona, a companion virtual agent like a tour guide, and a more trusting relationship with people. AI recommendations and smart agents for car brains are essential for creating a more personalized and engaging user experience. Huang and Rust (2021) mention that with the advancement of technology and the ability of AI to understand and analyze data, it can recommend personalized content and experiences that cater to the user's preferences and needs. In addition, smart agents can act as a companion for the user, providing assistance and guidance throughout their journey. Integrating mixed reality in the car cockpit can enhance the user experience by providing a more immersive and interactive environment that seamlessly blends the physical and digital worlds. In the next section, I explored the

[2] https://www.tiktok.com/en/

potential of mixed reality for creating a more engaging and immersive user experience in the car cockpit.

1.1.2 Mixed reality for cars

I mainly explore the scenario of mixed reality in the cockpit of a car. In the past, car design focused on the physical structure and optimizing the product based on human factors engineering. The interior design, materials used, and engine performance were all geared towards creating a luxurious and comfortable driving experience. However, with the emergence of Apple's cell phone, the way people interact with technology has drastically changed. In the same way, the automotive industry is also evolving towards integrating advanced technologies into cars to create a more seamless and personalized experience for users.

With the limitations of space and human behavior in the cockpit, there is a need to explore new human-computer interaction methods. This is where mixed reality comes in, offering a unique way of interacting with the car environment. By integrating mixed reality into the cockpit, we can create a more immersive and interactive experience for drivers and passengers alike.

In the past, people's definition of a car was more like a means of transportation or an asset to show off status and value. Car companies focused more on the beauty of the car's exterior, the materials used, the engine, and the design of the car's interior. Although it is also a human-centered design, because of the limitations of technology, product optimization focuses on the change of physical structure based on human factors engineering. Nowadays, cars not only physically adjust the seat automatically according to the user's habits and adjust parameters such as the temperature inside the car but also report to the user through a combination of voice and vision based on the user's geographic location and road conditions. Therefore, I mainly explore the human-computer interaction method of mixed reality in the future car scenario. There are certain restrictions on human behavior as well as space in the cockpit, so I have studied mixed reality with restrictions.

1.1.3 User experience design for cars

If the mouse opened the door to personal computers and touch technology brought mobile internet into people's lives, mixed reality is the next-generation universal computing platform connecting the metaverse. After identifying the in-cockpit intelligence in mixed reality and the scenarios of travel, the main goal of this work is to create and evaluate MRCIAC, a mixed reality intelligence that provides a companionable and safe journey for the owner and passengers on a trip. This prototype envisions a smart system that provides not only basic navigation assistance but also uses real-time data, such as eye gaze data, to remind the user to avoid driving fatigue. It also utilizes the user's location to recommend nearby restaurants and other relevant location-based information. However, this work focuses on examining small steps toward achieving this vision rather than implementing eye-tracking technology at this stage. I studied how the mixed reality intelligence in the vehicle cabin can actively interact with people in a multimodal way by acquiring different data from the user.

1.3 Research Summary

This research aims to explore how a mixed reality intelligence agent can support travelers in unfamiliar cities. The problem statement identifies the difficulties of finding relevant location information, a reliable local tour guide, and the potential distraction caused by the interaction with screens in the car. The main research question and subquestions focus on the design of an XR interface and intelligent agent to improve the tour experience. The goals and objectives of the project include designing an agent for recommendations, creating an innovative XR interface, building user-agent interaction, and evaluating the design using industry guidelines. The expected contributions include providing personalized recommendations and companionship for travelers and contributing to the future of the automotive industry. The scope and limitations of the project are discussed, and the six chapters of the thesis project are outlined.

1.3.1 Problem Statement

Four main problems prevent people from fully enjoying travel by car:

1. Difficulty finding popular locations: When a person is new to a city, it can be challenging to locate popular destinations using Google Maps or other local applications.
2. Finding a suitable travel buddy: It's often difficult to find a reliable local tour guide who can provide personalized recommendations and ensure a smooth travel experience.

3. Distractions in the car: With the increasing prevalence of larger screens in cars, drivers are more likely to get distracted during long drives, potentially compromising safety.
4. Neglecting passenger experience: In the past, cars were primarily viewed as a mode of transportation, with little regard for passenger comfort and enjoyment. However, with the advent of autonomous driving technology, there is an opportunity to prioritize the passenger experience and make car travel more enjoyable for everyone.

1.3.2 Questions and Subquestions

Main Research Question:

How can a Companion and Intelligence Mixed reality agent support traveling in the cockpit?

Sub-Research Questions:

- How can the XR smart agent provide a better tour experience in the future?
- How can the XR agent combine the Cockpit AI Intelligent Design?
- How does the XR agent actively interact with users in the cockpit?
- How can intelligent agents accompany users to visit a new city?
- How to evaluate a better tour experience in the future?

1.3.3 Goals and List of Objectives

The thesis project aims to investigate the potential of a mixed reality intelligence agent to improve travelers' experience in unfamiliar cities. The problem statement highlights the difficulties travelers face in finding relevant location information and a reliable local tour guide, as well as the potential distraction caused by screens in the car. The main research question and subquestions are focused on designing an XR interface and an intelligent agent that can enhance the tour experience.

The research question, which can be divided into the following objectives, aims to explore how a mixed reality intelligence agent can support travelers in unfamiliar cities:

- To design an agent that offers recommendations based on user behavior and data.
- To design an innovative XR interface in the car that seamlessly integrates the agent into the driving experience.
- To create a natural and intuitive relationship and interaction between the user and the agent.
- To build user journey scenarios that enhance the travel experience for the user.
- To evaluate the design of the agent and XR interface using industry guidelines and best practices.

1.3.4 Expected Contributions

The contributions of this thesis include both practical and theoretical contributions. From a practical perspective, the research contributes to developing prototypes that provide personalized recommendations and companionship for self-driving travelers in unfamiliar cities through a mixed-reality intelligent agent. The system is designed to enhance users' travel experience by addressing the challenges of finding relevant location information and a reliable local tour guide. It also considers the potential distraction caused by screens in the car and aims to provide a more natural and intuitive interaction between the user and the agent.

Theoretically, this research contributes to understanding how mixed reality and conversational AI technologies can be combined to create more interactive and intelligent in-car interfaces.

1.3.5 Scope and Limitations

The scope of this thesis is to build a concept of the future of mobility through the design and simulation of an agent actively interacting with the user in the cockpit of a mixed-reality vehicle. Specifically, the project aims to simulate the scenario in which an intelligent agent recommends nearby famous scenic spots and popular stores based on the user's geographic location. The project does not include the entire travel service and navigation. The focus is on the design of the XR interface and intelligent agent and their interaction with the user.

It is important to note that the real system is not developed in this thesis due to domain, technology, and access limitations. Instead, the project focuses on simulating the user-agent interaction in a virtual environment. Expert interviews and user testing are also out of the scope of this thesis.

However, the insights gained from this research can inform the design of future in-car interfaces that incorporate mixed reality and conversational AI technologies. Future work could include developing and testing a real-world system that provides personalized recommendations and companionship for self-driving travelers in unfamiliar cities. This would involve overcoming the limitations of the current research and addressing the challenges of building a fully functional and reliable system.

In summary, the scope of this thesis is focused on simulating the user-agent interaction in a virtual environment, while the limitations include the lack of a real system and the exclusion of expert interviews and user testing. Future work could build on this research by developing and testing a real-world system that incorporates the insights gained from this research.

1.4 Chapter overview

This thesis is structured into six chapters that build on each other to provide a comprehensive exploration of the potential of a mixed reality intelligence agent to enhance the travel experience of self-driving travelers in unfamiliar cities.

Chapter 1 introduces the motivation and industry development related to MRCIAC and offers an overview of the thesis project.

Chapter 2 presents a comprehensive literature review and related work on mixed reality in the car, the communication between smart agents and humans, and the habits and current situations of travelers today.

Chapter 3 outlines the methodology used to conduct background research, create, and evaluate user interface designs for the MR traveler project, including literature review, design thinking methodology, prototype iteration, and descriptive design evaluation.

Chapter 4 details the iterations of prototypes, from 2D visualization wireframes to 3D simulations uploaded to the Oculus Quest 2 platform.

Chapter 5 focuses on the evaluation of the prototype and the design of the project, including a discussion of the feedback obtained from user testing and expert reviews.

Chapter 6 provides a conclusion and outlines future work for the project, building on the insights gained throughout the thesis.

Chapter 2: Literature review

The literature review covers the topics of intelligent agents and conversational intelligent agents, mixed reality in the vehicle industry, relationships and experiences between travelers and cars, and related work in the industry. The definition of intelligent agents is discussed, as well as the development of conversational intelligent agents and their impact on various industries, including transportation. The use of mixed reality in the vehicle industry is explored, along with the development of mixed reality and its applications. The review also discusses traveler habits and needs in the car and related work in the industry, including the study of companion and intelligent agents in cars and mixed reality. Overall, the literature review provides a comprehensive overview of the current state of research on these topics (see Table 1).

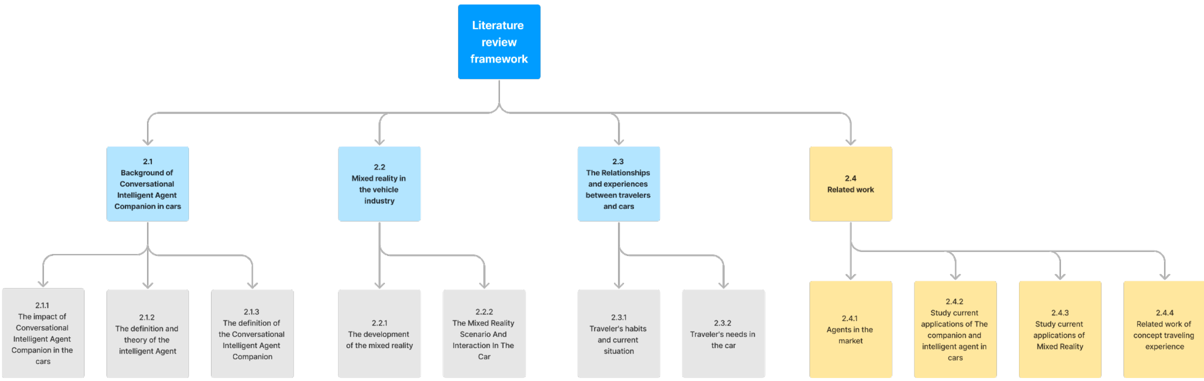

Figure 1: The visualization framework of the literature review

2.1 Background of Conversational Intelligent Agent Companion in cars

This section provides a concise yet comprehensive overview of Conversational Intelligent Agent Companions (CIACs) [3]in cars. It defines Intelligent Agents (IAs) and highlights their ability to perceive and act in their environment, and introduces Conversational Intelligent Agents (CIAs) and their utilization of machine learning and natural language processing.

2.1.1 The definition and theory of the intelligent Agent

According to Lee and Jeon (2022), an intelligent agent (IA) is a type of computer system designed to assist users in various tasks and applications. According to John McCarthy, who is considered one of the fathers of AI, an intelligent agent is defined as "anything that can be viewed as perceiving its environment through sensors and acting

[3] It is a concept derived from Conversational Intelligent Agents (CIA) as mentioned in Ammari's paper.

upon that environment through actuators." This definition emphasizes the ability of an intelligent agent to perceive and act in its environment (Lee & Jeon, 2022).

2.1.2 The definition of the Conversational Intelligent Agent Companion

According to Ammari et al. (2019), in 1960, J.C.R. Licklider[4] pondered if speech communication between humans and computers was possible and desirable. Popular examples of Conversational Intelligent Agents in the past few years include Siri, Alexa, and Google Home, commonly found in consumer-level devices and enterprise customer service systems (Murad et al., 2021). This shift from science fiction to practical implementation demonstrates the feasibility of speech in human-computer interaction (Ammari et al., 2019). With technological advancements, many Conversational Intelligent Agents (CIA) use machine learning and natural language processing to understand and respond to human commands, helping users achieve their goals. Today, ChatGPT[5] (An artificial intelligence chatbot developed by OpenAI) has changed our research method.

2.1.3 The impact of Conversational Intelligent Agent Companion in the cars

Autonomous driving allows passengers to spend more time and energy in the car rather than focusing on the driving itself (Jing et al., 2020). In other words, autonomous driving gives more importance to the passenger's experience. Conversational systems

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[4] He was an Internet pioneer with an early vision of a worldwide computer network long before it was built https://en.wikipedia.org/wiki/J._C._R._Licklider

[5] An artificial intelligence chatbot developed by OpenAI:https://openai.com/blog/chatgpt

in cars are designed for longer-term interactions, distinguishing them from task-based, brief conversational tasks in other domains, such as customer service. The ideal dashboard personal assistant should possess the ability to be observant, intelligent, proactive (particularly regarding the safety of the driver), and capable of learning the driver's habits (Jing et al., 2020).

Huang and Rust (2021) discussed the concept of "Hedonic relational service" in their work on defining AI in service. The article suggests that to build connections and customer relationships, a service should utilize feeling AI and skilled human employees with high emotional intelligence. Feeling AI can learn and adapt from emotional data to provide personalized conversations, as exemplified by the AI companion Replika[6]. The impact of Conversational Intelligent Agent Companions in cars is an example of emotionally sentient systems being adopted for real-world applications, as highlighted by McDuff and Czerwinski (2018). These agents, which can sense, interpret, and adapt to human emotions, impact various industries, including transportation. Conversational Intelligent Agent Companions in cars can take the form of dialogue systems or physically expressive humanoid robots and have the potential to provide emotional support to drivers, among other tasks. However, fundamental research questions still need to be answered regarding the design principles of emotionally sentient systems, including how to account for large

[6] https://aichatbots.co/replika-chatbot-your-ai-powered-virtual-friend/

interpersonal variability and avoid social faux pas and ethical considerations that need to be carefully addressed.

2.2 Mixed reality in the vehicle industry

This section discusses the development of mixed reality and its application in car environments, including the use of augmented reality to enhance interactions with in-car intelligent assistants. Integrating these assistants into the vehicle can provide personalized recommendations and services, improving the overall user experience. The following subsections also touch on the importance of digital platforms and services in travelers' experiences and the need for non-distracting displays in cars.

2.2.1 The development of the mixed reality

Milgram and Kishino (1994) define mixed reality as "a type of virtual reality that incorporates real-world objects or environments" and describe different types of mixed reality displays, including "see-through" displays and "video-see-through" displays. The authors also identify Mixed Reality (MR) as a technology that combines elements of Virtual Reality (VR) and Augmented Reality (AR) to create an immersive, interactive experience that blends the digital and physical worlds. The development of mixed reality has been a long journey, and it continues to evolve as new advances are made in the field.

Milgram and Kishino (1994) mention that the roots of mixed reality can be traced back to the 1960s when the first VR headsets were developed. However, it was not until the early 1990s that the term "mixed reality" was first coined by Paul Milgram[7] and Fumio Kishino[8] (Milgram and Kishino,1994), who introduced a taxonomy of virtual and real environments based on the degree of immersion. Based on research by Speicher et al. (2019), it is suggested that any studies related to mixed reality (MR) rely on the definition provided by Milgram and Kishino in their 1994 paper (Milgram and Kishino,1994). This indicates the importance of using a standardized definition in mixed reality research to ensure consistency and accuracy in the findings. According to this definition (see Figure 1), an MR environment combines elements of the real and virtual worlds into a single display and can occupy any point on the "virtuality continuum" between purely physical reality and completely simulated virtual reality.

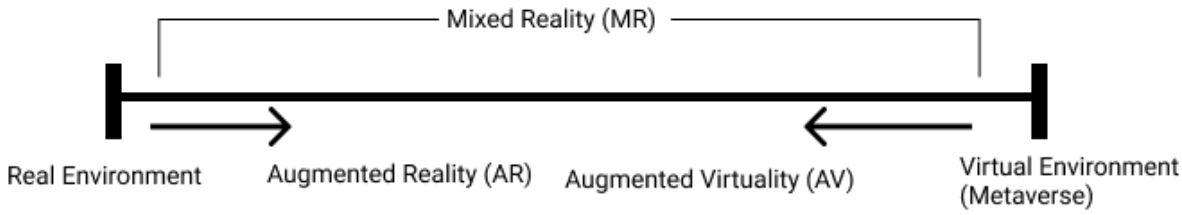

Figure 2: Reality–Virtuality Continuum adapted from Milgram & Kishino (1994).

2.2.2 The Mixed Reality Scenario And Interaction In The Car

"A virtual environment" refers to a fully computer-generated environment where the user can be immersed without external interaction, known as virtual reality.

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[7] https://www.mie.utoronto.ca/faculty_staff/milgram/
[8] https://ieeexplore.ieee.org/author/37284006700

Augmented virtuality, on the other hand, adds virtual content to a real environment, making it a part of Milgram's real-virtual continuum that can be tilted to one side (Milgram & Kishino, 1994). Augmented reality, which overlays digital information unto the real world, is also a part of this continuum (Milgram & Kishino, 1994). The closer the augmented virtuality or augmented reality experience is to the real environment, the less immersive it becomes, and the more limited the added content is (Parveau, 2018). Milgram and Kishino proposed a three-dimensional taxonomy that includes the following aspects—the degree of world knowledge, the authenticity of the replication, and the presence of metaphors. Suzuki (2022) mentioned that Augmented reality and mixed reality (AR/MR) have emerged as a new way to enhance human-robot interaction (HRI) and robotic interfaces (e.g., interfaces that drive and change shapes). For example, users can interact by collaborating and referencing the innovative table of The Foggy Side or by changing the shape of real objects by clicking on augmented reality interfaces (Suzuki, 2022). Milgram's real-virtual continuum is a framework that connects authentic, physical environments with entirely virtual ones, with varying degrees of mixed reality in between. The continuum provides a useful way to conceptualize and analyze the different types of mixed reality scenarios and interactions that can occur in various contexts, including in-car environments.

2.3 The Relationships and experiences between travelers and cars

In the early days of the UX industry, Steve Krug's book "Don't Make Me Think! Web & Mobile Usability - Das Intuitive Web" (2014) was one of the primers for user experience design. The book's main objective is to convey the idea that design can help users reduce their cognitive load. Anticipatory design[9] based on user behavior can play a significant role in achieving this goal. This approach recognizes the evolving relationship between technology and human intelligence and seeks to create a ubiquitous user experience.

As the number of service scenarios increases, the types of intelligent assistants become more and more diverse. Provoost et al. (2017) research supports Embodied Conversational Agents (ECAs)[10] are computer-generated characters that mimic human face-to-face communication, including verbal and nonverbal behaviors. It is typically designed to generate nonverbal behaviors to complement or enhance verbal communication. One such nonverbal form of behavior is co-speech gestures, in which the active agent involved communicates verbally with the arm and hand paired with it. According to Suzuki (2022), using augmented reality adds robotic hands and feet to the physical form of the basic robot or more appropriate interaction methods. As the space inside a car is limited, the use of mixed reality in intelligent assistants has become a promising direction to explore. By incorporating augmented reality, robotic hands and feet can be added to the basic physical form of the robot, or more appropriate interaction methods can be developed. This allows for more natural and intuitive interactions between users and intelligent assistants, enhancing the overall user experience inside the car. In addition, the interactive feedback of, the assistant can have visual feedback based on the influence of content and emotion

[9] https://www.smashingmagazine.com/2015/09/anticipatory-design/
[10] https://www.igi-global.com/dictionary/developing-enculturated-agents/9637

during the conversation. For example, voice is converted to text, and emotional keywords are obtained from the text. This is then visualized as Emobllon by analyzing the emotions of the keywords (Aoki, 2022). Augmented vision can also help users read other users' emotions or intelligent assistants' emotions (Şemsioğlu, 2022).

Inside the car, in-car intelligent assistants provide a unique opportunity to enhance the user experience by combining virtual and reality. As cars become more technologically advanced, the intelligent assistant will not be a stand-alone robot but an integrated part of the entire vehicle. This integration will allow for a more seamless and intuitive interaction between the user, the assistant, and the car itself. For example, the assistant could use information from the car's sensors to provide personalized recommendations and services, such as adjusting the temperature or lighting to the user's preferences. As cars continue to evolve, the potential for intelligent assistants to become an integral part of the overall driving experience will only continue to grow.

2.3.1 Traveler's habits and current situation

In today's digital age, digital platforms and services have become essential tools for people's travel experiences. Places to "check-in" or "clock in" have become an important part of how people travel. Rose et al. (2021) mentions that the proliferation of smartphone applications interfacing with digital platforms that increasingly mediate everyday urban life rapidly reconfigure how people experience cities. In China, some shopping districts in many cities have become online celebrities because of the popularity of special entertainment programs online. Clocking in now refers to not only checking in at work but also marking events, people, or things visited by tourists through media, especially via smartphones.

Clocking in" refers to checking in at work, but it has now become a way for tourists who actually visit certain places to use media (especially through smartphones) to mark events, people, or things (Fan & Tingting, 2022).

2.3.2 Traveler's needs in the car

Visual touchscreen displays are now common in modern vehicles, providing information related to the vehicle, navigation, infotainment, and control functionalities. These displays have replaced buttons and knobs in the head unit and offer multiple functionalities that can be customized to user requirements. However, these head-down displays (HDDs)[11] require visual attention and can cause distractions, requiring the driver to take their eyes off the road and increasing cognitive load while performing a primary task. Mercedes-Benz has recently showcased[12] its concept car with a central display emerging from the central console and separate side display units for personalized viewing.

[11] https://encyclopedia2.thefreedictionary.com/head-down+display

[12] https://www.theverge.com/2023/2/22/23610496/mercedes-benz-e-class-superscreen-tiktok-zoom-selfie

2.4 Related work

This section discusses various types of agent characters in the industry, categorized based on their level of virtual and physical presence and their relationship with users. The article also mentions the current application of companion and intelligent agents in cars, such as NOMI[13], a conversational assistant designed to provide a personalized and intuitive in-car experience. The article also discusses the current applications of mixed reality and the concept of traveling experience, such as the BMW i Vision DEE[14], which has an advanced Head-Up Display[15] with a Mixed Reality Slider and touch sensors.

2.4.1 Agents in the market

This section summarizes different types of agent characters in the industry, which can be categorized based on their degree of virtual and physical presence and the intimacy of their relationship with users (see Figure 3). Some of the agent characters discussed in the article include Qoobo[16], Joi [17] from Blade Runner 2049, Du[18] Chick from

[13] https://www.nio.com/blog/nomi-worlds-first-vehicle-artificial-intelligence
[14] https://www.bmw.ca/en/topics/fascination-bmw/bmw-concept-vehicle/bmw-vision-ivisiondee-2023.html
[15] https://en.wikipedia.org/wiki/Head-up_display
[16] https://qoobo.info/index-en/
[17] https://bladerunner.fandom.com/wiki/Joi
[18] https://www.duolingo.com/

Duolingo, Azuma Hikari[19] from Gatebox[20], Microsoft's Cortana[21], Facebook Messenger's AI assistant[22], Lil Miquela[23], Lovot[24], Luka[25], Erica[26], and Robear[27]. These agent characters vary in their functionalities, appearance, and level of interaction with users. Some of them, such as Lovot[28] and Robear[29], are designed to provide physical comfort and companionship, while others, like Cortana[30] and Facebook Messenger's AI assistant[31], are purely virtual and are designed to perform tasks and provide information for users (see Table 1).

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19 https://futurism.com/this-is-the-holographic-ai-servant-of-your-dreams-or-maybe-your-nightmares
20 https://www.gatebox.ai/
21 https://www.microsoft.com/en-us/cortana
22 https://www.pocket-lint.com/apps/news/facebook/140742-what-is-facebook-m-facebook-messenger-s-ai-assistant-explained/#:~:text=At%20launch%2C%20it%20will%20suggest,conversations%20or%20get%20things%20done.
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25 https://luka.ling.ai/
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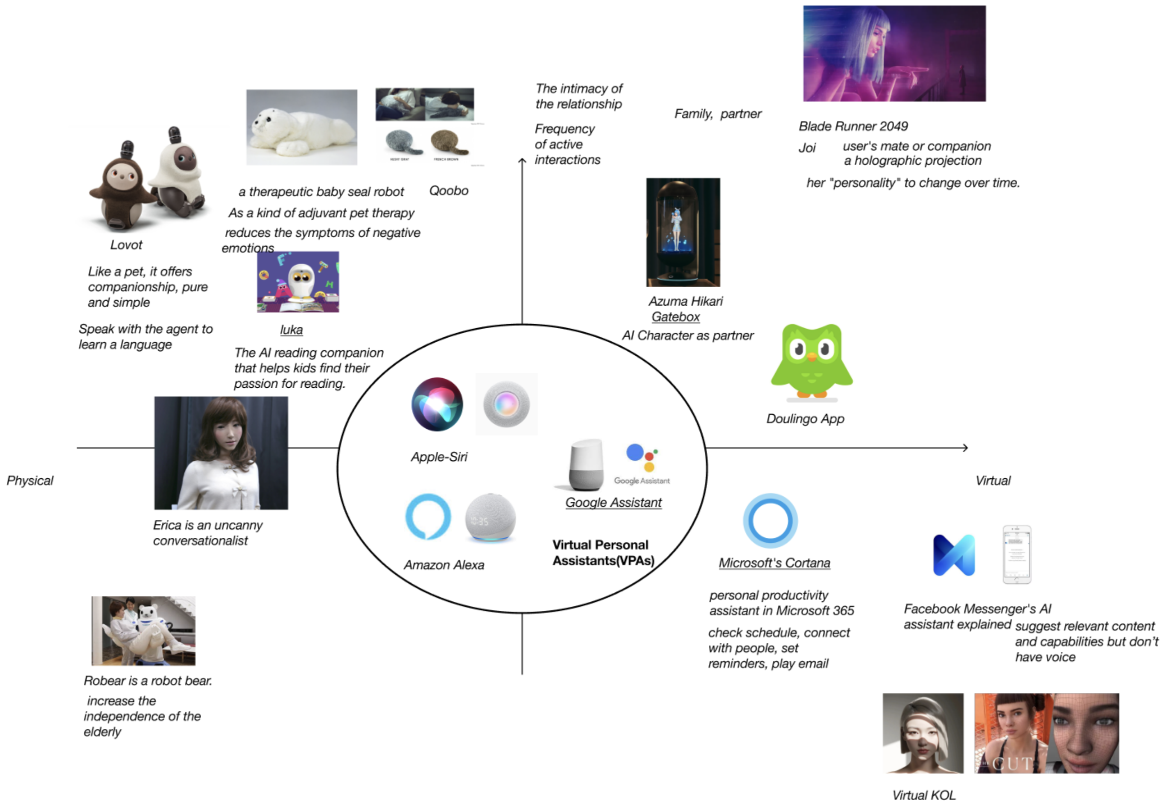

Figure 3: The diagram categorizes different types of agent characters in the industry based on their degree of virtual and physical presence and their level of intimacy with users.

Table 1: The table of different types of agent characters in the industry

	Introduction	Physical or virtual	The intimacy of the relationship with the user
qoobo[32]	Qoobo is a robotic cushion designed to mimic the sensation of a pet's tail.	The cushion has a soft, plush exterior and a tail that wags in response to physical touch, providing a sense of comfort and	It was created as a therapeutic tool for people who want the calming benefits of pet therapy without the responsibilities

[32] https://qoobo.info/index-en/

		relaxation to those who use it.	that come with owning a live animal.
Joi-Blade[33] Runner 2049	"Joi" is a character from the 2017 science fiction film "Blade Runner 2049".	She is projected into the real world through a device known as an "emitter."	She is an artificial intelligence designed as a virtual assistant and romantic partner for the film's protagonist.
Du Chick-Doulingo App[34]	Du Chick is a cute and friendly cartoon chicken that appears in some of the lessons and exercises on the Duolingo platform.	Du Chick is part of the gamification elements of Duolingo, and its appearance is meant to encourage users to continue their language learning journey.	The character is used to help explain grammar concepts and vocabulary in a fun and engaging way.
Azuma Hikari - Gatebox[35]	Azuma Hikari is also a character in the Japanese virtual home robot "Gatebox."	The virtual assistant is housed in a cylindrical device that can be placed in a user's home and interacts with the user through a combination of voice commands and an animated character projected onto a screen.	She is depicted as a cute and cheerful anime-style character who interacts with users in real-time, providing a unique and personalized experience.
Microsoft's Cortana[36]	Cortana is designed to help users perform tasks and access information more efficiently.	Cortana is a virtual assistant developed by Microsoft for Windows 10 and other Microsoft products.	Cortana is not capable of forming personal relationships. It is designed to provide information and perform tasks for users,
Facebook Messenger's AI assistant	It helps users perform tasks and access information more efficiently.	It is a virtual assistant integrated into the Facebook Messenger platform.	It is limited to a one-way exchange of information

[33] https://bladerunner.fandom.com/wiki/Joi
[34] https://www.duolingo.com/
[35] https://futurism.com/this-is-the-holographic-ai-servant-of-your-dreams-or-maybe-your-nightmares
[36] https://www.microsoft.com/en-us/cortana

explained [37]			
Lil Miquela[38]	It is a digital influencer and musician who gained popularity on social media platforms such as Instagram and Twitter.	She is a computer-generated character created using 3D modeling and animation techniques and is often referred to as a "virtual influencer."	Only one-way information output； No interaction
Lovot[39]	Lovot is a line of robotic pets developed by the Japanese company GROOVE X.	It is a doll-shaped robot equipped with various features, such as a built-in camera and speaker, that allow it to interact with its users in a variety of ways.	It is a small, spherical robot designed to provide comfort and companionship to its users.
Luka[40]	It is a virtual assistant developed by the Chinese company Luka AI.	It is a doll-shaped robot equipped with various features, and It exists in physical and virtual versions	It is also designed to be a companion and friend to children.
Erica[41]	Erica is an AI-powered virtual assistant that was developed by the Japanese technology company Sony Corporation.	She is a solid character robot with a female appearance	Erica is also designed to be highly personalized, learning from the user's preferences and habits over time to provide a more relevant and helpful experience.

[37] https://www.pocket-lint.com/apps/news/facebook/140742-what-is-facebook-m-facebook-messenger-s-ai-assistant-explained/#:~:text=At%20launch%2C%20it%20will%20suggest,conversations%20or%20get%20things%20done.
[38] https://www.instagram.com/lilmiquela/
[39] https://lovot.life/en/
[40] https://luka.ling.ai/
[41] https://www.livescience.com/61575-erica-robot-replace-japanese-news-anchor.html

Robear[42]	Robear is a robot developed by the Japanese company RIKEN and Sumitomo Riko Company.	It is a medical function-oriented physical robot	Its main purpose is to help health care professionals do some of their work, more like a colleague relationship
Apple-Siri[43] ; Google Assistant[44] ; Amazon Alexa [45]	They are all virtual assistants developed by technology companies to provide users with information and assistance.	Virtual personal assistants that are present on each relevant device side	It is designed to provide information and perform tasks for users

2.4.2 Study current applications of The companion and intelligent agent in cars

As a conversational assistant (see Figure 4), NOMI[46] is designed to provide NIO's customers with a personalized and intuitive in-car experience. It can recognize voice commands and perform various functions, such as adjusting the temperature, playing music, and providing navigation assistance. NOMI can also engage in natural language conversations with passengers and provide information about the vehicle's performance and features.

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42 https://www.theguardian.com/technology/2015/feb/27/robear-bear-shaped-nursing-care-robot
43 https://www.apple.com/ca/siri/
44 https://assistant.google.com/
45 https://alexa.amazon.com/
46 https://www.nio.com/blog/nomi-worlds-first-vehicle-artificial-intelligence

In addition to its in-car capabilities, NOMI can be accessed via the NIO app, allowing customers to remotely control and monitor their vehicles. The app enables features such as remote climate control, location tracking, and battery management. Overall, NOMI's conversational abilities and integration with the NIO app provide customers with a seamless and convenient user experience.

Figure 4: NIO NOMI[47]

2.4.3 Study current applications of Mixed Reality

The case of the Earth app[48] is used as a related work in the study of current applications of Mixed Reality because it showcases the immersive and interactive experiences that can be created using mixed reality technologies, including 3D avatars

[47] https://www.nio.com/blog/nomi-worlds-first-vehicle-artificial-intelligence
[48] https://www.wooorld.io/

with face and body tracking, games, and social aspects with voice chat (see Figure 5). Additionally, the app supports various XR technologies such as eye/face/hand/body tracking, 360 images, and color passthrough, demonstrating the potential of mixed reality for creating engaging and innovative experiences for users.

Figure 5: From https://www.wooorld.io/

2.4.4 Related work of concept traveling experience

The related work section on concept traveling experience presents various technologies that aim to enhance the driving experience. One such technology is the BMW i Vision DEE (see Figure 6), which features an advanced Head-Up Display (HUD) with a Mixed Reality Slider and touch sensors on the instrument panel. The Mixed Reality Slider allows the driver to select the amount of digital content displayed on the windscreen, while the touch sensors enable four different content levels. This digital technology enhances the driving experience and provides an immersive, customizable experience. Overall, these technologies demonstrate how digital advancements can improve the driving experience by providing more personalized and engaging features for drivers.

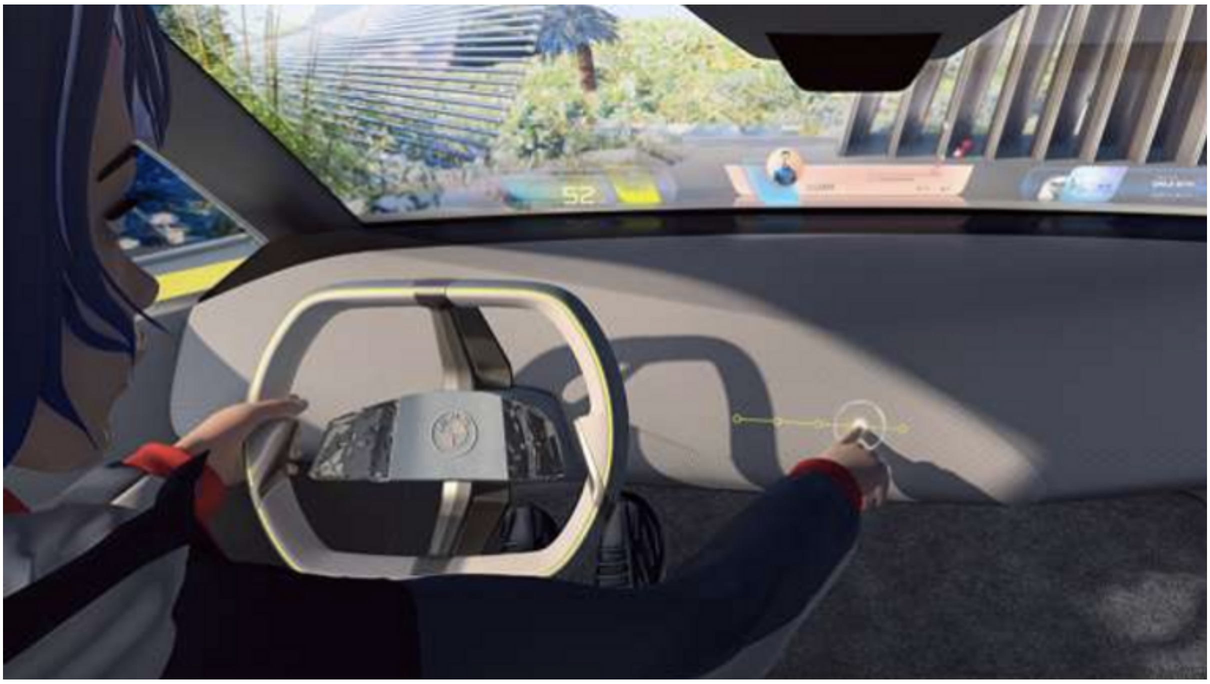

Figure 6: The concept design of DEE[49]

2.5 Summary of Chapter 2

The literature review provides a comprehensive overview of various topics related to developing and implementing mixed reality conversational intelligent agent companions in cars for supporting travel experiences. The review covers the definition and impact of intelligent agents and conversational intelligent agents in transportation, the use of mixed reality in the vehicle industry, traveler habits and needs in the car,

[49] https://www.bmw.ca/en/topics/fascination-bmw/bmw-concept-vehicle/bmw-vision-ivisiondee-2023.html

and related work in the industry. The integration of mixed reality and augmented reality technologies into in-car intelligent assistants can provide personalized recommendations and services, enhancing the overall user experience. The review also highlights the importance of digital platforms and services in travelers' experiences and the need for non-distracting displays in cars. In addition, the review explores the use of embodied conversational agents and co-speech gestures to create more natural and intuitive interactions between users and intelligent assistants. Current applications of intelligent agents and mixed reality in cars, such as NOMI by NIO and the BMW i Vision DEE, showcase the potential of these technologies to create personalized and immersive experiences for passengers. Overall, the literature review provides valuable insight into the current state of research on these topics and highlights the potential for future development and implementation of mixed reality conversational intelligent agent companions in cars.

Chapter 3: Methodology

The methods of Research through design (RTD), prototyping, and descriptive design evaluation are employed for conducting background research, creating, and evaluating user interface designs.

3.1 Research through design (RTD)

Research by Zimmerman et al. (2007) supports that Research through design (RTD) as a method for interaction design research in the field of Human-Computer Interaction (HCI), highlighting the unique insights gained through design practice. This approach to interaction design research allows interaction designers to make research contributions based on their strengths in solving constrained problems. The benefit of this approach is that it weakens or even removes the inadequate conditions of the current environment to build an ideal situation and conditions for the focused design. This approach provides a more appropriate environment and avenue for design research that allows designers to contribute to the field of human-computer interaction to the best of their ability, and the RTD approach is well suited to the study of disciplines that cover multiple areas, such as HCI (Zimmerman et al., 2007).

3.2 Prototype iteration

Prototype iteration refers to the process of refining a prototype or early-stage design by making incremental improvements and modifications. This process typically involves repeated cycles of testing and feedback, with each iteration building on the results of the previous one.

During prototype iteration, designers use feedback from users, stakeholders, and other sources to identify improvement areas and make design adjustments. These adjustments can include changes to the prototype's functionality, layout, or visual design.

The goal of prototype iteration is to create a highly usable, effective design that meets the intended audience's needs. By incorporating feedback and making continual improvements, designers can increase the likelihood that the final product will be successful and well-received by its users.

3.3 Descriptive Design Evaluation

The research paper utilized Hevner's Design Science in Information Systems Research (Hevner, 2004) to select a design evaluation method. Hevner introduced five methods, including observational, analytical, experimental, testing, and descriptive, to evaluate design artifacts' quality, utility, and efficiency. However, due to field constraints and limited access to patients, human participants could not be recruited, rendering the previous four methods unsuitable for this research.

To ensure the validity of the evaluation, the study drew upon Nielsen's heuristics, which are a set of principles for user interface design that focus on improving the usability of digital products (Nielsen, 2005). The heuristics provided a framework for assessing the usability of the prototype and identifying areas for improvement. Although human participants could not be recruited due to field constraints, the descriptive design evaluation method, combined with Nielsen's heuristics, provided valuable insights into the prototype's effectiveness and usability.

Nielsen's heuristics are a set of principles for user interface design that focus on improving the usability of digital products. These principles are widely recognized and have been extensively used in evaluating the usability of various digital products. By incorporating Nielsen's heuristics, the study was able to assess the usability of the prototype and identify areas for improvement. While the descriptive design evaluation method may not provide as much depth as user testing, it still provides valuable insights into the effectiveness and usability of the prototype.

The combination of Hevner's Design Science in Information Systems Research (2004), Nielsen's heuristics, and the descriptive design evaluation method allowed for a thorough and valid evaluation of the prototype's usability and effectiveness. These methods provided a framework for assessing the prototype and identifying areas for improvement, despite the limitations of field constraints and limited access to participants.

The purpose of descriptive design evaluation is to identify the strengths and weaknesses of a design and provide insights into how it can be improved. This method often involves user testing and collecting feedback from users to assess the design's effectiveness in meeting their needs.

Chapter 4: Iterative Prototyping Stages

So far, I have been visualizing scenarios where the Agent and the user interact during a journey, mainly through Figma. At the same time, I have spent most of my time learning Unity and developing a simulation of the journey game to provide an immersive experience for the user.

4.1 Prototype1: Concept design of the agent

4.1.1 Description

The concept design of an AI cognitive tour guide in the car aims to provide a personalized and interactive user experience. The tour guide collects the user's geographic location and actively recommends nearby attractions, presenting 3D information within MR glasses. The system is designed to be sensitive and adaptive to different users' requirements, and their journeys are mapped out to optimize their interactions with the tour guide throughout their journey. Additionally, the system issues virtual non-fungible token (NFT) souvenir gift boxes without human intervention, providing users with an added level of engagement. The use of NFTs allows for unique and rare virtual souvenirs to be issued to users, creating a sense of exclusivity and value. The system can also leverage the blockchain technology underlying NFTs to ensure authenticity and ownership of the souvenir. Overall, NFTs add an innovative and exciting dimension to the user experience, providing a memorable and valuable souvenir of their journey.

4.1.2 Process

I started by writing user stories (see Figure) in a user's text using the Agent throughout the day. Through this story, I uncovered the user's interactions using the Smart Assistant inside the car and found opportunity points to use in the feature's design (see Figure 7).

One family day with a car

Background

Winter, + city(Toronto)

Story

Agent knows she's used to going out at 8

Agent turns on the air conditioner ahead of time and make sure it's at the right temperature before using the car

The agent detects that Nobeia is in the car, and found out that she had an important meeting on her calendar at 9 o'clock.

The agent detected that Nobelia's daughter also got into the car, and found in the historical records that Nobelia will send her daughter to school first at this time of the working day

Nobeia chose the fastest route. Meanwhile she started the journey and played music

Nobeia's daughter doesn't like the music, tells mom she wants to hear nursery rhymes or stories。 Based on records of music she used to play in the car, Agent started recommending similar nursery rhymes.

I like YYY now

xxxxx

After several rounds of exchanges, Nobeia's daughter discovered new interesting stories

4:00PM

Nobelia is off work, she needs to pick up grandma and grandpa and bring dinner home

When grandpa and grandma got into the car, grandpa was in a bad mood because he encountered a very annoying thing today. and more and more excited

Agent found out that the grandparents entered the car through the voices of grandparents communicating.

And through the analysis of grandpa's volume, it can be seen that grandpa's emotions are strong. At the same time, the watch worn by the grandfather detected abnormal heart rate and blood pressure.

Agent finds out in grandpa's personal information that grandpa likes nature and animals

Nobelia got a message from her husband on the way to a restaurant to pick up food

Nobelia needs to concentrate on driving, but considering the curiosity of grandparents, let the agent share it on the screen in the back seat

At this time, it is 1 km away from the restaurant

Interaction

Morning
7：30 AM Nobeia wake up
Agent:Today is Friday. Are you still leaving at 8AM?

7：50AM
Receive a reminder from the Agent：
Nobeia, The temperature inside the car is 20°C
Do you need to drive to the door?

8:10AM
When Nobeia starts the car，
Agent says: Good morning, Nobeia
20 minutes from home to office based on current traffic conditions.

8:11AM

Agent says: I found the fastest route, it would take 35 minutes to get to King's Elementary School and then to the office. You have plenty of time until the first meeting on your schedule at 9:00

8:11AM

Agent asks: Do you want to continue listening to XXXX

8:12AM

xxxx

Agent shows smile on screen in back seat

Agent takes the initiative to break the tense atmosphere and say: take a deep breath. watch TV for a while

Agent plays short video of cat on screen in back seat

Nobelia says: help me read the information
Agent reads information： I got our daughter, she won first place in the singing contest, look at her

The agent shows the photo on the screen in the back seat

Food ordering app tip: The food you ordered is ready, take it away as soon as possible

The agent analyzes the location where it is easier to park nearby and recommends it

Touchpoint

The camera detects the co-pilot's daughter and recommends similar music based on the daughter's past playback history.

Agent's role transforms from assistant to peer-daughter conversation

Agent analyzes the voices of grandparents and grandparents to identify the identity of the user in the back seat. Agent also judges that grandpa is in a bad mood by analyzing the volume of grandpa's voice and the watch's detection of heartbeat and blood pressure exceeding normal values. Therefore, Agent helps grandpa take a deep breath and shift his attention to stabilize his emotions through professional emotional counseling.

The camera detects the co-pilot's daughter and recommends similar music based on the daughter's past playback history

Figure 7: Stories of a user using the Agent throughout the day.

Secondly, I defined the personality of this intelligent body based on its function, visual appearance, possible scenarios, and the digital device on which it is located (see Figure 8), including the cell phone side and the mixed reality glasses side.

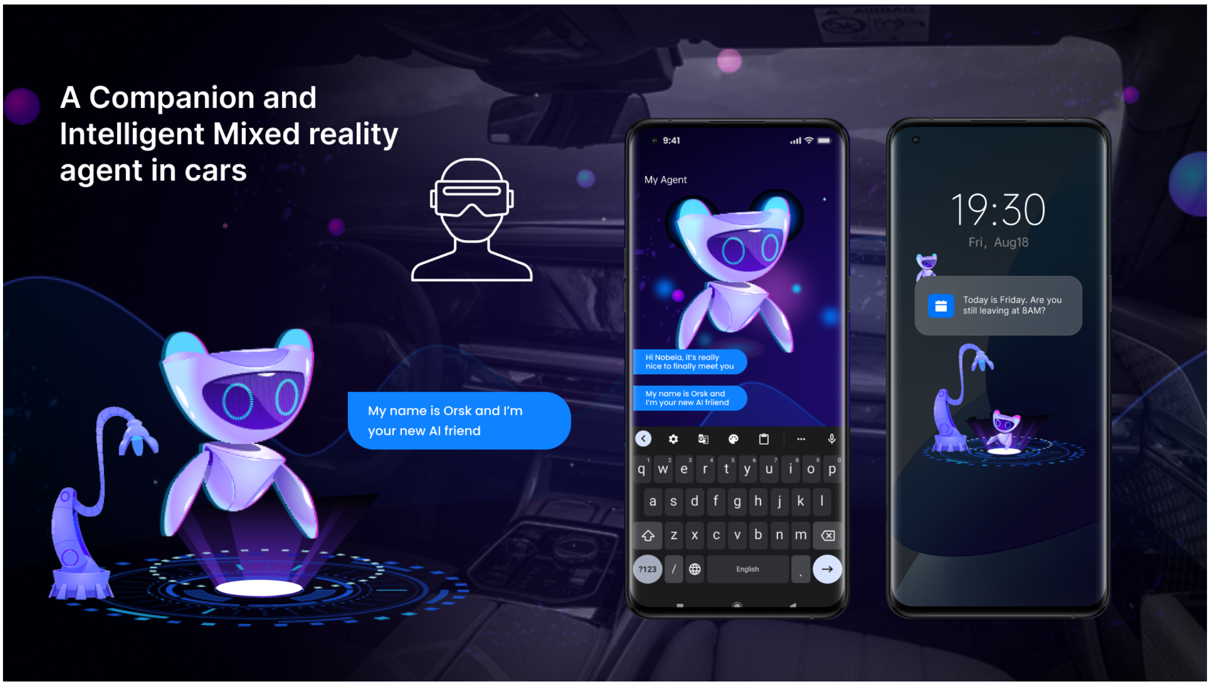

Figure 8: The visualization of the agent and the scene that appears

Based on the role setting of the Companion Intelligence Agent and the active interaction, I selected four scenarios (see Figure 9) in the car for visualization.

Scenario 1: The Agent actively recognized the user's account information by the user's facial features and started playing the music list in the user's account.

Scenario 2: The Agent recognized the user's account information by the user's voice feature and initiated to greet the user.

Scenario 3: The Agent gets the user's heartbeat through the user's watch, and also gets the size of the user's voice to determine the user's emotional ups and downs, and appeases the user's emotions by recommending videos or small talk.

Scenario 4: The Agent introduces the user to the interesting attractions around or the landmarks of Netflix hitting according to the user's geographic location.

Figure 9: 4 scenarios

Revised: As part of a visionary concept design, a technology framework for Scenario 4 was created using Figma (see Figure 10). This technology architecture consists of two main parts - a mixed reality interface and the acquisition of digital assets based on blockchain technology. In this vision, when the user is in the mixed reality environment, they can obtain Non-fungible token (NFT)[50] digital assets and record them on Solana's public chain. Here NFT is not a very important part, rather, it just represents another form of commemoration for passing by famous sites. It also is important to note that this is a vision for the future and has not yet been implemented.

[50] https://en.wikipedia.org/wiki/Non-fungible_token

This concept design focuses on showcasing the potential of mixed reality and blockchain technology to provide a unique and engaging user experience.

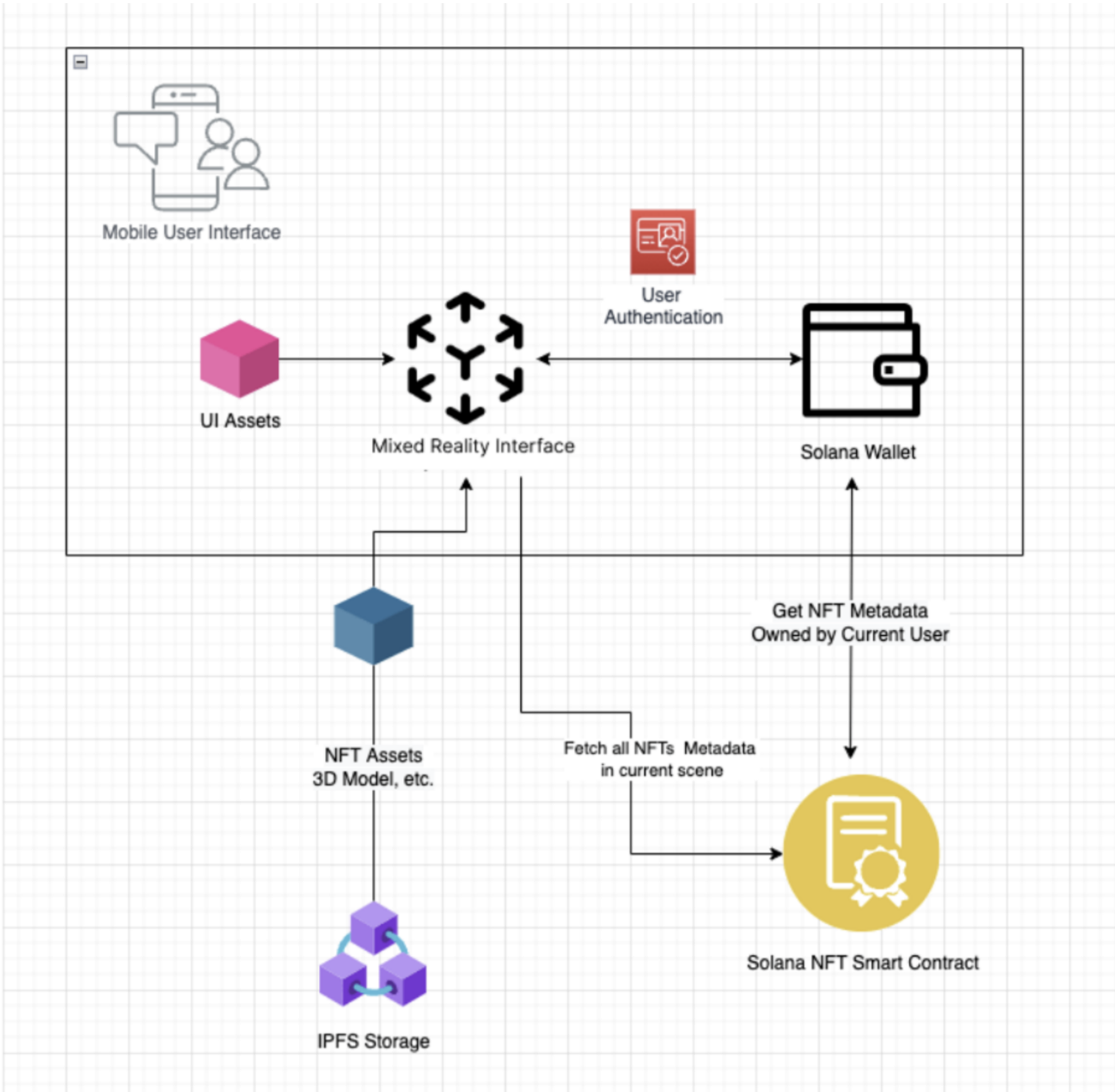

Figure 10: The figure represents an early ideation of a technology framework for Scenario 4, showcasing the potential of mixed reality and blockchain technology to enhance user experiences through a mixed reality interface and the acquisition of digital assets, specifically NFTs, for added value and exclusivity.

I then used Figma to create the basic interface of the mobile-based application (see Figure 11). It mainly revolves around the fact that the user is traveling by car, and the intelligent assistant finds a famous attraction nearby and tells the user about it, and the user learns about the attraction while getting a free virtual souvenir with it.

Figure 11: Visual design of the interface using Figma software

4.1.3 Results and Reflections

The concept design of an AI cognitive tour guide in the car was created to provide a personalized and interactive user experience. The design process involved building a user story, defining the intelligent agent's personality, and selecting scenarios for visualization. Additionally, a technology framework was created to showcase the potential of mixed reality and blockchain technology to enhance user experiences. A basic 2D interface was also designed for a mobile-based application. The focus was on validating ideas and selecting important parts for development.

4.2 Prototype2: VR simulation experience

4.2.1 Description

In this early concept design, an Agent is a virtual entity that appears on the mixed-reality interface when the car reaches a predefined location, providing users with interactive and personalized recommendations for nearby attractions. As part of the prototyping process, a prototype was developed based on Scenario 4 and uploaded to the VR glasses (Oculus quest 2) to simulate the real scenario. Currently, the model is bound to the user's location in the car, so when the car moves, the system triggers the Agent to appear on the interface, providing recommendations and triggering interactions.

4.2.2 Process

First, I drew a wireframe diagram of the interaction to sort out the relationship between different objects in the VR environment (see Figure 12).

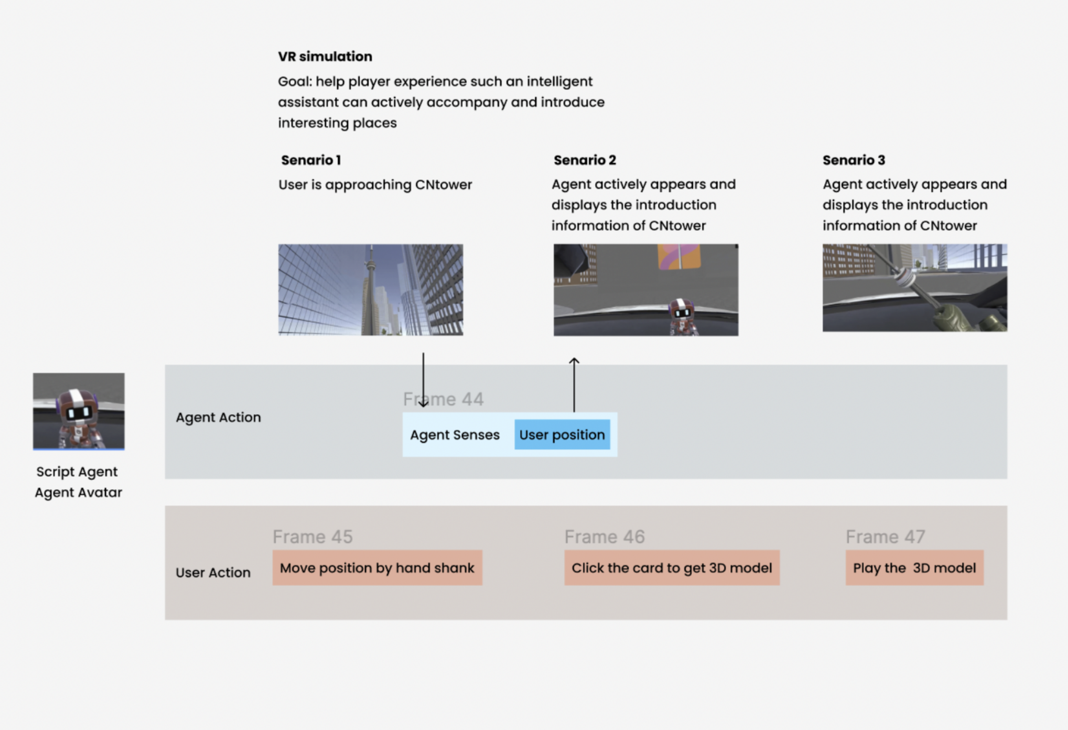

Figure 12: The wireframe of the VR simulation

The prototype developed for Scenario 4 was tested using Unity to develop the Virtual reality (VR)[51] environment with VR glasses (Oculus Quest 2[52]) to simulate the real environment (see Figure 13) . The process involved accurately binding the user's location to the car and triggering the Agent and interface when the car reached predefined positions. During the testing, the user was able to interact with a virtual

51 https://en.wikipedia.org/wiki/Virtual_reality
52 https://www.meta.com/ca/quest/products/quest-2/

representation of the CN-Tower using a handle to move and approach the CN-Tower[53]. Within a certain range, the agent display appeared and provided the user with a CN-Tower Card, which could be opened using the handle, revealing a 3D representation of the CN-Tower (see Figure 14) . The Agent was able to provide interactive and personalized recommendations for nearby attractions, and the interface was responsive to touch and hand gestures, providing users with an immersive and intuitive experience. Overall, this testing demonstrated the potential of mixed reality and virtual agents to enhance the user experience in a car and provided insights for further development and refinement of the system.

[53] https://www.cntower.ca/

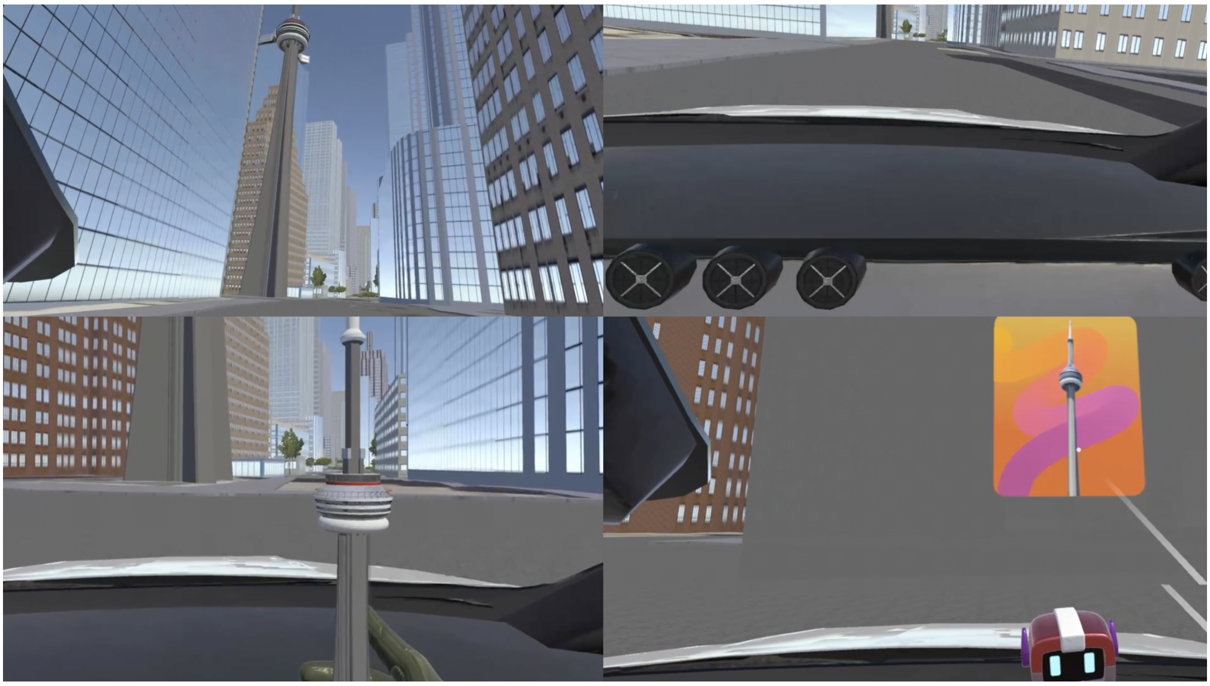

Figure 13: Some screenshots using the VR simulator

Figure 14: Users get the 3D model given by Agent near CN tower

4.2.2 Results and Reflections

This prototype was designed and developed to allow users to experience a Companion and Intelligence Mixed reality agent in the cockpit that could actively sense interesting things around and interact with the user through a 3D model to spend time with the user. This prototype does not need to reach the ideal state because recommending information based on geographic location in real-time requires huge data support and map information. This prototype is like a small proof of concept prototype, which means validating assumptions about product requirements with minimal time and development.

The prototype testing provided valuable insights into the potential of mixed reality and virtual agents to enhance the user experience in a car. However, the current prototype has several limitations that must be addressed in future development. First, the model is currently bound to the user's location in the car, limiting the system's ability to provide recommendations for locations beyond the car's immediate vicinity. Second, the prototype's ability to recommend information based on geographic location in real-time requires significant data support and map information, which may pose challenges in practical implementation. Finally, the current prototype is limited to a single virtual location (the CN-Tower), and further development is needed to expand the system's coverage to a wider range of locations. Despite these limitations, the prototype demonstrated promising potential for the use of mixed reality and virtual assistants in enhancing the user experience, and further development and refinement of the system can address these limitations and bring the concept closer to practical implementation.

4.3 Prototype 3: a Companion and Intelligent Mixed reality agent in the car

The third prototype builds upon the insights gained from the previous iterations and focuses on implementing a mixed reality intelligent agent within a vehicle to provide personalized recommendations and companionship for self-driving travelers in unfamiliar cities. The integration of ChatGPT and Unity technologies enables a more natural and intuitive interaction between the user and the agent, creating a more personalized and engaging travel experience.

4.3.1 Description

The prototype utilizes a mixed reality interface created using Unity, a game engine that supports the development of 2D and 3D interactive applications. The interface is designed to be displayed on the user's headset, providing relevant information without causing distractions. The development of Prototype 3 is guided by the research questions identified in Chapter 1, focusing on designing an XR interface and intelligent agent to improve the travel experience.

To provide a more engaging and personalized experience, three different personas were created using ChatGPT's OpenAI API. These personas are Zero, Sakura, and Ted. Each persona has unique characteristics and interests that can be used to provide personalized recommendations and companionship to self-driving travelers in unfamiliar cities.

Zero is a smart assistant with no shape, age, or gender, and likes philosophy. Sakura is a two-dimensional Japanese girl who can serve as a virtual girlfriend, and loves sports and music but dislikes mathematics. Ted is a 28-year-old designer living in downtown Toronto, with a good sense of humor and a passion for recommending nearby restaurants, famous attractions, and local music. The reason for choosing these three personas is to explore how different character profiles can shape the relationship and communication style between users and agents. Zero represents the typical voice assistant, like a robot with no human characteristics. Ted represents a personified agent, with a relatable personality and sense of humor. Sakura represents a popular idol and cartoon character, which can create a sense of emotional attachment and engagement with users. By incorporating these different personas into the prototype, we can provide users with a more personalized and engaging travel experience, allowing them to interact with the agent in a way that feels natural and enjoyable.

These personas were integrated into the prototype to allow users to choose to interact with different characters and have a more personalized travel experience. The use of language models to create the personas allows for a more emotional and humanized interaction between the user and the agent.

The mixed reality intelligent agent is powered by ChatGPT, a language model developed by OpenAI, allowing it to understand and respond to natural language queries, providing a more intuitive and seamless interaction for the user. The agent can provide personalized recommendations and companionship for self-driving travelers in unfamiliar cities. The mixed reality interface is designed to be displayed on the user's headset, providing relevant information without causing distractions.

(see Figure 15).

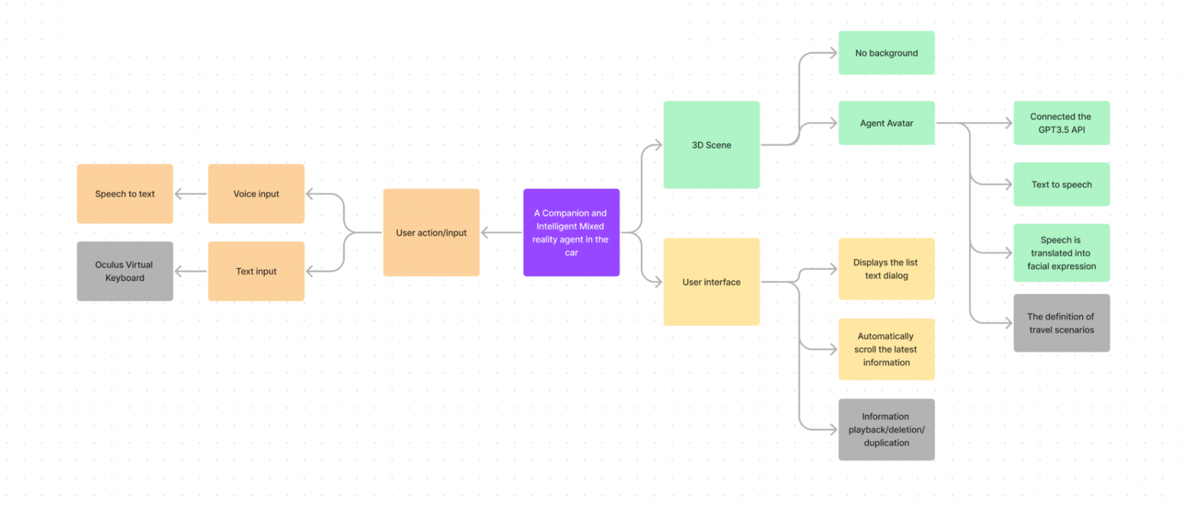

Figure 15: The architecture of technology usage

4.3.2 process

I focused on developing a fully functioning mixed-reality prototype incorporating a Companion and Intelligent Mixed Reality Agent in the vehicle. The prototype was built using Unity[54] to create a simulation environment that modeled a vehicle interior and a city landscape. The interactive features of the agent, such as voice commands and gesture recognition, were integrated to enable users to ask for recommendations and directions to nearby locations.

To further enhance the user experience, I integrated OPEN AI's GPT3.5[55] language model API (Application programming interface) into the agent's communication system, by following available tutorials[56]. This allowed for natural language conversations between the user and the agent and the ability to provide personalized recommendations based on the user's interests and preferences. Additionally, text-based language conversation functionality was added using speech-to-text technology to convert real-time speech to text (see Figure 16).

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54 https://unity.com/

55 https://openai.com/blog/introducing-chatgpt-and-whisper-apis

56 https://www.toutiao.com/video/7177640693844673039/?app=news_article&timestamp=1671294094&group_id=7177640693844673039&share_token=2c8ac7bf-652c-425e-8383-fb616277c513&tt_from=copy_link&utm_source=copy_link&utm_medium=toutiao_android&utm_campaign=client_share&source=m_redirect

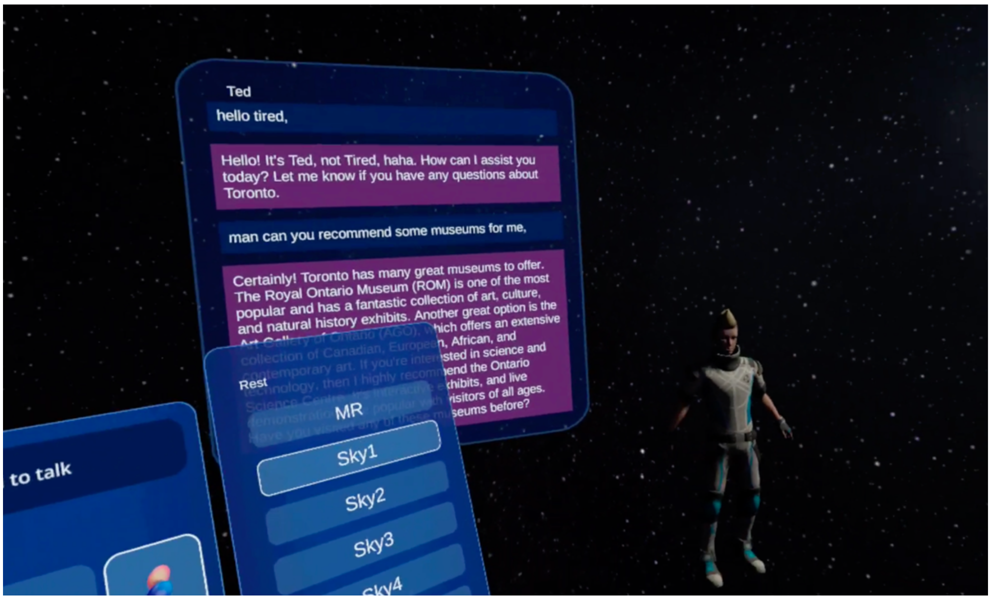


Figure 16: Screenshot of the Unity interface: connecting the GPT3.5 API

To create a more lifelike avatar for the agent, I used Blender to create a 3D Agent Avatar and connect the chat interface and agent avatar in Unity (see Figure 17).

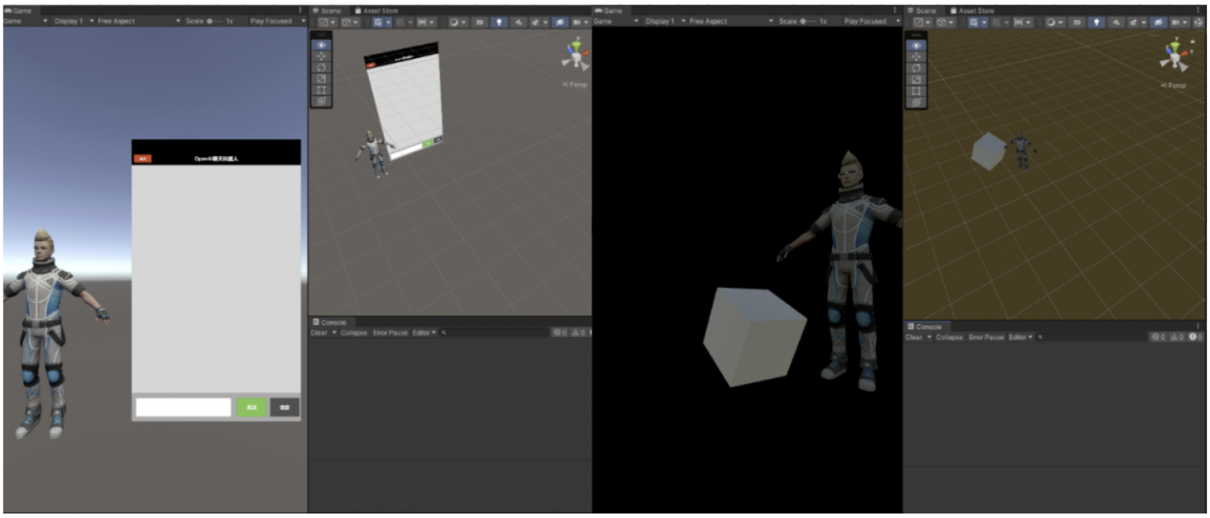


Figure 17: Connect chat interface and agent avatar in Unity

I bound Mixamo[57] (a 3D character animation tool) to create expressions and simple behaviors based on the content of the chat (see Figure 18).

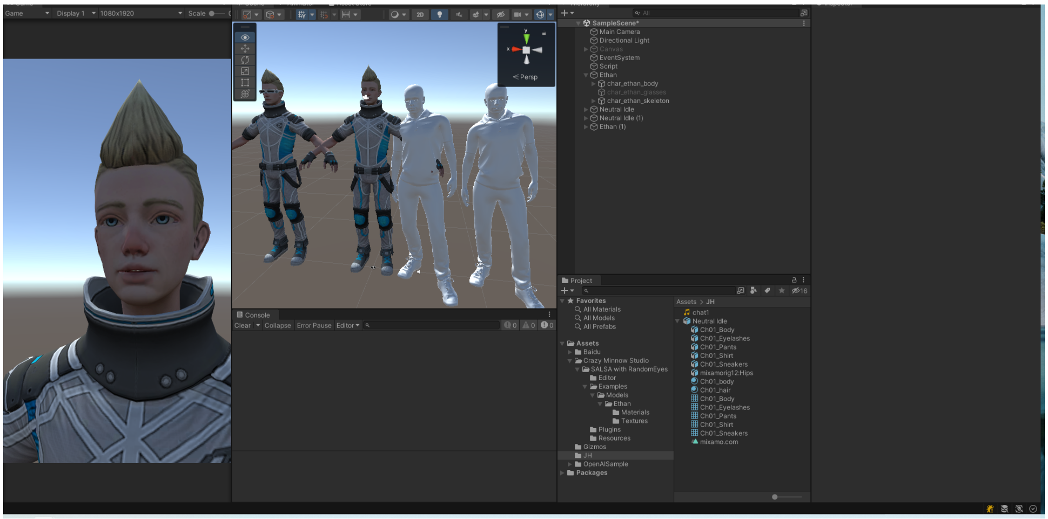


Figure 18: Bound Mixamo and Agent Avatar in the Unity

Finally, using Unity, I combined the creation of a mixed reality environment for the Oculus quest2[58] device with the agent avatar for voice communication. This allowed users to utilize the prototype in various in-car settings (see Figure 19).

57 https://www.mixamo.com/#/

58 https://www.meta.com/ca/quest/products/quest-2/

Figure 19: Communicate anything in any language with Agents in a hybrid environment.

4.3.3 Results and Reflections

The development of prototype 3 demonstrated the feasibility of using mixed reality and intelligent agents to improve the travel experience for self-driving travelers in unfamiliar cities. The integration of ChatGPT and Unity technologies allowed for a more natural and intuitive interaction between the user and the agent, creating a more personalized and engaging travel experience.

The mixed reality interface created using Unity provided a non-distracting, informative display that enhanced users' awareness of their surroundings. The voice commands capabilities of the agent provided a hands-free and intuitive way for users to interact with the system. The integration of OPEN AI's GPT3.5 language model API allowed the agent to understand and respond to natural language queries, providing a more seamless interaction for the user.

However, there were also some limitations in the prototype. For example, the prototype could only provide recommendations and directions to nearby locations based on the user's question and could not provide full travel services. In addition, the prototype was limited to a simulation environment and could not interact with real-world data.

Overall, the development of prototype 3 provided valuable insights into the design and implementation of mixed reality and intelligent agents in the travel industry. Future research can build on the findings of this study to develop more sophisticated and comprehensive systems that can provide more personalized and seamless travel experiences for users.

4.4 Summary

The chapter describes the development of three prototypes aimed at improving the travel experience of self-driving travelers in unfamiliar cities through the use of mixed reality and intelligent agents. The first prototype focused on creating an AI cognitive tour guide that could provide personalized and interactive recommendations for nearby attractions, and included the use of NFTs for added value and exclusivity. The second prototype involved the development of a VR simulation experience that demonstrated the potential of mixed reality and virtual agents to enhance the user experience in a car. The third prototype aimed to create a fully functioning mixed-reality intelligent agent within the vehicle that could provide personalized recommendations and companionship through the use of ChatGPT, a language model developed by OpenAI. The prototypes demonstrated the potential of mixed reality and intelligent agents to enhance the travel experience but also highlighted some limitations that must be addressed in future development. The integration of ChatGPT and Unity technologies allowed for more natural and intuitive interaction between the user and the agent, creating a more personalized and engaging travel experience.

Chapter 5: Discussion and Future Work

This thesis was evaluated using the Descriptive Design Evaluation method (Hevner, 2004), considering a thorough comprehension and an informed argument approach. The evaluation outcomes are subjective. Expert validation of these results is recommended to improve future work, though it falls outside the present study's scope.

This paper focuses on three prototypes to explore the possibility of intelligent agents for mixed reality in cars, and the emergence of ChatGPT in the process of writing the paper has provided prototype 3 with the technical support of natural language modeling, which can truly be an intelligent companion.

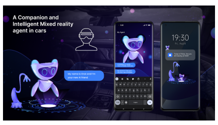
5.1 Evaluation of the Iterative Prototypes

This is an evaluation form for evaluating various prototypes. Each prototype begins with identifying a problem that requires exploration and resolution. The form showcases the capabilities of the prototypes and the features that users can activate. The "benefits and outcomes" column highlights the successes of the prototype, while the "limitations" section showcases areas that require further improvement.

5.1.1 Evaluation of prototype 1

Table 2 presents an organized overview of the evaluation of Prototype 1, which is an XR smart agent designed to provide a better tour experience. The table format provides a clear and concise summary of the prototype's features and benefits, as well as any limitations or areas for improvement. The takeaway from Table 2 is that Prototype 1 provides a personalized and interactive user experience by collecting users' geographic location and recommending nearby attractions, while also issuing virtual NFT souvenir blind boxes without human intervention to create a sense of exclusivity and value for users. However, there are areas where further improvement is needed to enhance accuracy and relevance of recommendations provided by the XR smart agent, address potential privacy concerns related to collecting user data, and ensure that all users find value in the virtual NFT souvenir blind boxes.

Table 2: the descriptive design evaluation of prototype 1

Prototype 1	

Corresponding research questions	**How can the XR smart agent provide a better tour experience in the future?**
Features	XR smart agent collects the user's geographic location and recommends nearby attractions The system is designed to be sensitive and adaptive to different users' requirements Virtual NFT souvenir blind boxes are issued without human intervention
Benefits and Outcomes	Provides a personalized and interactive user experience Allows for unique and rare virtual souvenirs to be issued to users, creating a sense of exclusivity and value Enhances the overall tour experience and makes it more memorable
Limitations	The concept design is still in the early stages and has not yet been implemented The use of MR glasses may not be feasible for all users or in all settings
Corresponding research questions	**How can the XR agent combine the Cockpit AI Intelligent Design?**

Features	XR agent can be integrated with Cockpit AI Intelligent Design to provide a seamless and intuitive interaction between the user, the assistant, and the car itself The assistant can use information from the car's sensors to provide personalized recommendations and services, such as adjusting the temperature or lighting to the user's preferences
Benefits and Outcomes	Provides a more efficient and convenient user experience while driving Increases the overall satisfaction of users
Limitations	Integration of the XR agent with Cockpit AI Intelligent Design may require significant technical resources and expertise The complexity of the integration may result in higher development costs
Corresponding research questions	**How does the XR agent actively interact with users in the cockpit?**
Features	The XR agent can use facial recognition and voice recognition to identify the user and initiate interaction The agent can also use sensors to detect the user's emotional state and adjust its responses accordingly

Benefits and Outcomes	Provides a more personalized and intuitive user experience Enhances the overall satisfaction of users
Limitations	The use of facial recognition technology may raise privacy concerns for some users The accuracy of the sensors in detecting emotional states may be limited
Corresponding research questions	**How can intelligent agents accompany users to visit a new city?**
Features	Intelligent agents can provide personalized recommendations and services based on the user's location and preferences Agents can use mixed reality to enhance the user's experience and provide visual representations of nearby attractions
Benefits and Outcomes	Provides a more efficient and convenient user experience while traveling Enhances the user's overall satisfaction and enjoyment of the trip
Limitations	The accuracy of the recommendations and services provided by the agent may be limited The use of mixed reality may not be feasible for all users or in all settings

5.1.2 Evaluation of prototype 2

Prototype 2 is a VR game that simulates an XR smart agent providing personalized recommendations and companionship for self-driving travelers in unfamiliar cities. Table 3 provides a descriptive design evaluation of Prototype 2, organized into four sections exploring the potential of the XR agent to enhance the user experience, its limitations, and how it can actively interact with users.

The table summarizes the features of Prototype 2, the benefits and outcomes of using this prototype, and its limitations. The takeaway from Table 3 is that Prototype 2 has several features that can enhance the tour experience for self-driving travelers, such as providing personalized recommendations and real-time geographic location tracking. However, the prototype has limitations, such as being limited by data support and map information, and the agent avatar simply appearing and not being a real intelligent assistant. Despite these limitations, the prototype demonstrates promising potential for enhancing the user experience, and further development and refinement of the system can address these limitations and bring the concept closer to practical implementation.

Table 3: the descriptive design evaluation of prototype 2

Prototype2	

Corresponding research questions	How can the XR smart agent provide a better tour experience in the future?
Features	Virtual avatar of the Agent, 2D and 3D information of CN-Tower, immersive and intuitive experience
Benefits and Outcomes	Use VR simulation games to give users an ideal state of story journey experience
Limitations	Limited by data support and map information; Agent avatar Simply appears, not really an intelligent assistant
Corresponding research questions	How can the XR agent combine the Cockpit AI Intelligent Design?
Features	Location recognition triggers agent avatar to appear
Benefits and Outcomes	The Agent is actively aware of the user's location and shows the user CN-Tower's recommendations
Limitations	Only the simulation actively recommends that CN-Tower's VR simulation is not supported by AI technology and geolocation technology

Corresponding research questions	How does the XR agent actively interact with users in the cockpit?
Features	Display information by identifying in VR whether the location of the user-bound vehicle arrives near the CN-Tower
Benefits and Outcomes	Simulate a human-computer interaction in which an intelligent machine can actively recognize user data
Limitations	This is scripted and not really active
Corresponding research questions	How can intelligent agents accompany users to visit a new city?
Features	Real-time geographic location tracking, interactive and personalized recommendations, virtual and mixed-reality representation
Benefits and Outcomes	Enhanced user experience, more efficient and effective recommendations, increased engagement and satisfaction
Limitations	Limited by data support and map information, may pose challenges in practical implementation, requires further development

5.1.3 Evaluation of prototype 3

Table 4 provides a descriptive design evaluation of Prototype 3, which explores the potential for XR (extended reality) smart agents to enhance the travel experience and interact with users in the cockpit. Table 4 highlights the key features, benefits, and limitations of Prototype 3, which is focused on the use of XR smart agents for personalized travel recommendations and conversational interaction interfaces in the cockpit. The prototype shows potential for improving the travel experience through hands-free, natural language interactions and reducing the need for screen time. However, limitations include a lack of real-world data integration and potential boredom in dialogue communication with only voice and text. Overall, the table provides a useful evaluation of Prototype 3's potential and limitations in these areas of research.

Table 4: the descriptive design evaluation of prototype 3

Prototype3	
Corresponding research questions	**How can XR smart agents provide a better tour experience in the future?**
Features	Through mixed reality interfaces and intelligent agents, XR smart agents can provide personalized recommendations and companionship for self-driving travelers in unfamiliar cities.

Benefits and Outcomes	This can lead to a more engaging, intuitive, and informative travel experience for users, improving their awareness of their surroundings and allowing for hands-free and natural language interactions.
Limitations	The prototype was limited to a simulation environment and could not interact with real-world data.
Corresponding research questions	**How can XR agents combine the Cockpit AI Intelligent Design?**
Features	XR agents can present conversational interaction interfaces by using natural language processing, speech recognition
Benefits and Outcomes	Realize a truly natural dialogue with the user in voice and text
Limitations	This prototype only developed a conversational interactive interface and did not integrate with more in-car features
Corresponding research questions	**How does the XR agent actively interact with users in the cockpit?**
Features	No active interaction developed

Benefits and Outcomes	No active interaction developed
Limitations	No active interaction developed
Corresponding research questions	**How can intelligent agents accompany users to visit a new city?**
Features	Mainly through the voice in a question-and-answer way to accompany the user
Benefits and Outcomes	Reduce the number of users looking at the screen to share and make it more natural and in line with the way users communicate with their friends on a daily basis
Limitations	Dialogue communication with only voice and text can be a bit boring

5.2 Evaluation of the prototype usability

Each prototype was evaluated against the standard set by Nielsen's 10 heuristics and a 5-point severity rating scale (SRS) (Nielsen, 1994). The SRS median scores were classified as 0=none, 1=cosmetic, 2=minor, 3=major, and 4=catastrophic (Bangor et al., 2009).

Since the project did not involve expert review or participant usability testing, the evaluation focused exclusively on the combination of augmented reality interactions and interfaces. This approach is considered valid as Nielsen's 10 heuristics are widely recognized for evaluating the interactive design and user interfaces. However, they are not specifically designed for automobile or augmented reality applications and thus have limitations when applied to in-car augmented reality agents.

5.2.1 Evaluation of the prototype1

Table 5 summarizes the Prototype Usability Evaluation of Prototype 1 by Nielson's 10 heuristics and SRS.

Table 5: Nielson's 10 heuristics evaluations for prototype1

	Heuristic	Prototype1	
		SRS(0=none, 1=cosmetic, 2=minor, 3=major, and 4=catastrophic)	Lessons Learned or Takeaways
1	Visibility of System Status	1 (cosmetic): The system provides clear status updates, such as the location of the user and nearby attractions, through the mobile-based application.	The use of mixed reality glasses to display 3D information and NFTs for souvenir delivery provides an innovative and engaging user experience.

2	Match Between System and the Real World	2 (minor): The prototype addresses this principle by recognizing the user's geographic location and providing relevant nearby attractions, thereby matching the system's recommendations with the real-world environment.	The system is designed to be sensitive and adaptive to different users' requirements, and their journeys are mapped out to optimize their interactions with the tour guide throughout their journey. This ensures that the system matches the real-world needs and requirements of the user.
3	User Control and Freedom	1(cosmetic): The prototype allows for user control and freedom by offering personalized recommendations and companionship while allowing users to choose whether or not to interact with the system.	The system allows for natural interaction through voice recognition and gesture recognition. This gives users a sense of control and freedom in their interaction with the system.
4	Consistency and Standards	1(cosmetic): Consistency and standards: The prototype adheres to consistency and	The personality of the intelligent agent is defined based on its function, visual appearance, and

		standards by using a familiar interface and language for the user.	possible scenarios. This ensures consistency and adherence to standards in the system's design.
5	Error prevention	2 (minor): The prototype does not have a specific error prevention mechanism, but it is designed to be sensitive and adaptive to different users' requirements to minimize errors.	The system issues virtual NFT souvenir blind boxes without human intervention, ensuring error prevention and reliability in the issuance of souvenirs.
6	Recognition Rather than Recall	1(cosmetic): The prototype does not require users to recall information; it collects the user's geographic location and provides recommendations accordingly.	The system actively recognizes the user's account information through facial features, voice recognition, and heartbeat sensing, eliminating the need for the user to recall and input this information.
7	Flexibility and Efficiency of Use	The prototype is flexible and efficient as it provides personalized recommendations based on the 1(cosmetic): user's	The system is designed to be sensitive and adaptive to different users' requirements, and their journeys are mapped out to optimize their interactions with the

		geographic location and interests. Severity rating	tour guide throughout their journey. This ensures flexibility and efficiency of use.
8	Aesthetic and Minimalist design	1(cosmetic): The prototype features an aesthetic and minimalist design that does not distract users from their surroundings.	The mixed reality interface and mobile-based application designed using Figma have a clean and minimalist design, providing an aesthetic and engaging user experience.
9	Help Users Recognize, Diagnose, and Recover from Errors	2 (minor): The prototype does not have a specific error recovery mechanism, but it is designed to be sensitive and adaptive to different users' requirements to minimize errors.	The system is designed to prevent errors, but in the case of any issues, the interface is designed to be easy to use and provide guidance for error recovery.
10	Help and Document ation	1(cosmetic): The prototype does not require extensive help and documentation as it is designed to be intuitive and easy to use.	The technology framework created using Figma and the mobile-based application's visual design provides clear and concise documentation for users to refer to when needed.

5.2.1 Evaluation of the prototype2

Table 6 summarizes the Prototype Usability Evaluation of Prototype 2 by Nielson's 10 heuristics and SRS.

Table 6: Nielson's 10 heuristics evaluations for prototype2

	Heuristic	Prototype2	
		SRS(0=none, 1=cosmetic, 2=minor, 3=major, and 4=catastrophic)	Lessons Learned or Takeaways
1	Visibility of System Status	4(catastrophic)The prototype does not provide clear feedback on the user's current location or the progress of the journey, which could cause confusion for the user.	This could be improved by providing more explicit status indicators, such as a progress bar or a map display.
2	Match Between System	3 (major): The prototype does not provide a completely realistic representation of the	This could be improved by expanding the system's coverage to a wider range of locations.

	and the Real World	real world, as it is limited to a single virtual location.	
3	User Control and Freedom	4(catastrophic): The prototype provides users with a handle to control the movement and approach of the virtual objects, which gives a sense of control and freedom.	Further development could give users more control over the virtual assistant's recommendations and interactions.
4	Consistency and Standards	1(cosmetic): The prototype provides consistent interactions and interfaces throughout the experience.	There is room for improvement in terms of consistency with real-world systems, such as using standard gestures for user interaction.
5	Error prevention	2 (minor): The prototype does not have many opportunities for errors, as it is a simulated environment.	Further development could include error prevention measures, such as confirmation prompts before triggering certain actions.
6	Recognition Rather than Recall	3 (major): The prototype provides clear visual representations of the	There is room for improvement in terms of reducing the user's cognitive load, such as providing

		recommended attractions, which helps with recognition.	text or audio descriptions of the attractions.
7	Flexibility and Efficiency of Use	3 (major): The prototype is efficient to use, as it allows for hands-free interaction and provides personalized recommendations.	There is room for improvement in terms of flexibility, such as allowing users to customize their preferences for recommendations.
8	Aesthetic and Minimalist design	1(cosmetic)The prototype has a visually appealing design.	There is room for improvement in terms of reducing the clutter and simplifying the interface.
9	Help Users Recognize, Diagnose, and Recover from Errors	2 (minor): The prototype does not have many opportunities for errors, but if errors occur, the system does not provide clear feedback on how to recover from them.	This could be improved by providing clear error messages and guidance on how to resolve the issue.
10	Help and Document ation	1(cosmetic): The prototype provides a basic interface and interaction instructions.	There is room for improvement in terms of providing more detailed

			documentation and guidance for users.

5.2.3 Evaluation of the prototype3

Table 7 summarizes the Prototype Usability Evaluation of Prototype 2 by Nielson's 10 heuristics and SRS.

Table 7: Nielson's 10 heuristics evaluations for prototype3

	Heuristic	Prototype3	
		SRS(0=none, 1=cosmetic, 2=minor, 3=major, and 4=catastrophic)	Lessons Learned or Takeaways
1	Visibility of System Status	1 (cosmetic)The system status is not explicitly mentioned in the text, which could confuse users who may not be sure whether the system is working or not.	This issue is not severe enough to cause major usability problems.
2	Match Between System	0 (none) The system appears to be designed to match the real-world environment,	-

	and the Real World	providing users with recommendations and directions that are relevant to their location and interests.	
3	User Control and Freedom	2 (minor) The prototype allows users to interact with the system through voice commands and gesture recognition, providing them with a hands-free and intuitive way to control the system.	The prototype is limited in terms of users' actions, as they can only ask for recommendations and directions to nearby locations.
4	Consistency and Standards	1(cosmetic): The use of ChatGPT and Unity technologies provides a consistent and standard approach to developing the mixed reality interface and intelligent agent.	There may be some inconsistencies in terms of the appearance and behavior of the agent avatar and the environment.
5	Error prevention	3 (major)The prototype does not appear to have any explicit error prevention mechanisms in place, which	For example, users may unintentionally ask for recommendations for the wrong

		could lead to usability issues for users who may accidentally trigger unintended actions.	location or direction, causing confusion and frustration.
6	Recognition Rather than Recall	0 (none)The system appears to be designed to recognize the user's current location and provide recommendations and directions based on that information without requiring the user to recall previous interactions or information.	-
7	Flexibility and Efficiency of Use	2 (minor)The prototype provides users a flexible and efficient way to interact with the system through voice commands and gesture recognition, allowing them to quickly and easily ask for recommendations and directions.	The prototype is limited regarding users' actions, as they can only ask for recommendations and directions to nearby locations.

8	Aesthetic and Minimalist design	1(cosmetic): The mixed reality interface created using Unity is designed to be non-distracting and informative, enhancing users' awareness of their surroundings without causing distractions.	There may be some aesthetic issues with the appearance and behavior of the agent avatar and the environment.
9	Help Users Recognize, Diagnose, and Recover from Errors	2 (minor): The prototype provides users with some help in recognizing and diagnosing errors, such as through the use of speech-to-text technology to convert real-time speech to text.	There may be some limitations regarding the system's ability to help users recover from errors, as the prototype is limited in terms of the actions that users can take.
10	Help and Document ation	1(cosmetic): The prototype does not appear to have any explicit help or documentation in place, which could cause usability issues for users who may not be familiar with the system or its features.	The use of ChatGPT and Unity technologies provides a standard and familiar approach to developing the mixed reality interface and intelligent agent, which may help users understand how to interact with the system.

5.3 Discussion

The Companion and Intelligent Mixed Reality Agent prototype represents an innovative approach to enhancing the travel experience for self-driving travelers in unfamiliar cities. By using mixed reality, the prototype provides a more engaging and intuitive interaction between the user and the agent. The integration of ChatGPT allows for more natural language conversations, while the use of Unity technologies provides a seamless and immersive user interface.

This thesis builds on related work in the field of mixed reality, intelligent agents, and travel experience design. While there have been previous attempts to create intelligent agents for use in vehicles, the use of mixed reality and natural language processing technologies represents a novel approach to enhancing the user experience.

Looking forward, the Companion and Intelligent Mixed Reality Agent prototypes have the potential to be further developed and integrated into self-driving vehicles as a standard feature. This could help alleviate the boredom and isolation often associated with long car rides and provide a more engaging and personalized travel experience.

In conclusion, the Companion and Intelligent Mixed Reality Agent prototype represent a significant step forward in the design of mixed reality and travel experience. The integration of ChatGPT and Unity technologies provides a more natural and engaging interaction between the user and the agent, improving the overall user experience. Further research and development of this prototype could lead to more widespread adoption and integration of intelligent agents in self-driving vehicles.

Chapter 6: Conclusion, Limitation, and Future Work

6.1 Conclusion

This thesis has explored the development and evaluation of a mixed reality intelligent agent called MRCIAC with the goal of providing a safe and friendly travel experience for self-driving travelers. By simulating a local tour guide, the system offers personalized recommendations and companionship, potentially reducing the stress and cognitive load of navigating unfamiliar territory. The study has demonstrated the possibilities of mixed reality technology in revolutionizing human-computer interaction in transportation, and the role of intelligent agents in enhancing travel experiences.

The research has also reflected on the importance of the human to agent relationship and the role of technology in shaping it for travel experiences. By leveraging ChatGPT's natural language processing capabilities, the prototype has been designed to provide a more human-like and engaging interaction for the user. This approach differs from more traditional voice assistants in cars by focusing on creating an immersive and personalized experience through the characterization of the agent.

While the use of language models to create personas has some limitations, such as the need for high-quality training data and the risk of perpetuating bias, the increasing popularity and advancements in AI-related language technologies have allowed for a closer relationship between machines and humans. This thesis provides practical and theoretical contributions toward the goal of advancing our understanding of enhancing travel experiences and improving human-computer interaction in transportation.

6.2 Limitation

One limitation of this study is that MRCIAC was only tested in a simulated environment. Further testing in real-world scenarios is needed to validate its effectiveness. Additionally, this study only focused on one type of travel experience (car travel), so future research could explore how MRCIAC could be adapted to other modes of transportation. While this thesis builds on related work in the field of mixed reality, intelligent agents, and travel experience design, one limitation of this work is that it focuses primarily on the design and evaluation of the prototypes, without exploring broader social and ethical implications of this technology. Future research should consider the potential impact of intelligent agents in self-driving vehicles, including privacy and data security concerns.

Another limitation of this work is that it does not address potential implementation challenges that may arise when integrating an XR smart agent into existing self-driving car systems. The technical challenges involved in creating a robust infrastructure to support the system and ensuring the privacy and security of user data pose significant challenges. Moreover, the compatibility of the system with different car models and the integration of the agent with existing self-driving car systems require technical expertise and resources. Technical and logistical challenges may arise during the implementation process, and further research is needed to explore these challenges and ensure the system's compatibility and effectiveness in real-world scenarios.

Despite these limitations, the Companion and Intelligent Mixed Reality Agent prototype has the potential to be further developed and integrated into self-driving vehicles as a standard feature. This would help alleviate boredom and isolation during long car rides and provide a more engaging and personalized travel experience for users.

6.3 Directions for Future Work

This section suggests various areas for future work, including improving natural language processing capabilities of CIACs in cars, exploring mixed reality technology, and personalizing the travel experience for passengers. The section concludes with remarks encouraging continued research and development in transportation technology, with an emphasis on opportunities presented by the future development of autonomous driving technology.

6.3.1 Conversational Intelligent Agent Companion in cars

Future work could focus on improving the accuracy and reliability of the natural language processing capabilities of conversational intelligent agent companions (CIACs) in cars. Additionally, further research could explore how CIACs could be integrated with other technologies, such as autonomous driving systems or smart city infrastructure.

6.3.2 Mixed reality in the vehicle industry

Future work could focus on developing new mixed-reality scenarios and interactions that can enhance the travel experience for passengers. Additionally, further research could explore how mixed reality technology can be used to improve safety and reduce cognitive load for drivers.

6.3.3 The Relationships and experiences between travelers and cars

Future work could focus on exploring new ways to personalize the travel experience for individual passengers. Additionally, further research could investigate how technology can be used to create a more seamless and enjoyable transition between different modes of transportation (e.g., from car to train or plane).

6.4 Final Remarks

In conclusion, this study has demonstrated that mixed reality intelligent agents like MRCIAC have great potential to revolutionize human-computer interaction in transportation. While there are still limitations and challenges to overcome, continued research in this area will lead to exciting new developments in transportation technology. With the future development of autonomous driving technology, there is an opportunity to explore new ways technology can enhance the travel experience for all vehicle occupants.

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