Graduate School of Fundamental Science and Engineering
Waseda University

博　士　論　文　概　要
Doctoral Dissertation Synopsis

論　文　題　目
Dissertation Title

Mixed Reality Navigation Interface Design to Promote Urban Exploration

都市における街歩きを促進する複合現実ナビゲーションインタフェースの設計

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December, 2022

This dissertation focuses on the interface design of future mobile mixed reality (MR) navigation to promote pedestrian engagement in urban exploration from the perspective of human-computer interaction (HCI).

Map navigation always plays a vital role in our daily life. With the development of immersive technology like virtual reality (VR), augmented reality (AR), and MR, the conventional user interface of navigation systems has also been evolving. These technologies have constantly changed how pedestrians learn and interact with location-based information, especially in urban exploratory activities. However, though mobile AR and MR technologies are gradually coming out of the laboratory and into our lives via smartphones, they have yet to be wholly embedded in specific scenarios. Furthermore, as people have become accustomed to accessing information via mobile devices from the internet, the interaction between humans and the digital interface has become more diverse and complicated. Therefore, the user interface design and navigation system's interaction might affect pedestrians' satisfaction and user experience from different aspects of detail.

Some researchers have focused on technology to resolve the challenges, such as GPS function, route planning recommendation, and navigation instruction visualization. In contrast, the study of user experience and exploration engagement during exploratory navigation is not relatively affluent. In recent years, more studies on HCI have started to pay attention to the usability and preference of user interface design for mobile AR and MR navigation to support efficient wayfinding. However, the interface of the navigation system also needs to be affective and emotionally pleasing to engage the exploration of pedestrians and produce a positive user experience, especially in urban exploratory activities. In addition, with the development of hardware devices like head-mounted displays (HMDs), hands-free MR navigation will bring a better experience in future urban exploration. Therefore, HCI researchers should investigate how to design future MR navigation via HMDs for urban exploration.

In this work, we aim to explore the design insight for the interface of future MR navigation via HMDs to promote urban exploration based on user-centered design theory. We designed three case studies and conducted experiments to discuss and summarize the design insights for future MR navigation for supporting urban exploration.

In the first case study, we combined the location-based gamified interaction with normal navigation in mobile AR and desktop VR to support urban exploration. We aim to explore the interaction expectations of pedestrians during urban exploration via navigations that utilize immersive technologies and the effects of the virtual interface of MR navigation on pedestrians in detail. In the second case study, we designed an interactive virtual map interface through MR HMD. We aim to explore the role of the virtual map interface in MR exploratory navigation and discuss the different levels of detail of the map to promote pedestrian satisfaction during urban exploration.

Finally, in the third case study, we designed different scenarios to examine how to visualize point of interest (POI) information for pedestrians to promote their experience and POI awareness of location-based information. We found that pedestrians prefer to utilize different POI visualization dynamically according to their current situations and needs.

This dissertation consists of eight chapters. Chapter 1 describes the introduction of this work and introduces the motivation, the contributions, and the organization of the dissertation. The emergence of AR and MR navigation studies has brought people's attention to the real-world interface and significantly changed the traditional method and interaction of information visualization, providing more imagination and possibilities for location-based applications and exploratory activities.

Chapter 2 describes the research background and related works in literature. Many researchers mainly focus on optimizing essential navigation functions, like GPS function, precise route-planning, and information visualization for everyday navigation. However, the study on promoting user engagement in urban exploration with MR exploratory navigation needs further discussion. In this chapter, we summarize the state-of-the-art technologies related to our work and describe the difference between this work and other studies. Also, we list our research objective and research questions in the rest of this section.

Chapter 3 describes the design approach and methodology used in our case study. Overall, this work follows the perspective of user-centered design (UCD) in the HCI research area, which utilizes various user research methods, such as questionnaires investigation and interviews for user needs, workshops, etc., throughout the research process. We also describe our case studies overview according to the design theory and research methodology. We aim to use the results of each case study to discuss future interface design considerations holistically.

Chapter 4 describes the first case study and explains the study process in detail. This study aims to investigate the interaction expectation of pedestrians via immersive technologies to support exploratory navigation. We implemented two gamified navigation systems, a mobile AR navigation and a desktop virtual tour navigation. Both systems combined gamified location-based interaction with navigation interface features. In the experiment, we asked different groups of participants to have a free-walking exploration in an assigned area of the urban streets via the system respectively. Based on our results, the interesting interaction between pedestrians and the navigation could help them acquire much more information and engage them in exploration. Moreover, we summarized the interaction requirements and preferences between the pedestrian and navigation interface. We found that the preference for different interface components is dynamic according to different scenario conditions.

Chapter 5 describes the second case study and explains the study process in detail. The results in case study 1 inspire us to use MR's advantages to design interactive navigation in future intelligent environments. In this case study, we aim to explore the role and effect of the virtual map interface of MR HMD navigation on pedestrian satisfaction. We proposed a virtual 3D minimap in which the pedestrian can manipulate the map by zooming, rotating, and transforming. We hope to provide a holistic view of spatial and environmental information for pedestrians and increase their interaction with the virtual content. Then, to further discuss the effect of the level of detail of the minimap interface on pedestrian satisfaction in exploratory navigation, we design two levels of detail of map modes, a normal one with complete spatial and environmental information and a simplified one with filtering the irrelevant information. We used two map modes to comprehensively experiment with measuring pedestrian mental satisfaction from specific navigation tasks. The experiment results showed participants a positive attitude toward the interactive virtual minimap interface. In addition, the simplified map interface could result in better performances and lower mental demand in specific navigation tasks.

Chapter 6 describes the third case study and explains the study process in detail. In this study, we expect to explore POI visualization methods in different scenario conditions to promote the interactivity between the location-based POIs and pedestrians in exploration. According to previous work in case study 1, we found that pedestrian motivation and needs in exploratory navigation are dynamic, so the interaction between the pedestrian and navigation interface should be discussed in different scenarios. Thus, in this study, we design different scenarios of exploratory navigation with varying designs of POI visualization methods to discuss how to visualize POIs during exploration to promote POI awareness. The results indicate that there are interaction effects between the three scenario condition levels (Target, Time, and Pull-Push) and different visualization methods. The results also indicate that the recommendation from the virtual avatar and the virtual content with Mixed reality features could help and engage the pedestrian to explore much more POIs.

Chapter 7 discusses and summarizes the findings from all case studies results and suggests further directions for future studies in this area. After summarizing the findings and limitations of the above works, the challenges, and possibilities for achieving them in the future are noted.

Chapter 8 makes a summary of this study. We summarize the arguments of this dissertation and the results and contributions we have identified.

List of research achievements for application of Doctor of Engineering, Waseda University

Full Name： _____ seal or signature

Date Submitted(yyyy/mm/dd): 2022/12/8

種類別 (By Type)	題名、 発表・発行掲載誌名、 発表・発行年月、 連名者（申請者含む） (theme, journal name, date & year of publication, name of authors inc. yourself)
Journal	○Zhang, Y.; Nakajima, T. Exploring the Design of a Mixed-Reality 3D Minimap to Enhance Pedestrian Satisfaction in Urban Exploratory Navigation. Future Internet 2022, Volume 14, Issue 11, Pages 325. doi:10.3390/fi14110325
Conference	○Zhang, Y.; Cao, Y.; Nakajima, T. Engaging New Residents' City Exploration Using a Gamified Location-Based Information Interactive System. HCII 2021, Virtual Event, July 24–29, 2021; Proceedings, Part I, 2021; pp.412-428. doi: 10.1007/978-3-030-78462-1_32 ○Cao, Y.; Zhang, Y.; Nakajima, T. Improving Information Acquisition in City Tours via Simplified Virtual Scenes with Location-Based POIs. HCII 2022, Proceedings. Springer Science and Business Media Deutschland GmbH. 2022. p. 37-52. doi: 10.1007/978-3-031-05431-0_3 ○Zhang, Y.; Nakajima, T. Exploring 3D Landmark-based Map Interface in AR Navigation System for City Exploration; In Proceedings of the 20th International Conference on Mobile and Ubiquitous Multimedia, MUM 2021. pp. 220-222. doi: 10.1145/3490632.3497858 ○Zhang, Y.; Nakajima, T. Gamified navigation system: Enhancing resident user experience in city exploration. In UbiComp/ISWC 2020 Adjunct - Proceedings of the 2020 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2020 ACM International Symposium on Wearable Computers. Association for Computing Machinery. 2020. p. 180-183. doi: 10.1145/3410530.3414405