
Re-build-ing Boundaries: The Roles of Boundaries in Mixed Reality Play

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Abstract

Emerging outdoor recreation activities such as location-based games, spatial mixed reality play, and exergames have proliferated in recent years, raising questions around boundaries, immersion, safety, and user experience. Designers of such outdoor games need to take into consideration how they select spaces, and how their selection effect the experience. In our prior work, we contribute a set of guidelines and design implications that support designers of outdoor mixed reality play to select and define boundaries of the physical-world region in which the mixed reality is experienced. However, few outdoor mixed reality research and games provide sufficient information on how they selected outdoor spaces, making it challenging to replicate. To support designers, we call for better reporting of space usage in mixed reality games and research. Future work will explore ways to bring together best practices, identify problems, and develop practical guidelines that can facilitate further development of outdoor mixed realities.

Author Keywords

HCI outdoors; mixed reality; augmented reality; outdoor; games; space; boundaries; user experience; game design.

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ACM Classification Keywords

H.5.1 [Information interfaces and presentation (e.g., HCI)]: Multimedia Information Systems.

Introduction

Recent advances in mobile and ubiquitous technologies, coupled with the ability to track users outdoors, have opened countless possibilities for the growth of outdoor mixed realities [1, 2, 6]. Systems that connect virtual and physical reality in some meaningful way through sensors, networks, computers, and databases are *mixed realities* [8, 11]. These range from augmented reality, in which conformal 3D imagery is integrated with a perspective on the physical world, to augmented virtuality, in which physical-world artifacts and spaces are integrated into a virtual world [3].

Applications of spatial mixed reality have included tourism (e.g., *Westwood Experience* [14]), education (e.g., *DERIVE* [4]), and games (e.g., *Pokémon GO* [9]). Spatial mixed realities take place in physical environments that afford and constrain action through a combination of layout, size, climate, history, purpose, technology, and/or social contracts. Designers of such outdoor games need to take into consideration how they select space and define the boundaries of the mixed reality game.

Our prior work addresses a number of these considerations that are important to HCI in the outdoor, including how to select space and make place [11], which display modalities fit best for the outdoors [12], and how to design wearable user interfaces [2]. These topics are usually considered by designers of spatial mixed realities. With this paper, we shed light upon opportunities, challenges, and future work around building boundaries for outdoor experiences and to facilitate further development in this domain.

Prior Work

Our prior research has directly addressed how designers select physical spaces to make places [11]. A *space* is a physical area, while a *place* is a space infused with meaning [5, 11]. Mixed reality games that make use of physical space *make and/or alter places*. In this work, we looked at prior designers' considerations in outdoor spaces through a grounded theory analysis of 71 research papers and 17 games. The resulting *space-selection framework* provides designers with insight into how to select outdoor spaces and places for mixed realities. The framework has two axes: *space continuity* and *specificity requirements*.

Space continuity considers the boundaries (or lack thereof) of the physical-world region in which a mixed reality can be experienced. In this prior work, we are not discussing physical size, but how boundaries are organized (Figure 1), which resulted in four classifications of space continuity:

- **individual spaces** offer mixed reality in one bounded location;
- **isolated spaces** connect together multiple individual spaces without mixed reality in between them;
- **continuous spaces** provide users with mixed reality along a route, but in this case this experience is continuous; and
- **ubiquitous spaces** are large-scale and feature poorly defined or undefined boundaries (possibly including anywhere in the world).

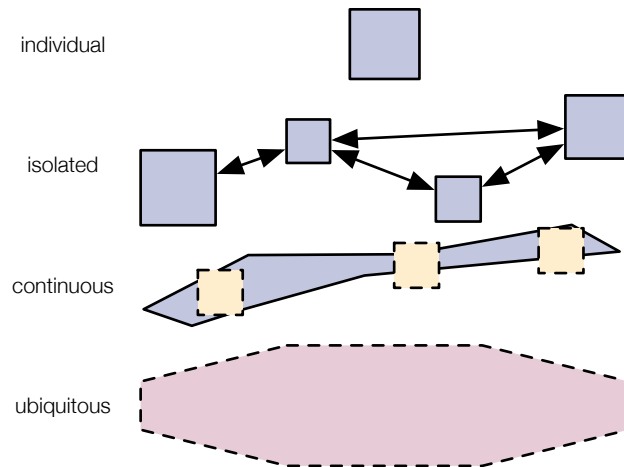


Figure 1: Graphical representation of the space continuity types found in the literature [11]. Individual spaces are self-contained, with definite boundaries. Isolated spaces are each self-contained and experienced in a sequence. Continuous spaces are like isolated spaces, but with mixed reality along a path. Ubiquitous spaces have poorly defined or no boundaries. This style of diagram can easily be used by designers to specify boundaries in their own spatial mixed realities.

As a second axis, we consider the *specificity requirements* for the researched spatial mixed realities, which accounts for how generic or specific a space needs to be to support the intended experience, including technological requirements. These include:

- **open space** mixed reality games do not require any particular affordances or constraints in the physical environment. These games can be experienced anywhere;

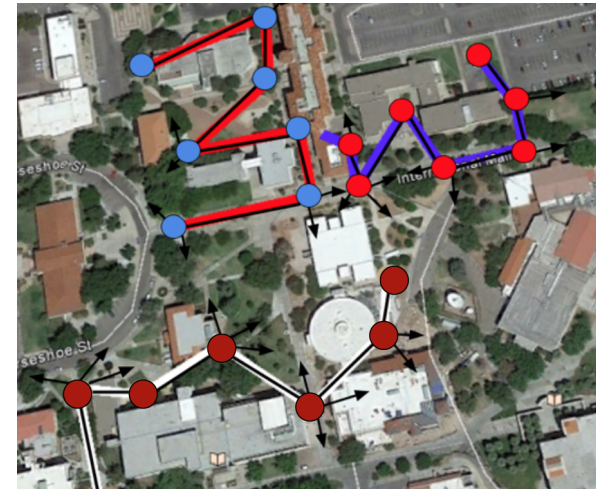


Figure 2: A map/layout of the outdoor location and boundaries of the mixed reality game *PhotoNav* [12]. The game is designed using isolated and continuous spaces, which enable building mixed realities along multiple routs, but disengage the user between them. Such design choice increase safety, since the designer can ensure that players can interact with the game in safe areas, but disengage when it is not safe.

- **templated space** mixed reality games may be created anywhere when specific requirements (e.g., location data sources) are met; and
- **place** mixed reality games are unique to a specific location where the experience cannot be replicated in a different geographic location.

Combining both axes, designers can define the physical boundaries of the intended mixed reality, and understand the affordances, constraints, and design implications of the selected space (Figure 2).

Mixed reality systems potentially enhance and are enhanced by the aura of places in which they are set [7]. One challenge that designers of mixed reality games might face is that authentic places, such as museums, are not always available for mixed reality creation. To overcome this challenge, places can be constructed, transposed, or evoked through the careful use of the virtual worlds of mixed reality. Space transforms to place through well-designed mixed reality [5].

Certainly, as the physical-world boundaries of a mixed reality experience expand, the level of risk increases with it. The design of a mixed reality experience in terms of its space continuity and layout, has significant implications for safety. The continuity of space drives the need for virtual data that is linked to a physical-world location: the larger and more continuous the space, the greater the need for virtual world data and connectivity.

Future Work

While the space selection framework [11] supports designers in selecting space to make place, future work need to address the practical steps designers need to apply the framework during the development process of mixed reality and how designers can define the boundaries of the experience. The findings from our prior work act as a starting point for further studies in which other variables that might effect the selection of spaces can be analyzed, such as day time, seasons, events, player preference, social fabric, and rules of the selected space [10]. Future work need to analyze the relation between space selection and its contribution in making a mixed reality experience engaging. One way to develop more engaging experiences is to examine mixed reality players behavior in outdoor settings, such as the reasons players prefer particular outdoor locations to play [13].

Conclusion

Designers of HCI in outdoor recreation setting can benefit from prior experiences of designing and developing spatial mixed realities. However, while conducting our prior research, few of the reviewed outdoor mixed reality research and games provided sufficient information on how they selected their outdoor space, space size, and space template, which can help reproduce the research performed and gain insights into design practices. Thus, we encourage future researchers and designers of outdoor recreation activities to ensure that their work makes available maps/layouts, boundaries, size descriptions, and template descriptions for the physical components of the designed outdoor experience.

While the development of lightweight computing devices and wireless networking is increasing, the need for defining and building boundaries for outdoor recreational experiences becomes necessary. It can be argued that it would be beneficial for the designers of such outdoor systems to understand the boundaries of outdoor recreational activities and how to select physical spaces for different experiences instead of just selecting random locations, which might impact the experience or cause it to be unsafe or unpleasant¹.

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¹A *Pokémon GO* player unknowingly walks into a police station in search of a Pokémon gym: <https://goo.gl/hbwaZN>

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