Mixed Reality meets Marine Spatial Planning

Exploring a new era of immersive collaborative planning

Introduction

Mixed Reality technologies have seen significant increases in technical abilities and reduced costs for both consumer and business uses. While Mixed Reality technologies have been deployed for data visualization, very little is known about the experience of using Mixed Reality in its current state for collaborative geospatial planning. We developed a prototype application which we tested in several play tests as part of our efforts to introduce Mixed Reality into the Marine Spatial Planning process. Recorded play testing sessions and round-table interviews with 15 participants were analyzed, indicating enjoyment and positive use of the platform for communication, as well as challenges on both technical and design levels. This research shows opportunities in using mixed reality for collaborative geospatial planning while highlighting considerations to provide a lasting positive experience.

Keywords: *Mixed Reality, Collaboration, Marine, Spatial Planning, Experience*

Literature Review

Marine Spatial Planning (MSP) is the process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives[1]. Its goal is to balance competing interests, such as fisheries, renewable energy, transport, and tourism, through data-driven approaches like scenario modeling and decision support. These approaches are supported by tools like 3D visualizations, digital twins, and simulation platforms [2], [3], [4].

When exploring the literature, it was not possible to find examples of MR technologies applied to the MSP process. However, other research demonstrates how MR can support planning processes by enhancing data visualization and enabling real-time collaboration. A clear example is demonstrated in studies where MR tools provided improved comprehension of spatial layouts and reduced decision-making errors in Bone Tumors for Surgical Planning [5]. Closer to the Marine domain, MARS (Marine Augmented Reality System) can transform traditional 2D nautical charts into 3D interactive displays, facilitating navigation and spatial planning [6]. Such tools can potentially improve engagement in the planning process, yet the use of AR technology seems limited due to technical constraints [7].

Similarly, MR applications in urban planning use holographic models to simulate zoning changes and infrastructure development, aiding decision-making and stakeholder communication [8]. There is also a mixed reality system for remote collaborative geospatial data analysis, emphasizing immersive visualization, real-time co-presence via avatars, and interaction capabilities, with private/shared virtual spaces for analysis [9]. The existing platforms have shown the potential of XR as a co-design tool and provide insight how its users can provide real-time input [10], [11]. These explorations in collaboration, geospatial visualization and data editing in XR environments inspired this work, where we focus on understanding how to use MR to assess the opportunities and challenges for decision-making support.

Methodology & Hardware

We used the Unity3D Engine to develop an interactive prototype for Quest 3 MR headsets, focused on exploration and collaboration. This prototype contains basic interactions for a concise planning experience, including toggleable geospatial data, vector-based drawing, colocation between 4 users, & hand occlusion. These interactions used the Unity XR Interaction Toolkit and Netcode plugins for a networked XR application using industry-default hand-gesture controls. The GeoSpatial scenario, data, as well as the tasks provided to

the participants, were decided by our in-house MSP and GIS experts and observe accurate data from the Waddenzee area near the Netherlands.

1) The room setup with 4 users, 2) Participants interact with the menu, 3) Participants interact with the map

5 play sessions, consisting of 3 participants each, were organized to gather observational data from video-recorded play sessions and audio recordings from subsequent roundtable discussions. We invited employees and students of the academy for AI, Games and Media, who provided written consent before the start of the sessions. During these sessions participants were: 1) Introduced to the topic, 2) Introduced to the MR device and the application, 3) Completed a minor task to familiarize themselves with co-located MR, 4) Completed a major task for evaluating the experience, where they were tasked to identify new locations for a potential wind-farm, 5) Joined a round-table discussion about their experience.

Round-table discussions were transcribed using WhisperAI [12], then manually verified and corrected and thematically coded. The thematic outcomes of the roundtable discussion guided observations from the video recordings. The findings of this study aim to inform our own decision-making process and the industry on the benefits and challenges of current MR technology in co-located collaborative environments.

Findings

Coding of the roundtable discussions shows several key themes which we outlined below.

Replicating traditional, physical interactions in an inviting and novel setting

MSP and GeoSpatial data are traditionally seen as serious tools for professional applications; while this goal must be maintained, we aimed to introduce a level of playfulness into the process. This was reflected by unanimous feedback from the participants indicating a level of enjoyment or fun. *6) Just doing things was fun. 13) I really enjoyed it. 10) It was pretty nice.*

While enjoyability is a high priority, the main goal remained exploration and identification of suitable areas for human activities. Participants noticed the presence of exploration, explaining that the application triggered them to explore what exists and where new items could be located. This level of engagement is thereby mentioned as one of the reasons for the high level of enjoyment. *8) I think, for one, because it's fun, people will kind of get engaged with it and just immediately start talking... You' re really getting to the mode of, oh, what already exists, and where should we plan something.*

Exploration was often connected to the physical tools which inspired our prototype. Participants mentioned whiteboards and tabletop games, suggesting the likeness to these known tools. The digital replications were not always faster but allowed for new, useful, and playful interactions. Suggestions were made to introduce placeable 3D objects, drawing further inspiration from board game mechanics. *13) almost like a [...] tabletop game 5) I think the interactions themselves are quicker to do on paper. But the fact that you have all of those filters, you can toggle on and off certain information. 12) instead of just like us trying to draw like a square or a circle where we want to place like the windmills.*

Using Mixed Reality interactions as a tool for communication and collaboration

Communication is an essential part of collaborative planning; discussions provided insight into how spatial MR interactions facilitated this. Co-located hand-tracked interactions, such as pointing and drawing, were mentioned by participants to communicate a specific location on the map. The researchers hereby observed that pointing was predominantly done by physically moving hands on top of the map, rather than from a distance. Observations from the session recordings also show that during 28% of the evaluative tasks, at least one participant points at or draws on the map. *6) Like we can reach across the table and circle areas and whatnot. I feel like you wouldn't get that if you were all huddled around a laptop*

Further discussions mentioned the importance of oral communication, both by itself and during physical interactions. Engagement with the application was mentioned as a catalyst of this communication. Observational data showed that 49%-60% of the evaluation task was spent communicating orally, as well as confirming that physical interaction was largely accompanied by oral communication. *8) people will kind of get engaged with it and just immediately start talking. 7) The combination between drawing and just talking was the best way to communicate.*

The overwhelmingly positive feedback did note that the applications seems most suitable for a small group scale, suggesting to steer away from high levels of detail. *9) For smaller discussions that don't go into detail I think this might be helpful.*

Satisfying controls and interesting technology can still provide issues

Responsive interactions are a must for XR applications to provide a comfortable experience. Positive responses by our participants indicate that this was both present and important to our participants. The real-time feedback and immediate visual updates are hereby part of the satisfaction and playfulness of the sessions. *14) Like, pressing the buttons was really satisfying. 5) It was, yeah, just real time instant feedback. 2) Being able to toggle on through the menu and being able to immediately visualize it in the map, really played into that playful aspect of it*

Despite positive feedback, several interaction failures were observed. Participants faced challenges with 2D and 3D interactions while interacting with the system. Observations highlighted three major complications:

1. ***Gesture mistakes**, where participants would repeatedly use the wrong gesture to grab items*
2. ***Overlapping physical interactions**, headsets would falsely recognize hands from nearby participants*
3. ***Overlapping digital interactions**, objects placed too close together causing participants to interact with the wrong object*

These issues reveal limitations of current tracking technology and industry-standard gesture controls, which impact application design. However, participants maintained a positive outlook on MR, even for those who had negative previous experiences in VR. *8) I kept dropping the pen. 1) Clearly, I was clicking the wrong things. 7) it still felt like I was in the real world. 5) I tried VR and I get nauseous. Here I didn't, both with and without glasses.*

Conclusion

The findings of this study indicate that Mixed Reality is ready to successfully merge enjoyment with functional exploration of GIS data, fostering engagement in a playful environment reminiscent of traditional physical interactions. Participants unanimously reported a level of enjoyment, driven by the exploratory nature of the application and technology, which encourages collaborative communication through hand gestures and oral interactions. While the digital interface offers unique advantages over physical maps, such as real-time data visualization and interactive elements, challenges remain in the form of technical limitations and gesture recognition issues that can hinder user experience. Overall, the mixed reality setting proves to be a promising tool for collaborative planning, though further refinements are necessary to enhance its usability and ensure inclusive participation in more complex discussions.

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