“SkyMap”: World-Scale Immersive Spatial Display

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ABSTRACT

To relate typical survey map features to the real world during navigation, users must make time-consuming, error-prone cognitive transformations in scale and rotation and make frequent realignments over time. In this paper, we introduce SkyMap, a novel immersive display device method that presents a world-scaled and world-aligned map above the user that evokes a huge mirror in the sky. This approach, which we have implemented in a VR-based testbed, potentially reduces cognitive effort associated with survey map use. We discuss first-hand observations and further areas of research. User evaluations to compare performance under various task scenarios are currently under way.

CCS CONCEPTS

• Geographic Visualization • Mixed / Augmented Reality • Ubiquitous and Mobile Computing Design and Evaluation Methods

KEYWORDS

Spatial Representation, Spatial Projections, Cognitive Maps, Navigation

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1 Introduction

Survey maps on paper or mobile devices provide a scaled version of the real world. Cognitive effort during navigation encompasses spatial translation, reorientation, and localization between an exocentric frame of reference (a map) and a user's egocentric (first-person) view of the real world. Working memory limitations necessitate frequent realignment, leading to disorientation, misalignment, compounding errors and diversion of mental effort in times of stress [1], factors that can prevent timely use of map-based information. This access effort can be reduced by placing map information in a user's forward field of view (FOV) [1]. Studies have demonstrated reduced cognitive burden with head-up displays (HUDs) and egocentric augmented reality (AR) for transitioning between the display and the environment [1,2].

Figure 1: Concept Sketch of SkyMap as an AR display. Map is scaled and aligned with the world above the user.

2 Approach

SkyMap is a digital map of the area around a viewer that is virtually projected as if it were above the user's head, thereby simulating a giant ‘mirror in the sky’ viewed from below (Figure 1). As a result, map features appear to the user at a similar scale, distance and orientation as their corresponding real-world features. To the user, map features are visible above their real-world locations in the distance. The effect is of a bird's eye view from below that augments the user's egocentric point of view with an aligned exocentric survey-like map. During navigation, users can orient toward an objective without the exo-to-ego-centric cognitive translation necessary when using survey maps. Because map features are rendered at real-world distances, the need for vision accommodation and vergence transitions when switching attention between real world and scaled maps can be naturally mitigated (if the required AR display capability is supported). Further, SkyMap placement above the horizon leverages a typically unutilized region of the users' FOV,

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allowing an unimpeded line of sight to ground-level features, traffic or terrain otherwise obscured by other AR navigation methods, such as in-scene markup or maps displayed below the horizon [3, 4]. Based on these observed properties, many hypothesized benefits require further investigation, including:

- Improved distance and orientation estimation.
- Increased map detail due to size of map image in FOV.
- Beyond-line-of-sight landmark visibility for continuous position updating.
- Faster access to real-time digital information such as sensor data, position-reporting entities, and threat conditions.
- Safer route-following while driving, due to reduced cognitive translations and vergence/accommodation switching.
- Improved movement-based task performance such as chasing moving targets or navigation in darkness or smoke.

3 Prototype Testbed Development

Due to AR device limitations in resolution, FOV, position tracking and outdoor contrast, a VR testbed using the Oculus Rift and Unity first-person game engine was developed to simulate an AR SkyMap display. This testbed (called "MITS" for Mirror in the Sky) places the user in a virtual environment below a 3D surface reflecting a texture-mapped image of the underlying environment. To further simulate an AR implementation, we also provide a 3D model of the environment (Figure 2). Users can look around or "walk" using standard gaming controls. As they move the mirror map graphics are continuously updated to reflect the viewers' current position and head pose. The testbed includes run-time adjustment of surface shape, translation and scale (including flat, curved, tilted, dome and cone surfaces), map texture coordinate transforms, and self-position indication adjustment.

4 Key Challenges and Investigations

4.1 Self-Position Marker Placement

Navigational aids require a "you are here" indicator [5]. In a "flat mirror" implementation, the user's position is reflected directly above their head, requiring them to awkwardly look straight up. Placement of the self-marker further forward in the FOV is a thus a key requirement and area of investigation. It requires continuous transformation of the mirror map image, which can introduce visual distortions and alignment issues as the user moves and changes head-pose.

4.2 Map Visibility Near Tall Structures

Nearby structures obscure the sky, but a SkyMap image can be placed in front of structures, use horizon detection to render behind structures, or combine these to make structures appear transparent (Figure 3).

4.3 User Adaptability to Reflected Maps

A mirrored map may affect a user's cognitive map of space. There may also be a cost to switching between survey and mirrored versions of maps.

4.4 Complex Space of Design Trade-Offs

There are complex space of design trade-offs due to the variety of parameters and perceptual side-effects. Key factors include:

- Emphasis on distant vs. local regions.
- Preservation and consistency of feature geometry.
- Alignment of map features to the real world depends on mirror shape, scale, altitude and other parameters. Some variation seems acceptable, but alignment at the horizon appears necessary to maintain the effect.

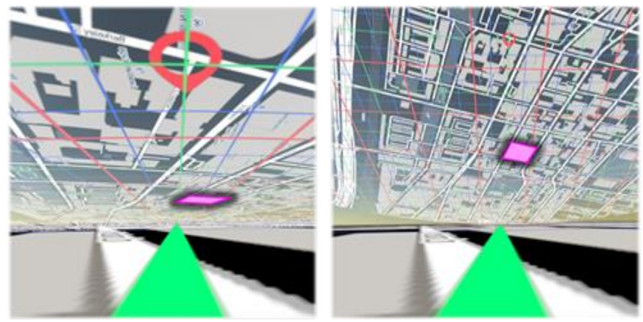

Figure 2: Different projections emphasize near or distant areas. Self-position is indicated by the red circle.

Figure 3: "Mirror in the Sky" testbed in a simulated urban environment. The route to follow is displayed in magenta.

5 Conclusions and Future Work

SkyMap introduces a new way to display spatial information as a world-scaled and oriented "mirror map". We have reasoned that this method may reduce cognitive translation effort associated with survey map use; however, formal human factors evaluations to compare SkyMap to familiar survey maps in various task situations are underway or in peer review. Initial results are encouraging. Evaluation task scenarios include:

- Route suitability evaluation in threat-laden environments
- Route following navigation in stress-induced environments
- Landmark learning performance
- Comparison of SkyMap projection variants

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