Visual Guidance Methods in Immersive and Interactive VR Environments with Connected 360° Videos

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Abstract

There is emerging research in using 360-degree panoramas in virtual reality (VR) for "360 VR" with choice of navigation and interaction. Unlike standard VR with the freedom of synthetic graphics, there are challenges in designing appropriate user interfaces (UIs) for 360 VR navigation within the limitations of fixed assets. We designed a novel software system called RealNodes that presents an interactive and explorable 360 VR environment. We developed four visual guidance UIs for 360 VR navigation. A comparative study determined choice of UI had a significant effect on task completion times, showing one of the methods, Arrow, was best.

Keywords: Immersive / 360° video; 3D user interaction; Non-fatiguing 3DUIs; Locomotion and navigation; 3DUI metaphors; Computer graphics techniques

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual Reality; Human-centered computing—Interaction design —Interaction design process and methods—User interface design;

1 Introduction

Recent VR research has reignited interest in producing 360-degree spherical panoramas of real-world environments to incorporate into "360 VR" experiences. Only within the last several years has both the technology and research advanced to expand beyond video and image viewing, exploring the technological and human factors challenges of enhancing immersion beyond strictly guided experiences.

Muhammad et al. [4] explored using Walking-In-Place (WIP) locomotion to control 360-video playback, finding that simulator sickness was reduced compared to passive video playback. Lin et al. developed two focus assistance interfaces for watching 360-video [2]: "Auto Pilot" directly changes the view, and "Visual Guidance" indicates a direction of interest. They found their methods improved ease of focus overall, but other positive effects depended on video content and viewer goals. MacQuarrie and Steed [3] developed virtual environments from connected 360-images and included three visual transitions: instantaneous teleport, linear movement through a 3D reconstruction, and an image-based morph. They found that 3D model or Möbius transitions gave a better feeling of motion. Rhee et al. developed MR360, software demonstrating real-time integration of interactive objects in a 360-video live stream, accurately lit with Image Based Lighting (IBL) [5], which improved presence compared to conventional 360-videos.

One problem in need of further investigation is appropriate UI metaphors for visual guidance, waypoint finding, and navigation geared specifically towards the limitations of 360 VR. Synthetic VR environments have the freedom of granular user position and environment geometry, while 360 VR is limited by fixed assets representing environment positions. To tackle this challenge, we developed a novel software system called RealNodes, an engine for developing scenarios combining 360-degree video and virtual assets into a cohesive interactive environment. We implemented four visual guidance UIs for RealNodes: Target, Ripple, Path, and Arrow (Fig. 1). A comparative study was performed on the UIs, in which participants performed a searching task four times, each with a different UI and object location. We present preliminary results that show one of the methods, Arrow, had a statistically significant difference in scenario competition times.

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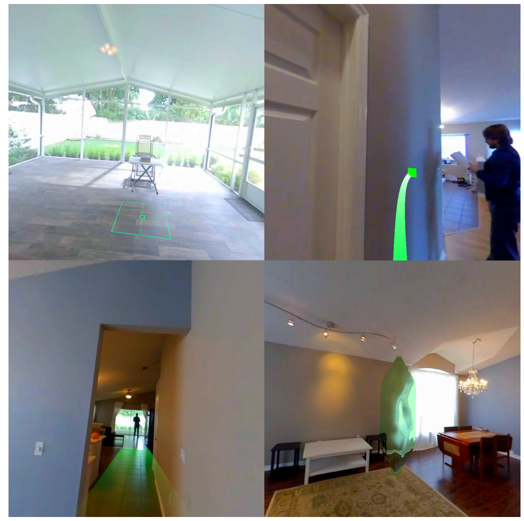

Figure 1: Images from RealNodes software displaying the four types of visual guidance UI. Top-left: Target; Top-right: Arrow; Bottom-left: Path; Bottom-right: Ripple.

2 Software Design

RealNodes is a novel software system for creating immersive and interactive 360 VR environments and scenarios. It was made with the Unity3D engine for deployment on SteamVR platforms. It presents separate locations as their own 360-video, each logically connected with 360-video transitions facilitating multi-path, bidirectional traversal. The user navigates with a WIP system that ties to the playback of the transitions. Visual guidance UI and WIP can be enabled/disabled by the user with a controller button press, allowing WIP only when the mode is activated and facing a navigable path, reducing false-positive steps. Another novel feature is layered video effects for blending and masking portions of video. This feature is used for smooth video transitions and to animate partial regions of video for events (Opening a drawer, closet, or book; lifting a rug; etc.). Interactive objects can be added to scenarios such as collectible objects and switches that trigger events, all lit accurately with IBL.

We implemented four visual guidance UIs for RealNodes. Their purpose is to indicate waypoint locations and when a user can perform WIP. Below are detailed explanations of each UI. Note that except the Arrow method, the UI is rendered only when navigation mode is active, and a user faces a waypoint.

Target indicates waypoints with a square shaped, semi-transparent target aligned with the ground plane. It is inspired by waypoints in conventional VR for teleport navigation [1].

Ripple indicates waypoints with a diamond shaped floating marker exhibiting a semi-transparent "ripple" visual effect. We were curious about how a guidance method with a "distortion" effect would affect engagement.

Path indicates the direction of a waypoint with a semi-transparent "lane" aligned with the ground plane and originating from the user. It was inspired by visualizations from Tanaka et al. [6] of ground-plane based indicators of where a user can navigate to.

Arrow indicates the direction of a waypoint with an arrow formed with a Bezier curve. It actively and smoothly points to the nearest waypoint based on shortest rotation from user to waypoint. Arrow renders when navigation mode is turned on. When not facing a waypoint, the arrow is blue. When facing a waypoint, the arrow is green. It was inspired by guidance methods from the work of Lin et al. for indicating points of interest in standard 360-video [2].

3 Method

A comparative study was performed on the four UIs in a 360 VR scenario environment (a house). The study was presented to 24 participants (18 males and 6 females) in a within-subjects design. Each condition had a unique UI and unique hidden object location for participants to find. Each participant was presented all four possible conditions, arranged in a randomized counterbalanced manner. An Event Log was produced recording scenario completion time. A Shapiro-Wilk test determined that all measures were non-normalized, so we used non-parametric tests. For all statistical measures, we used $\alpha = 0.05$.

4 Results and Discussion

We found a statistically significant difference in completion times depending on which visual guidance UI was chosen, indicated by a Friedman test ($\chi^2(3,24) = 12.75,\ p < 0.005$). After performing post-hoc analysis using the Wilcoxon Signed Rank Test on all possible pairs (see Table 1), significance was found with two of the pairwise tests: Arrow compared to the Path ($Z = -3.686,\ p < 0.001$) and Ripple compared to Path ($Z = -2.029,\ p < 0.05$).

Table 1: Wilcoxon Signed Rank Test statistics on all possible pairs.

Test	Result
Target-Ripple	$Z = -0.743,\ p = 0.458$
Target-Path	$Z = -1.914,\ p = 0.056$
Target-Arrow	$Z = -1.4,\ p = 0.162$
Ripple-Path	$Z = -2.029,\ p < 0.05$
Ripple-Arrow	$Z = -0.771,\ p = 0.44$
Path-Arrow	$Z = -3.686,\ p < 0.001$

After performing a Holm's sequential Bonferroni adjustment against the actual significance threshold, only the Arrow to Path pairwise was found to be significant and the Ripple to Path pairwise test was not, indicating a significant difference found between Arrow and Path ($Z = -3.686,\ p < 0.001$).

Mean and standard deviations for completion times in seconds for each condition (Fig. 2) match up with the data:($Target : M = 189.729,\ SD = 100.887, Ripple : M = 194.6,\ SD = 105.929, Path : M = 312.878,\ SD = 206.606, Arrow : M = 152.825,\ SD = 82.377$). Completion for Arrow is fastest on average, while Path is slowest (taking more than twice as long). This seems to indicate that Arrow is easier to get accustomed to for effectively searching an environment, and Path is slower to understand and use.

The Arrow UI is unique compared to the other methods. It always stays active on screen, while the others only display when facing a waypoint. Participants liked how Arrow smoothly curved towards the nearest waypoint, giving them active feedback. Participants liked how Arrow changed color to indicate whether they could activate WIP. One participant described it as "feeling good for exploration". Another described Arrow as "a combination" of showing direction and location compared to the other UIs.

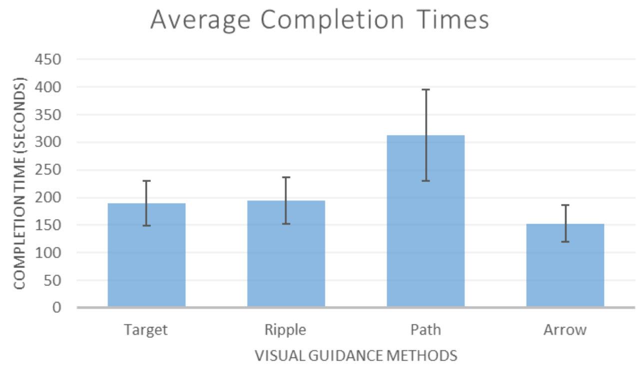

Figure 2: Average scenario completion times (in seconds) with 95% confidence error bars (lower is better). There is a significant difference between Arrow (fastest average), and Path (slowest average).

5 Conclusion and Future Work

We contribute a set of possible visual guidance UI elements for the application space of 360 VR. We additionally provide the results of a comparative evaluation. Conditions with the Arrow visual guidance had significantly faster completion times, more than two times faster than the slowest condition, the Path. This seems to indicate that the arrow is easier to get used to and continue to use in scenarios.

Refinements of the UIs we developed should be explored. Hybrids like Arrow and Target combined can simultaneously show exact location and direction of a waypoint. Our current system for indicating WIP start and end (visual guidance disappearing/reappearing) can be improved. A solution is a UI metaphor indicating progress during the walk, such as a progress indicator or an absolute waypoint getting closer as the cycle proceeds. Further research into authoring tools for 360 VR is needed, especially regarding asset management of video types used for transitions and composited animations. Participants reacted favorably to the background non-player character (NPC) present in the video, asking "Who is he?" and commenting on his presence. Methods to interact effectively with NPCs in a 360 VR environment need further investigation.

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