A 'Stopper' Metaphor for Persistent Visual Feedback in Touchless Interactions with Wall-Sized Displays

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Figure 1. A user points in mid-air to a target folder on a wall-sized display (left); *Stoppers* provide visual feedback as the user's gesture goes out of the display range (center) and guide her back (right).

ABSTRACT
To interact with wall-sized displays (WSD) from a five-to-ten feet distance, users can leverage touchless gestures tracked by depth sensors such as Microsoft's Kinect®. Yet when user's gestures inadvertently land outside the WSD range, no visual feedback appears on the screen. This leaves users to wonder what happened, and slows down their actions. To combat this problem, we introduce *Stoppers*, a subtle visual cue that appears at the gesture's last exit position informing the users that their gestures are off the WSD range, but being still tracked by sensors. In an 18-participant study investigating touchless selection tasks on an ultra-large 15.3M pixel WSD, introducing *Stoppers* made users twice as fast in getting their gesture back within the display range. Users reported *Stoppers* as intuitive, non-distracting and an easy-to-use visual guide. By providing persistent visual feedback, *Stoppers* show promise as a key ingredient to enhance fundamental mechanisms of user interaction in a broad range of touchless environments.

Author Keywords
Visual Feedback, Wall Displays, Touchless Interactions.

ACM Classification Keywords
H.5.2. **[Information Interfaces and presentation]**: User Interfaces—Interaction styles and strategies.

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INTRODUCTION
The dropping cost of display technologies and the growing need to visualize and interact with massive data sets are increasingly pushing *ultra-large, Wall-Sized Displays (WSD)* into meeting rooms, design studios and research labs [1, 2, 3]. Because of the scale and social proxemics of WSDs [4, 5], touchless user interfaces based on freehand, mid-air gestures can complement the WIMP (Windows-Icon-Menu-Pointer) paradigm in two major ways. First, touchless gestures support multi-user interaction (difficult with mice and keyboards) and *short-lived tasks* [3] (such as browsing, opening, panning, and zooming) that *do not require fine-grain editing*. Second, users can employ device-free, mid-air gestures while remaining *seated away from the wall display,* thus avoiding standing fatigue and gaining a *bird's eye* view of the display canvas [4].

Yet touchless interaction suffers from the lack of haptic feedback (due to the absence of a physical device), which may decrease the accuracy of object manipulation, sense of control and coordination [6, 7, 8]. Most importantly, touchless interaction exposes a difference between the *interaction space* (of mid-air gestures) and the *display space*. Specifically, the mismatch between the *sensor's tracking range* and the *system's display range* creates a gap between the system's behavior and the user's mental model. This happens when users perform a gesture that erroneously steps out of the WSD's range. When this occurs, visual feedback typically disappears from the display, leaving users disoriented. Unknown to users, the sensors, however, are still tracking users' gestures in such instances. How can we support users in resuming fluidly their touchless interactions when they accidentally go off the WSD range?

RELATED WORK

Feedback is fundamental to communicate to users the system status [9]. Previous studies on human performance in device-less input [8] indicate that, in the absence of kinesthetic feedback, visual representation of users' actions is key to allow immediate exteroceptive feedback. In state-of-the-art touchless applications, such as Kinect® Games, users' position is represented by avatars; for point-and-selection tasks in game menus, a transparent avatar and a hand shaped cursor is used. However, if users step out of the display range, Kinect® halts and prompts a *modal message* that interrupts the interaction flow and asks users to adjust their position. While this works for game consoles, we argue that knowledge work around a WSD requires less intrusive and more fluid ways to guide users back within the display range. Although a growing body of work is investigating human factors around WSD, the challenges associated to a mismatch between a wall display's range and the sensor's tracking range are still uncharted.

PERSISTENT VISUAL FEEDBACK WITH STOPPERS

Touchless environments consist of a sensor (like Vicon® or Kinect®) tracking user(s) and a system displaying the tracking information. In our informal observations with a 160" X 60", 15.3M pixel-WSD (Fig. 1), we found that when the users' gestures go off the WSD, and no on-screen visual feedback is available, users stop and get disoriented; this happens even when they are being tracked by the sensors. From our observations, we hypothesized that users halt because they perceive the lack of feedback as an error, and their reaction to an error is to slow down, a well-known phenomenon called post-error slowing [10].

Based on our hypothesis, we iteratively developed and tested *Stoppers* (Fig. 1), a novel visual cue in WSDs that uses the metaphor of stoppers (or plugs) to inform users that the system is still tracking their gesture, thus giving them the opportunity to instantly step back within the display's range. *Stoppers* support this action by providing visual feedforward (direction to move) and visual feedback (user's current position). As indicated in Fig. 1-left, if users gesture within the display range, visual feedback (such as a circle) is provided. When the users go off the display range, a semi-circle appears at the last-recorded within-display position of their gesture (Fig. 1-center). In our current instantiation of *Stoppers*, the change in feedback from a circle to a semi-circle subtly informs users that they are off the WSD and need to retrace their way to see the full feedback again. *Stoppers* disappear as soon as the user's gesture is back within the WSD range (Fig. 1-right).

RESULTS AND CONTRIBUTION

In a counterbalanced, repeated-measures study with two conditions (*Stoppers* and No *Stoppers*), 18 participants (9 males, 12 less than 25 years old) performed one-dimensional Fitt's reciprocal point-and-select tasks using touchless gestures in a custom environment (Fig. 1). One out of 18 user never landed outside the display range, while 7/18 users landed outside the display range in both *Stopper* and no *Stopper* conditions. A paired-samples *t*-test revealed that there was a significant difference in time to gesture back within the display range when *Stoppers* were present (M = 277ms, SD =115ms) compared to when *Stoppers* were not present (M = 722ms, SD =295ms), $t(6) = 4.65$, $p < .001$, $d = 2.25$. Time was manually recorded from post-video analysis and calculated using frames-per-second of the recorder. Further, users reported *Stoppers* as a non-distracting, helpful guide to keep them within the display's range and to help them retrace their steps. 4/18 users reported not even noticing *Stoppers* during the entire experiment, while post-experiment video-analysis revealed that most participants successfully used *Stoppers* for at least 10 times in a one-hour experiment session.

Several factors limit the generalizability of our results. These include the point-and-select task used, the size of and the distance from the display, and the Kinect® tracking sensors used. However, our findings show the potential of the *Stopper* metaphor to provide persistent visual feedback in any touchless environment, where the system's display range is lesser than the sensor's tracking range.

We are currently investigating how visual feedback affects individual and collaborative touchless WSD experience. Empirical data from these studies will generate the knowledge required to design next-generation interfaces for the collaborative use of high-resolution, wall-sized displays.

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