Laid-Back, Touchless Collaboration around Wall-size Displays: Visual Feedback and Affordances

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Abstract

To facilitate interaction and collaboration around ultra-high-resolution, Wall-Size Displays (WSD), post-WIMP interaction modes like touchless and multi-touch have opened up new, unprecedented opportunities. Yet to fully harness this potential, we still need to understand fundamental design factors for successful WSD experiences. Some of these include visual feedback for touchless interactions, novel interface affordances for at-a-distance, high-bandwidth input, and the techno-social ingredients supporting laid-back, relaxed collaboration around WSDs. This position paper highlights our progress in a long-term research program that examines these issues and spurs new, exciting research directions. We recently completed a study aimed at investigating the properties of visual feedback in touchless WSD interaction, and we discuss some of our findings here. Our work exemplifies how research in WSD interaction calls for re-conceptualizing basic, *first principles* of Human-Computer Interaction (HCI) to pioneer a suite of next-generation interaction environments.

Author Keywords

Touchless Gestures, Visual Feedback, Collaboration, Wall-size Displays.

ACM Classification Keywords

H.5.2. **[Information Interfaces and presentation]**: User Interfaces—Interaction styles and strategies.
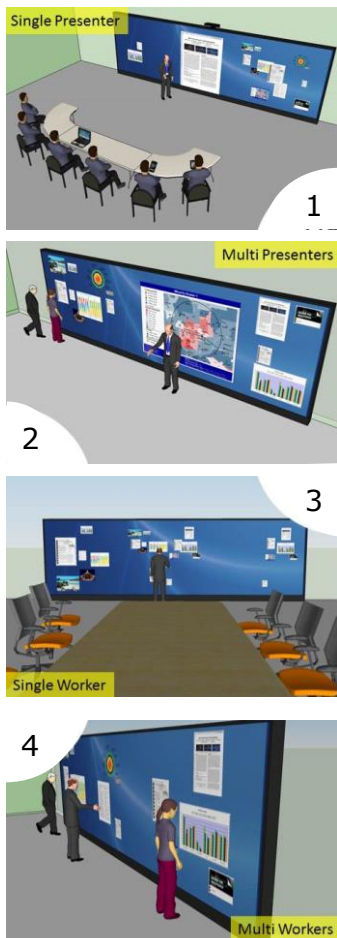
Figure 1. Four different Wall-size Display settings supporting individual and collaborative tasks.

Introduction

Ultra-high-resolution Wall-Size Displays (WSDs) promise great potential to embrace the challenges of "big data" interaction in a variety of collaborative settings (Fig. 1). To support the highest level of fluid interaction with WSDs, the traditional WIMP (Windows-Icon-Menu-Pointer) paradigm is being progressively complemented by touchless, mid-air input – especially for away-from-the-display tasks, multi-scale and multi-user scenarios [1][4][5]. However, such device-free interaction suffers from several, constraining factors [15], including (a) absence of haptic and visual feedback, (b) persistence of WIMP-based affordances and (c) frequent user fatigue. These issues sit in a high-level, physical interaction and collaborative space that can be broadly characterized by two dimensions: *interaction modality* and *user posture* (Fig. 2). Both greatly influence key elements of the WSD user experience, including the range of possible actions, user fatigue, as well as social factors like sustained, collocated collaboration. *Touch* and *Touchless* modes span the range of emerging interaction modalities for WSDs. Similarly, *Standing* and *Sitting* most basically reflect the proxemics of WSD experiences: *near* and *far* from the display.

Laid-Back At-a-Distance Touchless Interaction (LATIN)

Current WSD research spans across all quadrants (Fig. 2), but few works have investigated the potential of WSDs in supporting situations in which users are comfortably seated (laid-back), away from the display, and engaged in touchless, collaborative interactions [4]. This type of *Laid-Back At-a-Distance Touchless Interaction (LATIN)* (Fig. 2) is suited for a broad range of scenarios where interaction with the display has to
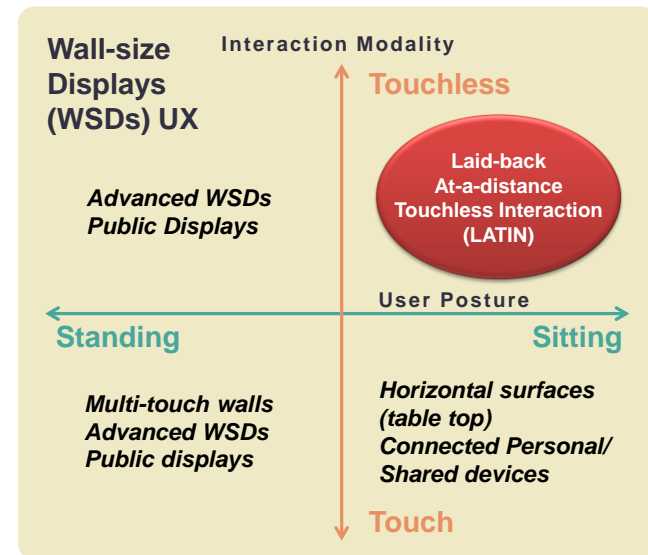

Figure 2. Our current **position** in the WSD research across interaction modalities and user postures: **Laid-back At-a-distance** Touchless Interaction (LATIN) with WSDs.

fluidly integrate with the fabric of the social collaboration already happening between users. For example, a typical LATIN scenario sees participants engaged in a design-brainstorming meeting that involves discussion and interaction with a variety of physical artifacts; *in addition*, participants may *sporadically* need to execute short-lived tasks, such as opening, closing, moving, zooming, and marking content assets on the WSD from a distance. In another instance, a group of WSD users may visualize a dataset to make decisions; they are situated away-from-the-display for a *bird's eye view* and may need to mark different areas and sub-areas (multi-scale exploration) for later review, draw connections among views, scroll around or pan-and-zoom. In these contexts, using touchless gestures become a fundamental and much

needed ingredient, because users may not have a flat surface readily available (for a mouse or track pads) during the dynamic interactions happening in a meeting.

Open Questions

LATIN opens up an exciting problem space and spurs novel, fundamental questions regarding the WSD user experience, including:

- What type of feedback (Where am I? What am I doing?) should be provided to users?
- What kind of affordance languages is appropriate for a LATIN user interface?
- How can we effectively map the system's model to the users' mental model?

In addition, relevant human-factor and group awareness questions also spring up:

- How can we model and predict task performance in LATIN environments?
- How can LATIN support the range of different user postures and social settings?

In our recent study, we tackle some of these quests.

Towards Understanding Visual Feedback

To shed light on some basic, fundamental interaction ingredients of LATIN, we recently conducted a pilot study that empirically examined the properties of *visual feedback* necessary to support touchless point-and-select (selection tasks) for Wall-Size Displays (WSD). Prior research proposes pointing techniques for very large displays along with audible and visual feedback [13], but the relationship between visual feedback [6] and user experience remains an unmapped area.

In an 18-participant study, we investigated touchless selection tasks on an ultra-large 15M pixel WSD to
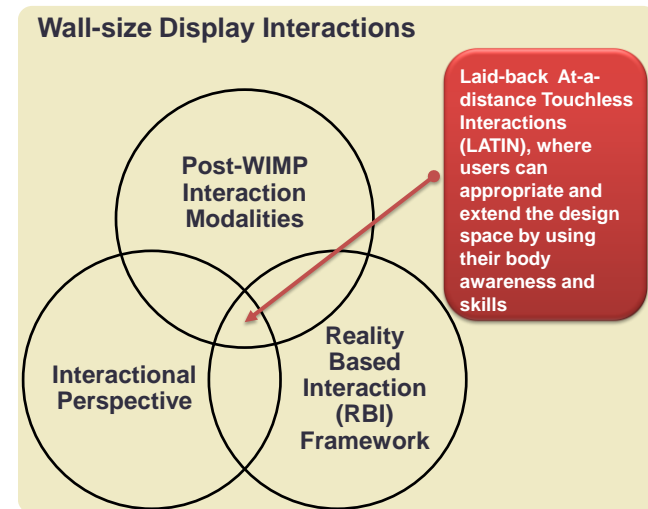

Wall-size Display Interactions

Post-WIMP Interaction Modalities

Interactional Perspective

Reality Based Interaction (RBI) Framework

Laid-back At-a-distance Touchless Interactions (LATIN), where users can appropriate and extend the design space by using their body awareness and skills

Figure 3. Our stance towards designing Laid-back At-a-distance Touchless Interaction (LATIN) is to let the **users appropriate and extend the design space by using their body awareness and skills**.

discern four pillars of touchless feedback: (1) guidance when gestures exit the WSD range; (2) alternative shapes, sizes and colors of feedback, (3) feedback status change, and (4) discrete vs. continuous feedback.

Broadly speaking, our work addresses the need of developing appropriate *Feedback Languages* for future innovation in touchless technologies and embraces the critique of gestural interfaces in terms of their intrinsic naturalness, intuitiveness and learnablility [7]. Focusing on multi-touch and surface computing, prior work [14] has reported that leveraging users' motor, cognitive, and social abilities can lead to production of better user interfaces that are both learnable and rich in communication bandwidth. We also build on the position proposed by the interactional perspective [10],
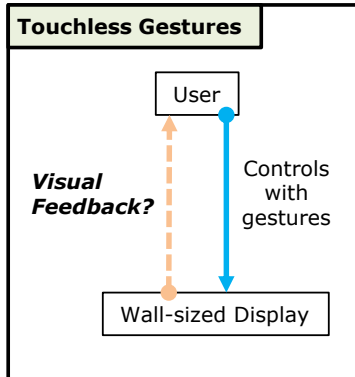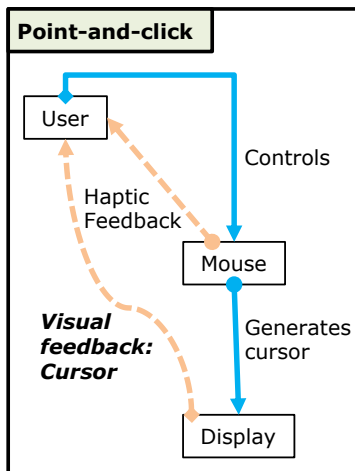
User

Controls

Haptic
Feedback

Mouse

*Visual
feedback:
Cursor*

Generates
cursor

Display

Touchless Gestures

User

Controls
with
gestures

*Visual
Feedback?*

Wall-sized Display

Figure 4. Designing Feedback Languages for Wall Displays: While the mechanisms for traditional mouse-based visual feedback are clear, the nature of visual feedback for touchless gestures in WSD (therefore in an absence of a pointing device) calls for new research.

in which users appropriate and extend the design space of natural user interfaces by using their own *body awareness and skills*, along with the knowledge acquired about the system's mental model. Using one's own *body awareness and skills* is part of Jacob's Reality-Based Interaction (RBI) Framework [3]. RBI's stance is that users engage in these environments by leveraging their pre-existing knowledge of the everyday world, their own bodies (naïve physics), as well the surrounding environment and social context (Fig. 3).

Feedback Designs and Controlled Experiments

To investigate the effect of visual feedback in touchless interactions for point and selection tasks (Fig. 4), we have developed and used the Wall Display Experience Research (WADER) interactive environment (Fig. 6), a system specifically designed to support user experiments on WSD interactions with off-the-shelf sensors (Kinect). With WADER, we focused our work on supporting and studying two *atomic* touchless interactions: *Select* and *De-select*. Using these two gestures users can do *basic* tasks: **selection** (select→deselect) and **movement** (select→ move→ deselect). We investigated the following dimensions.

Persistent Guidance when Gestures exit Sensor-Range
In touchless WSD interactions, a typical gap between system's behavior and users' mental model happens as users perform a gesture that erroneously steps out of the sensor's range (Fig. 9). When this occurs, visual feedback disappears from the display, leaving users disoriented and causing them to stop (even if the sensor is still tracking the users' behavior). Users perceive lack of feedback as an error, and users' reaction to an error is to slow down, a phenomenon called post-error slowing [8]. To combat this, we

developed and tested *Stoppers*, a novel visual cue in WSDs that use the metaphor of stoppers (or plugs) to inform users of an error and to slow them down, thus giving them the opportunity to step back within the sensor's range by providing both feedforward (direction to move) and feedback (their current position).

Alternative Visual Designs for Selection Feedback
While the traditional mouse cursor works well as feedback for close-to-the-display interaction aimed at fine grained motor movements, it falls short in supporting touchless WSD interactions that feature device-free, high-bandwidth input through ample movements directed to an ultra-large surface. Novel forms of touchless feedback are needed that are sufficiently visually salient (e.g., in shape, size, color) to inform users' of their movement and actions on a WSD. To explore the design space of touchless, visual feedback, we investigated five features of the feedback signifier on point and selection tasks. We designed and prototyped alternative shapes and colors (Fig. 7) based on their reported efficiency in counting tasks and visual search [2] because we wanted these signifiers to be sufficiently discriminatory [11] but not overtly distracting. *Alternative sizes* were also designed and developed based on their reported efficiency in information visualization. We used small (50%), medium (100%) and large sizes (200%) with respect to our target size (see [9]). *Opacity and dimensionality* [12] were systematically manipulated based on prior work that reports an effect of these properties on user experience for a variety of tasks such as visual search, desktop operations and information visualization.

Feedback Information Entropy on Selection Tasks
To explore how touchless feedback can convey a "change of status", such as the accomplishment of a

1. No Fill → Opaque

2. Opaque → No Fill

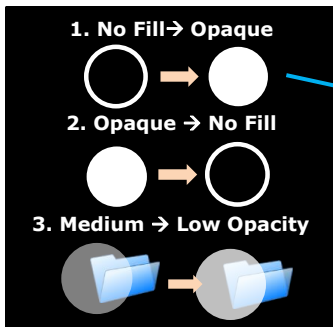**3. Medium → Low Opacity**

Figure 5. To support touchless "selection feedback" on WSDs, we explored alternative forms of signifiers. Participants rated items 1 and 3 as most salient feedback during WSD interactions.

Study Design

- 18 participants (9 M), 12 less than 25 yrs. old
- Prior Touchless Experience: Kinect 11%, Wii 17%, both 61%
- Training threshold: Picture-puzzle solving (Fig. 6) in less than 5 minutes.
- 5 within-participant experiments on *point* and *selection* tasks with varying feedback properties in WADER (Fig. 6);
- 1.5 hrs. of experience for each participant
- 6624 task instances collected across sessions per participant
- Measures: Efficiency (task errors and time on task), effectiveness (task success), and user satisfaction (self-reported preference).
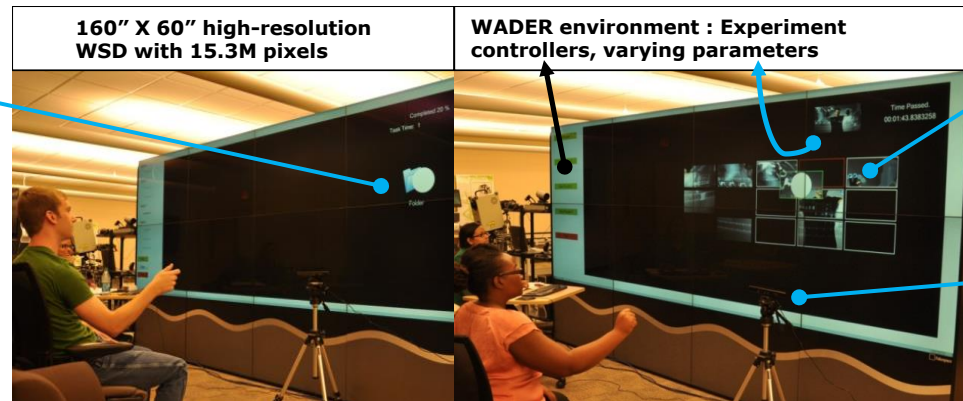
160" X 60" high-resolution WSD with 15.3M pixels

WADER environment : Experiment controllers, varying parameters

Study participants execute touchless gesture training tasks by solving picture puzzles.

Markerless Motion Tracking Sensor: Microsoft™ Kinect

Figure 6. The Wall Display Experience Research (WADER) interactive environment is designed to support user studies on touchless interaction with WSDs, directly deployed on the 160" X 60", ultra-high resolution, wall-sized display (15.3 million pixels).

basic action, we systematically varied the amount of visual feedback (Fig. 5) change in response to a selection task. We modeled this change of status in terms of "information entropy", indicating the amount of perceived new information that the feedback is providing towards user's uncertainty (system's interpretation of user's action). We tested what type of change in the feedback signifier (e.g., color, shape) best support user performance during selection. Does providing more information, make any difference? Which type of change is most preferred by users?

Discrete Vs. Continuous Presence of Feedback
Finally, to study the invocation of feedback, we further designed a no feedback condition (no explicit information on gesture's location, but a proximity clue) and two experimental conditions: 1) Continuous feedback, which is continually active with no need to invoke it; and 2) discrete feedback, invoked by stationary (*5s*) hand, to combat accidental invocation of gesture tracking and any unintended operations.

Preliminary Results
Investigating appropriate designs of visual feedback is critical for touchless WSD interactions because the distance from the display and the absence of haptic feedback create a gap (an open-loop) between the user's and the system's mental model. Research on touchless WSD interfaces can leverage our results to bridge this gap effectively and inform the design of touchless systems and WSD collaborative environments. In terms of feedback presence, both continuous and discrete feedback was equally efficient to support touchless gestures, and can be further explored as promising feedback modalities. As to the visual feedback signifier, our results suggest that *symmetrical shapes with at most 4 vertices* may be used to design an array of feedback signifiers for WSD users; medium size instead of large sized signifier can also be used without significant loss in user efficiency. While shape changes proved distracting (Fig. 8), feedback's status change (or information entropy) can be effectively increased
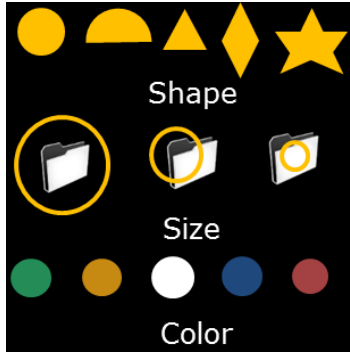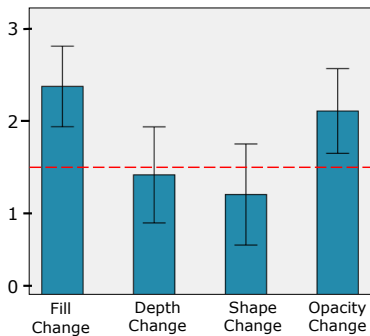
Figure 7. We manipulated different properties of the feedback signifier: shape, size (.5,1 and 2 times the folder) color (black background with green, yellow, white, blue and red), opacity and depth.

Mean Preference Score [0-3]

Types of Feedback Entropy Changes

Figure 8. Feedback information entropy had a significant effect on user preference for selection tasks: users preferred fill change and opacity change over change in depth or shape.
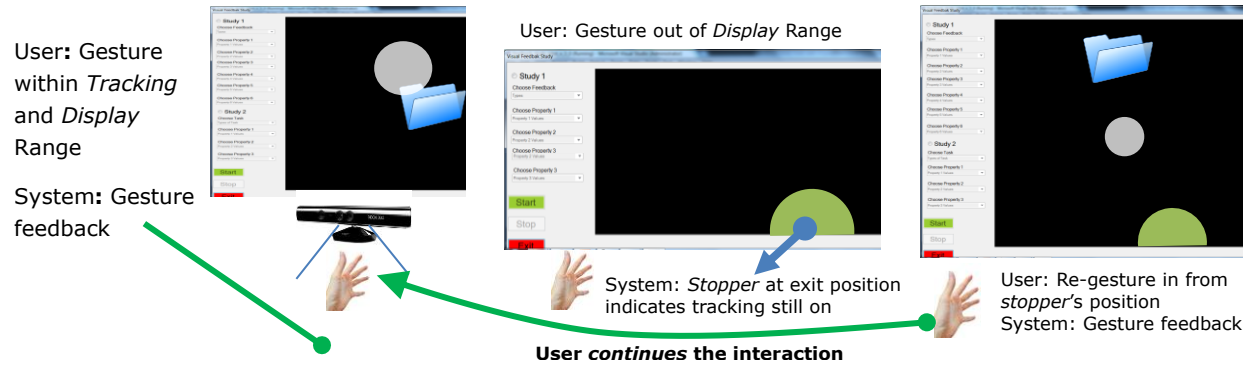
User**:** Gesture within *Tracking* and *Display* Range

System**:** Gesture feedback

User: Gesture out of *Display* Range

System: *Stopper* at exit position indicates tracking still on

User: Re-gesture in from *stopper*'s position
System: Gesture feedback

User *continues* the interaction

Figure 9. By introducing persistent visual feedback as users move out of the wall-display range, ***Stoppers*** decrease users' disorientation and facilitate the recovery of touchless gestures within visible range

by *transitioning an unfilled signifier into low opacity* to inform users of any successful selection. Finally, irrespective of the specific form of feedback, visual cues such as *Stoppers* perform a fundamental function to assist users when touchless gestures exit the WSD range. Our current and future work follows two directions: 1) understanding how collaborative visual feedback affects WSD collaborative task and touchless performance and 2) comparing WSDs' collaborative user experiences across a variety of interaction modalities, such as touchless, multi-touch and other tangible devices. Empirical data from these studies will generate the knowledge required to effectively design next-generation interfaces for the collaborative use of high-resolution, wall-sized displays.

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