MAGIC-Pointing on Large High-Resolution Displays

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Abstract

Display space in offices constantly increased in the last decades. We believe that this trend will continue and ultimately result in the use of wall-sized displays in the future office. One of the most challenging tasks while interacting with large high-resolution displays is target acquisition. The most important challenges reported in previous work are the long distances that need to be traveled with the pointer while still enabling precise selection as well as seeking for the pointer on the large display. In this paper, we investigate if MAGIC-Pointing, controlling the pointer through eye gaze, can help overcome both challenges. We implemented MAGIC-Pointing for a 2.85 m $\times$ 1.13 m large display. Using this system we conducted a target selection study. The results show that using MAGIC-Pointing for selecting targets on large high-resolution displays decreases the task completion time significantly and it also decreases the users' task load. We therefore argue that MAGIC-Pointing can help to make interaction with large high-resolution displays usable.

Author Keywords

Large high-resolution display, wall-sized display, eye-tracking, magic-pointing

ACM Classification Keywords

H.5.2 [User Interfaces]: Input devices and strategies.

Introduction and Related Work

Pointing is one of the most common tasks when interacting with computing systems. Different input techniques became widely accepted for different form factors. While direct touch became the prevalent technique for mobile devices, touchpads are commonly used with notebooks. The mouse is by far the most common pointing device for desktop computers. If we look at large high-resolution displays (LHRDs), however, we see an ongoing discussion about pointing techniques. As Esakia et al. [3] argue, a pointing technique for LHRD has to be fast to travel long distances but precise to enable distinguishing between small elements. Indirect pointing techniques that rely a pointer on screen have the additional challenge that users lose the cursor and have problems recovering [9].

As Kern et al. [8] point out, eye tracking can particularly beneficial as an interaction technique for switching between tasks, especially if they are presented in different visual areas. Thus, eye gaze-based interaction has been explored for larger screens. Dickie et al. [1] use gaze pointing to select one of three 17 inch screens. In a user study the authors show that gaze is significantly faster than using multiple keyboards or pressing a button for switching.

Fortmann et al. [5] designed two cursor recovery techniques for multiscreen environments based on the results of interviews and surveys. The first technique allows users to move the cursor to the currently focused area by pressing a key combination on the keyboard. The second technique, indicates the cursor position by displaying arrows from the currently focused area to the cursor position. The results of a user study indicate that users can recover the cursor faster, if the cursor is directly moved to the focus point. This results can also be applied to window activation. Fono and Vertegaal [4] show that users are able to select faster with eye tracking support and also prefer this technique.

Turner et al. [11] investigated the possible advantages for for graphical object transformations in visual rich environments. They implemented different complex interaction techniques (rotation, scaling, translation), but did not assess pointing. Their approach combines eye gaze and multitouch input which they evaluated in a lab study. They used a display with a size of $4\,\mathrm{m} \times 1.24\,\mathrm{m}$. This is similar in size to the apparatus used in this study, but has a lower resolution of 2560×800 pixels. The study results indicate that eye tracking speeds up these interaction tasks. This motivated us to assess pointing as a basic interaction and additionally, measure the task load.

Already in 1999, Zhai et al. [12] developed MAGIC-Pointing a concept that enables to move a cursor rapidly, precise, and makes recovering the cursor easy. They proposed to combine eye gaze with a standard input device. To respect the eyes' primary perceptual function, the authors implemented two different eye gaze-based pointing concepts.
In the first approach, the cursor is directly moved to users' gaze point. In the second concept, instead of warping the cursor directly, the cursor moves to user's focus point as soon as the manual pointing device is moved. In a lab study the authors compared both concepts with a standard isometric pointing stick. In a study with a 20 inch screen, it was shown that using MAGIC-Pointing decreased task completion time (TCT) for target selection tasks. Drewes et al. [2] improved this further by developing a touch sensitive mouse to trigger gaze pointing for faster selection. To select small objects Stellmach and Dachselt [10] proposed using a touch device to distinguish between objects in the area around the gaze point.

Overall, previous work recognized that indirect pointing techniques are challenging for very large displays. Previous research explored the use of eye gaze to select different screens or to perform complex object manipulations. Already in 1999, however, Zhai et al. proposed MAGIC-Pointing which has the potential to avoid the lost-cursor problem, enables very fast cursor movement and fine-grained control. In the following, we investigate the potential of MAGIC-Pointing for large high-resolution displays (LHRDs).

Evaluation

Study Design

The study used a within-subjects design with two conditions: using *gaze warp* and *mouse only*. In the *mouse only* condition, participants had to select the targets as fast as possible by moving the mouse cursor to the target position. In the *gaze warp* condition, the participant was able to jump the cursor position directly to his or her gaze position on the screen by pressing the right button of the mouse. While performing this condition the participant was still able to move the cursor using the mouse.

Apparatus

Display Setup: To evaluate MAGIC-Pointing on LHRDs we built an experimental setup consisting of four Panasonic TX-50AXW804 50 inch screens with a resolution of 3840 × 2160 pixels in portrait mode. Total display resolution was 8640 × 3840 pixels (96 PPI). Figure 1 shows all screens in portrait mode facing the participant's position. The two screens on the left and right were tilted to the central screens to have the same distance between the participants' position and all screens. The whole display had a size of 2.85 m × 1.13 m. To provide an optimal view on the display all screens were mounted 0.75 m above the floor.

Each of the four screens was tiled into a 3 × 6 grid, which leads to 72 possible target locations on the whole LHRD.

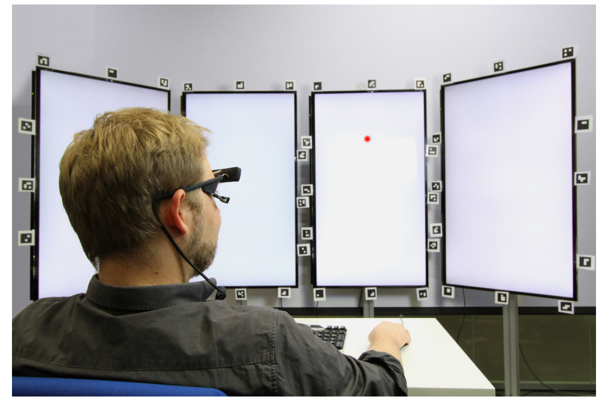

Figure 1: Pupil Pro eye tracker and LHRD experimental setup

Each target appeared twice in each condition, which results in 144 targets per condition. The order of the targets was randomized. We ensured that two targets do not appear at the same position directly after each other. We decided to place the starting point in the center of the second left screen. We used this position because the setup of four screens does not allow to use the center of the LHRD as starting position.

Participants were seated 1.5 meters away from the display resulting in an angular size of 79.1° (H), 40.3° (V). Size and color of the cursor were set to the default settings of Windows 8.1. The background color was white. The target was a red filled circle with 216 pixels in diameter (5.8 cm), which corresponds to a visual angle size of 2.26°.

Eye Tracking: We used the Pupil Pro [7] and the Pupil Capture software. The eye tracker is a head-mounted monocular eye tracker for eye tracking. We used a head-mounted eye tracker, because this allows participants to move the head while using the eye tracker. To the best of our knowledge no commercial stationary eye trackers can track the eye while rotating the head by 90° enough to see the whole display. To determine where the participants looked on the display we attached 12 markers on the bezels of each screen. We used the markers provided by Pupil Labs with a size of 4.5 cm × 4.5 cm.

The computer running the LHRD used Microsoft Windows 8.1. All screens of the LHRD were registered and mapped by the Pupil Capturing software according to the virtual desktops of the computer. By using *gaze warp* the mouse cursor could be placed to the computed gaze point on the LHRD.

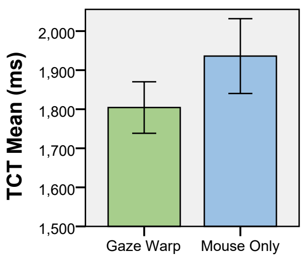

Figure 2: Average task completion time using gaze warp and mouse only condition. Error bars show standard error.

Procedure
We conducted the study with 12 participants (9 male, 3 female) aged between 20 and 39 (M = 26.1, SD = 4.8). The data from three additional participants could not be considered because the eye tracker could not track the pupil while the participant wore glasses or because the eye lashes occluded the pupil.

The participants were seated at a table in front of the LHRD. After explaining the task the eye tracker was set up for the participant. Following the default calibration routine of Pupil Capture software, a test run of the experiment was started and the participants were asked to familiarize themselves with the task for both conditions.

Upon pressing the space key on the keyboard, the next target appeared, and the mouse cursor was reset to the start position on the second left screen. A target selection ended when the left mouse button was clicked on the target position. Therefore, we did not count errors. After completing each condition we asked every participant to fill out a NASA-Task Load Index (NASA-TLX) questionnaire [6] to rate the task load. Afterwards, we conducted semi-structured interviews.

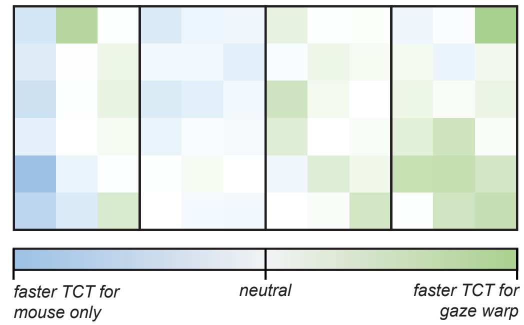

Figure 3: TCT distribution: blue indicates faster target hits for *mouse only*, green indicates faster hits using *gaze warp*. White implies on condition had an advantage.

Results

Task Completion Time
The TCTs were not normally distributed. Therefore, we performed a Wilcoxon signed-rank test. The test revealed a statistically significant effect of the input method on the TCT (N = 864, Z = 1.984, p < .047). Participants were significantly faster using gaze warp (Mdn = 1675.95, M = 1804.33) than using mouse only (Mdn = 1677.76, M = 1936.04).

To understand how the TCT differs across the screens, we analyzed the TCT for each target position. As Figure 3 shows, TCT is heterogeneously distributed. There is a tendency at the left-hand side of the LHRD for shorter TCTs of the *mouse only* condition and at the right-hand side for shorter TCTs of the *gaze warp* condition. The comparison of the average TCT per target shows that the mouse only condition was maximal 1.763 sec. faster than gaze warp. For the *gaze warp* condition the TCT average per target was maximal 1.541 sec. better than the *mouse only* condition.

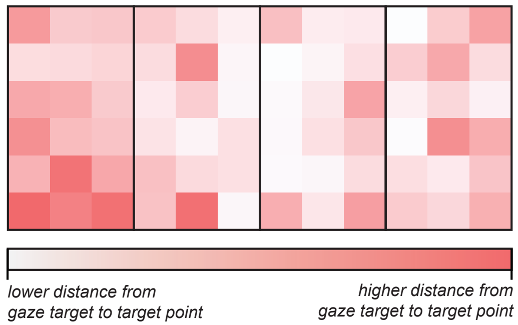

Figure 4: Distance between cursor position after gaze warp and target position.

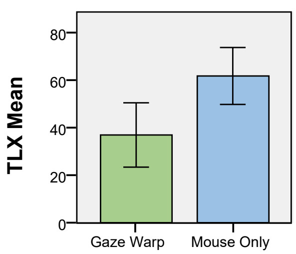

Figure 5: Average NASA-TLX-score of gaze warp and mouse only. Error bars show standard error.

To get deeper insights why the TCT is heterogeneously distributed, we analyzed the angle between the position, on which the cursor was warped, and the target position. On average the deviation between cursor position after gaze warp and target was 3.56° (SD = 3.55°) (which is equivalent to M = 352 pixels, SD = 352 pixels). Figure 4 shows the deviations for each target location. The angle with lowest average from cursor position after warping to the target location is 1.79°, the highest angle between both is 6.26°.

Furthermore, we compared how many gaze warps the participants performed to acquire targets. On average, participants used 0.97 (SD = 0.36) gaze warps per target acquisition. Figure 6 shows the frequency of gaze warps per target acquisition. The target with the fewest average number of gaze warps was focused 0.542 times per target acquisition. The target with the highest average number of gaze warps was focused 1.208 times per target acquisition.

Subjective Feedback

We analyzed the perceived work load measured through the TLX questionnaire (see Figure 5). A paired sample

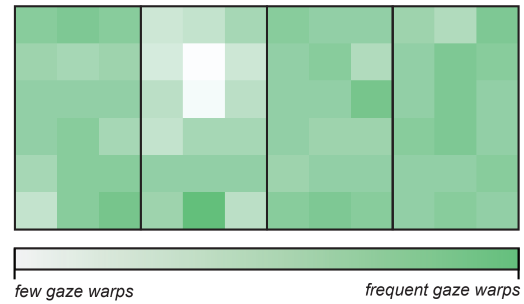

Figure 6: Frequency of gaze warps. Green color indicates more overall use of gaze warps on a target location.

t-test of the normally distributed scores revealed a significantly lower work load using gaze warp (M = 36.91, SD = 23.43) than using mouse only (M = 61.75, SD = 20.75).

The results from the NASA-TLX support the qualitative feedback from the participants. All but one participant appreciated describe gaze warping on LHRDs as valuable and pleasant to use. An important aspect reported by one participant was that using the mouse for large distances requires a large area on the desk. Another noteworthy observation is that positive subjective ratings of the gaze warp condition does not necessarily correlate with the task completion times of the users. Participants with similar completion times after performing both conditions still favoured using gaze warp instead of mouse only.

Discussion and Future Work

Overall the results of our study are very positive, both in terms of TCT and task load. They indicate that using MAGIC-Pointing on LHRDs is beneficial. The results revealed a significantly shorter TCT when using MAGIC-Pointing on LHRD. However, a more detailed analysis indicated heterogeneously distributed TCTs over the display space. The analysis of TCTs per target shows a difference between the left side of the LHRD for improved task performance of the *mouse only* condition and to the right for the *gaze warp* condition (see Figure 3).

The analysis of distances between target position and cursor position, after gaze warp, also shows heterogeneously results. Gazes to the left displays of the LHRD are detected less precise. In the areas, where the *mouse only* condition revealed shorter TCTs, the distances between cursor position after gaze warp were larger than in areas where the *gaze warp* condition revealed shorter TCTs (compare Figure 3 and Figure 4). The larger distances between both points could be caused by participants not look directly on the targets in this area. However, more probably, the quality of the gaze data is heterogeneous over the display space. This was probably due to the monocular Pupil Pro eye tracker which detects eye movements of the right eye from the right side. We would have assumed more homogeneous results when repeating the experiment with a binocular eye tracker, instead of a monocular one. In contrast to TCT, frequency of performed gaze warps where relatively homogeneous over the whole display space (see Figure 6). The optimum would be one gaze warp per target acquisition. Then, participants are expected to be faster using MAGIC-Pointing. If more than one gaze warp is performed, the cursor is not moved to the target position in the first trail. Participants used the gaze warps on all areas of the LHRD. Only on the screen where the cursor was placed in the beginning of each trial, participants used less gaze warps.

Participant's task load decreased significantly with MAGIC-Pointing. The significant lower task load indicates that participants had to care less about the current cursor position and can work more focused on their main task. Additionally we assume that, with trainingTCT will further decrease.

In the next step, we will analyze how MAGIC-Pointing on LHRD is influencing users' performance for regular office tasks. We expect to identify a number of applications for eye-tracking in combination with LHRD-workplaces. Eye tracking allows applications to gather knowledge about what the user has seen or not. Thereby, systems can conclude how focused the user currently is. On one hand, this would allow to guide needed attention to not noticed information like notifications. On the other hand, the system could help the user focus and automatically hide not focused information in the peripheral view. Similar to the work by Turner et al. [11], eye tracking could be used in an office scenario for window manipulation. Users could select windows with gaze and reorder or re-size them using a touch pad or a mouse.

To conclude, the results of our work show that MAGIC-Pointing is a beneficial option to improve pointing on LHRD. In future experiments, we will synthesise positive effects in novel interaction techniques.

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