Interaction Techniques for Window Management on Large High-Resolution Displays

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ABSTRACT

Large high-resolution displays (LHRDs) present new opportunities for interaction design in areas such as interactive visualization and data analytics. Design processes for graphical interfaces for LHRDs are still challenging. In this paper, we explore the design space of graphical interfaces for LHRDs by engaging in the creation of four prototypes for supporting office work. Specifically, we investigate how users can effectively manage application windows on LHRDs using four window alignment techniques: curved zooming, window grouping, window spinning and side pane navigation. We present the design and implementation of these window alignment techniques in a sample office application. Based on a mixed-methods user study of our prototypes, we contribute insights on designing future graphical interfaces for LHRDs. We show that potential users appreciate techniques, which enhance focus switching without changing the spatial relation between related windows.

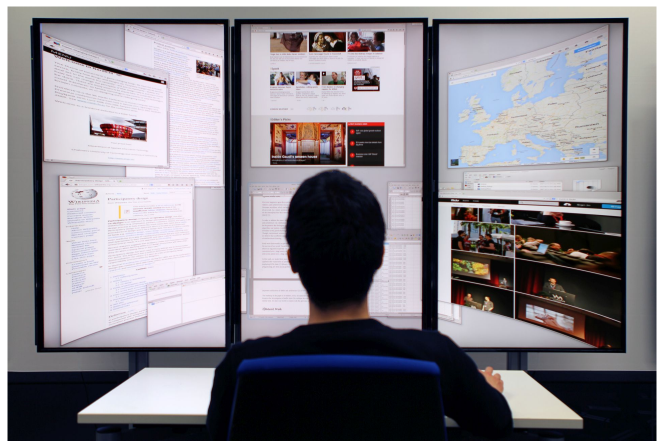

Figure 1. The study setup we used in our evaluation study with the *Curved Zooming*.

Author Keywords

Large High-Resolution Displays; Interface Design; Desktop Environments; Office Environments.

ACM Classification Keywords

H.5.2 User Interfaces

INTRODUCTION & BACKGROUND

Over the last decades, screen size and resolution increased continuously. While monitors of IBM's first PCs had a diagonal of 13″, monitors today often have more than 20″ diagonal. This increase in display space enhanced working productivity [9]. In line with visionary concepts, like the i-Land [26] and due to technical advances in hard- and software technology, we assume that displays exceeding human vision in size and resolution will become commonplace in office environments in the next years. For describing such displays, we use the definition by Andrews et al. [2] and call them LHRDs. Today, large displays are widely available as smart TV screens, and we assume that the screen resolution will still increase in the next years. However, the potential of LHRDs is not fully used due to user interface (UI) challenges. We expect that LHRDs will increase productivity for many tasks e.g., control rooms [29]. Furthermore, new possible working processes will allow users to perform novel tasks and support collaboration.

LHRDs allow visual content to be distributed across a large area, which enables users to display more content at a time. Furthermore, the large visual space enables new techniques for attention switching. Users can shift their attention to secondary information in the periphery without hiding main task information [17]. Additionally, this space can be used for spatial content arrangement [3], as placing information in a meaningful and efficient way is one of the core capabilities of humans [11]. This is particularly important for exploring and understanding relationships between different data sets [4]. Hence, Wei et al. [27] designed an LHRD setup for data analysts, analyzing network processes. Rooney and Ruddle [23] presented HiReD, a multidisplay desktop environment for visual analytics as a starting point for designing novel interfaces for LHRDs. Both Rooney and Ruddle [23], as well as Wei et al. [27], focus on the implementation of an LHRD system.

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LHRDs can improve user performance in seated scenarios or office environments [9], which is the dominant pose in which users work with office computers. Bi and Balakrishnan [8] asked office workers to perform their work over a period of five days on an LHRD. The LHRD was preferred by all participants to using their regular set with one or two desktop screens. Additionally, Rajabiyazdi et al. [20] argue that working with LHRDs enable users to get new insights in data sets. Consequently, future generations of desktop environments should scale up.

Designing UIs for LHRD setups is still challenging. Hence, Rajabiyazdi et al. [20] call for rethinking interface design for LHRDs. On the one hand, the larger visual space allows displaying more information. On the other hand, window management and alignment becomes more critical and time-consuming than on regular desktop screens [8, 21]. Therefore, it is important to provide well-designed access to all visual objects on a screen, even if the distance to the object increases [21]. For example, guidance to group visual information and windows in meaningful spatial areas would be beneficial when using LHRDs. That would help identify all visual objects and quickly select them for interacting with them. Furthermore, the balance between providing a large and detailed overview and avoiding distraction while working focused is key. Users need UIs that allow them to focus on their work and display large amounts of visual information without visual overload.

To provide an overview without distracting the user, Baudisch et al. [5] proposed to lower resolution in the preferential areas. This approach seems to be also suitable for collaborative office work [19]. In contrast, our approach allows moving the focus area dynamically. For keeping an overview over multiple windows, Bi et al. [7] suggest offering predefined window arrangements for several tasks. Among other things, they propose spreading out a group of windows or piling them. However, this does not support custom spatial arrangements. We recognize the need to allow users to switch context while keeping relevant spatial relations.

Several publications propose radically novel UI designs for interacting with content on LHRDs. However, all of them focus on activities which are currently rarely performed on PCs. These novel interfaces focus on exploring visual data while standing or moving in front of an LHRD [12, 13, 14, 24]. LHRDs are well suited for exploring while standing or moving. However, we suppose that LHRDs will, in future, also be used for tasks users performing on desktop setups today. Replacing well-known UIs is challenging because users are highly trained in using traditional interaction metaphors. Due to legacy issues, we extend common desktop interfaces.

The contribution of this paper is the design of four different window alignment techniques for office work on LHRDs. We present the design process as well as the implementation written in C++ and OpenGL for the desktop environment KDE Plasma. To our knowledge, our work constitutes the first exploration of desktop windowing environments for office work on LHRDs.

DESIGN

We envision that LHRDs will become commonplace in office environments. We designed four window alignment technique extending classical window management, assuming future LHRDs will have a size of at least $2 \times 1\,m$ (see Figure 1) and a high screen resolution (minimal 80 PPI). We synthesized all four window alignment techniques from previous work:

Curved Zooming

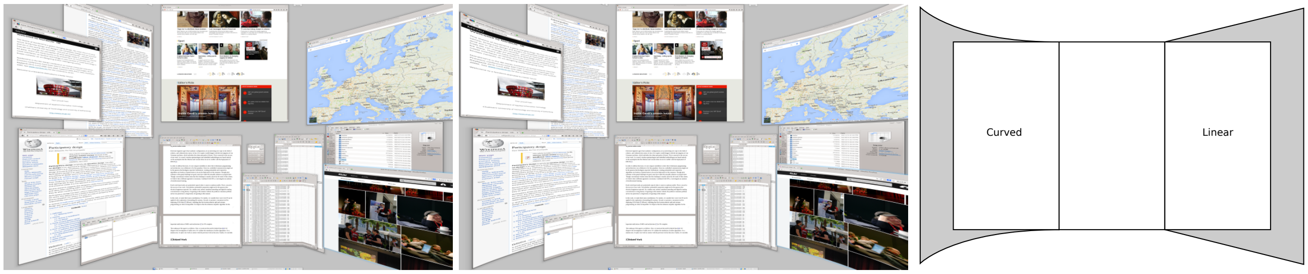
Mackinlay et al. [18] proposed the "perspective wall" which provides details in the center of the display while perspectively decreasing details on the left and the right side. Thereby, the user shall get a better spatial overview of limited screen space. In contrast, Shupp et al. [25] show that performance when working with a large curved screen is better than when using a large flat screen. A curved LHRD has the advantage that the viewing distance is equal to the whole screen space. Hence, all visual content is perceived to be the same size. However, curved display arrangements are not always possible. Due to the physical size of flat LHRDs, content in the periphery is perceived smaller and might be too small to read. We envision a digital zoom of right and left the side to overcome the readability issue. Hence, the content displayed in the center has the original size, and content in peripheral areas is zoomed. Further, we envision two types of zoom: A constant zoom factor resulting in a *Linear Curved Zooming* (see Figure 2a) and a squared zoom factor resulting in a *Squared Curved Zooming* (see Figure 2b).

Side Pane Navigation

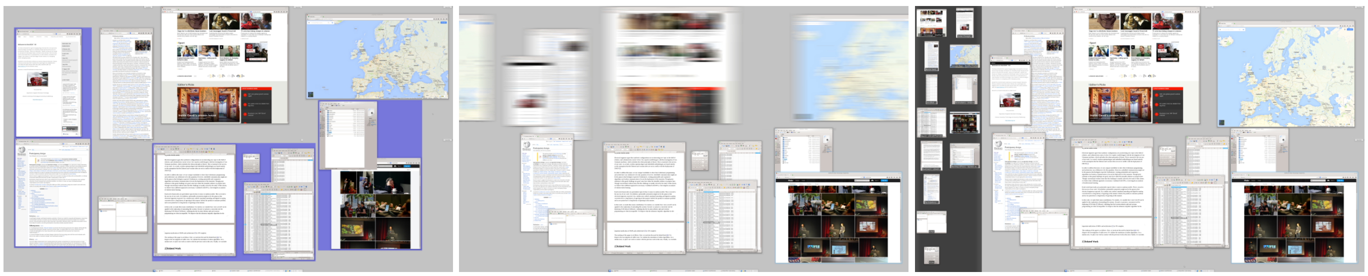
Hutchings et al. [10] argue that large screens lead to more open windows at a time. Bezerianos and Balakrishnan [6] show that users tend to separate content on single screens. To keep track of all open windows, we introduce *Side Pane Navigation*, which presents a real-time thumbnail of each window on the left side of the screen (see Figure 2f). Furthermore, Andrews et al. [1] stated that moving the head is faster than directing the cursor with the mouse. Therefore, we see a need for a shortcut to move the mouse to the *Side Pane Navigation*. As a consequence we implemented a keyboard shortcut to jump to the *Side Pane Navigation* bar. Also, when selecting a window in the *Side Pane Navigation* bar, the cursor jumps to the window and the window will be highlighted.

Window Spinning

Andrews et al. [1] report that LHRDs enable spatial arrangements of information, which changes the way users work and think. However, this requires a physical move to get an overview or to switch focus. In line with Roberson et al.'s [21] Tablecloth, we designed *Window Spinning* to allow content switching without changing the seating position. This enables the user to move the whole screen content to the left and right side. The screen content will be moved when pressing a predefined shortcut combination on the keyboard while moving the mouse in the desired direction, as shown in Figure 2e. If a window moves out of the display, this window will appear on the other side of the display again. Hence, it is possible to "rotate" all windows. While other windows are moved to the focus area, the relative spatial relation between windows remains consistent.



(a) Linear Curved Zooming (b) Curved Zooming (c) Schematic comparison between Linear Curved Zooming and Curved Zooming.



(d) Window Groups (e) Window Spinning (f) Side Pane Navigation

Figure 2. a) - c) shows the two implementations of *Curved Zooming* and a sketch representing the behaviour. b) - d) shows the three other window alignment techniques.

Window Groups

According to Kirsh [11], humans make use of arranging tools and information spatially for quick access and easy understanding. Robertson et al. [22] proposed using a plus-focus approach on desktop computers and group windows by content. Currently non focused groups can be moved to the periphery and will be displayed in smaller size. We adjusted this concept and, designed a technique where it is possible to group multiple windows. These groups are visually highlighted and can be moved as one object. Furthermore, adding and removing windows is possible using shortcuts as well as moving windows within the group. A group is visualized with an underlying colored frame, as shown in Figure 2d.

STUDY

We conducted a repeated measures study to collect qualitative feedback from potential users. We therefore invited 12 participants (1 female) aged between 22 and 39 years ($M = 29.3$; $SD = 5.1$) into our controlled lab environment. Further, we conducted this study to identify the best-suited parameter values for three out of our four window alignment techniques which allow for configuration through a number of parameters. In detail, we compared linear against curved zoom for the *Curved Zooming* window alignment technique under seven zoom conditions. For the *Side Pane Navigation*, we compared the size of the thumbnails. *Window Spinning* allows splitting the screen into several horizontal areas. Hence, we presented one, two and three areas. *Window Groups* has no adjustable parameters.

Apparatus

The center of the screen was used as the main focus point. Related work shows that a display with a width of up to $2.4\,m$ allows seated office work [16]. Hence, we decided to use three $50''$ displays, namely Panasonic TX-50AXW804, with 4K resolution. We arranged the three displays in portrait mode, resulting in a display area of $2.02 \times 1.13\,m$ and a resolution of $6480 \times 3840\,px$. We used Ubuntu 14.04 with KDE Plasma Workspaces 4. The KDE desktop environment provides the possibility to adjust the UI though so-called "desktop effects". This provides the opportunity to manipulate the UI for all running applications.

For the user study, we placed a desk and an office chair in front of the setup with an approximate distance of one meter between the chair and the display. For interacting with the system, we provided keyboard and mouse.

Procedure

After welcoming our participants, we asked them to take a seat centered in front of our setup. Afterward, we asked them to fill in a consent form and a demographics questionnaire. We started by showing all window adjustment techniques to the participants. We showed the window alignment techniques in a random order, each with each configuration. We explained each effect before the participants tried interacting with it by using a standardized protocol. During the explanation phase, we did not give participants a specific task. Instead, we opened a high number of windows simultaneously to simulate a work environment with several different tasks and to encourage interacting with different types of content. After exploring the window alignment techniques in the sandbox interaction session, we asked about preferred technique and parameter values on a 7-point Likert-scale. Furthermore, we conducted a semi-structured interview.

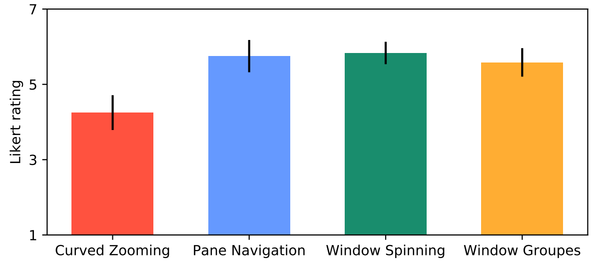


Figure 3. Rating how useful the window alignment techniques were perceived by participants (From 1-"not useful at all" to 7-"definitely useful"). The error bars show the standard error.

RESULTS

First, we analysed if participants rated one window alignment technique over another. Participants rated *Window Spinning* best with $M = 5.83$ ($SD = 1.03$), then *Side Pane Navigation* with $M = 5.75$ ($SD = 1.49$), then *Window Groups* with $M = 5.58$ ($SD = 1.31$), and with the lowest rating *Curved Zooming* $M = 4.25$ ($SD = 1.60$), see Figure 3. We further conducted a non-parametric Friedman test of differences among reported measures. However, Friedman's test rendered a Chi-square value of 7.147 which was not statistically significant $p = .067$. Thus we assume that all four window alignment techniques are equally useful. The qualitative feedback indicated more detailed that participants saw the need for novel UI designs for LHRDs. Participants liked the window alignment techniques as they mentioned for instance:

> without this kind of customization large displays may be not used so effectively *(P5)*,

and more statements indicate detailed advantages and possible improvements for each window alignment techniques.

Curved Zooming: Participants rated *Curved Zooming* less useful than the other window alignment techniques (see Figure 3). The main drawback of *Curved Zooming* seems to be the distortion of the content in the peripheral areas left and right. Three participants stated that it was uncomfortable to read distorted text or to work with skewed images. Furthermore, two participants argued that the linear zooming allowed for easier reading than the squared curved zooming. On the other hand, users reflected this also can have positive aspects:

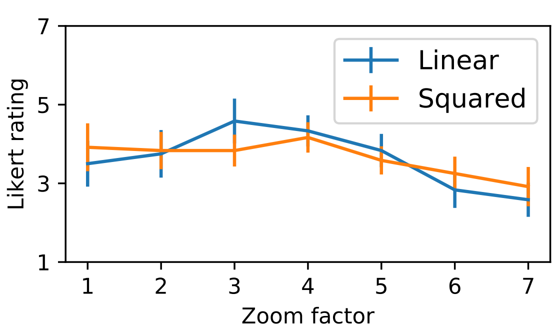


Figure 4. Rating of parameter values for *Curved Zooming*. The error bars are showing the standard error.

> The gaming experience would be really good with this effect *(P11)*

and

> It makes me feel closer to the screen, which is a positive thing *(P2)*.

Four participants argued that this window alignment technique helps to focus on the center of the screen and to keep an overview. These arguments are also represented in the preferred medium zoom level (see Figure 4).

To analyze if participants rated one CURVINGTECHNIQUE over the other in respect to the different ZOOMFACTOR we applied the Aligned Rank Transform (ART) [28] procedure to the feasible RATINGS, used the ARTool toolkit[1] to align and rank our data. This allows us to conduct a two-way repeated measures analysis of variance (RM-ANOVA). Our analysis revealed a significant main effect for ZOOMFACTOR ($F_{6,143} = 4.4$, $p < .001$). However, no significant main effect on CURVINGTECHNIQUE ($F_{1,143} = .067$, $p = .796$). There was no significant two-way interaction between CURVINGTECHNIQUE $\times$ ZOOMFACTOR ($F_{6,143} = .634$, $p = .701$). We further conducted post hoc tests using a Wilcoxon signed-rank test with a Holm-Bonferroni correction. None of the comparisons were statistically significant ($p > .05$).

Side Pane Navigation: Six participants stated that the *Side Pane Navigation* helped keep track of changes in several windows. Participants also argued that it was easier to keep an overview:

> [*Side Pane Navigation*] works great for multitasking *(P11)*.

P6 explained that he appreciated that he was not required to recall the position of single windows.

Participants had different opinions about mouse cursor jumps. While P6 strongly welcomed the reduced cursor travel, P2 stated that the jumps were not intuitive and irritating. Most participants acknowledged having 10 windows as thumbnails in one column (see Figure 5), and four participants argued that the *Side Pane Navigation* required too much space. Furthermore, P3 mentioned that the *Side Pane Navigation* moved the focus point to the left, which required more head movement.

We further conducted a non-parametric Friedman test of differences among the window count. However, Friedman's test rendered a Chi-square value of 6.836 which was not statistically significant $p = .145$, see Figure 5.

Window Spinning: Participants rated *Window Spinning* most useful (see Figure 3). Six participants argued that this helped to keep focus:

> [*Window Spinning*] is good to keep windows organized *(P4)*.

[1] http://depts.washington.edu/madlab/proj/art/index.html last accessed: 21-08-2017

Participants further stated:

> Windows can be ordered as they would be one group on screen [and then moved entirely] *(P6)*.

The *Window Spinning* is particularly helpful when switching between different tasks frequently. The participants were able to move multiple windows in the focus area at once. This results in less head movement. P3 explained that he liked multiple separately movable areas. This allowed content to be explored in multiple windows on the upper half of the display while combining the gained information to a text document in a window in the lower half of the display. Three participants mentioned it could be difficult to oversee the relation between area and window. This was particularly challenging with more than two areas. Hence, participants preferred two areas over one or three. Participants had no negative comments about *Window Spinning*, maybe because it looks like the classical KDE Desktop if the *Window Spinning* interaction is not used.

We statistically compared the rating of one, two and three spinning bands $M = 5.3$ ($SD = 1.4$), $M = 5.58$ ($SD = .8$), and $M = 3.75$ ($SD = 1.7$) respectively. We further conducted a non-parametric Friedman test of differences among the spinning bands. However, Friedman's test rendered a Chi-square value of 5.209 which was not statistically significant $p = .074$. However, the descriptive statistic suggests that two spinning bands are optimal.

Window Groups: Participants rated *Window Groups* less useful than *Window Spinning* and *Side Pane Navigation* (see Figure 3). The concept behind *Window Groups* was well known to the participants. Hence, four participants assumed that this was the natural adjustment of virtual desktops for LHRDs. Similar to when using virtual desktops, participants would use *Window Groups* to classify different tasks they were working on, for instance one participant stated:

> [I would group] windows which belong to each other logical, for instance to accomplish one specific task *(P2)*.

In particular, P8 would use this for office work. Overall, participants perceived grouping windows to be intuitive. Participants did not mention any criticism or improvements.

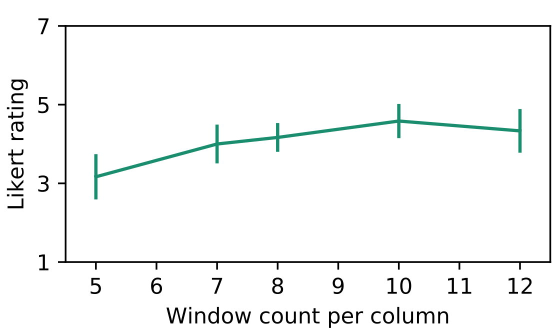


Figure 5. Rating of parameter values for *Side Pane Navigation*. The error bars are showing the standard error.

DISCUSSION & CONCLUSION

In this paper, we presented four novel window alignment technique for LHRD workplaces synthesized from related work and their evaluation. Based on our inquiry, we can observe that well-explored window alignment technique for desktop environments are not automatically applicable for LHRDs. The results show that users of LHRDs appreciate window alignment techniques with enhanced support for window management. Thereby, managing the user's focus and attention is the key challenge for such window alignment techniques. The feedback related to *Curved Zooming* and *Side Pane Navigation* shows that breaking well-established techniques was not appreciated by participants. Despite the fact that the participants described *Curved Zooming* as more immersive and supporting focus better, they were disturbed by the distortion. In the case of *Side Pane Navigation*, some participants were confused by the abrupt jumps of the mouse cursor and did not appreciate the shorter mouse movements. Consequently, future interaction techniques for LHRDs should consider that task immersion, arrangement, visibility and legacy issues need to balanced according to the task before the user.

Participants argued that *Side Pane Navigation* lowers the need for recalling the window positions. On the one hand, it is beneficial to draw attention to the actual task, instead of on the positions of windows. On the other hand, it raises the question, if all users would arrange windows in a meaningful way, i.e., whether the interaction technique may benefit from the affordances of large surfaces as described by Kirsh [11].

Participants preferred windows alignment techniques which resembled traditional desktop patterns more i.e. *Window Spinning* or *Window Groups*. Both window alignment techniques were perceived as providing additional support without changing the well-known UI behavior. In particular, *Window Spinning* was appreciated because it allowed switching focus without reordering all windows and the underlining structure when switching focus. This shows that legacy issues are likely to prevail when performing tasks which are already commonplace when, possibly, users transition to LHRDs. Due to this, augmenting existing window alignment techniques appears to be an effective way of designing window alignment techniques for LHRD-Interfaces used for office work. In contrast, for scenarios which are not adequately supported through desktop setups, related work shows that radically novel window alignment techniques are beneficial.

The small number of participants and the artificial setup of a controlled lab study limit the results of our study. For future development, more detailed user feedback is needed, preferably collected in a field study. However, even with a small number of participants, we were able to identify several improvements for future investigation and development.

In future work, we will explore the concept of *Window Spinning* more detail. As participants recommended, also vertical movements of the windows is a valid possibility. In particular, because users of LHRDs tend to separate tasks horizontally [15].

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