Designing of an Effective Monitor Partitioning System with Adjustable Virtual Bezel

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Abstract. We suggested a new monitor environment with an adjustable virtual partition in order to incorporate advantages from both the multiple monitor and single monitor. We conducted a user study by making a prototype. Results showed that the prototypes enhanced the user work performance while it reduced the temporal demand. We believe that our design suggestion and the user study results can make a contribution to future single large monitor distributions from the user's need of a bigger screen which provides a more immersive experience, as well as to a new computing environment such as laptops and tabletop computing that does not allow multiple monitor establishments.

Keywords: Window management, Interface design, Multiple monitor, large monitor, partitioning.

1 Introduction

The use of monitors on computers is continuously researched as an important topic in the HCI field. As people want more effective work environments, many workplaces nowadays are equipped with multiple monitors, and according to previous researches, those setups actually enhance work efficiency [4, 10].

However, there is a contemporary tendency to find strength of a single monitor environment. Foremost reason is the falling price for large displays. In addition, the immersive experience in terms of consuming movies and games has become more important, and those activities are better supported by a single large monitor [2]. Thirdly, people may better concentrate on one work, as there are studies that conclude that a sufficiently large screen brings about higher productivity than dual monitors [1, 2].

Yet, while many studies were conducted to understand advantages of different screen setups, there are little attempts to combine the strength of both single and multiple monitor environments. As actual use cases vary, so do the needs for a flexible monitor environment. Thereby, the monitor bezel plays a key role. For example, in the case of exploring a large city map on a dual monitor setup, the bezels cutting through the map is disadvantageous [3]. Yet, the same setup might prove to be beneficial when working on tasks that require switching between multiple documents or

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programs. In this case the bezel helps users to organize their work into different activities that are partitioned physically by the different monitors [4].

In this paper we have thought of a new environment, in which the strength of both multiple and single monitor setup can be combined. A dual-monitor, on the one hand, might bring productivity advantages by physically separating the workspace into two parts, yet the partition is a static one that is defined by the physical size of the displays. A virtual partition on a large single monitor, on the other hand, allows changing the proportions by moving the partition. It even allows removing the partition to use the display as one large monitor. Through this, a user can maximize the positive aspects of a dual-monitor environment by having a partition in the wanted location, while still maintaining the merits of a single monitor.

Based on this idea, we made a prototype as a new monitor environment with a flexible partition that users can adjust according to their needs. To verify the efficiency, we conducted a user-study with 32 participants.

2 Related Works

2.1 Concept of Space

Grudin [4] presented some of the first work describing everyday multiple-monitor users where he points out the benefits of an arbitrary division of space, claiming that a single large space has disadvantages, as it limits the possibility to park objects out in a defined periphery. This claim implied the necessity of a virtual partition.

When considering the idea of partitions in the virtual world it comes naturally to draw analogies to the real space and architecture. Architecture is primarily about the designing of space, but also the designing of constructional entities that demarcate space. The difference is concerned in the way in which space is experienced. In one respect there are spaces in which one can dwell and act, in another there are spaces where there is only room for the roaming eye. So, there are spaces for use, as opposed to spaces for merely looking at. The English ‘space’ and the French ‘espace’, both derived from the Latin ‘spatium’, are primarily concerned with extensiveness and the distance between objects. The German translation ‘Raum’, on the other hand, etymologically akin to the English word ‘room’ considers space as both that which is enclosed as well as the enclosure itself. This means that a German-speaker will think of' ‘Raum’ as a small separated portion of the limitless space. With regard to this dual meaning of ‘space’ and ‘Raum’, our present-day concept of space for the digital world ought to be redefined, according to the notion of continuity and distance on the one hand, and the idea of limitation and enclosure on the other.

2.2 Partitioning Real Space

In the example of partitioning the space of a house, people generally value more rooms over room sizes. A house with one large bedroom is not the same as a house with two bedrooms of moderate size. In the two-bedroom house, the second room is used for different purposes, e.g. as a guest room or office. Different tasks are optimal in one or the other room. The wall makes a difference by creating a space with a dedicated purpose and an exclusive accessibility. Here we already can see that reasons for partitioning space in the real world are diverse. They range from aims to order and structure the space, to separating functional units from each other, to providing visual separations, and to enable privacy as well as democracy and equality.

2.3 Partitioning Virtual Space

Based on the concept of partitioning space in the real world, previous researches have approached the question of why and how people partition digital worlds. Henderson et al. proposed Rooms [6], an comprehensive virtual desktop system, allowing users to arrange sets of windows to correspond with tasks and switch among the sets with very simple input actions. Grudin [4] examined how to partition digital worlds effectively and how people with a lot of display space arrange information. He identified a Focal and Peripheral Awareness in Multiple Monitor Use and concluded that having to open and close windows, obstructs the train of thought, as finding features buried in menus is more time-consuming than visually scanning the full set of functions on a second monitor. Based on Grudin, Czerwinski et al. studied the productivity and performance benefits of very large displays [2]. The study resulted in design guidelines for enhancing user interaction across large display surfaces. Furthermore, Hutchings proposed various window management techniques for a more efficient and enjoyable multiple-monitor experience [7,8,9], and Kang and Stasko conducted a comparative study to quantitatively examine how people perform common tasks with one or two monitors [10]. Both, Hutching's and Kang's studies emphasized the faster performance and the reduced workload of participants with two monitors, and also stressed the subjective preference for multiple monitors. Finally, Bi and Balakrishnan [1] discovered benefits from using a wallsize large high-resolution display by observing users' behaviors when using such a display for daily computing. Those were the facilitation of multi-window and rich information tasks, the enhancement of users' awareness of peripheral applications, and the opportunity for a more immersive experience.

The two distinct usage patterns in partitioning screen real estate and managing windows on a large display were (1) the reduction of window minimizing and maximizing, and the increase of window moving and resizing, as well as (2) the division of space into task zones, where the center part represents the focal region, and the remaining space the peripheral region.

Related to these studies, this research identifies ways that can help people make better use of the increased screen area through the application of a flexible virtual partition. Furthermore, it reports on a preliminary study of people performing specific tasks on a computer while using a flexible virtual partition to divide a single display.

According to Robertson et al. [3], the bezels in a multiple display present both opportunities and problems. There are several practical solutions to address this issue, such as *WinSplit Revolution* [11], software to provide the ability to move a window to a specific position on the screen. However, current solutions are just focusing on managing windows, not on the adjustable 'bezel' concept. This study thus will introduce and explore the effectiveness of a virtual bezel for single display that remains adjustable by user at any time.

3 System Design and Implementations

Our design goal is to combine both strength of a dual and a single (large) monitor through adjustable virtual partitioning of display (Figure 1). Our basic design concept is allowing the partition (bezel) between the two monitors in the existing dual monitor environment to move organically so that it can take in advantages from both sides. This will allow expanding a monitor's width for certain situations as well as widening one side into whole size, providing full space for a single task according to different needs.

The largest consideration in terms of interface was how to adjust this virtual variable partition. First, having the single monitor idea as the most direct and initial idea, we had a tangible stick on the monitor to move the partition physically. However, according to observing the monitor environment of the laboratory personnel, we found out that it was difficult to tangibly control the monitor directly in many situations. In the end we concluded that adjustment using the mouse, which is most frequently used in the PC environment, is the optimum choice both for the performance and for user convenience.

The final prototype was made so that the Logitech MX500 mouse's middle button shortcut can make adjustments. Program was made as a C++, residing in the tray in the Window environment and makes a single monitor into a virtual dual monitor that has left and right parts. The operated program is initially designated to the left part but can be put on to the right part by moving the window. The user can move the mouse while holding on to the button shortcut on the mouse to move the partition to a desired position.

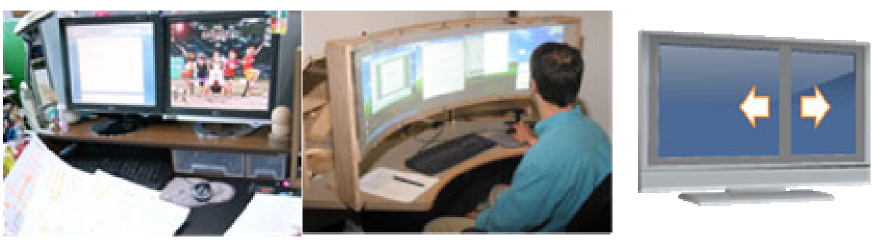

Fig. 1. Dual and Single large monitor setup (left and middle) and our Virtual Bezel concept (right)

4 User Study

We conducted a user study in order evaluate our suggested prototype. Study measured the task completion time for task efficiency and task workload at the time. Also, a qualitative study was conducted on behalf of the user experience aspect in order to see if our expected user scenario was actually useful.

4.1 Expected User Scenario and Benefits

When we design and conduct user study with our virtual bezel concept, our expected user scenario and benefits are as follows.

First, when users are working simultaneously with different programs, adjusting the screen proportion might increases the work efficiency. Through the prototype, it might possible to extend the work efficiency and convenience by a flexible adjustment of the proportion between the work screen and the source screen. When the source screen has much information, expanding the source area to find the wanted page will be beneficial. Also, when focusing on the content production, extending the contents area will help to focus on the work.

Secondly, while users are working in full-screen mode, checking the parallel task might be more effective. One of the largest benefits of a single display is being able to concentrate on a task while feeling a sense of immersion by having one program in a full-screen mode. It is even greater for visual work such as image editing, watching a movie, or studying at a map. In case of a dual-monitor, these tasks might be inefficient, since the remaining screen is useless to the full-screen mode. However, a dual-monitor has the advantage of displaying peripheral information through gadgets, messengers, or weather applications on the remaining monitor, while being in full-screen mode. We expect that users might take both benefits of them by using our prototype environment.

Task switches do not cut the flow of perception and support a fast processing.

Also, when users are executing two tasks in turns, under the ‘Windows’ environment, switching between two windows usually is done by using ALT-TAB. However, there is confusion in switching windows in a multiple monitor environment, as the focus on a layer can be on either monitor. In our prototype, a user might able to arrange two windows on each screen area onto the same monitor. By having the partition located on the left end or the right end, it is possible to maximize the two windows individually. Under such a condition, by moving the partition from the right end to the left end, it is possible to clearly identify the focus on a layer. By being able to mentally grasp that each program naturally is located in each part, it might be possible to switch a task without ending the flow of perception.

We will test our expected user scenario during the user study as well as other quantitative and qualitative analysis.

4.2 Study Setup

We recruited 32 users from design students (avg. age=26.8, SD age=4.26): 16 who used a single monitor, and 16 who used a dual monitor configuration for their daily computing. To evaluate the effect of the virtual bezel on both dual and single monitor users we tested 8 of the 16 dual monitor users in the dual monitor setting (G1) while 8 of them conducted tasks using the virtual bezel (G2). Similarly, 16 of the single monitor users were divided so that 8 of them were tested in a single monitor setting (G4) while 8 conducted tasks on our prototype (G3) (Figure 2).

To control every variable except for the bezel settings, every study was conducted in a same lab using the same environment: 24 inch screen size, 16:9 ratio, 1920x1080 resolution, LCD monitor on a PC with Window 7 installed. The users were to conduct a virtual task of producing a school seminar poster (Figure 3). Information and design requirements for the poster were listed on a MS PowerPoint file in a text format and

G1 (8 people): Use *dual-monitor* in day work / Use *dual-monitor* setup for this study
G2 (8 people): Use *dual-monitor* in day work / Use *single monitor with virtual bezel* setup for this study
G3 (8 people): Use *single monitor* in day work / Use *single monitor with virtual bezel* setup for this study
G4 (8 people): Use *single monitor* in day work / Use *single monitor* for this study

Fig. 2. User groups for this study

they were to design an A1 size poster using Adobe Illustrator with the given information. In regard to the familiarity of the task, using a program with another program taken as a source is a quite common activity in office environments and thus is a task conducted frequently in existing studies that tested the dual monitor environment's efficiency.

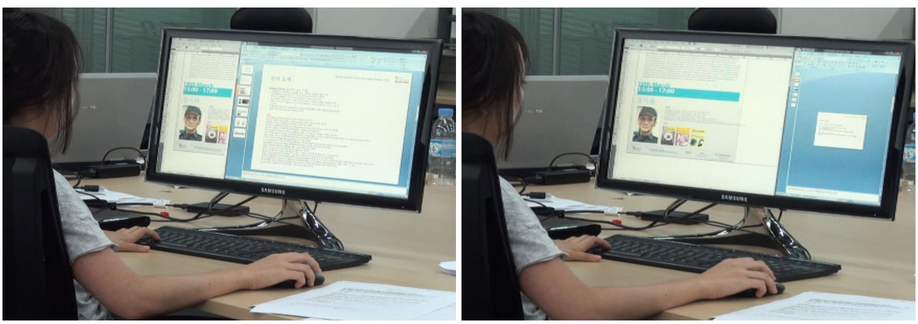

Fig. 3. Users can adjust virtual partition in any position according to their needs using the prototype we made

We made the users to think aloud while the task operations were video-taped. After the test we conducted a NASA-TLX [5] survey, a workload analysis method, and listened to the post-task comments through interviews. NASA-TLX, a subjective workload assessment tool, is separated into six items, i.e. Mental Demand(MD), Physical Demand(PD), Temporal Demand(TD), Performance(PR), Effort(EF) and Frustration-level(FR) to enumerate the degree of the demands quantified by comparison of each item. Through this process we made the users evaluate the prototype workload by themselves in a subjective manner in order to recognize the prototype's advantageous and shortcomings when compared to the existing counterpart.

On the other hand, after a short break after the task test we had all 32 participants experience utilization situations for a short period: 1) Checking the weather gadget on the wallpaper while watching a movie and expanding the movie to full size 2) Watching two different web pages alternately by moving partitions. Each set up situation was to be experienced for approximately 2 minutes, and then we asked questions on their subjective ideas on whether the prototype could be utilized effectively in real life situations.

4.3 Study Result

For task completion time, there was a significant difference between conventional and dual displays (G1: for group information, see Figure 2) and conventional single display (G4) setting: dual displays setting took 16% less than the task completion time in a single monitor setting. When introducing the virtual adjustable bezel, there was no significant time improvement for conventional dual-monitor users (G1 shows 28 minutes,G2 shows 30 minutes) However, participants using a single monitor in their daily work showed a significant improvement from 33 minutes (G4) to 27 minutes (G3) when applying the virtual bezel (t=3.230, df=14, p=0.006). (Figure 4)

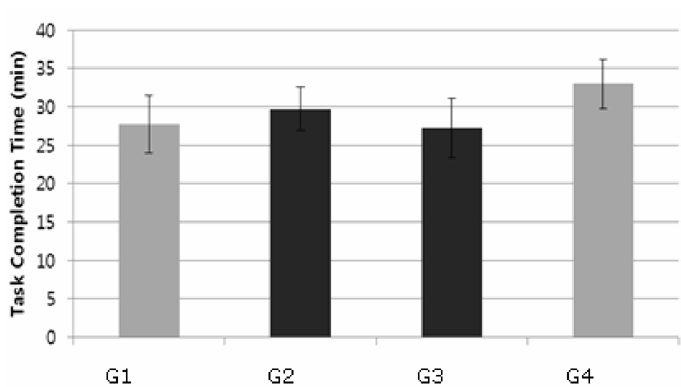

Fig. 4. Task completion time between user groups

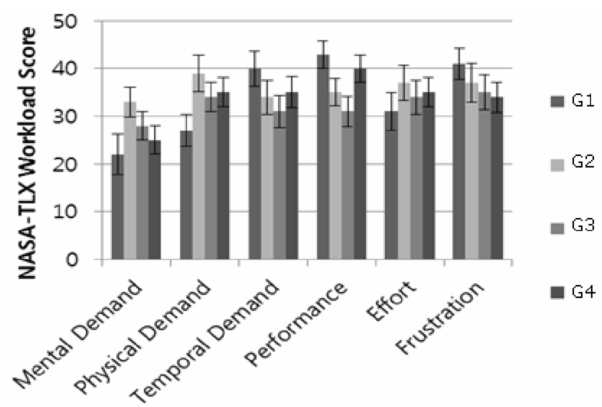

Fig. 5. Task workload between user group

Results of the workload analysis using NASA-TLX (Figure 5) shows that the virtual adjustable bezel brings the biggest improvement in performance. Everyday dual monitor users showed a decrease in their performance load from 43 (G1) to 35 (G2) (less is better), and everyday single monitor users also showed a decrease from

40 (G4) to 31 (G3). Both differences were statistically significant (t=4.287, df=14, p=0.001; t=5.286, df=14, p=0.000). For the temporal demand, which subjectively measures how much time pressure is felt during the task, dual monitor users showed a 15% decrease when using the virtual bezel (G1 and G2), and single monitor users showed an approximate 12% decrease in their temporal demand (G4 and G3). Both were statistically meaningful reductions (t=4.837, df=14, p=0.000; t=-4.185, df=14, p=0.001). However, everyday dual monitor users showed a huge increase in both their mental and physical demand when they used the virtual bezel. Other quantitative results are shown in Figure 5.

From the observation and interview, we could see the ways of users manipulating the adjustable virtual bezel during the given task. When working simultaneously with two different programs, users were trying to adjust the screen proportion between the work screen and the source screen. Since the source screen has much information, expanding the source area to find the wanted information was beneficial. Also, when focusing on the content production, extending the contents area helped to focus on the work. Also, users could switch tasks quickly and naturally, although not expected from our prototype. When executing two tasks in turns, under the 'Windows' environment, switching between two windows usually is done by using ALT-TAB. However, there is confusion in switching windows in a multiple monitor environment, as the focus on a layer can be on either monitor. In our prototype, a user was able to arrange two windows on each screen area onto the same monitor. By having the partition located on the left end or the right end, it is possible to maximize the two windows individually. Under such a condition, by moving the partition from the right end to the left end, it is possible to clearly identify the focus on a layer. By being able to mentally grasp that each program naturally is located in each part, it is possible to switch a task without ending the flow of perception.

6 Discussions

The results of this study show that the *virtual bezel* reduces the task completion time of a normal single display setting. It is, however, less efficient than a dual display setting. Since we use the same monitor type for every study setting, a dual-monitor setting (G1) with two monitors has twice as much screen space, compared to the single-monitor setting that applies the *virtual bezel* (G2, G3, G4). Thus, G1 can see more information than the other user groups. We need further studies that compare conventional dual-monitor settings with single-monitor virtual bezel settings, under the condition that in both setups the total screen size remains the same. With the same screen size in a single-monitor setting, the results show that applying a virtual bezel brings improvements in performance (G3 vs. G4). Most participants (G4, 8 out of 9) use ALT-Tab frequently for switching programs, while only one out of nine in a virtual bezel setting (G3) uses ALT-Tab for switching.

The NASA-TLX survey result shows that there is a significant improvement of the *performance load* and *temporal demand*. *Performance load index* shows a great improvement effect indicated by how much the users subjectively perceive to have achieved. This implies that users can feel more satisfaction with the *virtual bezel* for both the dual and single monitor setting. This is the level of their recognized performance being directly linked to the level of satisfaction. Thus, great improvement on this item is very encouraging.

On the other hand, the increase in *mental* and *physical demands* needs to be discussed. The main reason seems to be that users initially are not familiar with the virtual bezel concept and the interface using a mouse's customized button. Many participants (7 out of 16) mentioned that the interface is simple yet confusing. Although it might improve as they get used to the interface, a more intuitive interface, such as a gesture interface should be considered. Also, some participants (2 out of 16) pointed out that the partitioning of the screen using a virtual bezel lacked the 'dividing-strength' of a physical bezel. Thus, we may consider a real physical bezel for an adjustable partitioning in further studies.

As an interesting finding, some users (4 out of 16) commented that the virtual bezel concept may be useful in a mobile laptop environment where dual monitor setup is generally not possible. Thus, it will be promising to discover ways to use a small single screen more efficiently.

7 Conclusions and Future Works

As increasingly larger monitors become more available to users, it is appropriate to devise new interfaces that help carry out activities on computers more efficiently. In this paper, we introduced the idea of a virtual bezel that allows users to split a single monitor. We conducted an initial exploratory user study to understand and explore the effectiveness of an adjustable virtual bezel. The study showed that an adjustable virtual bezel can bring about productivity advantages by splitting the workspace, compared to a conventional single monitor of the same size.

This study was not able to find out how much effect long term utilization could bring when operations are made familiar. Future observations in the actual context with long term use will provide a deeper insight regarding a more efficient and convenient desktop work environment.

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