Towards Understanding Spontaneous Interaction on Curved Displays

Henri Palleis
University of Munich (LMU)
Amalienstr. 17
80333 Munich, Germany
henri.palleis@ifi.lmu.de

Heinrich Hussmann
University of Munich (LMU)
Amalienstr. 17
80333 Munich, Germany
hussmann@ifi.lmu.de

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Abstract

Vertically curved displays feature a curved segment that seamlessly combines a horizontal with a vertical display segment. A potential application domain for such displays is their use in public settings. We created a quiz game on our curved display and exposed it to visitors of our open lab day to gather first insights into how people encounter such a device in a real world context. We report on our observations during the exhibition and present preliminary findings of a subsequent experiment comparing different variations of the game.

Author Keywords

Curved display; cross-display interaction

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Vertically curved displays [3], [8] combine a horizontal with a vertical touch screen through a curved connection. One application domain for large interactive displays is their use as interactive installations in public places like museums or libraries. Curved displays might provide additional benefits for this domain as their display arrangement can be used to structure the

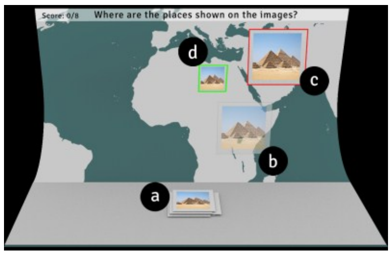

Figure 1 Conceptual overview: a) piled images on image area, b) semi-transparent image while being dragged onto the map, c) image with red border released on the wrong country, d) image released on the correct country with green border.

interaction with digital assets and information in a way that considers the distinctive adequacies of horizontal and vertical displays. Additionally, they might allow for new forms of side-by-side collaboration without orientation problems.

Our intention was to a) understand if the visual and haptic continuity of the display make it obvious for the player that digital objects can be dragged across the curve, b) create an engaging application helping us to observe how users experience the touch interaction with a curved display in a real world context and c) explore how the spatial layout of the user interface might influence the interaction with such a display. In order to gather first insights into these questions, we built a geography quiz application for a curved display that made distinctive use of the horizontal and vertical parts of the display and involved dragging digital objects across them. We report on our observations from exposing the game at our open lab day and present initial findings from a subsequent experiment.

Related Work

Previous work has shown that for touch input, the combination of visual and haptic display continuity leads to accurate and well received cross-display dragging interactions [3]. Weiss et al. also investigated cross-display dragging gestures on a curved display [8]. Voelker et al. [6] have explored the combination of indirect touch input on a horizontal surface and visual output on a vertical display. Hennecke et al. [4] used a pair of curved displays to create a seamless collaboration space that allowed two users to interact across a physical-to-virtual tabletop setup. Watson et al. [7] used a simple game to compare touch and mouse input regarding performance and user experience and found that in their case touch input outperformed mouse input on both horizontal and vertical displays.

The Quiz Game

Our application uses the two distinctive display parts to combine an area that contains images of famous places with an area showing an interactive world map (figure 1). The quiz asks the player to assign the places shown on the images to their corresponding location on the world map by dragging the image from the image area across the curve onto the according country on the world map. The game was implemented with the MT4J framework [2]. An image area with a grey background was placed on the plane horizontal part of the display and the map was placed on the curved and the vertical parts. On the one hand, this decision was based on the metaphors of photo browsing on a table and wall-mounted maps featuring pins. On the other hand, an ergonomic assessment of the application layout was not obvious, since both areas were designed to be interactive.

At game start, the map was zoomed out to show the whole world. It then could be panned with a one finger dragging gesture and zoomed with a pinch-to-zoom gesture. Images were initially piled in the center of the image plane and could be dragged (no rotation and zoom) around the whole display. When dragged and held over the map component, an image became semi-transparent to enable a precise placement on the map using the dragging finger as cursor. When released over the correct country on the map, the image was scaled down to a miniature and fixed to the map. Feedback on the player’s answer was given as colored border (figure 1). As the display can handle up to 20

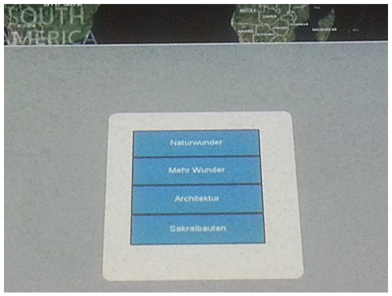

Figure 2 Simple menu to start different question sets.


Figure 3 Visitor of the “Open Lab Day” playing the quiz on the curved display. Visitors of the event are mainly prospective students, parents, industry partners and alumni.

touch cursors simultaneously, it was possible to interact with the images and the map at the same time.

We prepared six image sets (e.g. nature, ancient wonders, architecture etc.) that contained between seven and 13 questions, consisting of images depicting places from three to five continents. We added a simple menu and navigation to create a complete gaming experience (figure 2).

Exhibition at a Public Event

We exposed the quiz game at our annually held “Open Lab Day” [5], where we present research results and prototypes to the public (figure 3). During the four-hour evening event we invited visitors passing by to play the quiz game without giving them instructions how to operate the game. While they interacted with the game we observed them by making handwritten notes using a predefined matrix containing categories such as *recognition of the game’s interaction principle*, *recognition of applicable multi-touch gestures*, *game strategies* or *problems*. After finishing the game, we asked them to fill out a short questionnaire if they had completed at least one set of questions. The questionnaire asked for demographic characteristics and touch screen experience and contained five-point Likert scales (1 = “I strongly disagree”, 5 = “I strongly agree”) to record subjective data. If groups played the quiz, we asked the main player who sat on the provided chair to fill out the questionnaire.

Six people and six groups consisting of two to five people completed at least one set of questions. Accordingly, twelve players (five female) filled out our questionnaire. Two players were in the age range *14-19 years*, nine in *20-29 years* and one in *40-49 years*. All of them stated to regularly use a touch-screen phone and to have experience with tablets.

Results In ten out of twelve cases, the possibility to drag images across the curve was recognized without further inquiry. In two cases, players tried to answer quiz questions by sequentially tapping on the image and the country. The panning and zooming capabilities of the map were detected by ten players/groups without help.

We observed different strategies, both for single players and groups of players. Single player strategies differed concerning the image browsing behavior. About half of the players used the image plane to spread and sort the piled images before dragging them onto the map. The other players worked through the piled images one after another without using the image area for browsing. None of the players or groups used the map component to put down images temporarily. Instead, when not released over the correct country, images were always dragged back down onto the image area.

Group interactions involved one player sitting on the provided chair and one player standing aside. Additional group members took the role as advisors standing behind the sitting player. Observed group strategies can be distinguished between taking turns, i.e. one player operating the game at a time, and control sharing, i.e. one player browsing and dragging the images and the other one navigating the map. When sharing control, players communicated to help each other (e.g. finding a country on a map and talking about or handing over pictures), to issue commands

Figure 4 Participant of the experiment playing the quiz in the condition *NEW*.

("Zoom in!") or to argue ("You have to do it that way!").

The subjective data show that players rated dragging pictures onto the map to answer questions as fun (median=5). Overall, the game was considered as easy-to-use (median=4) and both the interaction with the images and the world map was rated as easy (median=4). Players did not consider the interaction with the vertical map as physically demanding (median=3), however ratings were less clear in this case.

Discussion In general, the quiz game was an effective mean to observe people using the device, because their ambition to score well made them play more than two question sets on average. The many positive comments ("It's so cool that I can touch it!", "I can't stop" etc.), the data from the questionnaire and the long gaming times confirm that the game principle led to a joyful experience. The observation revealed that players who did not know the curved display had no difficulties to learn the principle of the game quickly. This suggests that the display's haptic and visual continuity advises users to understand its cross-display interaction capability. The visual separation of the areas possibly indicated not only a visual, but also a logical structure, as players refused to leave images on the map in case of wrong answers. However, the inevitable error checking when releasing images on the map might have troubled players to do so.

We were rather surprised about the observed group interactions. The spontaneous sharing of control, the simultaneous interaction and the communication between the cooperators suggest that this type of display may enable new forms of cooperative work.

We did not observe signs of exhaustion and players did not complain about heavy arms, although the interaction with the map on the vertical part of the display outweighed the interaction in the horizontal image area. We had chosen the game layout based on metaphoric considerations. But being aware that literature suggests to concentrate touch interaction on the horizontal part of the display [6], we were interested if inverting the game layout would lead to an improved user experience.

Lab Study

Following the observed exhibition at the public event, we conducted a lab experiment. We created an alternative version of the quiz, showing the world map on the horizontal part and the image/menu area on the vertical part of the display (figure 4). The sizes of the areas remained unchanged, which means that the map filled the horizontal and the curved parts of the display and the image area filled the vertical display plane.

We used a within-subjects design in our experiment. One half of the participants started with condition *OLD* (the original layout) and the other half started with condition *NEW* (the inverted layout). From the six question sets we chose four sets (*A*, *B*, *C*, *D*) and fixed the number of images to eight in each set. Sets *A*, *B* and *C* contained images from four continents, D contained images from two continents. We randomized the order of the sets during the experiment. The order of the images within the sets (i.e. the order of the piles of images) was not altered.

Figure 5 Overlaid image dragging trajectories from all participants in condition *OLD*.

Figure 6 Overlaid image dragging trajectories from all participants in condition *NEW*.

After signing a consent form and filling out a short demographic questionnaire, participants were asked to read a written explanation and schedule of the experiment. To reduce the influence of individual knowledge and potential fears of being embarrassed by the questions, we assigned them the role of testers of a new game for museums. They were instructed to figure out the game principle themselves to test the self-explanatory nature of the game. Furthermore, they were instructed that it is neither important nor probable to know all the places in the images and to ask for places and locations they could not identify or locate.

We logged all touch events in order to determine the amount of image and map interactions, the total dragging distance of both map and images and to draw trajectories of the dragging interactions.

After each condition, we asked the users to fill out an paper and pencil NASA RTLX questionnaire to measure the workload and a couple of five-point Likert scales ranging from 1 ("I strongly disagree") to five ("I strongly agree") to collect subjective data. At the end of the experiment, we conducted a short interview, during which we asked the participants whether they have a clear preference for one of the conditions and whether they prefer dragging images downwards or upwards.

Our main hypotheses were: (H1) "Condition *NEW* causes less workload than *OLD" and* (H2) "Participants prefer condition *NEW".*

Twelve participants (four female) took part in the study. Eleven were between 20 and 29 years and one was between 30 and 39 years old. None of them had prior experience with the curved display. All of them had experience with touch-screens on smartphones and tablet devices.

Results The recorded TLX scores are lower for condition *NEW* (29.01, sd = 7.9) than for condition *OLD* (32.40, sd = 6.5). A one-tailed paired t-test results in a p-value of 0.008, which hints at a confirmation of H1.

When asked for a clear preference, ten of twelve participants stated that they preferred the *NEW* condition. The most frequently mentioned reason (n=7) was that playing the game in this condition was less exhaustive and more comfortable. Further reasons were that dragging pictures from the vertical part of the display towards the body felt better and "more natural" (n=4) and that the horizontal placement of the map felt better (n=3), because this was the "natural" way to interact with maps and allowed for a better overview and readability. One participant preferred condition *NEW* concerning the ease of interaction, but preferred condition *OLD* because of a better overview. One participant clearly preferred condition *OLD*, because this setting felt more natural. In general, ten participants stated that dragging images downwards felt better than upwards.

The subjective data from the questionnaire do not show differences between the conditions. In both conditions participants rated dragging pictures onto the map to answer questions as fun (median=5) and easy (median=4 for *OLD*, 5 for *NEW*). The interaction with the map was considered easy (median=4) as well as the interaction with the images (median=4 for *OLD*, 5 for *NEW*).

Figure 7 Example for concentrating the interaction on the horizontal display: zooming the map on the grey area with the left hand and dragging images with the right hand.

A look at the logged data reveals that there seem to be two factors that differ between the conditions. First, the total map dragging distance measured in pixels is higher in condition *NEW*. Second, the vertical dragging distance of images is lower in condition *OLD*. Visualizing the trajectories of the image movements (figure 5 and 6) also hints at a slightly higher image movement within the image area in condition *OLD*.

Discussion Placing the more interactive task on the horizontal led to less workload and was preferred by the participants. However, for tasks that differ less in the degree of necessary interaction (e.g. because of an additional sorting task in the image area), the placement is less obvious. One helping factor might be the dragging direction, as dragging images downwards was preferred by the majority of the participants, which is in line with findings from a previous study [8].

Discussion and Future Work

The observation of our quiz application at a public event and the initial results from the lab study revealed three preliminary findings: First, the display shape makes dragging objects across the curve an obvious option even for first time users. This is important when developing applications for public places. Second, full-screen touch interactions on a vertically curved display can be used to create engaging applications that support spontaneous side-by-side cooperation. In contrast to tabletops, this setup avoids orientation problems, opening up a range of dyadic cooperation scenarios. Third, the degree of interactivity of different subtasks is one factor for the spatial layout of user interface parts to the display areas, but further research is necessary to understand how to assign interactive tasks to different parts of the display.

Potential solutions could be to allow layout switching during operation or to concentrate interaction on the horizontal part of the display as proposed in [6] using adequate metaphors (figure 7). Furthermore, we are interested in the influence of visual structures on the interaction. As people use bezels in multi-monitor setups to organize data [1], visual structures might influence the interaction on curved displays. At last, we plan to further explore dyadic scenarios that make use of the potential of the curved display to both separate and share control in a fluid manner.

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