A Concept for 3D Interaction on a Curved Touch Display

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Abstract
The handling of 3D content increasingly permeates amateur activities and occurs spontaneously on public displays. The design of interaction techniques for such scenarios is subject to tensions between established expert user interfaces, 3D touch interaction and the requirements of the usage context. We present a novel concept for 3D touch interaction on a curved display targeted at non-expert and spontaneous interaction scenarios. We further present preliminary results from an experiment, during which we compared our interaction technique with an established one for different 3D interaction tasks. The results indicate that for the chosen tasks both techniques perform equally well and point out room for further improvement.

Author Keywords
3D interaction; indirect touch; curved display

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

Introduction
The creation and presentation of 3D content has been gaining in importance in recent years. Apart from industries that have been using professional 3D software for many years (e.g. engineering, movie

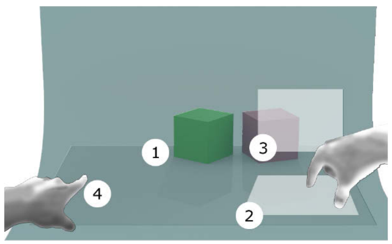

Figure 1 **(1)** 3D scene that seamlessly extends into the depth, **(2)** horizontal touchpad for indirect touch control: the selected object can be translated by one-finger dragging within the XZ-plane and rotated with a two-finger rotation gesture around the Y-Axis, **(3)** vertical touchpad: the selected object can be translated within the XY-plane and rotated with a two-finger rotation gesture around the Z-Axis, **(4)** the virtual camera can be rotated around the scene by dragging it left or right. First rotating the scene and then using the vertical touchpad can achieve object rotations around the X-axis.

studios, computer games), the handling of 3D content increasingly permeates amateur and hobbyist activities often subsumed under the term Maker culture. Further, as public touch displays become more widespread, the exposure to 3D content occurs spontaneously (e.g. navigation help, interactive museum exhibits), requiring interaction techniques that are suitable for a walk-up-and-use context [5].

We present a concept for 3D touch interaction on a curved display (figure 1). The display's form factor is used to (1) visualize the 3D scene as a virtual extension of the physical horizontal surface, (2) extend the dimensionality of touch gestures by using a pair of semi-transparent virtual touchpads that map touch gesture input to 3D manipulations depending on the orientation of the input surface and (3) allow for an ergonomically optimized division of touch input and visual perception.

Additionally, we present findings from an initial lab experiment, where we compared our input technique and an established widget-based input technique to get first insights on performance and user acceptance.

Background

The exploration of 3D content on planar surfaces has been facing the challenge of mapping of 2D touch input to six degrees of freedom (DoFs). This challenge has been addressed with several dedicated multi-touch gesture sets (e.g. [3], [6]) on the one hand, and graphical widgets (e.g. [2], [7]) on the other. While 3D gesture sets allow for high-bandwidth (integral control of multiple DoFs, no explicit mode switches), they don't offer visual guidance and need to be learned. In contrast, widget-based input supplies visual structures that allow manipulating multiple degrees of freedom (e.g. transformation gizmo as in figure 2b). If visually coupled with an object, they can make interaction on large or vertically oriented displays strenuous (reach, heavy arms).

We were therefore looking for an approach targeted at non-expert users that offers visual guidance, the benefits of high-bandwidth control offered by multi-touch gestures and a physically relaxed style of interaction.

3D-Content on a Curved Display

The seamless connection between a horizontal and a vertical display found in [9] or [10] enables a visualization of 3D content that has a spatial reference in the real world: the horizontal display acts both as desk and as physical part of a virtually continued tabletop display. This visualization technique has been explored in different scenarios ([4] [8]) and based on it we developed a prototype for viewing and interacting with 3D content (figure 1, 2).

The horizontal part of the curved display, which resembles a desk surface, is virtually continued into a plane that is projected into the curved part of the display. The virtual horizontal plane appearing "in the depth" is shown in green color and is the ground plane on which the 3D scene is built. 3D objects are visualized in the virtual space above the ground plane on the vertical part of the display. This setup should give the user the impression of sitting in front of a table with a 3D environment on top of it.

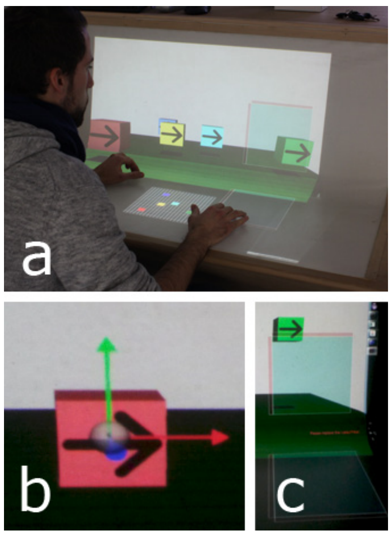

Figure 2 Images from the prototype. **a)** The visualization of the 3D scene with selection widget (middle) and virtual touchpads (right), **b)** the transformation gizmo for direct touch interaction and **c)** virtual touch pads for indirect touch interaction.

Input Method
Our *indirect input method* is based on two virtual track pads that spatially imitate the display's arrangement (see figure 2c, 3). The rationale of this design is that known multi-touch gestures (dragging, pinch-to-zoom, and two-finger-rotation) can be mapped to different dimensions in 3D space using the pad's orientation as an additional input parameter. The horizontal track pad is used to control transformations of a selected object in the (global) XZ-layer and the vertical one for the XY-layer.

The touchpads support both integral and separate control of DoFs for translations: if dragging gestures are initiated on the small visual bars on the sides of the pad (figure 3), the corresponding translation is restricted to the respective axis.

For object selection, a small top view map of the 3D scene was displayed on the horizontal part of the display (figure 2a), allowing users to select objects indirectly by tapping on the minified objects in the map.

Additionally, it was possible to rotate the scene around the Y-axis by dragging the visual ground layer left or right to enable transformations in the global YZ-layer (see figure 4).

As a baseline, we implemented a *transformation gizmo* known from most professional 3D-software (see figure 2b, 5), operated by direct touch. In translation mode, a dragging gesture started on one of the axes translated the object in the chosen dimension. In rotation mode, surrounding circles in the three coordinate dimensions could be used to rotate the object. Modes were switched using the keys *t* or *r* on a standard keyboard. Additionally, a semi-transparent sphere around the gizmo's origin allowed transforming the object in the plane parallel to the display plane. Selection was done by directly tapping on the objects and scene rotation worked as described before.

Evaluation
We conducted an experiment to examine the effect of the two different input techniques (direct touch with translation gizmo, indirect touch with 3D track pad) on 3D manipulation tasks. The following research question was investigated: How does the indirect input technique affect the performance of rotation and translation compared to direct touch?

Design and Participants
We used a within-subjects design with *input method* as the main factor and *task* as secondary factor. One half of the participants started with *direct*, the other half with *indirect input*. With each input method, the participants had to fulfill three tasks: docking, selection and navigation. The order of tasks was kept constant and the order of the single docking operations was randomized.

We recruited 17 right-handed participants (9 female, 8 male, aged between 21 and 61, 9 students and 8 participants with various occupational backgrounds) via an announcement on our lab's page in a social network and offered them compensation in form of a voucher (10 Euros) for an online store.

Procedure
Each participant was seated centered in front of the prototype. The three tasks were carried out consecutively with both input techniques. A short

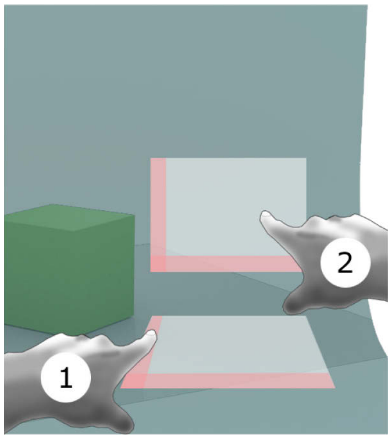

Figure 3 **(1)** translation constrained to one axis (Z-axis), **(2)** 2D-translation (XY-layer).

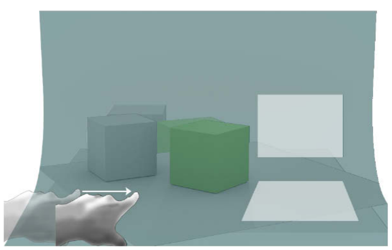
Figure 4 Scene rotation by dragging the scene left or right.

training phase preceded each task. Qualitative data were collected with paper questionnaires after each group of tasks and at the end of the study.

Tasks
Introduced by Zhai and Milgram [11], the docking task requires the participant to align one movable cube to another fixed one, using 3D transformations. Since we were not interested in the performance of a specific gesture set but in the concept of our input method, we omitted scaling to simplify the study design. We used docking tasks of two difficulty levels: *L1* included transformations in only one coordinate plane (i.e. 2D translation or 1D rotation), whereas *L2* included unrestricted 3D transformations. Further, we used different distances and angles, resulting in 18 different docking tasks.

In the selection task, the participants had to copy a given figure consisting of five differently colored cubes. One of the cubes had a fixed position and the other ones had to be selected and then translated to their according position.

The navigation task was similar to the docking task but involved barriers between the movable cube and the goal. The barrier consisted of four cubes that were not allowed to be touched. The position of the cubes was chosen in a way that a rotation of the whole scene was necessary to accomplish the task.

Measures
For each task, we measured task completion times and the number of applied transformations. For each transformation we recorded completion time and distance/rotation. Additionally, we recorded the amount of scene rotations.

Post-questionnaires were used to assess the participants' opinion regarding ease of use, understandability and ergonomics. We used 5-point Likert scales ranging from 1 (best) to 5 (worst) for these questions.

Results
We combine and compare objective data as well as subjective data and observations in four categories: *task completion time*, *perceived performance*, *perceived accuracy*, and *convenience*.

Task Completion Time
A repeated measure ANOVA did not reveal a significant main effect of *input method* ($F_{(1,13)} = 2.432$, $p=.143$). For *task*, there was a significant main effect ($F_{(1.2,15.606)} = 80.325$, $p < .001$); selection (M = 103.837s, SD = 7.387) took more time than docking (M = 40.308s, SD = 2.488) and navigation (M = 34.132s, SD = 2.577) (Bonferonni corrected). Mauchly's test indicated that sphericity had been violated. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .001$). Figure 6 summarizes the average task completion time per *input method* and *task*. There was a significant interaction effect between input and task ($F_{(2,26)} = 10.857$, $p < .001$). Selection took longer with direct input than with indirect input.

Perceived Performance
Participants were asked to rate their performance (completion time) separately for translation and rotation. For translation, performance was perceived slightly better with indirect touch (*median* = 2) than

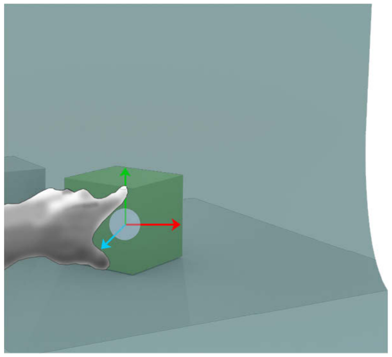

Figure 5 Object manipulation using the gizmo.

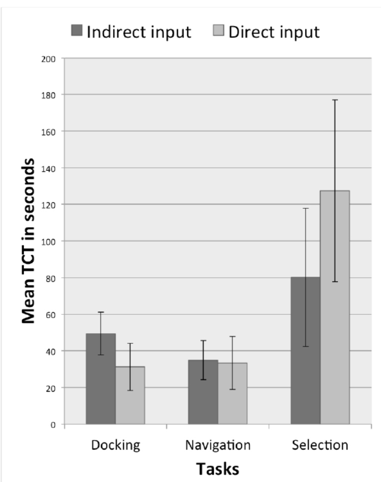

Figure 6 Average task completion time per task and input method (error bars: 95% confidence interval).

with direct touch (3). For rotation, the participants' perception was equal with both indirect and direct input (3). For the selection task and the navigation task, performance was perceived as equal (2).

Perceived Accuracy

The perceived accuracy during the docking tasks was rated separately for translation and rotation. There were no perceived differences between indirect and direct input. Translation (2) was perceived as more accurate than rotation (3). For the selection task and the navigation task, accuracy was perceived as equal (2).

Convenience

At the end of each task, participants were asked with which input method they felt more comfortable. 53% stated that they preferred indirect touch input for the docking tasks, 65% preferred indirect touch for the selection task and 53% preferred indirect input for the navigation task.

Further findings

For rotations, we observed that the visual guidance offered by the gizmo supported the participants in their spatial sense, whereas with the indirect touch pads, participants continually had to try out rotations to determine if they resulted in the desired effect.

Discussion

Our preliminary results indicate that for the chosen tasks, our indirect input method neither outperforms the direct touch gizmo nor leads to an inferior performance concerning task completion time. This is reflected in the subjective ratings of perceived performance. We find this encouraging, since the gizmo is an established tool.

The subjective data indicate a slight preference for the indirect input method. However, more research is necessary to better understand the reasons for it. At the current stage, the gizmo's visual axes and rotation circles seem to better support spatial sense, whereas the indirect input method seems to be more comfortable. Integrating similar visual guidance into the virtual touchpads might lead to clearer results here.

While not the main focus of our concept, the study results show that in our setup the indirect selection technique was faster than direct touch selection. While at the current state the selection widget is separated from the virtual touchpads, an integration of both mechanisms seems interesting, as the transformation of objects with the touchpads requires a previous selection of an object.

Potential Use Cases

While at the current stage our concept is still preliminary and has only been tested with abstract tasks, we see several potential use cases for it.

Interactive Museum exhibits

Applications in this category focus on the exploration of virtual exhibits or collections. They might involve assembling and disassembling complex objects (e.g. a model of an engine) and have strong requirements concerning learnability and ease-of-use.

Planning and Presentation Tools

Here, the focus is on tasks that do not require an extensive tool palette and high precision, but offer capabilities to manipulate and present 3D environments (e.g. a room planner).

Remote Collaboration

Hennecke et al. [4] presented an approach to teleconferencing that relied on the same visualization technique as described in this paper. In such a setting, our interaction concept can be used for manipulating objects in a shared virtual space.

Future Steps

Currently, we are mainly interested in two aspects of the concept: (1) we are interested in enhancing the indirect touchpads with visual structures that support the spatial sense as well as integrating a selection mechanism. While in the current setup placement and size of the touchpads were chosen on the basis of self-tests, the effect of these factors will need to be explored more formally. (2) Also, we want to focus on the bimanual interaction techniques that our concept enables. While splitting control of navigation (scene rotation) and manipulation (object transformations) between hands has been studied before [1], we did not focus on this aspect yet. (3) An important step for us is to pick a suitable use case and develop a prototypical application in order to test our concept in a concrete setting.

References

[1] Balakrishnan, R., Kurtenbach, G. Exploring bimanual camera control and object manipulation in 3D graphics interfaces. In Proc. CHI ’99. ACM Press (1999), 56-62.

[2] Cohé, A., Dècle, F., Hachet, M. tBox: a 3d transformation widget designed for touch-screens. In Proc. CHI ‘11. ACM Press (2011), 3005-3008.

[3] Edelmann, J., Schilling, A., Fleck, S. The DabR-a multitouch system for intuitive 3D scene navigation. 3DTV Conference: The True Vision-Capture, Transmission and Display of 3D Video, 2009. IEEE, 2009.

[4] Hennecke, F., Völker, S., Schenk, M., Schaper, H., Butz, A. (2013). PerspectiveTable: blending physical and virtual collaborative workspaces. In workshop 'Blended Interaction: Envisioning Future Collaborative Interactive Spaces'. CHI ’13.

[5] Hinrichs, U., Carpendale, S. Gestures in the wild: studying multi-touch gesture sequences on interactive tabletop exhibits. In Proc. CHI '11. ACM Press (2011), USA, 3023-3032.

[6] Liu, J., Au, O.K.C., Fu, H., Tai, C.L. Two-Finger Gestures for 6DOF Manipulation of 3D Objects. Computer Graphics Forum. Vol. 31. No. 7. Blackwell Publishing Ltd, 2012.

[7] Schmidt, R., Singh, K., Balakrishnan, R. Sketching and composing widgets for 3d manipulation. Computer Graphics Forum. Vol. 27. No. 2. Blackwell Publishing Ltd, 2008.

[8] Schwarz, T., Hennecke, F., Lauber, F., Reiterer, H. Perspective+ detail: a visualization technique for vertically curved displays. In Proc. AVI ’12. ACM Press (2012), 485-488.

[9] Weiss, M., Voelker, S., Sutter, C., Borchers, J. BendDesk: dragging across the curve. In Proc. ITS ’10. ACM Press (2010), 1-10.

[10] Wimmer, R., Hennecke, F., Schulz, F., Boring, S., Butz, A., Hußmann, H. Curve: revisiting the digital desk. In Proc. NordiCHI ’10. ACM Press (2010), 561-570.

Zhai, S., Milgram, P. Quantifying coordination in multiple DOF movement and its application to evaluating 6 DOF input devices. In Proc. CHI ’98. ACM Press (1998), 320–327.