BendDesk: Seamless Integration of Horizontal and Vertical Multi-Touch Surfaces in Desk Environments

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ABSTRACT
We present BendDesk, a desk environment that combines a horizontal and a vertical interactive surface that are seamlessly connected by a curved surface. This increases the perception of spatial cohesiveness and provides a continuous interaction. Furthermore, the curve functions as a storage for virtual objects and as a display for system events. The system avoids changing input modalities by supporting direct touch and pen input on the entire surface.

Author Keywords
Multi-touch, horizontal and vertical surface, curved display

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*Input Devices and Strategies*

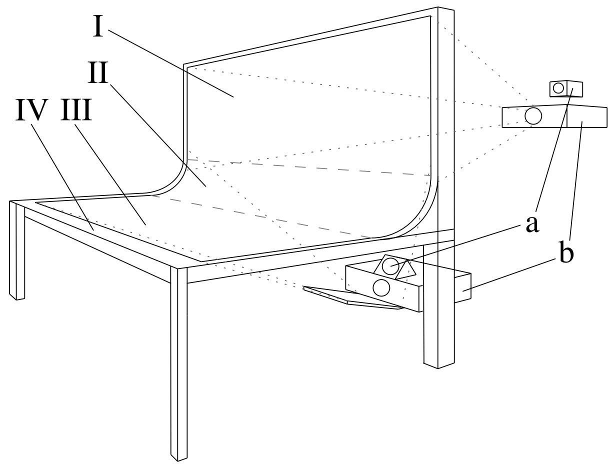

Figure 1. Hardware setup with interactive areas (I) Wall, (II) Curve, (III) Tabletop, (IV) non-interactive strip. a) IR cameras. b) Projectors.

INTRODUCTION
Vertical and horizontal interactive displays expose specific assets and drawbacks, and the choice of the appropriate angle depends on the user's task. On the one hand, vertical displays are the established output technology in desktop environments where keyboard and mouse provide efficient and well-optimized input devices. On the other hand, horizontal displays are more efficient for drawing tasks, such as annotation and graphics design tasks.

BendDesk represents a hybrid desk environment that combines both, a vertical and a horizontal surface. Unlike previous approaches involving multiple displays, both surfaces consist of one-piece and are seamlessly merged by a curve. This facilitates the perception of a spatially cohesive workspace, it allows to perform dragging gestures from one display to the other, and it offers an additional interactive area, the curve. BendDesk supports direct touch and pen input on all areas.

RELATED WORK
BendDesk is inspired by the Sun Starfire vision video [4], which anticipates a single-user desk that combines a vertical and a horizontal surface and is sensitive to a variety of input methods.

Morris et al. [2] evaluate several input modalities for reading and writing tasks on interactive surfaces. Vertical displays are preferred for entering text (using a keyboard) but users favor horizontal tablets for annotation and note taking (using a digital pen). The authors recommend a hybrid system that includes vertical and horizontal displays and that allows users to move data from one surface to the other. Based on a later study [3], the authors propose several design guidelines for the use of both surface types. They emphasize that designers "must account for the difficulty users have observing two different planes simultaneously". One of the problems users faced in the study was that they perceived the involved displays as isolated areas. BendDesk overcomes this issue because it provides a seamless transition between both surfaces. Morris et al. also point out the difficulty of changing input modality when switching from the horizontal to the vertical display or vice versa. We avoid this input barrier by supporting direct touch and pen interaction on all surfaces.

SYSTEM DESIGN
As illustrated in Figure 1, our prototype consists of a bended acrylic board that divides the surface into three interactive areas. The 39in $\times$ 15in horizontal *tabletop* is mounted in a height of 28in to allow comfortable sitting. The vertical *wall* amounts to a size of 39in $\times$ 19in and is placed in a depth of 18in to be reachable by an average adult person. The surfaces are connected by a *curve* with a bending radius of 4in. In order to support the users's ecology of objects [3], we include a small non-interactive strip of 3in $\times$ 39in in front of the user to allow her to rest her hands and to deposit

items. We derived the sizes for all areas from preliminary user tests.

One regular and one short-throw projector, which avoids a mirror beneath the table, render the user interface on a diffusor layer which is mounted on top of the surface. We employ Frustrated Total Internal Reflection (FTIR) [1] to detect touches on the surface: LED ribbons attached to all boundaries radiate infrared light into the acrylic. A layer of foamed silicone between the acrylic and the diffusor causes a spot in the camera image when a user puts down a finger on the surface. We preprocess the camera and the projector image to compensate for the distortion caused by the bend area. We employ an Anoto digital pen[1] for additional high-precision input. It determines its position using a dot pattern that is printed on the diffusor and sends it out via Bluetooth.

USER INTERFACE

The vertical and the horizontal surface can be used equitable. The user may choose which surface she wants to use for which task, e.g., a text can be displayed on the vertical surface for a reading task and on the horizontal surface for annotations. Direct touch interaction is used for moving, rotating, and scaling objects, as it is known for standard multi-touch applications. Because we aim for a continuous interaction, the entire surface is touch sensitive, i.e., an object can be steadily dragged or flung from the vertical to the horizontal display and vice versa. Pen input is exclusively used to modify objects, e.g., to write text, to annotate documents, or to draw associations.

The curve fulfills two specific functions: Firstly, it acts as a storage for virtual objects. If the user drags an object and drops it in this area, it is minimized to an icon. This can be helpful to avoid occlusions and cluttering on the other surfaces. By dragging the object back to the vertical or horizontal surface, it is resized and available for editing again. Secondly, the curve is used to notify the user about events. E.g., if a virtual object showing a live video stream has lost its internet connection, a brief message appears in the curve which is visually connected to the video object by a line. These notifications are particularly helpful if an event occurs on a surface that the user is not paying attention to [3].

REMOTE COLLABORATION

Many collaborative tasks require a private space for users to work on a specific subtask and a public space to assemble the results and to expose them to the group. We believe that BendDesk is potentially useful for remote collaboration because it naturally offers these particular spaces. When working with a group of remote users, the wall could represent the shared public document that is displayed to all users, e.g., the CAD map of a building. If a user wants to modify a specific part of the document, she can just drag it to the tabletop, the private space which is only visible to her. When done, she integrates her changes back into the public document by dragging it to the wall.

Moreover, the curve can act as an intermediate step in the process of collaborative work. Sometimes a set of subtasks have to be performed that are interdependent, e.g., a change of a node in a process chart might require adjusting other successive nodes. To avoid damaging the integrity of the public document, the user could accumulate all modifications in the curved area. When all dependent changes are performed, she can then integrate them all together into the public document by dragging them from the curve to the wall. This creates a continuous workflow from the private data to the public document.

USER STUDIES

In our user studies, we intend to explore whether the seamless merge between the vertical and horizontal area outperforms a system with two isolated areas in respect to efficiency and acceptance by the user. We are especially interested in the question if an increased spatial cohesiveness and a support of the same input modalities on the entire surface leads to a stronger involvement of all the areas to solve a specific task. We will further employ an iterative design approach to find appropriate gestures to move virtual objects between the interactive areas.

FUTURE WORK

We are building the hardware prototype and implementing the software interface. Futhermore, we will design a set of applications that make use of the table setup. Accordingly, we will conduct the aforementioned user studies to evaluate the usefulness of our system. Finally, we intend to explore how the table can facilitate remote collaboration.

ACKNOWLEDGEMENTS

This work was funded in part by the German B-IT Foundation.

REFERENCES

1. J. Y. Han. Low-Cost Multi-Touch Sensing Through Frustrated Total Internal Reflection. In *UIST '05*, pages 115–118, New York, NY, USA, 2005. ACM.
2. M. Morris, A. Brush, and B. Meyers. Reading Revisited: Evaluating the Usability of Digital Display Surfaces for Active Reading Tasks. In *Tabletop 2007*, pages 79–86, Oct. 2007.
3. M. Morris, A. Brush, and B. Meyers. A Field Study of Knowledge Workers Use of Interactive Horizontal Displays. In *Tabletop 2008*, pages 105–112, Oct. 2008.
4. B. Tognazzini. The "Starfire" Video Prototype Project: A Case History. In *CHI '94*, pages 99–105, New York, NY, USA, 1994. ACM.

[1] http://www.anoto.com/