Towards an Interaction Model for Multi-Surface Personal Computing Spaces

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Abstract
The prototype *Curve* was developed at our lab and its basic effects on touch interaction as well as elementary applications were explored in the recent dissertation of Hennecke [3]. My work is concerned with the concretion of his initial findings. In particular I am interested in (1) contextualizing the device by exploring specific application scenarios and (2) finding adequate interaction models that allow people using the display's input and output capabilities effectively and conveniently. In my thesis I want to provide guidelines that help user interface designers to develop interaction techniques for multi-surface personal computing spaces that comprise both horizontal and vertical touchscreens and show potential benefits of a seamless connection between them (e.g. a curved display segment).

Multi-Surface Personal Computing Spaces
I use this term to refer to computer workstations that are primarily intended for personal use. As such, it includes public terminals (e.g. in libraries, museums etc.), general-purpose personal computers (i.e. today's PC) as well as expert workspaces (e.g. in architecture offices or control rooms). Although intended for single user operation, they might be co-operated temporarily.

The integration of interactive surfaces into personal computing spaces (e.g. interactive tabletop with desktop computer) brings together WIMP and NUI interaction styles. On the one hand, this results in the coexistence of different interaction techniques. On the other hand, a combination of differently oriented interactive surfaces may help to retain an ergonomic workspace by enabling a better structuring of touch input (horizontal surface) and visual output (vertical surface). Further, a connection between these surfaces may allow for context-dependent transitions of digital content according to particular needs. To enable people to conveniently engage with digital content across differently oriented interactive surfaces, it is important to find a suitable interaction model.

Background

Several research and design prototypes propose to rethink personal computing spaces. In many cases these prototypes include large interactive surfaces. The envisioned properties of such "workspaces of the future" evolve around the broader context they emerge from.

Efforts from the NUI community mainly focus on exploiting the interaction capabilities of new hardware (e.g. interactive table-top computers). For instance, Matulic explores how to support productivity document tasks using pen and touch gestures on interactive table-top computers [7].

A different approach is illustrated by the Magic Desk [2] project (figure 1) from AutoDesk or the design concept iDesk. In these cases, WIMP and NUI interaction techniques complement one another: rich touch input can be used to enhance WIMP tasks (indirect pointing, window management, augmented mouse) and windows are used to display content on the desk. In this example, the multi-touch surface plays a subordinate role, since the use of a conventional personal computer is assumed and the prevailing interaction style (WIMP) is not in question.

Prototypes like *Curve* [15] or *BendDesk* [14] merge properties of both worlds: On the one hand, the large multi-touch surface (and the software framework used to build applications) relates it to the NUI community. On the other hand, the display's form factor picks up the idea of vertical displays known from standard computers and can easily contain all its components (dual use of the horizontal surface). Apart from ergonomic considerations ("gorilla arms", "stiff neck"), little is known about how these spheres might relate in the context of personal computing spaces.

A special property of such prototypes – the curved display segment – may help to think about possible relations between elements from NUIs and WIMP interfaces. First, it physically highlights that both spheres are connected and functionally equal. This might help to explore the interaction from a less predetermined point of view. Second, it presents a previously unallocated display space that can take on meaning.

Further combinations of vertical and horizontal interactive surfaces include for example SpaceTop [5] or MisTable [10]. These prototypes are based on the idea of an interactive see-trough (in case of MisTable even reach-through) vertical screen that also establishes a relationship with interactive surfaces or spaces behind it.

Figure 1 Magic Desk [2]

Approach

My approach is based on experimenting with different application areas, building interactive prototypes and extracting specific questions regarding the interaction model. I write multi-touch applications for the curved display using the MT4J-Framework. These applications occupy different dimensions of the above-mentioned term *Personal Computing Spaces*, such as applications for the public or expert workspaces. Specific and generalizable research questions concerning the interaction model evolve during the development of the prototypes. The goal is to identify (a) usage scenarios that involve the horizontal, the vertical and the curved part of the display and (b) to explore touch interaction techniques for these scenarios. Eventually, I hope to produce a set of guidelines that can inform the design of user interfaces for display setups with similar form factors.

Prototypes

Several interactive prototypes have been developed so far: (1) a quiz game featuring an interactive world map on one part of the display and pictures of famous places on the other part of the display (see figure 2a) [9]. The task is to answer the question "*Where is the place in the picture located*" by dragging the picture across the curve onto the corresponding location on the world map. I publicly exposed the game at our annual open lab day and observed how people approached the game. My key interest was if people without previous knowledge would recognize the possibility to drag pictures across the curve. (2) A music application (see figure 2b) allowing the composition of sound collages and rhythmic patterns. It features several components known from digital audio workstations and integrates a physical pad controller. Here, the idea was to explore how the form factor of the display can inform the design of an expert workplace. (3) A collaborative photo book layout application (see figure 2c) allowed two people to select pictures and arrange them with templates in a virtual photo book. The main focus was on the mutual awareness of two equal collaborators. (4) The latest project is an application to view and transform 3D content (see figure 2d) and is based on the visualization technique *Perspective+Detail* [11]. Here, the goal is to explore alternative ways to interact with 3D content by mapping the different orientations of the input surfaces to different.

By building and evolving these prototypes, I identified two main areas of interest, which I want to explore in my dissertation. The first *is (cross-display) object movement* and the second is *direct + indirect touch interaction*. Both topics are important for many computer-based tasks.

(Cross-Display) Object Movement

Object movement is of central importance in direct manipulation: within the borders of our monitors, we move windows, files and folders and the constant visual feedback helps us to continuously validate our actions.

Also, it helps us to structure the virtual space as well as our minds.

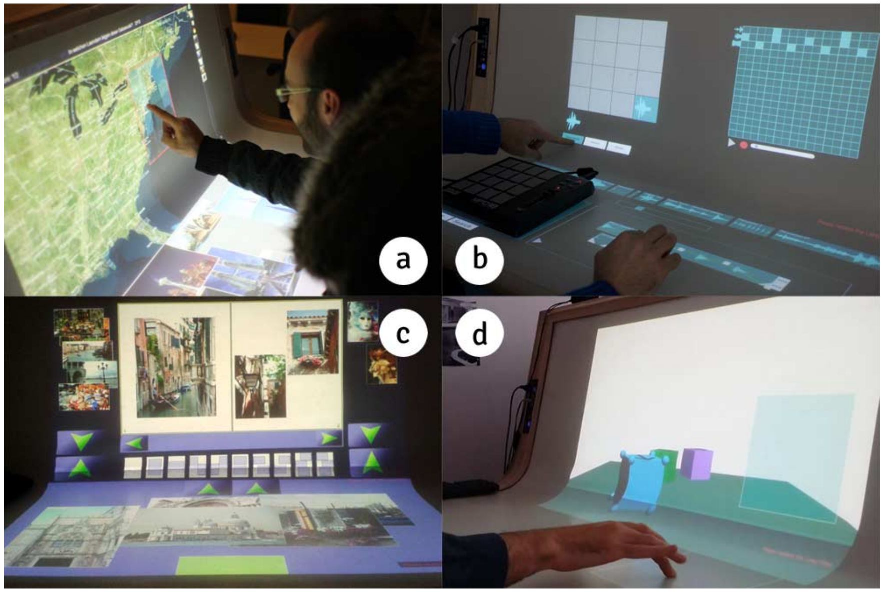

Figure 2 Prototypes: a) Quiz game, b) music application, c) photo book layout application, d) 3D manipulation.

I argue that independent from the underlying interaction style, extending the borders of the available display and input space requires also extending the ability to conveniently move digital objects across the whole display space. For example, it should be easily possible to comfortably arrange several text documents across both the vertical and the horizontal display without switching between mouse and touch input. In the context of *Curve* and *BendDesk*, dragging and flicking interaction techniques have been explored. While dragging across the curve is easily understandable and fun [9], it is not suited for prolonged usage due to physical demands. Flicking is an interaction technique that enables to move objects to distant places with sliding gestures. It is an open loop technique and its accuracy and error rate on a non-flat display arrangement depend on several factors (e.g. start location, direction etc.) [12]. Therefore, it is important to explore further interaction techniques that a) are accurate, b) efficient and c) comfortable. A starting point for my exploration is the work of Nacenta [8], who proposed a model for cross-display object movement and an extensive taxonomy of interaction techniques.

Direct + Indirect Touch

A second area of interest is the relation between direct and indirect touch input. Voelker has explored several state-switching techniques for indirect touch input to implement a three-state model of graphical input in Buxton's sense [12]. He used two identical touch displays with a clear separation between input (horizontal) and output (vertical) and a 1:1 spatial mapping. I am interested in how direct touch (and pen) interaction on the horizontal part of the display can be combined with the benefits of indirect touch interaction used to manipulate content on the vertical display (precision, gain, no occlusion). I think it is important to consider indirect touch not only in terms of pointing with a cursor, but as a context-dependent interaction technique that can have varying designs. Potential approaches range from a) dedicated virtual touchpads (as in Magic Table) to b) more implicit mappings that use unallocated display space on the horizontal display as input space and c) an approach where digital objects on the horizontal area allow both direct (i.e. dragging, rotation etc.) and indirect (manipulation of associated object on the vertical) touch interaction. An example for b) is illustrated in figure 3, where the gray space around the images can be used to pan and zoom the world map.

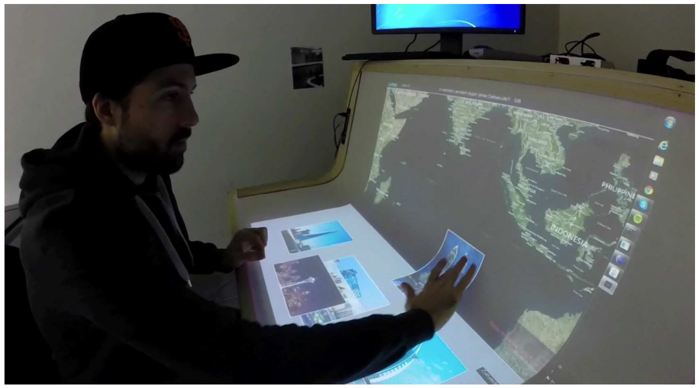

Figure 3 Indirect and direct touch

Current Projects

The Curve as File Browser

In order to improve my understanding of the interaction with the Curve, I built a simple musical application that allows the composition of sound collages. The main components of the app (sound editor, physical controller, sequencer) where distributed across the horizontal and the vertical display. One interesting outcome was the use of a horizontal file browser located in the curved area of the display. Through the use of the curved display space, the file browser may optimize cross-display interaction techniques, since a) it reduces distances and b) it might reduce errors due to the curved connection (e.g. aiming errors when flicking across the curve [13]).

Object Movement

Currently I am analyzing different contexts and interaction techniques for cross-display object movement. At the moment, I am focusing on techniques, that allow users to move objects from the horizontal to the vertical part of the display, as previous results indicate that dragging in this direction is less comfortable that dragging objects from the vertical display through the curve down onto the horizontal surface.

Virtual Mouse

For tasks that require high precision (e.g.) and for established software based on WIMP, it might be necessary to provide an adequate pointing device. In a current project I evaluate different versions of virtual mice that have been proposed for interactive surfaces. [1][6].

Indirect Touch 3D

The last current project is based on the visualization technique described in *Perspective+Detail* [11] and *Perspective Table* [4]. Here the goal is to find suitable ways to manipulate 3D objects located on the virtual part of the table by means of touch gestures on the physical part of the table. The form factor of the display allows exploring indirect touch input techniques that map the spatial arrangement of the display (i.e. horizontal layer (XZ-layer) and vertical layer (XY-layer)) to the transformation of 3D objects.

Next Steps

In the remaining time of my research I want to focus on the combination of direct and indirect touch input using the example of the 3D environment described above. Here, I want to investigate different input techniques for a set of basic tasks (e.g. selection, navigation, transformation). These input techniques can be classified along different dimensions: direct/indirect, horizontal/vertical display, graphical user interface/gesture set, touch/tangible.

Further, I am interested in how findings from the work with the Curve may be generalized to similar setups. Therefore, I currently use a combination of two conventional 23 inch touch screens as an alternative test bed. The form factor of this setup is similar to the curve, but it is smaller and the curved connection is missing.

Eventually, I want to provide design guidelines for the development of interaction techniques for multi-surface personal computing spaces that comprise both horizontal and vertical touchscreens and show potential benefits of a seamless connection between them.

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