Towards a Design Space for Non-Flat Interactive Displays

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Abstract

The design and construction of non-flat interactive surfaces is an emerging field of research. In this paper, we propose a design space for such displays in order to support structured discussions about differences and design possibilities within this area. Our design space is spanned by basic dimensions of shaped display surfaces, such as size, form and texture. As a starting point, we classify three prototypes from diverse deployment scenarios within it. Based on existing user studies, we discuss possible effects of the respective display categories. At the workshop, we would like to discuss and enhance the design space by integrating further novel non-flat displays, possibly identify additional dimensions and generalizable effects of the different display properties.

Towards a Design Space

Current research discusses non-flat displays mostly with regard to their technical realization, the effects on interaction and their potential for novel interfaces and visualizations. We propose a design space to provide a basic understanding of non-flat displays and a unified vocabulary to describe their properties. Non-flat displays can be classified according to the following dimensions: (1) *Shape* and (2) *Size* of the display as well as its (3) *Curvature* and (4) *Structure*. In a further step, we also involve the interaction-related dimensions (5) *Style* and (6) *Texture* to distinguish user interaction with such displays. These factors should apply to most

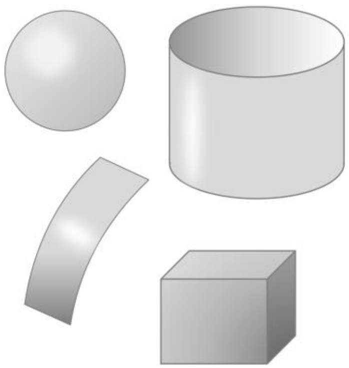

Figure 1: Examples for different shapes: a sphere, a column or barrel (depending on the user's position), a curve, and a cube.

non-flat interactive displays, but of course might have to be extended with further uses cases.

Dimensions of the Design Space

For now, we will only discuss two basic categories of design dimensions: those related to either form factor or interaction. More complex categories such as context of use are intentionally left out for later discussion.

Form Factor

These dimensions describe the physical properties of non-flat displays.

Shape means the geometrical form of the display (see Figure 1), which can range from curved surfaces such as curves or waves to geometric primitives such as cylinders, semi-cylinders, spheres, hemispheres or ellipsoid domes. In addition, combinations of multiple elementary shapes are possible, and flexible displays might even change their shape over time.

The shape of a display should *integrate well* with the environment (e.g., car, office, urban architecture), but it can also provide an interesting *mapping* between digital content and the display (e.g., a globe benefits from being displayed on a sphere [1]). In this way, shapes can strongly support a *metaphor* in the respective interface.

Size describes the physical dimensions of the display. It can vary from a small (e.g. wristwatches or glasses) to large-scale objects such as urban displays. Categorizations along the size dimension have been defined in relation to the human body, as in the classic tabs/pads/boards distinction [11].

The size, next to other factors such as the curvature, determines whether the non-flat display supports *immersive* or rather *non-immersive* experiences. Digital domes are examples for non-flat projection surfaces with large-size concave shapes to enclose the user and create total immersion.

Curvature is a property of non-flat displays that distinguishes them from other three-dimensional displays. A non-flat surface can be curved in a homogenous way, e.g., a *convex* or *concave* arch or sphere, or consist of *multiple curvatures* to create more complex surfaces. Planar subareas can be linked by a continuous *curved link* or a *sharp bend* to form an overall non-flat display.

Structure applies to displays composed of multiple *subareas,* which create complex non-flat surfaces. Each of the subareas can by itself have a distinct shape, and their size and connection type can determine the intended use. Discontinuities caused by bezels can distort visualizations between different display areas [7], but also be used to create separate working areas. In contrast, seamless connections between individual display portions allow a convenient visualization of transitions.

Interaction

These dimensions describe how people interact with non-flat displays.

Style: Shaped interactive displays can support manipulation via touch, but can also support contact-free interaction using gestures or body movements. For large non-flat displays, *touch interaction* is only possible with surface areas that are in reach of the

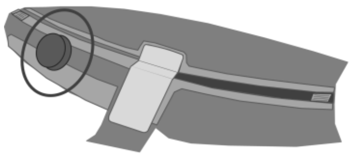

Figure 2: The Structured Center Stack is an interactive in-car display area with a convex and a concave bend. It is designed to ease touch interaction.

Figure 3: Curve is a non-flat display working environment designed to ease the transition between different subareas.

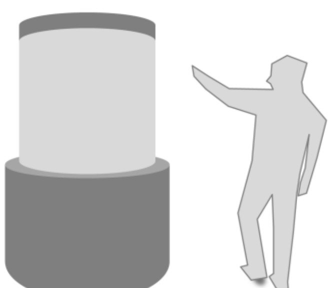

Figure 4: The Digital Advertising Column is a cylindrical display designed to engage passers-by in public spaces.

user. Therefore, the often-cited “Starfire” workplace design [10] curves the screen so that all parts can be directly interacted with. *Touch-free interaction* can be used to interact with distant spaces. Gestures and body movements should be designed in a way that they comply with the actual and perceived action possibilities of different display shapes. Additional interaction styles include tangible interaction [5] or deformation [3].

Texture describes how the surface of the display feels or is perceived. Smooth brinks or holes can provide guidance and feedback for touch interaction. Such *haptic textures* can help to complete actions with less effort and without visual attention. Roudaut et al. [8] showed that the texture of interactive objects at least influences touch behavior and accuracy. With touch-less displays, the mere perception of shaped surfaces may likewise create *implicit textures* that influence which movements or actions are performed.

Case Studies

In the following section, we present three prototypes we used to investigate the potential of shaped surfaces in different contexts.

Structured Center Stack

The Structured Center Stack is an example for a non-flat display within the automotive domain. Its structured shape fits a car's center console, and consists of convex and concave curvatures, organizing the surface into various subareas (see Figure 2). It serves as an interactive area that allows controlling infotainment functionality through touch. First usability tests revealed that the surface texture eases interaction when it supports the interface concept haptically.

Similar to corners and borders in desktop environments or on mobile phones [6], textures such as edges, indentations or holes help the user to interact on non-flat surfaces. This can be especially useful when interaction is the secondary task and should not distract the user’s visual attention from a different primary task, such as driving.

Curve

Curve is a large non-flat display within the domain of working environments (see Figure 3). Today's computerized work environments typically consist of at least one digital *vertical* display and a physical *horizontal* desk. Several projects [9,10] aimed to combine those working areas and their advantages to offer well-suited display areas for different tasks. One interesting property of this special display form is the ease of transition between differently oriented displays using a curve [4]. Moreover, a curved display allows special visualization techniques such as Perspective+Detail [9]: A virtual plane seems to extend the physical horizontal screen into a larger virtual desk behind the display. A first evaluation identified potential benefits of this visualization.

Digital Advertising Column

The digital advertising column (see Figure 4) is a large non-flat display in public space. The display encourages users to interact with it by reacting to the initial unaware movements of passers-by. Once engaging, users control visual content by touch-free gestures. Its shape is cylindrical and its curvature convex, which distinguishes it from state-of-the-art flat digital screens. The surface is also homogeneous and not structured in any way. A comparative lab study [2] with the prototype and a flat screen revealed that the two display shapes provoked different movement patterns, body postures and positions of users. With the flat display, users were facing the display frontally and hardly leaving a small spot from where they had the best perspective on the screen, while when interacting with the column they were moving most of the time, with a lateral body orientation to the screen.

Extending the Design Space

In this paper, we presented a first approach towards a unified design space of large non-flat displays. Based on our approach, we briefly discussed possible effects of each design dimension on interaction and presented three case studies that show some of these effects and further possibilities of non-flat displays. We hope that our work can support the discussions in the workshop and that we can extend and solidify our proposed structure there.

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