
Enhancing Flat Interactive Surfaces With Hollows: Prototyping And Interaction Approaches

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Abstract

One important property of non-flat interactive surfaces is that they provide haptically perceivable structures. The *visual* processing of information on the screen can be enhanced by *haptic* processing. Especially in the automotive domain, a main requirement for infotainment systems is to keep visual distraction below certain threshold values for glance durations. By utilizing non-flat interactive surfaces, we aim to ease the interaction with touchscreens. In this paper, we present our approach to prototype non-flat interactive surfaces. We describe our design process for a structured center console, featuring horizontal bends as well as hollows. We developed a variable prototype based on rear projection which allows comparing differently shaped surfaces. Moreover, we suggest concepts how to interact with the created shapes and report initial results of a user study. Overall, we want to inspire future development of non-flat interactive surfaces by providing methods for their fabrication, as well as interaction techniques.

Author Keywords

Automotive user interfaces; hollows; interactive surfaces; prototyping; touch gestures.

ACM Classification Keywords

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – Prototyping, Haptic I/O, Input devices and strategies (e.g., mouse, touchscreen), Interaction styles (e.g., commands, menus, forms, direct manipulation).

Introduction

Large touchscreens are hitting the automotive market. They provide the driver with flexible content presentation and the possibility to adapt to the current context and driving situation. Thus, they potentially declutter the cockpit. The main task in the car, however, is the driving task; interaction with the infotainment system is only performed as a side task. Yet, it remains unclear how to control touchscreens without visual attention and, as a result, without a decrease of driving safety. Due to the lack of haptic feedback, visual attention is required to locate interactive elements on the screen and perform the input; the only haptic feedback is that the finger touches the surfaces. Disburdening the visual channel can take place when we allow making use of further modalities. Auditory or dynamic tactile feedback can be applied to enable eyes-free interaction. However, they can be annoying and might not be applicable in the car, where people tend to listen to music and car vibrations are apparent. Therefore, we propose to use static haptics to make the screen surface tangible. The user can then explore their interaction space haptically.

Existing Non-Flat Interactive Surfaces

There is a growing amount of research in the field of non-flat interactive surfaces. We do not aim to cover the whole topic of shape-changing materials, but want to focus on static haptics.

Overall device shape

A device can be shaped as a whole. This has been proposed for architectural objects like advertising columns to enable the integration of a seamless interactive surface [2]. In a workplace environment, a user may prefer to read a document in the horizontal, but edit it in the vertical plane; both areas can be merged by bending the whole area to a large *Curve* [8]. Benko et al. [1] have developed *Sphere*, a multi-touch-capable spherical display that can ideally be used to present spherical data.

Add structure to flat surfaces

Differently, one can not only shape the device's body, but also add material to break planarity. El-Glaly and Quek [3] have developed an e-reader for visually impaired people. By adding a tactile overlay, they introduce physical landmarks on the screen surface that support the user without requiring visual attention. Zimmermann et al. [9] have taken a similar approach in an automotive context, by applying silicon foil on a touchpad to create a static non-flat surface. They propose a new type of interaction – dragging across the structure's border to select the item that was dragged – to integrate non-planarity in the interaction.

Apply embossments

Roudaut et al. [6] have proposed small shapes, namely convex and concave bulges, which are stamped into a flat surface. They showed that the orientation has an impact on interaction: convex bulges result in a higher accuracy, while concave bulges lead to lower spread of different users' finger positions when targeting the center of the bulge. This might be explained by the tactile guidance the depression provides.

Prototyping shapes (low fidelity)

Modeling clay and acrylic glass are well suited for prototyping shapes.

With *modeling material*, the visualization of ideas is possible that can also be haptically perceived. Its disadvantage is that objects lose their shape when they are touched with pressure.

Acrylic glass has certain characteristics of glass, such as its smoothness, and prototypes are resistant to pressure. Processing acrylic glass, however, is more complex. We heated the acrylic glass up for about 2 minutes in an oven at about 170 °C. We used further tools such as knives to create sharp edges and indents in the softened material.

Design Process

Previous work

The idea of a structured center stack for the car, which is based on convex and concave horizontal bends to fit into cockpit geometries, has been presented earlier [5]. Those bends have been shown to support interaction in terms of subjective comfort, and allow for new ways of interaction on touchscreens [5].

Shape inspiration phase

Similar to Schmid et al. [7], we started this project by exploring material properties and possible shapes. Therefore, we created a diverse set of shapes (Fig. 1). Those were created with modeling material and acrylic glass. We chose different types and sizes of bends, hollows, and rotary-controller-like shapes.



Figure 1. Set of shapes for the workshop.

Using those objects, we conducted an expert workshop, consisting of seven participants with a technical, design and psychology background. The workshop was performed in two steps. First, we placed the shapes behind a curtain, so people could not see, but only perceive them with their sense of touch (Fig. 2). They were instructed to imagine the shapes as elements of a touchscreen and think of ways how to interact with them, without giving them any specific function. Bends

were alternately placed vertically and horizontally. We took videos of the interaction behind the curtain. After the objects were revealed, the second phase of the workshop was to discuss the experiences and to create new ideas and combinations of shapes.



Figure 2. Eyes-free exploration phase.

Participants were surprised by the objects visual appearance. During the manual exploration, details appeared larger than they actually were. Horizontal bends were said to be more convenient to explore than vertical ones, as they give hold to the fingers. This was confirmed by the video analysis: fingers remained longer on horizontal bends and therefore also explored the hollows and other details more extensively. In contrast, on vertical bends, people used their whole hand to grasp the bend, to resist gravity, and therefore it was more difficult to explore the small structures. Moreover, we observed that people tended to perform a vertical scanning movement, which made it easier to detect the horizontal bends. People spent most time exploring the hollows: they dragged their fingers across the shaped surfaces and stopped when entering a

Prototyping shapes (medium fidelity)

Bending *acrylic glass* in a controlled way, a hot-air-gun can be used to heat up specific parts. We heated up the acrylic glass by blowing continuously for about 2 minutes along the area where the bend was supposed to be until the material was bendable. Then, we stopped blowing and pushed the material in the correct position. Within less than one minute, the material is rigid again.

Milling allows creating consistent, round shapes. With our tools, this left a Braille-like bulge that we either polished out or left as a further haptic reference point.

A *laser cutter* can be used to cut exact shapes, but also to create engravings. We used it to cut identical plates of acrylic glass. We also used it to refine the hollows we milled into the plates. For example, to provide further haptic cues, we engraved coarse- and fine-grained grids into the hollows. Moreover, we used it to cut the poplar wood for the housing.

hollow. They performed gestures around the borders, tapped inside and dragged their finger out in different directions, mainly with their index fingers. They commented that hollows “*afford to drag in and out*” and “*can serve as a reference point for further interaction*”.

Prototyping Non-Flat Interactive Surfaces

Based on the results of our previous work and the workshop, we decided to integrate hollows in a refined version of the structured center console [5]. Hollows are not suitable for all kinds of applications. In the case of a map application, a large flat portion is preferred to one that is interrupted by haptic elements. Moreover, visual content should be displayed vertically to allow for an optimal viewing angle, while touch should be supported by a hold, so we decided to integrate hollows into the horizontal portion between the bends (Fig. 6). This way, the touchscreen is separated in a display area and an administrative area.

Bending the overall shape

To create the overall shape of one convex and one concave bend, we used 4 mm acrylic glass. We bent the curves and combined them leaving a gap for exchangeable plates. These plates contain differently structured surfaces. This way we are able to compare a diverse set of interaction concepts on the same basic prototype.

Creating hollows

Hollows were created with a milling machine. We chose a diameter of 20 mm which corresponds to the doubled width of a standard finger tip. Additional to simple hollows, we created hollows with “children”, where we placed a smaller hollow next to the larger one, which overlapped and thus created a support when dragging

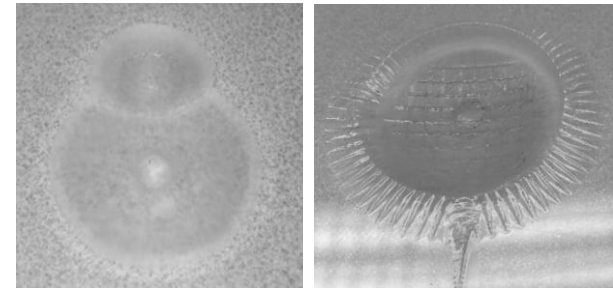


Figure 3. Milled hollow with “child” (left) & engravings (right).

in or out. Moreover, we created textures; inside to make different hollows distinguishable by making them feel smooth or coarse-grained, and outside to afford dragging along the ruffle into the hollow and support circular scanning along the border (Fig. 3).

Rear projection

We used a rear-projection setup (Fig. 4) with a laser projection (Microvision SHOWWX+) to have a sharp image in the different depth planes. As a diffuser, we used rear projection paint (white Screen Goo) which we applied to the flat backside of the acrylic glass plates. The housing was made from 4 mm poplar wood. We

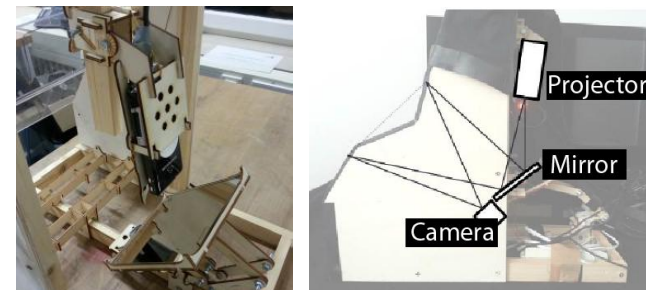


Figure 4. Back and side view of the prototype.

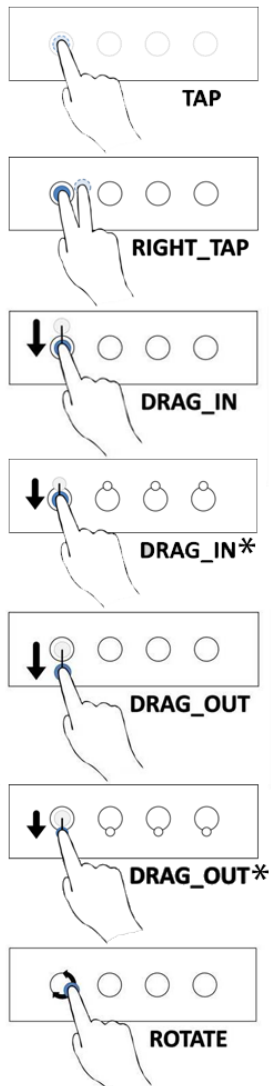


Figure 5. Our selection of gestures on and around hollows.

set up a rear diffuse illumination optical touch tracking (IR LEDs, Firefly camera), and used CCV 1.5 to convert the camera image into touch events using the TUIO protocol [4].

Basic Interaction With Non-Flat Surfaces

To see how hollows can support the interaction compared to a flat surface, we chose a selection task. This can be difficult on flat touchscreens while driving: an item must be targeted visually, then the finger must be moved towards it and finally touch it exactly. Instead of this direct selection when hitting the screen surface, hollows in combination with touch gestures make it possible to first explore the screen around an item. A specific action has to be performed for selection. This can also reduce unintentional triggering.

With our prototype, hollows are placed between the two bends. The user first positions the hand and the fingers and then starts to explore the screen. For the selection phase, we examined four different concepts (Fig. 5):

TAP: As on most today's touch systems, an element is selected by simple tapping into a hollow.

RIGHT_TAP: Inspired by using a mouse, the hollow is first entered with one finger (hover); then, a second finger is used to confirm the selection (click).

DRAG_IN: An element is selected by dragging from the top downwards into the hollow.

DRAG_OUT: An element is selected by dragging from the center of a hollow downwards out of it.

The downward dragging direction of the last two concepts were driven by preliminary evaluations, where an upwards movement was regarded as unpleasant.

We evaluated the different approaches either on a flat surface or with the haptic support of hollows. The order was counterbalanced. 20 participants had to perform a car-following task in a driving simulator environment. As a secondary task, they had to select items announced by pre-recorded audio commands.

Even for a simple TAP, participants preferred the hollows compared to a flat surface, although there is no help of the hollows when simply tapping. People felt more confident in performing the selection correctly, and felt less distracted from the driving task when supported by the hollows. Those hollow-supported interactions were rated better than tapping on a flat surface in terms of subjective visual distraction and confidence. Hollows with "children" were rated equally as without, but limit the flexibility.



Figure 6. A user is performing a selection with DRAG_IN by positioning the hand on the convex bend, placing the fingers on the horizontally oriented surface and dragging into a hollow.

Menu Concept Based On Hollows

To follow up with these results, we are currently developing a more complex system integrating the hollows. Users can interact with a menu, including the selection of items, scrolling in list and the adjustment of continuous values.

Textures in the hollows are used to make them feel different, so users can associate a function to a certain texture and identify it blindly. Different actions are possible with the hollows (Fig. 5):

DRAG_IN: Dragging in is used to select and activate a menu item.

DRAG_OUT: Dragging out is used to deselect and deactivate a menu item.

ROTATE: Dragging along the border of the hollow is used to adjust continuous values or navigate in a list.

As a next step, we want to conduct further user studies to evaluate those ideas and see what haptic structures and interactions make people rely on their sense of touch, and how the concentration on the haptic perception of the finger tip influences cognitive load.

Conclusion

In this paper, we have presented the design and prototyping process of a non-flat interface, to be used in an automotive environment. Different tools and processing methods can be used in different stages of the development. Hollows are a specific example for shapes on a screen surface. Initial ideas of how to integrate hollows into a larger touchscreen that consists of an overall shape with different types of bends, were motivated and realized in a prototype. Preliminary results show that static haptics can support interaction and make people feel less visually distracted. In the

future, we plan to further investigate the effect of haptic guidance on touch surfaces, to give interaction designers a further dimension for the development of interactive systems.

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