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Physical Fights Back: Introducing a Model for Bridging Analog Digital Interactions

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Abstract

Current transformational developments in automotive user interface (UI) technology are causing a shift in emphasis from safety and efficiency to emotion and flexibility. The many factors to consider in parallel make this a difficult process, in which technological affordances all too easily push the user to the background. To address this issue, this paper introduces an interaction model linking the different tangible control elements, including smartphone functionality, and shows how non-driving-related activities (e.g. climate control, multimedia access) can be represented physically. Next, a working prototype is presented that supports the design and development of novel tactile UIs. By integrating layers of sensors and actuators, a flexible UI is created that pushes technology to the background, giving proper attention to the user again and enabling effective research on how to make the digital world tangible for users.

Author Keywords

Tangible user interface; smart materials; shape-changing interfaces; haptic feedback;

ACM Concepts

Human-centered computing → Interaction design theory, concepts and paradigms

Introduction

Although natural user interfaces (NUI), such as speech-based interactions combined with large information displays in the dashboard and consumer electronic devices (CED) are seen as a key players in future user interface (UI) systems, several studies show that speech can result in higher workloads [1, 2], and the increasing usage of a phone decreases safety [3], thus advocating for the tangible ease of pressing a button to turn on simple in-car comfort functions such lights, climate etc. In fact, not only controlling safety- and effortlessness profit as Ishii [4] states that tactile feedback also prevents user frustration.

Preference of input and output devices during highly automated driving activities have been studied by Pfleging et al. [5], showing that smartphones are favored the most, followed by in-vehicle information systems. However, the study does not take basic yet essential comfort related non-driving-related activities (NDRA) into account, such as controlling temperature, nor does it acknowledge novel tangible user interfaces (TUI) modalities that enable hybrid versions of digital-analogue controls, such as active haptic feedback or shape changing surfaces.

According to Ishii [4], TUIs have always been special purpose whereas graphical UIs are general purpose and in that sense are flexible to adapt to most use-cases. With new technological- and material advancement however, such as printed electronics, smart materials [6] and smart textiles, potential interfaces could contribute to what Frens [7] calls rich user interaction. In here, action possibilities instead of controls interact with the user on an aesthetic basis and thus form, interaction and function are combined into one interface element.

Within the automotive industry several concepts with novel TUI have recently been presented, such as the “shy-tech” fabric media and wooden touchpad controls of the BMW iNEXT [8]. Although it could be argued that these UI surfaces are purely used for aesthetical reasons, Norman argues that beauty also contributes to a better understanding of a product [9].

Contribution Statement

While it is still relevant to measure effectiveness and distraction of new TUI [10], based on the shift towards autonomous driving, the importance/emphasis of TUI is turning towards a) how users can be surprised by novel TUI again instead of having black smooth surfaces that resemble CEDs, and b) how novel TUI can support the needed flexibility for future UI concepts.

Digital content from CEDs can be represented digitally into in-car screens in many ways, ranging from completely integrating physical CED objects into car UI objects to mirroring displays [11]. In addition to the two previous challenges, the relation between NDRAs and their enablers concerning comfort and entertainment functions poses a third challenge: c) how can “shy-tech” enable the CED to have physical roots, while maintaining flexibility, regardless of future CED development.

Figure 1: Graphical representation of media control

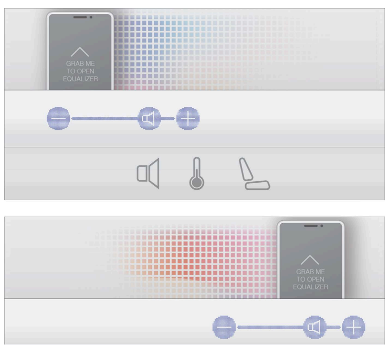

Figure 2: Graphical representation of positional interconnection with CED: the interface moves along with the CED

This paper reports on 1) a basic model how NDRAs, such as comfort and multimedia functions, could be represented physically, 2) the translation to a preliminary prototype that permits UI to be designed independently from the technology, and 3) next steps

UI Model for NDRA's

Surface Modalities

In order for TUIs to continue to contribute valuably in future transportation interior's human machine interfaces systems, the interface has to provide flexibility by a) maintaining the appeal of "real materials" while blending digital expectations and content, and b) supporting the variety of positions the user will adopt in future interiors.

Many 2D UI surfaces can be found in automotive TUI, ranging from traditional resistive or capacitive sensing displays and trackpads to the iNEXT's material integrated UI surfaces. According to Alexander et al. [12] shape changing interfaces can solve many relevant challenges. Various classification models exist on shape-changing interfaces [10, 13, 14, 15] but because of high abstraction levels, none of the models are applicable to transportation interiors. Therefore, table 1 introduces the physical varieties of relevant UI surfaces, or 2.5D surfaces (surfaces with fixed boundaries -fixed in a window- that are capable of expanding elastically within that boundary).

2.5D Surface Modalities	Invisible physical interface shapes	Visibly physical interface shapes
Non-physically actuated	(2) Transforming surfaces	(1) Passive search haptics
Physically actuated	(3) Active haptic feedback	(4) Morphing shapes

Table 1: Simplified physical varieties of 2.5D surfaces. Note that modalities can also be combined.

1. Passive search haptics [16] with integrated sensing and lighting can provide surprising UI in combination with materials generally not associated with UI.
2. Transforming surfaces communicate information to the user via changes in temperature or texture (e.g. electroadhesion).
3. Active haptics can fuse general- and special purpose according to use-case (the prototype presented in the next chapter of this paper includes this modality).
4. With morphing shapes, the aesthetics are inherently connected with the function's state (e.g. when a function is active, the physical appearance can change).

Interface Hierarchy

In order to give face to the modalities in coherence to Ishii's division of purposes, this work-in-progress paper presents a three-row model to control NDRAs and tertiary comfort and entertainment functions. As seen in table 2, each row increases in fidelity of information, thus creating a three-step hierarchy.

Row	Function	Example	Enabler
1	Basic selection	Media control	Fixed buttons
2	Main controls	Pause/scroll/skip	Hybrid system
3a	Extensive control	Equalizer	CED
3b	NUI/CED support	Notifications	Low-res display

Figure 3: Close-up of possible graphical representation of volume use-case through woven fabric

Row	Technology
n.a.	Local piezo haptics for confirmation haptics
1	Side-fire RGB LEDs for symbol lighting
2	Linear array of piezo’s for search haptics
	Flexible 25-PPI passive matrix mini-LED display
	Stitched conductive yarn for capacitive sensing position finger
3a	Stitched conductive yarn for capacitive sensing position CED
3b	Flexible 5-PPI smart LED display

Table 3: Overview of used technologies and materials.

Table 2: Hierarchical model bridging the gap between analog and digital TUI

In here, the position of a CED is detected in row 3b and row two moves with CED accordingly. Also, different use-cases are provided with different haptic feedback patterns in row one and two. By offering such a flexible system, NDRAs that are embedded into the car and CED focused NDRAs (e.g. adjusting seating positions and browsing social media) can happen simultaneously.

Embodiment of UI Model

Although the final objective is to investigate and develop UI possibilities with all 2.5D modalities, as a second delivery this paper combines a first set of technologies into a preliminary prototype. Following up on Heijboer et al. [17], this prototype will help to investigate active haptic feedback (2.5D surface modality 3) use-cases for digital interactions represented in the physical world.

As a technological basis, the Light.Touch.Matters project [18] provided guidelines in a first attempt to combine various smart materials into a “one-layer” flexible UI material. With the ambition to include materials such as RESi [19], conductive carbon fibers [20] or PEDOT-pTS dyed yarn [21] to pursue the elegance of thin layers, table 3 lists the technologies and materials that have been used.

Next to the two benefits mentioned in surface modalities, this prototype presents a first attempt to integrate TUI with freedom of top surface material (as seen in figure 3) and freedom of form (as seen in figure 4).

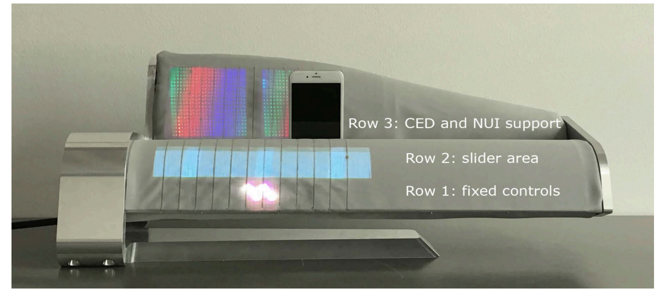

Figure 4: Functional prototype with 3 interaction areas behind a fabric top surface

Conclusion and Future Work

This work-in-progress paper explores how NDRAs in connection to mobility interiors can be fulfilled by novel TUI. The prototype has provided the authors with initial insights on the influence that interfaces, technologies, materials and shapes have on each other. Insights include possible relationships between a CED and corresponding TUI position, influence of display resolutions on graphical interfaces, the impact of search haptics on top surface material, and transmission effects of low- and medium resolution displays (5-30 pixels per inch) on yarn-based material.

For next steps, various iterations on integrating other technologies and materials will be carried out. Updated prototypes will enable further research on the liking and exploring of novel TUIs while providing feedback to the technology side.

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