

# In-Vehicle Touchscreen Concepts Revisited: Approaches and Possibilities

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## ABSTRACT

The last years have seen an increasing amount of innovations in the functionality of car electronics (e.g. advanced driver assistant systems (ADAS) and in-vehicle infotainment systems (IVIS)). These electrical systems are not reserved for premium cars anymore, but additionally reach mid-size, compact, and subcompact cars.

The growing number of functionalities in these cars entails increasing amount of interfaces, which may confuse, overload, or annoy the driver. Accompanying this, there is a trend towards the integration of capacitive touchscreens as user interfaces. These touchscreens were implemented first in consumer electronics and had a substantial impact on the way in which users interact with technology. This in turn has led to an increased user driven demand for the technology to be implemented in other domains, even in safety-critical ones like the automotive area.

Capacitive touchscreens have certain drawbacks in their distraction potential and their usability, leading to safety-critical situations and negative user feedback.

This paper will present a problem-driven approach towards touch input and a range of technical solution possibilities. The focus lies on the generation of a holistic touch experience: auditory, visual, and haptic feedbacks are combined with accurate force sensing for activation and deactivation. The reader will be given an overview over previous subjective and objective user research on force-sensing switching technologies. Additionally, he will be provided with applications that are able to fulfill the user needs of different vehicle classes. Although different in design, all applications aim at a common goal: maximizing driver safety, minimizing distraction and frustration, and enhancing the driving experience.

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## INTRODUCTION

The manual interaction with an input device in the automotive domain is a broad field of research. The first and still most important manual input feature is the steering wheel: In order to stay safe on the road, the driver needs to perform correction steering movements during every part of the drive. Manual interactions are also the ones which are highly trained during a lifetime's experience, and these interactions change with the technology that people are using: if someone tried to swipe away an image on a TV ten years ago, it would have been

considered strange, whereas young children who are used to a tablet may wonder why swiping gestures do not work on an older TV.

In the automotive context, the development of nomadic devices such as smartphones from the consumer electronics domain, has had a huge impact on the introduction of new functions, new technologies, displays and interaction possibilities. Some Original equipment manufacturers (OEMs) perceive a marketpull by their customers to adapt the interaction concepts of their products to those of nomadic devices [1].

Constant connectivity can become a problem, particularly in regard to driver distraction. Consumers have become accustomed to frequent internet access, during idle time or in fact during most regular activities. The websites accessed offer varying immersive experiences, many of which are highly distracting. Most OEMs therefore limit the internet connection while driving to specific applications. Applications themselves are another transfer from the consumer electronics domain.

One of the latest technology transfers was the implementation of touchscreens into the car. This is especially stunning as the first implementation of a touchscreen into the automotive sector occurred as early as in 1986 with the GM Riviera [2], but was dropped in 1990 as users were of the opinion that it was "onerous and distracting" [3]. Today's touchscreen technology has definitely improved technically, but it is still an input device which is prone to errors. For most integration concepts, the touchscreen is merely an additional input device and is not singularly responsible for a specific function (compare AUDI's or BMW's touchpad concepts).

Some OEMs are even drawing back from the introduction of touchscreens reverting back to mechanical buttons, based on negative user feedback. In fact touchscreens have certain disadvantages compared to mechanical buttons. The advantages of mechanical buttons include the direct feedback with kinaesthetic information, that they are usable with gloves and their robustness towards faulty activations compared to touchscreens.

A technology which can combine the advantages of mechanical buttons and touchscreens will be presented in the following chapters.

First, some background information on HMI design in both consumer electronics and the automotive domain is given. Synthesizing that, a short description of the problems when transferring interaction principles from one domain to the other is provided.

Secondly, the technical feasibility is discussed, which includes the drawbacks of conventional touchscreens in the automotive area, both for resistive and capacitive touchscreens. Afterwards, a new technology development is presented and its possible advantages over conventional touchscreen technology is discussed. The closing of this section includes design considerations and first usability studies with the new technology.

The third part consists of possible applications and interaction designs. The technology is discussed as a substitute for conventional mechanical buttons, a rather conservative and cost-driven approach, and later on for the integration of smart surfaces on the steering wheel. Possibilities for the substitution of buttons and touchscreens on the center stack are discussed as well.

## HMI ASPECTS OF HAPTIC INPUT DEVICES

When a user attempts to interact with a technical device, the specific design of the input device is crucial. Most input possibilities are haptic, some function via voice control, and some even via freehand gestures. Each of those input devices has its advantages and challenges. As the first option, haptic input, is of crucial interest for the presented technology, the focus of the following paragraph remains on this possibility.

### *HMI of Haptic Input Devices in Consumer Electronics*

Haptic input devices have the advantage that most of the everyday interactions such as opening a door or switching on an electric kettle are in fact haptic. This means that a haptic interaction feels rather natural to a user, as it is performed regularly in a similar way. One form of this haptic interaction is the depression of a common mechanical button. Due to their mechanical characteristics, mechanical buttons create a multimodal, intuitive feedback, consisting of haptic, kinesthetic, visual and auditory information [4]. A function is either activated or not, and the feedback about this activation should be immediate, unambiguous and accurate [5]. This increases the precision of an interaction.

Virtual buttons, as used on a touchscreen, are depictions of buttons on a resistive or capacitive surface. They occur on smartphones, tablets, and similar devices. There are two activation possibilities: either by contact force (resistive) or by the time a finger is sensed in a capacitive field [6]. The feedback of virtual buttons is artificial and consists mainly of the visual feedback that an action took place, an acoustic feedback which imitates some form of click, and sometimes a haptic feedback. In contrast to mechanical buttons, there is normally no kinesthetic feedback, so additional acoustic feedback is usually implemented as according to DIN EN ISO 9241-4 [7]. Some devices give additional vibratory feedback, which offers a wide range of design opportunities. Vibratory feedback is either activating the whole surface of a device, or rather at a small section of the screen.

Varying design possibilities of vibration duration, vibration amplitude and sound influence perception and preference of virtual buttons on consumer electronics [8]. Even the waveform of the vibration can have an influence on the usability of an interface [9]. The accuracy of the vibratory feedback is highly dependent on the technical design of the device.

Another advantage of this input technology is that the position of the screen and the activated hand normally can be moved, which avoids the fatigue effects which may occur with a fixed touchscreen [10] or freehand gesture control (known as the "gorilla arm syndrome", cp. [11]).

## HMI of Haptic Input Devices in the Automotive Context

In the last years, more systems like ADAS or IVIS were introduced in the automotive sector. More systems lead to an increase of functions which can be selected by the driver. As a function must be assigned to one control element to be attributed unambiguously, this leads to a vast amount of new input devices. This amount can become confusing in the first place and, when the driver needs to search for a button, even dangerously distracting. When those functions are conglomerated into a central controller computer unit, the risk of distraction is so high that most functions are not recommended for use while driving.

When implementing a function or a haptic input element into the automotive domain, its reachability is the first concern. This is standardized within the DIN ISO 3958 [12]. The location of a button on a steering wheel is of particular benefit as the driver does not have to take his hand off the steering wheel or search visually for a button in the center stack, which may cause distraction. The DIN ISO 15005 [13] regulates the design and position of controls in the automotive context as well as the dialogue rules for input and output of a system. It states that “hand controls that are frequently used in conjunction with steering activities (e.g. cruise-control switches) will be positioned within fingertip reach of the steering-wheel rim” [13]. Functions which are frequently used definitely should be put on the steering wheel, but there are also other possibilities of integrating other functionalities than those on the steering wheel.

The functions which are integrated vary highly between the original equipment manufacturers (OEMs). Common features include comfort functions such as push-to-talk, scrolling and selection functions, volume control and other, but also ADAS functions like the mentioned setting of the speed limit for a cruise control (ACC). Complex interactions, such as a central controller computer unit, are sometimes performed via rotary-and-push knobs. The latest trends are touch interactions (cp. [14]), with the possibility of handwriting recognition.

### Transfer from Consumer to Automotive

When transferring input functions from the consumer electronics domain into the automotive sector, careful examination of the suitability must be conducted. There are two main reasons for that. First, consumer electronics' interactions are designed for them being a primary activity, with no attention needed for another task. In contrast to that, in the automotive domain, the primary task must be driving and the attention to the road must have the highest priority. Second, the immersion of an interaction may be high when it is a primary task in consumer electronics; when the interaction instead is designed to be used while driving, the immersion must be kept low. The input devices in the automotive area should be easy to use, easy to learn, efficient, controllable and should have as little impact on the driving task as possible (cp. [15]).

If virtual buttons are introduced into the car, they face several issues. Touchscreens with no haptic vibratory feedback do not perform well in terms of usability (cp. [16]). Additionally, the high road vibrations during driving make capacitive touchscreens prone to errors, whereas the visibility of resistive touchscreens may be suboptimal for the automotive context. The visual feedback modality can be used as a subsidiary option only, as the distraction from the road ahead should be as little as possible [17]. Acoustic signals, which work fine for a consumer electronic device, may be too subtle for a noisy environment like the typical one of a car, and not be heard at all or, opposite to that, too distractive to be suitable.

The successful transfer to the automotive context depends highly on the adaptation of acoustic feedback to the particular environment and the reduction of the visual demand to as little as possible. In contrast to that, the feedback of the activation and the deactivation of a function must be very precise. Haptic feedback can transport this information, but the specific design of the haptic feedback and its vibration patterns is crucial. Another topic to be evaluated carefully is the actual button behavior. Activation and deactivation force, snap ratio or, for scrolling functions, the time constant must be designed very carefully. Unfortunately, this is often not the case. The risks and drawbacks of implementing a device before those factors are fulfilled are high. Users may be distracted which can cause accidents, or become frustrated with the clumsy interaction and refuse the product. And even the most careful feedback design cannot compensate for imperfect sensing elements.

For a careful evaluation, user centered design is an approach which can be used to minimize these risks. It is aimed to include the user as early as possible into and throughout the whole development process, with respect to his tasks and the environment he is interacting with [18]. Different qualitative and quantitative user test methods can be employed to ensure the safest in-vehicle interaction as possible. For the evaluation of the interaction, different tools like e.g. driving simulators can be used, but nevertheless the feasibility of a technical device must be taken into account.

The limitations and borders of a technology regarding its suitability may vary. Some indications about the suitability of conventional touchscreens and the technology presented in this paper are explained in the next chapter.

### Technical Feasibility

It is clear that the proliferation of capacitive touch screens in consumer electronics is now, after a tumultuous start, generally well accepted, and has become almost synonymous with modern electronics. The majority of those capacitive touch screen implementations naturally require the user to visually focus on the interaction task when operating the device, and in return the user is rewarded with immediate visual feedback. The importance therefore of tactile feedback is not essential for effective operation.