Mobile Device Integration and Interaction in the Automotive Domain

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ABSTRACT
People feel very comfortable when they interact with their mobile devices by using natural user interfaces (NUIs). However, when they enter a vehicle, this feeling degrades rapidly, since many in-vehicle infotainment systems (IVIs) still do not offer natural user interfaces and use different user interface interaction paradigms. For this reason, we show how mobile devices can be integrated and used in the automotive domain. We first elaborate on architectural concerns and then summarize possible benefits of a mobile device integration. A basic set of interaction scenarios is presented in order to show how integrated mobile devices can contribute to NUI experience in vehicles. Finally, two available approaches are introduced and their potential for NUI integration is initially evaluated.

Author Keywords
Mobile device integration, nomadic device, NUI upgrade.

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: Miscellaneous

INTRODUCTION
Mobile devices, such as smart phones and tablet PCs, are today's most popular devices that offer natural user interfaces and will be used for interacting with future internet services [5]. People of all ages use those devices by performing intuitive (multi)-touch gestures and using the interactive voice response (IVR) systems, due to the easy learnability of natural user interfaces. The ease of use and the availability of interactive and useful applications made mobile devices daily companions. They provide services like location-specific information, user-preferred multimedia content, mobile internet access or comprehensive communication, anywhere anytime. However when a mobile device user enters a car, the "anywhere, anytime" seems to end. Although many automotive manufacturers already integrate connected in-vehicle infotainment (IVI) systems in their cars, these systems are often at their very beginning, and thus are only offering some basic user interfaces. In many mid-sized cars or compact cars, there is often no head unit at all. Integrating mobile devices into the vehicles' IVI systems could solve many problems related to NUI and IVI.

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Based on the current development, we give examples how natural user interfaces of mobile devices could be used in the automotive domain. We first motivate the mobile device integration by giving examples. We then give an overview of possible architectural integration methods. The second part shows, how interactions between the IVI and the integrated mobile devices could be designed. Table 1 gives an overview of possible interaction scenarios and the different roles of the mobile device and the IVI system. Finally, we classify two currently available systems for integrating mobile devices in vehicle systems by means of their integration method and interaction possibilities.

BENEFITS OF THE INTEGRATION OF MOBILE DEVICES
Mobile devices are used by people of all ages, due to the easy learnability of natural user interfaces. Norman, in his article "Natural user interfaces are not natural" [7], supports this, but also highlights, that natural user interface paradigms are still not standardized and, for that reason, people have to get used to each different system they use. It can be observed that most users are more familiar with the handling of their mobile devices, than with handling different in-vehicle infotainment systems. Especially while driving, it is important that the user can interact with the IVI without having to concentrate on the handling itself. This can, for example, be achieved when the mobile phone is used for interpreting the gestures or voice input. Sonnenberg claims that "[t]he system shall respond in a clear, predictable and consistent way [...]" [9]. We believe this can be achieved with mobile devices, since the user is familiar with their mobile device's system, and can comprehend and predict the behavior of it.

Another benefit of using mobile devices together with – or as a replacement for – embedded in-vehicle infotainment is the ability to bridge the lifecycle gap between automotive and consumer devices. By now, the lifecycles of automotive hardware and software can be measured in years and decades. In contrast, the lifecycles of smart phones and tablet PCs are measured in months or years. In 2010, mobile device owners in the United States replaced their hardware on average after one year and nine months usage[1]. The lifecycle of mobile applications can be measured in weeks or months today. Automotive manufacturers try to keep track with the innovation cycle of consumer devices, but a real affordable possibility for updating or upgrading in-vehicle infotainment systems is not yet in sight. In general, only new models benefit from new systems. In addition to the lack of update possibilities,

[1] `http://mobilefuture.org/page/handset-replacement-cycle.pdf`

the specialized solutions for the in-car systems are often very expensive. A simple embedded navigation system can easily cause up to 3,000 Euro extra costs for a new car. The following yearly map updates cost on average between 150 and 200 Euro. Assuming a car lifetime of 10 years, the user could also use the money to buy a new up-to-date mobile device (including up-to-date maps) every year. Despite of having updated software, the user would also have new hardware and could directly benefit of updated interaction possibilities, and thereby NUIs.

Natural user interfaces consist not only of gestures and IVR systems. The inclusion of contextual information is also an important factor. Especially mobile devices, as ubiquitous personal devices, can access, calculate and provide a lot of information and data of their owners to adapt and contextualize in-vehicle infotainment systems. They are configured and adjusted to fit the user's needs. A simple example is the user's language that could be derived from the language set on the mobile device and thus be set for the in-vehicle interfaces. Most users also use their mobile device as calendar, and thus the device could derive where the user probably wants to go or when he/she should arrive. The navigation system of the mobile device can access the contact list and could automatically calculate routes to friends or meeting partners. Whereas saying "Navigate me to John Doe's working address" would confuse a classical in-vehicle navigation system, a mobile device based system could use its additional context-information to correctly interpret the user's command. The mobile device, a personal assistant, never leaves our side. It could also be used for storing in-car preferences, such as the preferred seat adjustment or temperature. This would simplify changing from one car to another car. As a kind of digital memory, the mobile device could enable a more energy efficient and more comfortable driving. For example, the known route, the driver's way of driving, which could be stored on the mobile device, and information from digital maps could be used to predict the charge levels of hybrid electric vehicles. Based on these predictions, the charge profile could be optimized: for example, driving up a hill could consume the whole battery charge, since it would get charged anyway during driving down.

Coupling the mobile device to the IVI would also enable transferring states between the systems. For example, when a user cannot park their car near the destination, the navigation task can be split up. In a first step, the system navigates to a parking lot and when the user leaves the car, the mobile device shows him/her the way to the destination. By using the internet connectivity of the mobile device, this could even incorporate public transport. At the same time, the mobile device can remember the position of the parked vehicle and lead the user back to it afterwards.

INTEGRATION OF MOBILE DEVICES

The integration of the mobile device into the vehicle's system is a key point in order to create a system that can benefit of the coupling. Besides thinking about the physical connection, one has also to consider the data interface. For the physical connection, there are, in general, two possibilities: *wired* and *wireless*. The following list describes wired connections that are commonly supported by mobile devices:

- Universal Serial Bus (USB): Up to 480 Mbit/s (for USB 2.0) bidirectional multipurpose link with charging support.
- Mobile High-definition Link (MHL): Charging and at the same time 1080p high-definition (HD) video and digital audio output via a single low pin-count interface.
- High-Definition Multimedia Interface (HDMI): Uncompressed HD video (inclusive 3D video) and digital audio output.
- Audio Line-In/Line-Out: Analogue audio input/output.

Modern docking stations allow an easy connection of the different wired outputs. Most mobile devices further have an option to detect whether they are docked to a car docking station or to a normal desk docking station. This allows, for example, automatic switching to a car optimized user interface with larger icons, or to switch off animations which could distract the driver. On the wireless connection side, the most common links are:

- Wireless Local Area Network (WLAN): Multipurpose network connection with a theoretical maximum throughput of 600 MBit/s (for IEEE 802.11n, 2.4 and 5 GHz)
- Bluetooth: Different protocols allow various communication types, for example audio distribution or IP networking.
- Near Field Communication (NFC): Simplifies device pairing and enables secure data transmission (up to 424 kbit/s) for a very limited distance.
- Mobile Network: Telephony and data services.

Figure 1. ***paragon's cTablet Docking Station*** **enables docking the tablet PC** ***Samsung Galaxy Tab 7.0"*** **in two normed car mounting bays. Source:** ***paragon AG***

Although inductive charging solutions are available for several years now [2], there are still only a few mobile devices that actually can be charged wireless. A wired connection with charging support is preferable for longer journeys. Dependent on the required data exchange between the mobile device and the car system, one has to choose the right connection type. When the mobile device shall be used as input and output unit at the same time, bidirectional multipurpose links, such as USB, WLAN or Bluetooth, are a good choice. For the output of multimedia content MHL, HDMI or WLAN with DLNA (Digital Living Network Alliance) software support could be used. A combination of different connection links allows high flexibility and performance at the same time. Especially when services should be provided for all car occupants, a wireless data or multimedia connection is the most convenient solution. The same applies for short trips, since the driver can leave their mobile device in the pocket. When femto-cells get integrated in vehicles, the mobile network could also be used for the coupling by providing the network for the car occupants.

The *cTablet Docking Station*[2] from *paragon AG* is shown in Figure 1. It allows connecting a 7 inch Android tablet PC to the car via two normed car mounting bays at the vertical center stack. The device is charged via USB and the connection to the car's system is established using Bluetooth. The example shows another key issue of integration the mobile device in the vehicle: especially when the mobile device should be used as head unit, and thus also should provide the natural user interface, it is important to put it to a place where the driver can interact with it in a natural way with eyes still being (mainly) on the road. Kern et al. [3] present an overview about the design space for driver-based automotive user interfaces. These investigations provide a good starting point for thinking about a suitable position where the mobile device could be placed in the car for interaction. This design space has, so far, not been defined conclusively. When the mobile device's display is used for output, it should be placed somewhere at the vertical part of the car where the driver can look at without looking too far away from the street. The mobile device can also be used as input device only. For example, it could be mounted at the horizontal center stack and the user can perform multi-touch gestures on the switched off touch display.

Another important challenge is the establishment of the in-car data interfaces. Since automotive innovation cycles are still measured in multiples of years (even 10s of years), a well-conceived, comprising and extensible interface has to be specified. A high-level solution, which is detached from the low level communication systems of vehicles, is highly preferable. There should be no need to interface directly with the in-car bus systems, such as CAN (Controller Area Network) or MOST (Media Oriented Systems Transport). Kranz et al. [6] proposed an open-access vehicular data interface for in-car context inference and adaptive automotive human-machine interfaces. An advantage of the system is that one can easily read out the current car state without the burden of acquiring a CAN matrix. The CODAR viewer [4] is an example for a situation-aware driver assistance system based on vehicle-to-x (V2X) communication. It demonstrates how V2X data can be provided efficiently to a visualization system. Slegers [8] shows how the integration of a personal navigation device (PND) in the car system could look like. He also introduces the *Reflection Interface Definition* (RID) language that allows simple description of changing interfaces. Those data interfaces are mainly focused on the context exchange part of the integration.

[2]http://www.paragon-online.de/en/2011/06/07/artikelblock-2/

For interacting with natural user interfaces using gestures on a touch display or speech interaction in vehicles, another set of interfaces are necessary. Human interface device (HID) classes are, for example, available for USB and Bluetooth. These base classes can be used or adapted for many input and output devices. Depending on the role of the mobile device, it can act as *host* or as *device*. When it is used as head unit replacement, it can work as a *host* and receive and interpret inputs from other car input devices, such as buttons, sliders or knobs. When the device is acting as input device, it can register itself as a *device* and provide inputs for the car system. Camera images, that can be used for gesture recognition, or audio input for interactive voice response systems can be transferred using available multimedia protocols for USB or Bluetooth. When an IP network connection is used, streaming protocols like the Real Time Streaming Protocol (RTSP) can be used.

INTERACTION WITH INTEGRATED MOBILE DEVICES

There are various ways, how an interaction between the integrated mobile device and the car's system could look like. For a simpler overview, we have summarized some common cases in Table 1. A combination of several scenarios will be actually used in many cases. A clear distinction is not always possible.

Looking at the different scenarios, one can derive benefits for a natural user interface from each single scenario. Even when the mobile device only acts as content provider, it can be beneficial for a natural user interface. It is most likely that the content on the phone describes the user's preferences. The content can even be used for deriving contextual information, such as preferred music genre by scanning the collection on the phone. The connectivity provider scenario can be considered as a support technique. It allows, for instance, connecting to social networks and cloud services using the user's private credentials that are stored on their mobile device.

CURRENT APPROACHES AND AVAILABLE SYSTEMS

Automakers and suppliers have developed already several interfaces for integrating mobile devices in the IVI systems. *MirrorLink* (former called *Terminal Mode*) [1] is the open industry standards solution of the Car Connectivity Consortium[3]. This protocol is an example for the *Head unit as mobile device remote display/control* scenario of Table 1. It uses IP technologies over USB and WLAN. Virtual Network Computing (VNC) is used for replicating the phones display on the head unit and to send key and touch events back to the mobile device. Audio can be streamed via Real-Time Protocol (RTP) or via the Bluetooth audio profile. This system allows using the natural user interfaces of the mobile device directly on the vehicle's human machine interface (HMI). Since the mobile device is used as the main system, the state is preserved on entering and leaving a vehicle.

iPod Out[4], developed by *Apple* and *BMW*, is an example for the "mobile device (MD) as partial user interface provider"

[3]http://www.terminalmode.org/en/agenda/consortium

[4]https://www.press.bmwgroup.com/pressclub/p/gb/pressDetail.html?outputChannelId=8&id=T0082250EN_GB&left_menu_item=node__2369

Interaction scenario	Role of in-vehicle infotainment (IVI) system	Role of integrated mobile device (MD)
MD as head unit	Provides vehicle parameters, gateway to different input and output systems (e.g. audio).	Provides all applications. Touch display used for input and output.
Head unit as MD remote display/control	Provides a display and can forward inputs to the mobile device. Only basic applications are running on the system.	Provides most of the applications. Sends output to the built-in head unit. Accepts inputs from IVI.
MD as partial user interface provider	Provides main interface. Allows to integrate external UI in selected views.	Provides UI content for the IVI.
MD as content provider (portable cloud)	Built-in head unit can request information from the MD. Provides all applications.	Provides access to e.g. available multi-media content, calender or contacts.
MD as context provider	Runs applications. Handles context itself.	Provides context such as language settings or saved seat adjustments.
MD as input device	Has own display. Runs applications.	Sends inputs such as detected touch gestures or evaluated speech input to the IVI.
MD as connectivity provider	Runs applications, uses telephony and internet connection of mobile device.	Mobile device provides telephony and internet connection to IVI.

Table 1. The mobile device's and the in-vehicle infotainment's roles for different interaction scenarios.

and "MD as content provider (portable cloud)" scenarios. A TCP/IP connection via USB or Bluetooth is used for transferring rendered images of the media gallery from a connected *Apple iPhone* or *iPod* to the HMI which displays the received content in a reserved view area. This allows the user a fast recognition of the displayed content, since the content is presented to him/her in the same way as it would be displayed on the mobile device itself. The system can be controlled via the HMI of the car. Since it has the same layout and follows the same interaction paradigms, the user can benefit partially of the mobile device's natural user interface. The car audio system is used for playing the selected content.

CONCLUSION

Mobile device integration in the automotive domain allows using the advanced natural user interfaces of the mobile device for the in-vehicle infotainment system. In order to enhance the experience for the users, it is important to choose the appropriate integration architecture. Besides selecting a physical connection type, future-proof standardized data and interaction interfaces have to be established. In this work, we summarized possible architectural approaches and provided a set of interaction scenarios. By describing the respective roles of the IVI system and the mobile device for those scenarios, we highlighted, what combinations are possible and what benefits result from the mobile device integration.

Considering the current available systems, one can recognize that there are already some usable approaches. It is for us, to use this technology in order to bring natural user interfaces into vehicles.

REFERENCES

1. Bose, R., Brakensiek, J., and Park, K.-Y. Terminal mode: transforming mobile devices into automotive application platforms. In *Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '10, ACM (New York, NY, USA, 2010), 148–155.
2. Hui, S., and Ho, W. A new generation of universal contactless battery charging platform for portable consumer electronic equipment. In *Power Electronics Specialists Conference, 2004. PESC 04. 2004 IEEE 35th Annual*, vol. 1 (june 2004), 638 – 644 Vol.1.
3. Kern, D., and Schmidt, A. Design space for driver-based automotive user interfaces. In *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '09, ACM (New York, NY, USA, 2009), 3–10.
4. Kranz, M., Franz, A., Röckl, M., Andreas, L., and Strang, T. CODAR Viewer - A Situation-Aware Driver Assistance System. In *Pervasive 2008 Demonstration*, vol. 236 of *Advances in Pervasive Computing*, Austrian Computer Society (May 2008), 126–129.
5. Kranz, M., Schmidt, A., and Holleis, P. Embedded Interaction: Interacting with the Internet of Things. *IEEE Internet Computing 14*, 2 (March-April 2010), 46 – 53.
6. Kranz, M., Weber, E., Frank, K., and Galceran, D. H. Open vehicular data interfaces for in-car context inference. In *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '09, ACM (New York, NY, USA, 2009), 57–62.
7. Norman, D. A. Natural user interfaces are not natural. *interactions 17* (May 2010), 6–10.
8. Slegers, W. J. Building automotive product lines around managed interfaces. In *Proceedings of the 13th International Software Product Line Conference*, SPLC '09, Carnegie Mellon University (Pittsburgh, PA, USA, 2009), 257–264.
9. Sonnenberg, J. Service and user interface transfer from nomadic devices to car infotainment systems. In *Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, AutomotiveUI '10, ACM (New York, NY, USA, 2010), 162–165.