AGILE DESIGN EXPLORATION: EXAMINING USER INTERFACE CONCEPTS FOR FUTURE NAVIGATION SYSTEMS

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Abstract

The design space for navigation systems is much bigger than what is seen in commercial products today. Innovation in navigation systems currently reaching the market often focuses on "eyecandy" that adds little to the usability of the systems. There is, however, a large opportunity to improve input, output, functionality and adaptivity of navigation systems. We report how an agile design exploration process was applied to examine this design space and develop system probes for use scenarios in pedestrian navigation, small-craft sailing and on/off road car navigation. We discuss the user feedback and its implications for future interface concepts for navigation systems.

The market for so called personal navigation devices (PNDs) has experienced a rapid expansion in recent years. Until 2001 the automotive navigation market had been dominated by embedded navigation systems. Since then portable PNDs have taken over a large percentage of the market. While marketed as personal devices that are "portable" and suitable for "hand-held" use, the current generation of PNDs is designed specifically for in-car use on the road network. Efforts to address the specific requirements of pedestrians, cyclists, bikers or off-road navigation have been very limited so far. While there is a lot of variety in the details of the interaction mechanisms and presentation styles used in current PNDs most systems use a common design, employing a touch screen (and sometimes speech recognition) for input and a 2D map or 2.5D perspective view combined with audio output to convey the guidance information. With the increasing competition in the PND market developers are currently looking at a variety of innovations to distinguish their products from the competition. Typical examples include the use of wide-screen displays, the use of textured 3D models in the visualization or the integration with on-line services to provide "intelligent" routing. While many of these new features are certainly effective from a marketing perspective they seem to add little to the usability of the systems, as experience reports of users show.

A large opportunity exists to advance the usability of future navigation systems by improving input, output and functionality and adapting them better to users and the task at hand. A user-centred process is required to develop innovations in these domains that are of actual benefit to the user. In the work reported here we have applied an agile design process to explore the design space for navigation systems without limiting the process to established standard hardware platforms. Selected system probes were developed and tested to validate key assumptions and inform future design decisions.

Introduction

The central aim of the research reported here is to identify promising design directions to improve the usability of future navigation systems. As background information we gathered data and user feedback on current navigation systems and conducted a number of pilot-studies to gather additional user comments and feedback. Since car navigation PNDs are most widely used they are familiar to many users and a large amount of information is available (though surprisingly few formal usability studies are published). To complement this we also gathered information on different usage scenarios, in which personal navigation systems are or could be used, including pedestrian navigation in city environments, cyclists, other sports, small craft-sailing, cross country trekking and off-road driving.

While a comprehensive summary of the results over such diverse domains is difficult, two findings appear in all categories: users are still easily frustrated with the available user interfaces even when using current best in class devices and users rate many of the current innovations lower after practical experience than in a pre-use interview. A typical example of this was illustrated in an informal test of the Tomtom Go 930Traffic, a current high-end PND. Five users who were familiar with older PNDs were asked to rate several features of the system in a pre-use questionnaire. They then had the opportunity to use the system for 90 minutes and where then asked to rate the effectiveness of the features. Two of the most highly ranked features in the pre-use questionnaire were “large wide-screen display” and “IQ routes intelligent routing”. Regarding the wide screen display a typical after use comment was: “It sounds like a good idea, and obviously it looks nice. It shows lots more left and right to the road – this is quite obviously not where information is needed.”. Regarding the IQ routes system that aims to exploit knowledge gathered by users over several years on average speeds at different days and times no user was able to identify its impact (“was it on? I can’t tell.”; “well, I guess it didn’t hurt”). Similar indecisive comments were observed after the use of a prototype system that uses 3D city models in the visualization, a current hot topic in PND marketing. While novel features received less importance after practical use, test users placed a high importance on the ease of interaction, especially selecting and modifying destinations and routes. This was even more pronounced for the non-standard navigation applications, e.g. pedestrian navigation and sailing. Obviously, there remains a lot of potential in improving navigation systems in ways that users regard as relevant.

Objectives

The results from our pilot-studies motivated the more detailed examination of several possible design directions for future PNDs, reported in this paper. A wide variety of concepts have been proposed that could help to ease navigation, including context adaptation, 3D visualization, augmented and mixed reality, specialized guidance systems and the extensions of paper maps. A key challenge is to evaluate which of these approaches are ultimately useful for end-users. A comparison is rendered difficult since both the principle concept and their actual implementation influence the user experience in tests. Furthermore, the close connection between devices, interaction, visualization and the context of use introduces additional variables, such as hardware, data and infrastructure requirements that can be hard to capture, especially for emerging technologies like augmented reality. While practices from user centred design (UCD) (Mayhew, 1999) are well established and similar techniques have a long history in cartography (Nivala et al., 2007) the incorporation of emerging technologies requires a new approach that considers the need for rapid and cost effective exploration of systems that incorporate hardware, software and infrastructure components. Using an agile process for design space exploration the central objective of the research reported here is to explore the large design space of promising concepts for future personal navigation systems in a user centred fashion, in order to establish base-line data and identify promising directions for future PND implementations.

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Interface Paradigms in Personal Navigation Devices

Users interact with a computer system, like a PND, through a user interface. The user interface consists of all the input devices with which a human user can interact, the software that interprets the user's actions, the visualizations and other feedback generated by the device and the corresponding displays and output devices. User interfaces can be categorized by styles or paradigms. The most well known paradigm is the so called WIMP style (labelled after the characterizing elements of windows, icons, menus, pointer) that is ubiquitous in desktop applications. While WIMP interfaces have many benefits in desktop settings they can be difficult to use in mobile applications. Early PNDs employed a very restricted interface with rudimentary input and output consisting of spoken navigation instructions and direction arrows. Most current PNDs employ a style that borrows from WIMP interfaces and modify them with the use of a touchscreen as the main input device (pointer) and an output presentation style that is based on the metaphor of classic road maps (instead of a "desktop" with "windows" and "folders"). More experimental systems employ a style centered around concrete visualizations (e.g. satellite images and textured 3D environment models), inspired by 3D world viewers like Google Earth. Interaction styles with these systems vary, but are often modifications of the more traditional PND interfaces. A fourth group of systems focuses on visualization techniques from Augmented Reality (AR) and combines real-world views with abstract information. Combinations of all approaches are possible and a promising approach is to adapt the interaction and presentation style to the usage context. The following paragraphs summarize characteristics of these interface paradigms in PNDs, using four categories that we analyzed in the pilot study:

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Arrow and Instruction PNDs (Historic):

Description: Output consisting of spoken navigation instructions and direction arrows. Input typically a very restricted form of alpha-numeric input. Functionality limited to simple routing.

Examples: Early embedded navigation systems for the automobile market like the Blaupunkt Travelpilot RGS 05 (Bosch, 2005)

Characteristics: Simple guidance, very abstract visual display (arrows only)

Benefits: No distraction, automatic guidance compared to maps

Shortcomings: Lack of additional information display, rudimentary functionality

Afforded interactions: Alpha-numeric location input through a small number of buttons

Map-based PNDs (Current standard):

Description: Based on the metaphor of classic road maps, map-based PNDs enhance the presentation of arrow and instruction PNDs with graphical map display. Common in PNDs and onboard systems.

Examples: TomTom GO 930 Traffic (TomTom, 2009), Garmin Nüvi (Garmin, 2009)

Characteristics: Map like 2D (or 2.5D) representation at a high level of abstraction. Textual input of start/destination.

Benefits: Familiar look, large coverage of available data sets, applicable in mobile and build-in systems.

Shortcomings: Optimized for in-car A to B navigation, lack of adaptation and flexibility.

Afforded interactions: Visual and alpha-numeric location input, zoom, 2D pan and search through touchscreen and additional buttons.

3D World-View PNDs:

Description: Based on the concept of 3D world-viewers like Google Earth, incorporates techniques from map-based PNDs into a perspective 3D visualization

Examples: VW Google Earth Navigation Prototype (Volkswagen, 2006), partial implementations with limited coverage in some current high-end PNDs.

Characteristics: Visual display at a low level of abstraction using satellite images and textured 3D models combined with additional meta-information visualizations like labels and annotations

Benefits: Easy visual specification of locations, visual landmarks, enhanced POI presentation, entertainment
Shortcomings: Possibly the lack of abstraction (e.g. photorealistic depictions can be irritating if they do not match the season or time of day), lack of available 3D data sets for many areas.

Afforded interactions: 3D zoom and pan in addition to the functionality of map-based PNDs

Augmented Reality PNDs:

Description: Spatially registered guidance information is embedded into the real-world view of the user.

Examples: Only research prototypes like “Mixed Reality Navigation” (Tönnies et al., 2006) and “Augmented Reality Navigation” (Siemens, 2005). Current commercial systems like the HUD navigation system in some BMWs and the “video navigation” option in current Blaupunkt PNDs offer only limited spatial registration and do not realize a true augmented reality navigation in their guidance functionality.

Characteristics: Combination of real-world with abstract information. With the use of appropriate displays the separation between navigation device and real-world environment can be removed.

Benefits: Intuitive presentation, integration of night vision and other warnings possible. Possible improvement in situation awareness and reduction of distraction.

Shortcomings: Current lack of suitable positioning and display technologies. Requirement for very precise and current data sets.

Afforded interaction: Often combined with more conventional navigation functionality for route specification and interaction.

Design Space Exploration

The examples of PNDs with different user interface paradigms shows that a wide variety of design options exists. If the application area is expanded beyond typical car navigation even more options are of interest. The effective design of a system that aims to support users in navigation must take the specific circumstances and constraints of the intended use into account. Navigation systems, like many other mobile applications, are used for short episodes, possibly as one task among many. The intentions of users may vary from effective A to B navigation to more entertainment oriented uses with an integrated wayfinding component, as in mobile tourist guides or mobile games. In all use cases the system should be functional and usable. User centered design (UCD) processes (e.g. processes based on ISO-13407 (1999)) are well suited to address such requirements. However, established UCD processes require an extension when non-standard hardware or novel infrastructures form a significant part of the new system. We have therefore developed a specific exploratory development process that combines concepts from agile software development with user centred design and usability techniques. Using this process in various stages of refinement we have developed a number of system probes to explore the design space of PNDs in various directions.

The key principle behind our exploratory development process illustrated in Figure 1 is to iteratively develop refinements of the system in rapid succession, as advocated by agile software engineering practices like scrum (Larman, 2004; Schwaber and Beedle, 2002) . These prototypes are then used to evaluate the system with users and to validate base technologies. The results guide the refinement in the next iteration. In general, development starts with a rough approximation and then proceeds towards components that are increasingly refined and more complex. Scrum is a popular agile process in which development activities are organized into short 30 day iterations, called sprints. Each sprint starts with a planning meeting in which the functionality to be developed is selected from the product backlog, a flexible requirements repository that evolves with the product. In the beginning it only contains high-level requirements and its content gets more and more precise with each sprint. The scrum team and its manager – the scrum master – meet in short, daily meetings, called daily scrum, to report progress, impediments and further proceedings. Every sprint ends with a sprint review, where the current product increment is demonstrated to project stakeholders. The flexibility of scrum allows to integrate user centered design activities and to address technology constraints. We have integrated requirements elicitation, user centred design and usablitity evaluation activities into a scrum based process to derive a procedure that is well suited for exploratory development purposes. Details on the process are reported in Paelke and Nebe (2008). In the following sections we describe a number of system probes that were developed to explore the design space for future PNDs.

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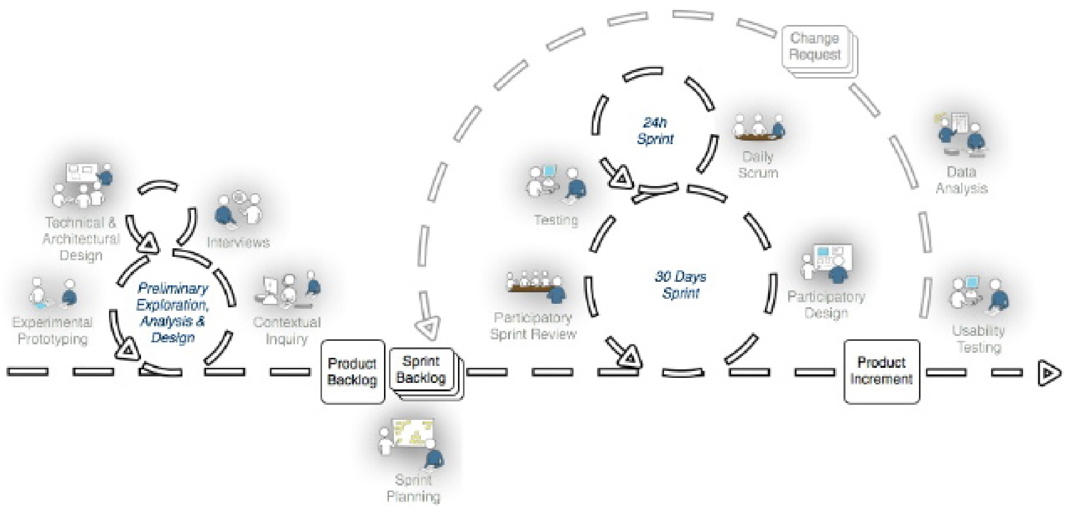

Figure 1: Overview of extended scrum development process

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System Probes

Con formato: Inglés (Estados Unidos)

Off-road Navigation

Off-road navigation is an example for a specific navigation use-case with user and technical requirements that are not handled by standard PNDs. In some sense off-road navigation is more similar to pedestrian navigation than to conventional car navigation: movement is not restricted to a well defined road-network and distinct street names or well defined decision points (that are ubiquitous in on-road navigation) may be lacking. Since pure off-road use is an unlikely scenario the actual navigation task to be supported depends on the context, covering both physical aspects (on-road/off-road) and usage (in-car/out-of-car).

In off-road navigation users still want to get from one point to a specific destination, but there may be obstacles on their way, such as rivers or flooding, woods, rocks, etc. These obstacles cannot always be presented on a navigational device (as they vary over time) and can, therefore, not be used for routing. Instead, information about the orientation (north, south, east, west), a visualization of the topography and straight connection to the destination might be more useful. Thus, depending on the tasks and the surrounding context, there are different information needs to be displayed. Some existing devices offer different ways of performing navigation tasks but they do not always consider the context in its full extent. Existing devices also do not support a switch between different interaction mechanisms, which may be necessary to ensure continued system use. A very precise interaction concept can be challenging while driving on a bumpy road, but would be suitable while standing and could result in faster interaction when applicable. Especially in situations in which the context changes frequently, abruptly or significantly, a context adaptive interface offers benefits in comparison to non-adaptive systems.

To evaluate the impact of context, especially in the interaction, we developed a prototype off-road navigation system (Figure 2) that supports different ways of entering data by switching input devices and also adapts the information display depending on context parameters. The context parameters considered in the prototype include: location, speed, driving direction and track conditions (on-road or off-road). If the user drives from a road onto off-road terrain the system automatically switches display (road vs. map view) and data entry techniques (robust and slow for off-road use vs. faster but less robust input in less challenging contexts). The agile user-centered design process was used to develop the prototype. It was installed in a

4WD car on a Windows-based Car-PC, equipped with GPS for position tracking, a TFT for visualization and three input devices (touchscreen, multifunction know, wheel slider) for testing various user interaction mechanisms. Using this prototype several experiments were performed in which users were observed in real on-road and off-road situations.

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In the experiments we examined if users were able to follow the adaptation to use the newly created possibilities (affordances) and if the system was regarded as suitable to reach user goals in an efficient, effective and satisfying way. We also determined the reaction of users towards adaptation in general as well as their assessment of the individual visualization and interaction styles.

Our observations show a strong contrast in acceptance between adaptive information display and adaptive interaction mechanism. Users did not like to change their preferred interaction mechanism, especially not if this was enforced by the system. While users liked the idea to have multiple mechanisms (and devices) to interact with the system, depending on the context they were frequently irritated and sometimes frustrated that they had not been notified by the system about the adaptation (e.g. when the system denies using one mechanism, as one is not allowed to use the touch screen while driving). The change of displaying information depending on the context (e.g. when users drove off the mapped tracks the on-road style changed to an off-road style) was well accepted and easily understood by all users. All users willingly accepted that the way information is being displayed changed without being asked. Users appreciated an adapted information display when the adaptation made sense to them (e.g. when driving off-road). Further research is required to examine how a variety of techniques and interface paradigms can be supported in a consistent and usable way.

Figure 2: Visualizations for on-road (left) and off-road navigation (middle); User tests performed on-road and off- road (right).

Augmented Paper Map - APM

Paper maps and mobile electronic devices have complementary strengths and shortcomings. In uses like small craft sailing or cross-country trekking a complete replacement of maps is often neither useful nor desirable. Paper maps are fail-safe, cheap, offer superior resolution and provide large-scale overview. In safety critical uses like sailing it is therefore mandatory to carry adequate maps. GPS based mobile devices, on the other hand, offer useful features like automatic positioning and plotting, real-time information update and dynamic adaptation to user requirements. In the APM project we have augmented paper maps with interactive functionality. A mobile device is used as a see-trough lens over a conventional paper map that is augmented with some modifications to enable a precise positioning of the device on the map. Using this setup it becomes possible to augment the printed map with additional dynamic content and interactive functionality (Figure 3). The APM project illustrates an example of a navigation system that differs significantly in its hardware structure and interaction techniques from current standard PNDs. A specialized software framework for the implementation of APM techniques has been applied (Radomski, 2008) to enable experimentation with different APM interaction and visualization techniques. Detailed information on the APM is available in Paelke and Sester (2007). Relevant results and conclusions from the APM project have been included in the results.

Figure 3: APM prototype setups for experimentation with visualization and interaction techniques.

Pedestrian Navigation - PedNav

PedNav examines different strategies for the use case of pedestrian navigation. In ongoing research we apply the agile exploration process to the examination of a wide variety of different types of pedestrian navigation systems. Much recent research in pedestrian guidance and mobile cartography has addressed the appropriate communication of routes and the associated wayfinding instructions. Most available commercial systems that claim to support pedestrian navigation are simply adaptations of car navigation systems. Research has shown that pedestrians have very distinct requirements and are subject to a different set of constraints (Raubal and Winter, 2002; Elias and Brenner, 2004) than standard car navigation. It has been shown that the integration of landmarks into routing instructions is essential for effective pedestrian navigation and a number of experiments have already been conducted to examine various forms of information presentation. In several prototypes and a number of user tests we have examined various forms of landmark and route visualizations (Elias and Paelke, 2008; Figure 4), varying presentation styles ranging from classical maps over route descriptions to stories that are designed to give a memorable account of a path, the differences in landmark recognition for abstracted and concrete representations and the use of augmented display techniques for user guidance. Preliminary results from these experiments in pedestrian navigation have been included in the following results.

Figure 4: PedNav examines varying forms of navigation instructions for pedestrians: Examples: Classical map display with integrated landmark images (left), 3D view based on Google Earth (middle) and augmented reality view (right)

Results and Conclusions

The design space for personal navigation devices is much bigger than what we see today.

As our experiments show there is a wide range of possibilities to improve personal navigation systems, especially regarding interaction and information presentation. User centred design is critical to realize the potential of advanced interaction and visualization techniques. Regarding the results of our experiments we can distinguish results and experiences with respect to the exploratory design process and those that provide direct feedback on the viability of certain user interface paradigms in general or specific interaction and visualization techniques in particular.

Regarding the process we can confirm that an agile process helped considerably in combining exploratory design activities with user centred design as well as hard- and software implementation activities. We have found that agile processes from software engineering support a high amount of flexibility in development and therefore provide a promising foundation into which design activities from other disciplines like cartography, user interface design and hardware engineering can be integrated. By adapting the scrum process we were able to build on existing expertise in software engineering and transfer it to an experimental and exploratory development environment where the ability to quickly react to changing requirements is essential and the rapid creation of results is highly desirable. The process model used in the development of our system probes evolved between different projects. The lightweight nature of an agile process like scrum makes it possible to adapt the process to the specific needs of a project and incorporate changes suggested by the design team without a major overhead.

With regards to the design space of future PNDs we have explored a number of very diverse approaches. We have found that specialized solutions that go beyond the current standard have a high potential to improve usability and user satisfaction in all studied application domains from car navigation over pedestrian navigation to navigation in outdoor sports. While many findings are specific to the individual application domain or even the specific prototype some findings generalize to the level of user interface paradigms and can thus serve as general cues for the development of future PNDs:

- Future navigation concepts should go beyond „eyecandy“ and must provide a sensible and usable solution to a real world problem. Many of the “innovations” currently marketed in PNDs like 3D visualization have indeed the potential to improve the usability of a navigation system, but only if they are carefully and well designed with the user in mind. Most currently available systems focus on the novelty factor alone and fall short with regards to usability, resulting in systems that are sometimes less usable then their simple predecessors. In the long run the almost instant disillusionment of users with such highly touted “innovations” (as observed in our pilot tests) could become a hurdle for the introduction of real innovations.
- Purpose build designs can significantly improve the user experience compared to more generic PNDs like the current generation of portable devices. While generic “one-size-fits-all” PNDs will continue to exist, it is most likely that these will be mostly in the form of integrated navigation functionality in mobile phones, as GPS receivers become pervasive for this device category. The design space of devices that consider not only modifications in the visualization and incremental changes in the interaction techniques (e.g. the move from single-touch to multi-touch interaction or improved speech recognition) is vast and offers the opportunity to improve the user experience in specific use cases significantly. The need to consider the hardware platform or even

a possible infrastructure as additional variable during the design process introduces additional challenges for developers.

- One of the most promising approaches to improve navigation systems in all application domains considered in our studies is adaptivity. The inclusion of context parameters and automatic adaptation based on these has high potential to improve the usability of systems. While much research has already been devoted to adaptation in navigation systems only very limited adaptation is currently available in commercial systems. Existing research provides some very interesting insights into adaptation, especially of content selection and display, but many questions remain open, notably if systems with more diverse and specialized hardware are considered, e.g. enabling the system to switch between different input and output modalities.
- While nice visuals and attractive hardware with novel features alone provide no improvement in usability they are nevertheless important from a practical point of view, as they constitute major arguments at the point of sale. The practical implication of this is that in addition to user centred design and software engineering activities other forms of design activities like the development of new hardware and industrial design must also be integrated. We have found that agile processes (in our case adapted from the widely used scrum process) have great potential for the practical organization of such multidisciplinary design and development teams.

The results described in this paper should be viewed as an initial step towards the development of future personal navigation devices. Our agile process provides a flexible design and development methodology to conduct the necessary exploratory development that is required to explore the vast design space available. The system probes demonstrate that there is great potential for improving usability in PNDs, especially in use cases that go beyond classical A to B car navigation.

Acknowledgments

We would like to thank our colleagues Birgit Elias, Claus Brenner, Sascha Tönnies, Stefan Radomski, Marcel Chaouali (Leibniz Universität Hannover), Julian Masuhr (D-LABS GmbH, Potsdam), Markus Düchting, Florian Klompmaker (C-LAB, Paderborn) and Christian Reimann (Siemens SiS, Paderborn) for their contributions in developing and evaluating the various system probes.

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