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THE NEXT STEP – OPEN PROTOTYPING

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Abstract

Software applications in the car are gaining in importance as a driver for innovation and value creation for the car manufacturers and their suppliers. These novel software functions, e.g., mobile services or car-to-car enabled applications, are increasingly designed and developed using early prototypes. Building on open innovation literature, this paper goes beyond extant knowledge on prototyping and proposes a novel paradigm of 'open prototyping'. It assumes that organizations can and should use external input as well as internal input in form of prototypes, as the firms look to advance their technology. Set in the empirical field of the automotive industry, we follow a design-oriented research approach to design, develop and evaluate an open prototyping approach consisting ofa toolkit and process. The open prototyping toolkit, HIMEPP, has a component-oriented architecture. Combined with the open prototyping process, it supports the development of diagonal high-fidelity prototypes together with persons from outside the R&D department. The study allows for generalizations to other industries and points tosignificant managerial as well as academic implications, which can be expectedfrom opening the next step of the innovation process.

Keywords: prototyping, innovation, automotive, software development

1 Introduction

Software applications in the car are gaining in importance as a driver for innovation and value creation for the car manufacturers and their suppliers. These novel software functions, e.g., mobile services or car-to-car enabled applications, allow manufacturers to fulfill customers' rising need for more information and comfort while driving as well as to introduce novel assistive and safety features (Tinham 2007). One approach taken by software designers to improve the success rate for such innovative applications revolves around understanding users' needs, building a comprehensive knowledge of all requirements and exploring multiple different design options to meet these requirements. Among researchers as well as practitioners in the field, there is broad consensus that usage of early prototypes is suitable to integrate end users into the design process in innovation projects (Davis 1992).

There is empirical evidence that the integration of end users, consumers, partners or other stakeholders from outside the corporate R&D departments, leads to innovative concepts (e.g.Borst 2010;Piller&Walcher 2006). Previous research in the field of IS as well as innovation management has shown that organizations can harness the innovative potential of these external, distributed individuals by involving them in the innovation process (e.g. Bullinger et al. 2010; Leimeister et al. 2010). The terms *crowdsourcing* (Howe 2008) and *open innovation* (Chesbrough 2003) have been coined to describe this opening of traditionally very closed innovation processes. However, current endeavors in research as well as practice focus on the opening of the two early stages of the innovation process, i.e. generation and collection of innovative concepts (*ideation*) as well asselection and evaluation of concepts for future prototyping and development (*evaluation*). For these stages, a number of IT-based or IT-supported tools have been developed and tested, e.g. the lead user method (Luethje&Herstatt 2004), toolkits (Piller&Walcher 2006) or innovation communities (Acar&Ende 2011; Riedl et al. 2010). During recent years, open innovation approaches have been using developments in the field of web 2.0. Thishas for example led to asurge of realizations of online innovation contests (Adamczyk et al. 2011; Leimeister et al. 2010), a web-based tool to attract and activate capable and interested potential participants of the innovation process.

However, whilethere exists a body of knowledge on the opening of the ideation and the evaluation stage, IT support of the next step in an open innovation process, i.e. *prototyping*, is still underresearched. This is mirrored by the fact that a recent study of 73 innovation contests has shown that the required *degree of elaboration* is to a majority rather low(Bullinger et al. 2010). More than two thirds of the sample asked potential participants to submit ideas, sketches and concepts; *prototypes* or even fully functional solutions have been less required. This is surprising as e.g. the *lead user method*has shown that innovators from outside the corporate R&D department are capable and willing to develop functional prototypes (Luethje&Herstatt 2004; Piller&Walcher 2006).

Building on existing research on prototyping andIT-based open innovation processes, we focus our research on the potential to open the stage of *prototyping* in order to integrate innovators from outside the R&D department in the innovation process.In analogy to the definition of *Open Innovation*as proposed by Henry Chesbrough (2003, p. xxiv), we delimit *open prototyping* as follows: "Open prototyping is a paradigm that assumes that organizations can and should use external input as well as internal input *in form of prototypes*, as the firms look to advance their *technology*."In contrast to *open source*, the infrastructure on which the prototypes are developed belongs to the focal organization and is provided to innovators for the process of open prototyping. Resulting prototypes can only be used within the infrastructure of the focal organization.

Research of this paper uses a *design science approach* to examine the potential of opening the stage of prototyping.Given the increasing importance of software in the car, we use a joint industry-university researchproject on in-car applicationsin the automotive industryasthe empirical field.In sum, the research has the following goals:

1. From a theoretical perspective, we extent prototyping literature as well as previous open innovation research by providing a first proof of concept on the possibilities of *open prototyping*.
2. From a methodological perspective, the research draws on a *design science* research approach to *design, develop and evaluate* a toolkit as well as a process that enable organizations to open the stage of prototyping.
3. From a practical perspective, our research provides implicationsto open the innovation process beyond the stages of *ideation* and *evaluation* to the stage of *prototyping*.

The paper is structured as follows. Subsequent,extant knowledge on prototypingand its application in automotive software development is presented. We then describethe empirical field and our research methodology. The remainder of the paper then presents the toolkit for *open prototyping*, the results of the evaluation and a discussion of both.

2 Foundation: Prototyping in automotive software development

The term “prototyping” is widely used in academic as well as in industrial settings to describe a stage of a creative process which, in the context of this paper, is the innovation process. However, the concepts behind the term vary broadly between different domains and even within domains. Among prototyping researchers, there is consensusthat a prototype is an artifact created in the innovation process of developing a final product; it includes a subset of final products features and thus is easier, cheaper and faster to develop (Floyd 1983; Pomberger et al. 1992). Extant literature differentiates prototyping concepts using the dimensions *purpose*, *approach* and*functional section*.

The *purpose* of prototyping distinguishes between the results aspired by developing or employing a prototype. Most often, prototypes are used in *requirements elicitation* for the product (Ramesh et al. 2008), to improve *communication* between different types of innovators (Dix et al. 2004), to *evaluate* intermediate results (Davis&Venkatesh 2004)or a combination thereof during an iterative, evolutionary innovation process (Davis 1992; Kordon&Luqi 2002).

The prototyping *approach* describes the prototyping process to achieve the purpose of the prototype. In general, prototypes can either be discarded (*throw-away-prototypes*) after fulfilling their purpose, or they can be reused later in the innovation process. This iterative approach is known as *evolutionary prototyping*, where a prototype is sequentially improved until itrepresents a final product (Luqi et al. 2000). For *throw-away-prototypes*, literature distinguishes*exploratory prototyping*, focusing on the elicitation, communication and negotiation of product requirements (Davis 1992; Floyd 1983) from *experimental prototyping*, which lets developers, i.e. members of the R&D department, determine the completeness and technical feasibility ofa chosen design alternative (Davis 1992; Floyd 1983). While exploratory prototyping is usuallyused for User Interface Design,e.g.,tocollect evaluations from users, experimental prototyping is most often usedto support *internal* architectural and technical decisions (Pomberger et al. 1992).

The *functional section* of a prototype describes the functional realization of the chosen prototyping approach. Itranges from *low-fidelity* prototypesto usable *high-fidelity* prototypes – which allow users to experience the usage of a function. *Low-fidelity* prototypes are realized in a non-technical fashion, e.g. sketches. They are usually cheap to make, allow the user to participate in earlystagesof the innovation process but are limited when it comes to perceiving the use of the innovation in daily life. *High-fidelity* prototypes include technical functionality to supply a usable system for evaluation. They are split into *horizontal prototypes*, featuring all the (user) interfaces and options and *vertical prototypes*, featuring few of the functionsbut technically implemented in a way that can be used in the final product(Floyd 1983). It is also possible to mix both approaches and implement a *diagonal prototype*– displaying all functionality, with certain key functions implemented in the aspired technical form. Thisallowsthe developers to evaluate their prototypes in the aspired usage context (Hoffmann et al. 2010).

When developing innovative applications to be used in the context of a car, creating prototypes that allow the userto experience his or her idea in a real life scenario is a major challenge. Those prototypes have to run in an environment where user distraction is a safety issue, anddrivers also have a decisive opinion of what they expect from an in-car application. Currently, most prototype evaluations, in research as well as in the industry, take place in form of simulations on the computer or in driving simulators. Latest research shows, however, that using a simulated environment biases the test subjects' behavior and hence distorts the evaluation results of the studied applications (Riener 2010). There are two major differences in the subjects' behavior in the driving simulator versus the real usage situation: making a mistake driving in the simulator doesnot put the subjects in any danger, so they concentrate less on the task of driving. Additionally, breaking traffic rules and regulations in the simulator does not yield in any punishment or have repercussions, so subjects do not follow them as strictly as they would in reality.

Moreover, Riener (2010) identified the simulator itself as problematic, stating that the surreal behavior of the simulation (e.g., lacking noises, unrealistic, sometimes crude scenery) – have a negative impact on the validity of the subjects' measured behavior in the car. These results lead to the conclusion that it is necessary to integrate the developed prototypes into the automobile in order to obtain reliable results from end-user evaluations – allowing the innovatorsto experience the application while driving a car on a test track or even in real traffic.

Domain experts from inside the car manufacturer today create new applications, so coping with the complex technical infrastructure of the car as well as the complexity of the applications running in the car is time consuming and expensive, but possible (Broy et al. 2007). To open up the innovation process to be able to include innovators from outside the R&D department however, it is necessary to provide them with tools they can use to create a prototypical application without the need for expert knowledge and methodologically guide them through the design process.

3 Methodological Approach

3.1 Empirical field

The empirical field of this research is part of a large, joint research initiative of two universities (TechnischeUniversitätMünchen, Technical University Darmstadt), a university of applied sciences (FH Nürtingen-Geislingen) and a major car manufacturer based in southern Germany.

A central goal of the collaborative research project, called "Mobile Automotive Cooperative Services" (MACS),is the design, development and evaluation of *software applications* that could be *used in the car*. Applications are expected to be usable both while driving or while standing, e.g. because the driver is stuck in traffic. These applications should be *perceived useful*by the driver and thus result in an increased willingness to pay for the service. In order to effectively build and evaluate several prototypes (instead of just one) and to integrate innovators from outside the corporate R&D in this innovation process, a concept for a *prototyping toolkit*is developed.

As a first software applicationrealized with the prototyping toolkit, an application allowing the driver to listen to and interactively edit their personal newscast is designed and developed. The resulting prototypical application is extensively evaluated concerning safety and usability as well as concerning perceived usefulness and users' willingness to pay.

3.2 Methods

To provide the means for innovators from outside the R&D department, to create working (high fidelity) prototypes within the context of the automobile in a structured and rigorous way, a design-oriented research approach is applied. In design-oriented research *artifacts* – artificial, man-made things – are the central objects of research (Simon 1996). They are specially crafted in order to fulfill certain purposes and goals given their functions and adaptability. This enables researchers to assess their results by determining the degree to which the artifacts achieved the predetermined goals and comparing artifacts among themselves. March & Smith (1995) compile a list of possible artifacts in IS research: constructs, models, methods and instantiations. The aspired research outputs we describe in this contribution are *constructs* – the conceptualization used to describe the problem of creating automotive applications for non-domain innovators – as well as an *instantiation* – the realization of an artifact in its target environment – in form of the concept and implementation of the “Highly Integrated Modular Embedded Prototyping Platform” (HIMEPP).

In contrast to the well defined and broadly accepted rigorous approaches found e.g. in the social sciences, there is no agreed upon procedure for conducting design-oriented research. However, there are similarities between the proposed phases of design-oriented research found in the literature (cf. Hevner et al. 2004; March & Smith 1995; Takeda et al. 1990) anda certain consensus has been established on a *basic structure* for design-oriented research. Since design-oriented research follows a problem-solving paradigm, the first step is to *identify* the problem and its context. Based on that insight, a possible solution is *designed*, defining the goals for the artifact and the desired outcome when putting the artifact to use. This artifact is then *implemented* in the next step of the process and put to use in the context it was designed for. Based on the changes that can be observed, the artifact is then *evaluated*. From evaluation, conclusions are drawn and documented, e.g. as new input for another iteration of the process or as the basis to theorize.The following figure shows the research process adapted form Takeda et al. (1990) which we follow in this contribution.

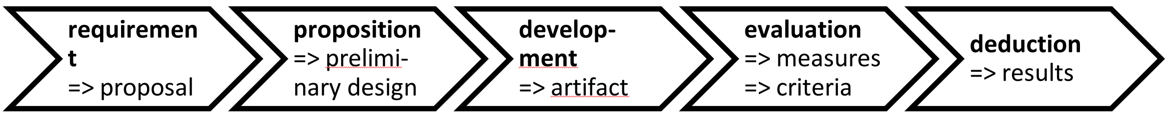

Figure 1. Process steps followed in this research (adapted from Takeda et al. (1990))

In terms of *data collection* during requirements elicitation, development and evaluation, we used triangulation of various data sources (Yin, 2003). First, we draw on *semi-structured interviews* with the members of the R&D department and other employees of the car manufacturer, which centred on requirements and usage information for the prototyping tool. For evaluation of the prototyping toolkit, data from about 75 *site visits* during the course of three years, which allowed for ample observation of usage patterns was combined with semi-structured interviews based on the eight determinants of user acceptance of information technology (UTAUT, Venkatesh et al. 2003).Interviews were transcribed and coded using software for qualitative data analysis (atlas.ti).Second, as a consequence of the joint industry-university research project, we had also access to a huge amount of *internal and often informal data* (e.g., workshops, discussions, internal documents and presentations, data from internal databases).

4 Open Prototyping: Toolkitand Process

Our proposed prototyping approach, whichconsists of a *toolkit* and a *process,*allows organizations to open the stage of prototyping to innovators from outside the R&D department. The prototyping *toolkit*, the “Highly Integrated Modular Embedded Prototyping Platform (HIMEPP)”, whichallows the design and development of *high fidelity prototypes*, is described in the next section. Subsequent, we present the iterative open prototyping *process*with its five main steps (cf. section 4.2).

4.1 Architecture of the Toolkit for Open Prototyping

The goal of the Highly Integrated Modular Embedded Prototyping Platform (HIMEPP) is to provide a prototyping tool that allows the creation, presentation and evaluation of prototypes of novel software functions inside the automobile. By this, it is expected to obtain evaluation data of higher quality in comparison to the data obtained by simulator runs. In order to create high fidelity prototypes that can be integrated and evaluated *in the car*, two challenges have to be met. First, all functionalities have to be represented in the prototype andsecond,the prototype has to be integrated into the technical infrastructure of the car. Hence HIMEPP needs to support an approach for developing diagonal high-fidelity(see section 2.1) prototypes, which helps non domain experts (i.e. innovators from outside R&D) to meet the challenges of automotive software development (cf.section 2.2).In order to effectively create prototypes, a component-oriented architecture (cf. figure 2) was chosen for the HIMEPP platform, as this enables domain experts within the manufacturer and its suppliers (i.e. members of the respective R&D departments) to create a collection of easy to use components as building blocks.

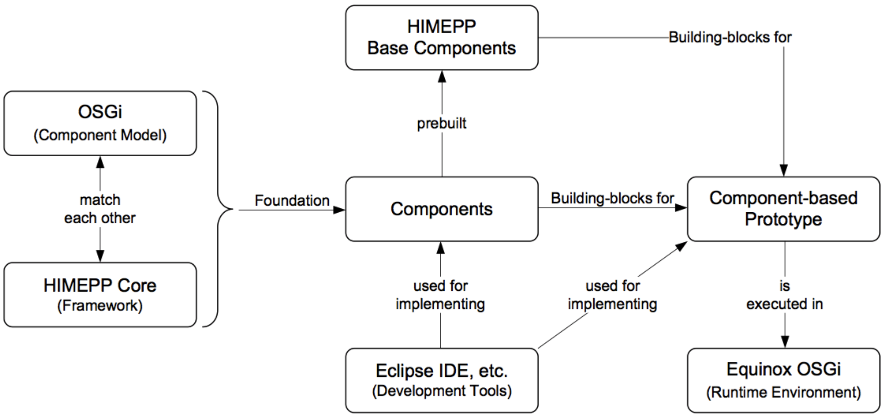

Figure 2 HIMEPP's component-oriented architecture (Hoffmann et al. 2010)

The overall structureof HIMEPP, shownin figure 3 and explained in more detail in (Hoffmann 2010), relies on OSGi, an established standard for component-oriented Java development, so as toestablish a common ground for different platform developers. Added as a *domain specific abstraction layer*, the HIMEPP Core framework ensures that all HIMEPP components are using the OSGi infrastructure similarly and provides functionality to ease the development of HIMEPP components. These components can be classified as HIMEPP Services, which provide functionality, mostly interfaces to external hard- and software or mobile-specific functions (see below), HIMEPP Semantic Components, which interpret user input and can easily be changed to explore different user experiences, and HIMEPP Client components, holding the prototype's application logic. As HIMEPP Services and Semantics are relevant for all prototypes and, they are provided as reusable components, called "base components", to the innovator in order to directly support hisdevelopment efforts. A prototype created with HIMEPP thus is comprised of HIMEPP Service and Semantic components that run together with the innovators code in the HIMEPP Client component on the HIMEPP Core framework &OSGiTo identify thebase components most useful to innovators, we analysed the applications currently either available in the manufacturer's stock cars or currently developed in other research projects.

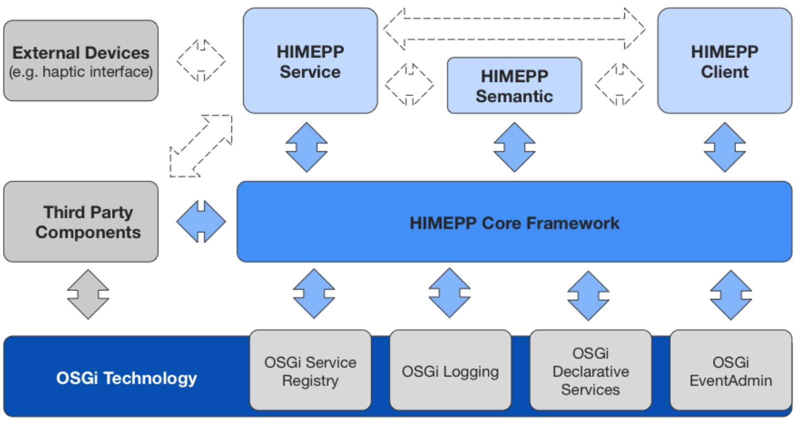

Figure 3 Architecture of the open prototyping toolkit

The resulting *base components*,which are used by innovators as building blocks for their own applications, can be structured into five different categories:

- *Audio- and speech components* provide user interfaces for prototypes. They allow playing audio files, reading out texts using speech synthesis software and recognizing spoken commands.
- Components for the *haptic interface* also provide a user interface. Theyare split up into *data communication* with the controller device integrated in the car and *semantic interpretation*thereof.
- *Infrastructure components* allow (reading) access to the infrastructure of the car, providing an abstraction layer for determining e.g. a button's state or a sensor reading fill level of the tank.
- *Mobile service components* offer functions to determine the current location using GPS, provide internet access via cellular broadband and enable sending cell phone text messages.
- *Service and support components* support the prototyping process as such. They provide standard functions often used in a prototype (e.g., loading system properties, displaying a splash screen).

These base components represent a complete toolkit for creating novel applications for the car without requiring an understanding of the inner workings of the technical infrastructure in the car. Hence HIMEPP supports deploying diagonal high-fidelity prototypes to a defined context. It reduces the complexity of the technically demanding approach by providing easy to use building blocks,which allows innovators from within and outside the R&D departmentto assemble prototypes.

4.2 Open Prototyping Process

The HIMEPP platform described in the preceding sectionallows innovators from within or outside the R&D departmentwho dispose of some knowledge in computer programming to create their own automotive applications. It is neither necessary to introduce those interested innovators to the complex technical infrastructure of an automobile nor to create a deeper understanding about the underlying prototyping platform. HIMEPP supports the prototyping activities of innovators in a dual way: First, itprovides the base components necessary to prototype the components most often found in mobile applications. Second, it serves as scaffolding for the project,as all HIMEPP components share a similar layout and a project "wizard" to develop new HIMEPP applications is offered. Both aspects steepen the learning curve of innovators.

The process of open prototyping startswithopening the HIMEPP development environment, which is based on the Eclipse Project's widely used IDE.The central five steps of the iterative prototyping processaredescribed in detail subsequent to figure 4 below.

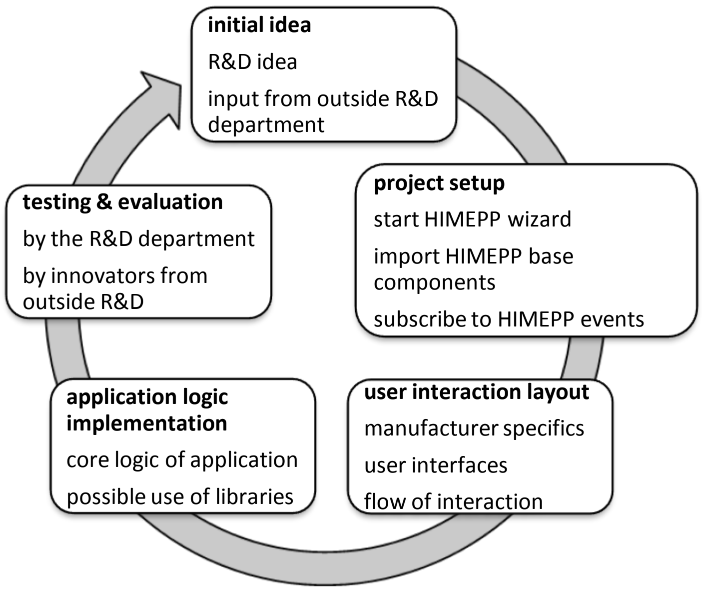

Figure 4 *Process of open prototyping*

When choosing to *set up a new project*, the innovator can choose "HIMEPP Project" from the list of project wizards offered. On the subsequent pages, the complete scaffolding of components is filled by using the interactive wizard:

- *Software functions* provided by other components are selected by the innovator. Consequently, the required references are imported and stubs for calling the methods are inserted in the source code template.
- *Events*that trigger a reaction in the prototype, are selected by the innovator – the respective stubs for the event handling methods are generated automatically by the wizard.
- *Resources*, e.g. media files like pictures etc. and dynamic native libraries can be selected for inclusion in the new application.

After completingthe wizard, innovatorshave a completely set up HIMEPP component in their development environment. The second step is *laying out the user interaction*. This step is very specific to the manufacturer and is comprised of determining the flow of interaction as well as choosing matching user interfaces. This process is supported by the structure of the code for the graphical user interface, which is developed by the manufacturer. The graphical user interface uses a declarative approach for defining different screens and their associated menus and interaction possibilities.

The third and final step in the core process is the *implementation of the application's logic*. As the HIMEPP platform shall not limit the kinds of novel applications that can be built, no direct support for developing the application logic can be given. However, the code stubs created by the HIMEPP wizard during project setup ease realizing the application logic. The developer can fill these stubs created for method calling and event handling with the application code, and thus has a structured environment for implementing the application's logic.

Upon finishing the application code, innovatorsare free to run and test their application directly on the development machine. This is possible as HIMEPP provides simulation components for those interfaces only found in the car, e.g. a simulator for the "push-to-talk" key on the CAN bus. When the application is running as expected, the application itself and its configuration files can be easily copied to the target platform in the car via a wireless network link. After that, the new prototype is available for evaluation in the car.

5 Evaluationof Open Prototyping

Evaluation of the open prototyping toolkit and process has been two-fold. First, we tested the feasibility of the prototyping process and second,a generic usage scenario was distilled.

To test the *prototyping process*, a set of 15 innovators from outside the R&D department have been recruited to test the toolkit in early versions and provide feedback; they were self-selected following a call from the R&D department. Second, once development was finished, the *toolkit* has been deployed and evaluated by a set of 10 innovators from outside the organization.Observation of their behaviour and subsequent analysis iteratively led to a typical usage scenario. With both groups, we performed semi-structured interviews based on the unified theory of acceptance and use of technology as presented by Venkatesh et al. (2003). Interviews covered the constructs of *performance expectancy, effort expectancy, facilitating conditions* and *social influence* and also analysed the moderators*age, gender, experience* and *voluntariness of use.*

In general, working with the *open prototyping toolkit* was perceived as very supportive for the development of software applications compared to previously existing solutions. One statement of a marketing manager summarizes the attitude toward the prototyping toolkit often expressed by innovators from outside the R&D department:

"Now I have a possibility to realize my ideas very quickly and really *show* them to my superior. That is an important improvement to previous times, when we had only sketches and slides!" (*marketing*)

Innovators stressed the usefulness of the toolkit for their job and how it helped them to accomplish their tasks; feedback on the quality of the software, however, was rare. In general, effort to work with HIMEPP has been experienced to be rather low which freed energy for other tasks. This frequentlyreported experience is illustrated by the following statement of a member of the corporate strategy department:

”HIMEPP greatly broadened the spectrum of prototypes I can develop. Now I can focus on great new service ideas and stop worrying about the technology in the car.” (*corporate strategy)*

In addition to evaluation by the innovators from outside the R&D department, the toolkit was deployed in subsequent joint industry-university research projects on in-car applications in the automotive industry. Thus, also innovators from outside the organization tested and evaluated the toolkit and the process of open prototyping. The joint projects were run by a group of eight researchers with varying degrees of familiarity with the Java programming language and no prior knowledge of automotive software design or development. During these projects, more than a dozen novel applications for the use in the automobile have been created, e.g. for providing eMail access, Voice Chat (Skype) connectivity and off-board routing. An outstanding prototypes developed with the help of the open prototyping, is the Virtual CoDriver System (Nicolescu 2009). This application brings natural human-computer-interaction into the car via an avatar and has also been extensively evaluated in the drivable car.

Interestingly, analysis of interviews with innovators from outside the organization brought about morefeedback on the quality of HIMEPP, in particular regarding ease of use and stability. These innovators who did not know the situation *without* the prototyping toolkitare not aware of the problems,which arise if a prototypical application for the car is developed. This led to evaluation results differing from those distilled from the statements ushered by innovators from outside the R&D department, but inside the organization. Among the interview data, it is most remarkable that innovators from outside the organizationstress their anxiety to lose information if they use the toolkit in the wrong way and even fear to make incorrigible results. Says one PhD student:

“I am often surprised if the toolkit accepts an entry because I expect it to crash if I make the wrong choices. Therefore, I prefer to ask someone to guide me during the implementation.” (*masterstudent in engineering*)

This feedback is remarkable, as innovatorsfrom *outside the R&D department* but *inside the organization*, have not voiced these concerns. Despite this respect for the inner workings of the toolkit, also innovators fromoutside the organization are convinced of the potential of HIMEPP and state an interest in future deployment. They perceive the open prototyping toolkit and process as useful to solve their tasks, i.e. to develop applications for in-car usage and state a possibility to learn:

“In the beginning, I thought that as an amateur, HIMEPP would be hard for me to use. Now I am really looking forward to the next project and will use it again as I learned a lot while building my first prototype.” (*doctoral student in information systems*)

6 Discussion

The present research set out to explore the possibility to further open the innovation process of an organization by demonstrating a process and toolkit to facilitate prototyping in open innovation. The component-based open prototyping toolkit, HIMEPP, and the five-step iterative open prototyping processare designed to support development of *diagonal high-fidelity prototypes*together with innovators from outside the R&D department. HIMEPP enables for the first time these innovators, who are not automotive domain experts, to prototype applications for in-car use.The*evaluation* process has shown that the toolkit is perceived as supportive when developing prototypical applications in the car. However, innovators from outside the organization were more anxious about usage of the toolkit.

The identified differences in evaluation by innovators from *outside the R&D department*, but *inside the organization* and innovators from *outside the organization* are in line with extant research on different *types of innovators*. Neyer and colleagues (2009) have pointed to a necessary distinction between *peripheral inside innovators*, i.e. persons outside the R&D department, and *outside innovators*, i.e. innovators from beyond the boundaries of organization. *Peripheral inside innovators* are employees across all business units who, by their daily work, have become knowledgeable and involved experts. This group is interested in and has the potential to produce innovative ideas and contribute to the innovation process by suggesting, supporting or refining innovative concepts as well as prototypes.

It is interesting that both, research on prototyping as well as research on open innovation, has not yet fully explored the potential of these*peripheral inside innovators.* Extant research on *prototyping*has focused on closed innovation endeavors, which integrate *outside innovators* in two ways. On one hand, prototypes are used to *passively integrate outside innovators*, i.e. a prototype is built within the organization and then used for evaluation with outside innovators. On the other hand, tools like product configurators require *active participation* from *outside innovators*. Prototypes are still built within the organization, but outside innovators supply concrete ideas in form of e.g. sketches or small low-fidelity prototypes. Hence, the potential of (high fidelity) prototypesto integrate *peripheral innovators* – as examined in this research – has not received adequate attention. In the field of *open innovation* and *crowdsourcing*, studies mostly examine the integration of *outside innovators*(e.g. Borst 2010; Howe 2006; Riedl et al. 2010) in the innovation process. Our research adds to this knowledge by enabling the integration of *peripheral inside innovators*, i.e. innovative members of the organization who are not part of the innovation or R&D department.

For *practice*, these possibilities hold important implications. First, deploying the *open prototyping toolkit* and the five-step iterative process, companies will be able to fulfill the potential of *open prototyping* that"organizations can and should use external input as well as internal input *in form of prototypes*, as the firms look to advance their *technology*."Second, for the members of the R&D department – so-called core inside innovators, i.e. the persons in the organization who are responsible for innovations (Neyer et al. 2009) – prototyping of applications has become easier and faster. It hence holds the possibility to increase the efficiency of prototyping for the R&D department. Those prototypes can be presented to decision makers – to allow them to create a better image of the possibilities – and also provide better results on how evaluation subjects react to the prototype in a real-life situation (cf. Riener 2010).Third, HIMEPP allows for the integration of persons in the prototyping process who beforehand had little possibilities to realize their ideas and present them for discussion. Accordingly, the set of persons who can take part in the process of prototyping has been enlarged – a change process, which requires management attention in order to overcome, e.g. not invented here syndromes between the groups (Neyer et al. 2010). Fourth, integration ofthe *outside innovators*, the globally dispersed crowd (cf. Borst 2010; Howe 2008) is possible with the open prototyping toolkit. Insights from the field of innovation contests and online innovation communities need to be taken into account in order to successfully manage this process (e.g. Acar&Ende 2011 as well as Borst 2010 on *motivation* and *reward size*; Adamczyk et al. 2011 on *community functionalities*, Bullinger et al. 2010 on *competition and collaboration*; Riedl et al. 2010 on details of *evaluation*). Finally, results of the evaluation show that *peripheral inside innovators* and *outside innovators* interact differently with the tool, with peripheral inside innovators focusing more on perceived usefulness and outside innovators focusing on usability aspects. We suppose this is due to the fact that persons from within the organization at least peripherally know the traditional development process and can adapt to the new process and its new possibilities – i.e. early, usable, testable software prototypes – more easily as they perceive the benefits. On the other hand, outside innovators start from a different level: They take availability of the toolkit for granted, not knowing about the obstacles usually faced in automotive software development, and proceed to judge HIMEPP strictly from a usability perspective. As they lack the knowledge of automotive software development processes, but are knowledgeable concerning general software engineering frameworks, their requirements are higher, e.g. in terms of support in interaction with the toolkit. These requirements need to be taken into account if an organization offers an open prototyping toolkit to different groups of innovators. It can be suggested that a basic version is suitable for innovators from outside the R&D department, but from inside the organization, while the design of the toolkit provided to the crowd outside the organization would require more efforts in terms of usability.

Prior to outline future research directions, it is necessary to recognize some of the *limitations* of our study. The study stems from a joint industry-university project in the automotive industry. Results, while probably transferable to other manufacturing industriesmight hence not be fully applicable to the service industry. As we suppose that similar procedures are possible for services, we thus suggest this as a future research direction. Second, our sample of innovators who were integrated in the project is rather small. While we judge the set of innovators as sufficiently large for design and development of the toolkit as well as for a first set of evaluations, future studies should in particular research the possibility to open prototyping to a large crowd of outside innovators. This opening would also enable to further explore differences between the distinct types of innovators. It can be expected that our first findings on the differences in perception of the tool by the *peripheral inside innovators* and the *outsideinnovators* will be detailed and more multi-faceted. From a methodological point of view, our approach with semi-structured interviews might be complemented by experimental data. Third, in our study, outside innovators have been to the degree pre-selected, as they were either part of one of three participating universities or affiliated with the manufacturer. It would be interesting to test the open prototyping tool with self-selected participants both inside and outside the organization.

The present work advances innovation research and prototyping research by providing a toolkit and a process, which allow to open the process step *prototyping* to interested and capable innovators from insideand outside the boundaries of an organization.

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