Focusing the first phase – an interdisciplinary approach to modeling an interactive system on the Use-Case Indoor-Blind-Navigation

Ken Pierre Kleemann [0000-0001-9961-5870], Nadine Schumann [0000-0001-5431-8266], Veronika Heuten,
and Hans-Gert Gräbe [0000-0002-3934-413X]

Leipzig University, Leipzig, Germany

Abstract. Concepts such as “resource” or “system” pose a challenge when it comes to adapting to the context. So the main problem is to adapt the concepts and the development process to the requirements of the users. The user is not only the methodological foundation of the concepts, but also a resource and a component of the system. Therefore, the initial phase of the development process becomes crucial. In order to explore the basic requirements of the product and the requirements of the potential use, it is necessary to combine several methods for interactive modeling. By linking qualitative research methods and formal iteration processes, new insights are generated. For handling the complexity of the problem, the experiences of AppPlant, Gräbert GmbH and a team at Leipzig University are applied. The project “Outdoor and Indoor Navigation for Blind and Visually Impaired People” (IBN) combines systems research with the application of social methods to improve successful human-machine interaction. The developed solution is based on the term “interactive system” of ISO 9241-11 as a methodological starting point. The key concept for an interactive system is usability, which describes the extension to “which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. In order to focus on user requirements, the iterative approach of Design Thinking, TRIZ Modeling and Mixed Methods of social sciences were combined.

Keywords: Human-machine interaction, design thinking, qualitative research, Outdoor-Indoor-Blind-Navigation, TRIZ and requirements analysis

Introduction

In general, developers must face several problems in the first phase of development processes. Especially when it comes to reconciling the products requirements with demands on functions of the potential use. The aim of this text is to present an interdisciplinary approach to modeling an interactive system on the use case Indoor-Blind-Navigation. On the one hand we show the enhancement of the initial phase and how the management of the whole process can be adapted to the user-machine-interaction on the other. Design Thinking works with associative power of brainstorming, where TRIZ, instead, favors systematic modeling. In fact, both strategies are helpful for the determination of requirements and contexts. Considering our special user group, defining the specific requirements is problematic at first. Therefore, this first phase (Define phase in [1]) depends on the identification of the requirements of blind and visually impaired people as well as on the determination of the categories for conceptual definition. The specific demands and conditions of the respective environment as well as the interrelations of the product to be developed are predominantly influential.

We combine a mixture of technological possibilities and adaptation to the user as well as innovation methods. For the determination of the categories for the conceptual definition we used methods of qualitative social sciences, which lead us to a better understanding of the user both as system and component for a user-centered modeling at different systemic levels. The Define phase is therefore enhanced and also not complete with a first model but complemented with newly discovered demands of the user over the whole time of the project. The linking of different approaches of innovation methodology and qualitative social sciences research is considered promising for successful human-machine-interaction in an indoor-outdoor-navigation-system.

Problem

Concepts such as “resource” or “system” pose a challenge when it comes to adapting to the context. Accordingly, the main problem is to adapt the concepts and the development process to the requirements of the users. The user is not only the methodological foundation of the concepts, but also a resource and a component of the system. Therefore, the initial phase of the development process becomes crucial. In project management this initial phase is called strategic orientation, in software engineering requirements analysis, in TRIZ it is Part I of ARIZ-85C. In our case it is all the same, but our first phase is longer, more intensive, focused on iteration expansion and on continuous productive intervention even beyond the normally seen first phase. Our first phase is therefore a different concept. In order to explore the basic requirements of the product and the requirements of its potential use, it is necessary to combine several methods for interactive modeling. By linking qualitative research methods and formal iteration processes, new insights are generated, which are a remarkable progress for users with special interests.

To cope with the complexity of the problem, the experiences of AppPlant, Gräbert GmbH and a team at Leipzig University are applied. The project “Outdoor and Indoor Navigation for Blind and Visually Impaired People” (IBN) [2] combines systems research with the application of social methods to improve successful human-machine interaction. The special interest of this group can be channeled and brought to the development of functions which are suitable for the special needs.

While such instruments for visually impaired people in the outdoor area based on GPS already exist and a smartphone-based solution is offered by the partner AppPlant, navigation in the indoor area is more difficult. Up to now there are no established solutions comparable to GPS. Instead, island solutions based on different technologies are used, which require special instrumentation of the respective buildings (beacons, induction loops) or the technical signatures of fixed digital devices (such as WLAN routers) for orientation.

Accordingly, dealing with today's possibilities of machine guidance in buildings is a concern that is important both for the systemic development of user-centered applications and for the lifeworld possibilities of participatory and inclusive design of society.

To highlight the problems complexity the experience of the process management, available at AppPlant and the team at Leipzig University, is used. The project outdoor and indoor navigation for blind and visually impaired people combines system research and the observation of user-machine interaction.

The digital evolution of today's progress requires not only a non-linearity of its decentralized infrastructure in the physical sense, but a decentralized and non-linear way of working. This more comprehensive infrastructure has been dominated for a long time by concepts of an agile and flexible nature, in which accessibility, interoperability and usability are in the central focus. This means the close alignment of consumer, producer, and device makes an iterative procedure a straightforward obligation. Consequently, innovation methods against this background cannot be limited to promoting creativity or technical efficiency. Rather, they are set in a complex infrastructure, which in turn affects the application and design of innovation methods.

However, there are experiences of relevant innovation methods which, on the one hand, can and have to meet the complex infrastructure requirements and, on the other hand, have followed the spectrum of free association and systematic invention. On the one hand, the established innovation methodology of design thinking combines both iterative work organization with creative unsystematic brainstorming. On the other side, the large complex of TRIZ approaches cultivates iterative procedures more relying on systematic modeling for creativity control.

Taken together, both methods meet a research interest that wants to understand the connection between technical progress and innovation as well as the comprehensive infrastructural context of modern work organization. A sufficient system of outdoor and indoor navigation for visually impaired and blind people needs the straight interaction of researchers, developers and users.

Methods

The solution to be developed is based on the term *interactive system* of ISO 9241-11 as a methodological starting point. [3] Human-machine-interaction is here defined as interactive system (ISO 9241-11:2018: 3.1.5), namely, as “combination of hardware and/or software and/or services, and/or people that users interact with in order to achieve specific goals” (ibid.: 3.1.5). By contrast, the term *system* is outlined as a “combination of interacting elements organized to achieve one or more stated purposes” (ibid.: 3.1.4). The key concept for an interactive system is *usability*, which describes the extension to “which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". To focus on the users demands the iterative approach of Design Thinking, TRIZ Modeling and Mixed Methods of social sciences were combined.

1 Interactive System

In the first step the interactive system is seen to be built of two linked systems, based on:

1) User-Requirements, speech interaction concept (SIC)
2) Infrastructure, processed data /BIM (BIM – Building Information Modeling), Conceptualization process

The application is conceptualized as a complex system of combined resources and as well a concept of management. In our view the user is not only a part of the supersystem, organizing the interaction between user and device as bi-system, but also a component in that system. Therefore, our user centered-modeling cannot follow a pure formal method of defining the needs in the first phase. We need to develop a methodology which includes the requirements, models and developed infrastructure.
Our approach combines in the second step Design Thinking, TRIZ Modeling and Mixed Methods of social sciences in the IBN use case. This form of interdisciplinarity has clear advantages for the development of innovative applications because user expectations and technical possibilities are thought together from the very beginning. We emphasize the importance of a tight feedback loop between requirements elicitation and rapid prototyping within an iterative TRIZ based development process. The initial phase of TRIZ and Design Thinking (DT) is extended by mixed methods of social sciences.

2 Design Thinking

Design Thinking is a powerful process of problem solving. This solution-based approach provides a well-known analysis methodology that plays a selective role in teaching at Leipzig University, and which is used in the project for a classical requirements analysis with special consideration of the specific target group [4]. Design Thinking stands out in its function as an innovation method especially through the combination of two characteristics. These are interdisciplinarity and a continuous iterative evaluation of the project stages. In groups from different disciplines, experts are to jointly identify and develop innovations in several stages, constantly evaluate them, and constructively incorporate these results into the work process. The first step involves defining the so-called "Design Challenge". This is the most important starting point at the beginning of the process and is constantly changing due to the various findings of the respective phases and the correlation of these. In the following step, the previously defined design challenge must be understood. Here, users are depicted in typical situations, analyzed, and as much information as possible is collected on the topic. These findings are fed back into the first phase and help to realign the design challenge and better frame the topic. The third phase is to help to define the viewpoint. This essentially means that the results of the previous phases are processed, interpreted and weighted. On this basis, typical user profiles are created. These created profiles are tested again and readjusted if they were not defined precisely enough. In the step of idea generation, creative methods are used to realize the needs already identified. These ideas are developed into prototypes, which are then tested by the already defined target group. The final step involves integrating the prototype into the product or service. The phases are always compared and fed back to use the latest results for the specification of the previous phase. The combination of rapid prototyping and user centered design is the part of this method which was adapted by the team of Leipzig University. It was transformed to an iteration process which enhances the first stage of DT with tools and methods from TRIZ for creating a permanent feedback loop for the whole project work. The aim of our approach is to systematize brainstorming, rather than just using it for inspiration.

3 TRIZ

DT usually starts with brainstorming and empathy. This is replaced by context modeling and TRIZ functional analysis of users demands. Here, TRIZ and methods from social sciences are applied and lead to useful knowledge generation [5]. We do not use TRIZ as a formal method, but as a use-case related methodology.

TRIZ already played an important role in the GDR inventor schools in the 1980s. The reappraisal of these experiences was the starting point for LIFIS, since 2016, to develop a corresponding focus on innovation management and systematic learning. In the WUMM project, we have been focusing our activities on the Central Germany region since mid-2018, for contradiction-oriented systematic innovation methodologies in the field of management consulting and for academic teaching in the region as well [6]. The academic core of the WUMM project is the development of a multilingual dataset of established TRIZ concepts and methods as well as of metadata of corresponding research activities in an Open Data Space. Using established concepts of semantic technologies is the seed of a more comprehensive research data infrastructure on the topic of Systematic Innovation Methodologies.

Just like Design Thinking, the iterative and self-referential process is the crucial point. In addition, however, a lot of time and methodical effort is spent on the initial phase. There, from a systematic point of view and through effective alignment to the existing infrastructure, modeling is used instead of brainstorming. There are also different approaches for this modeling of a so-called ideal final result. Common to all of them, however, is to integrate a product- and consumer-specific orientation into this modeling of the ideal outcome. Thus, this ideal final result becomes the variable basis and the motor of further project development. By the analysis of problems and final contradictions differences and levels of penetration of the systematic possibilities as well as limitations of the project and of the product can be received.

This trait of the innovation method serves on the one hand to obtain an associative creativity, but on the other hand the systematic processing of this creativity should get a context and framework of the feasible. Directly, technical progress and innovation are achieved through agile work organization and systematic contextualization. Contradictions can be recognized and uncovered here. This enables not only problem solving, but also an awareness of contradictions, which leads to further insights and approaches in an iterative process. In this sense, a very close connection to the needs and requirements of the users can be generated; a prosumer [7] approach can be systematically incorporated into the development. Thus, indoor navigation for the visually impaired and blind not only provides insights into a complex methodological work, but also a possibility of crucial starting points for the development of this technical field itself.

First, the purpose, principle and problems of this system are determined as a black box. During its use, the application evolves from a formal-functional to a living technical system with its own systemic development logic, which appears in the context of the project as intended functionalities in the requirements analysis and in the system test with test persons of the target group as proof of concept. The modeling of the application system assumes a bi-system of user and device. Users use the application as the top-level systemic structure (application system), which in turn is embedded in one or several social supersystems. At this system level, both users as a whole group of subjects and AppPlant as app-maintainer can be addressed to understand the relationship and synergetic effects of the interaction of these two stakeholder classes (such as the improvement of the data basis and data pool of all users). In addition to the classes, user instances and application instances are to be distinguished. Next, the main useful function is formulated for the app and therefore for the project as system.

The project context comprises three components (the project partners as black boxes, since they organize their internal processes autonomously in each case). The main useful function as emergent outcome results (ideally) from the design of the interactions between these components.

As a black box, the project context is characterized by:

- Useful product: The app as a technical artifact (its operation is not part of it).
- Useful principle: Development of the app
- Problem: Organization of the interaction based on the division of labor

A further distinction must be made between systemic developments within the context of the project, of which the app is a product, and systemic developments that arise while using the app.

The components user and application as subsystems of the bi-system are now modeled in more detail at the level of prototypical instances (i.e., in the language of OO programming their attributes and functions are modeled).

In addition to project-centered systemic modeling, a product-centered systemic modeling is also required. Specific attribute characteristics are important for the performance of a more detailed requirements analysis in contact with potential users, using preserved sociological methods.

We use therefore an iterative approach of system transformation (TRIZ) and rapid prototyping (DT) to further detail the functional analysis. This repeated evaluation of experienced results leads to a significant improvement of the system design.

4 Mixed Methods

In order to determine the requirements of the technical assistance system from the perspective of the end user, a participant observation was conducted at the very beginning to evaluate the special needs and hurdles of blind and visually impaired people. The methodological approach of participant observation is on the one hand pluralistic, as different methods can be combined (triangulation and mixed methods) [8]. And on the other hand it is directivly, as second-person participant observation is carried out in a team. In the phase of data collection, different sources are considered: participant observation, open interview, video recording, field notes. Data collection in participant observation consists of a one-to-two-hour interaction with the subjects and two participant observers. The inspection of the building, subsequent interview and video documentation are done in the areas of selected partners. The data are then processed, that means transcriptions of the interviews were made, field notes were taken, and videos were edited (of the most striking situation, e.g., in the entrance area). The data are analyzed according to the data form afterwards and the contents are typified. Data interpretation and typing are done in a team with the aim of filtering out the main hurdles and needs.

Thus, different interpretations of the data set from different perspectives can be considered. During this, a joint evaluation is carried out in the sense of clustering the specific main points. In the following, the individual clusters are sorted by frequency and then prioritized. The prioritization is purely quantitative and is then grouped thematically. This results in general categories that run from user to device and from device to user. The most common categories are the need for security, demand and communication. The device is seen by the user as an aid to greater autonomy and independence. This leads to a prioritization of the general requirements. A decisive prerequisite for the realization of such an application is the transmission and warning of immobile obstacles, additional information about the location (e.g., information about reception and info point) and changing environments (ground texture), which could occur as stress factors regarding the device-user interaction. Thus, the main task of the application is to provide security and thus reduce stress that can arise from being overwhelmed with an unknown situation. On the one hand, this resulted in the desire for a preparation mode in which the respective route can be displayed and practiced independently of the current location of the user. On the other hand, the desire for a graduated level of detail depending on the user configuration emerged. This points to the importance of the profile configuration of the application before its use.

Our analyses shows that at least three modes are to be distinguished: Preparation, Orientation, and Navigation. When implementing the language concepts, it is imperative to consider the life world of blind people. This leads to an approach that should consider the verbalization of information by blind people for blind people. It must be noted that the transition from indoor to outdoor, and the accompanying change in acoustics, presents a particular challenge. Another requirement for a digital orientation aid is compatibility with other applications. The identified requirements for the technical assistance system will be passed on to the developers. In our use case, a preparation mode for navigation was derived and incorporated into the technical architecture at an early stage. The architecture is currently in a process of adaptation and the results are monitored through a combination of development modeling and social science analysis. Here also Social Research, Design Thinking and TRIZ-modeling go interdisciplinary hand in hand.

5 Modeling in the Triangle

An ideal modeling can be derived from the results of the preceding analyses. The TRIZ-modeling serves to clarify the interaction of infrastructure and user function, which are brought together in the execution of the assistance system. As it turns out, the different modes already discussed are of particular importance. The differences of the preparation, navigation and orientation modes result from the target group specific requirements and the processuality of the configuration space.

This is used in a further step for the extraction of detailed scenarios of the individual modes. On the one hand, the specific requirements and the conditions of the infrastructure serve as a starting point. On the other hand, the user functions are used according to their respective importance in relation to the infrastructure. These user functions are derived from the functionalization. In the user function the mutual dependence of user-device and device-user perspectives takes effect. Due to the process-like sequence of the individual steps, which refer to themselves as well as to each other, a reciprocal relationship results in the application. When considering the user function description, this distinction and their interaction is taken up again in specific terms. The specific stakeholder requirements reflect user requirements and the specific infrastructural conditions. Here, infrastructure is understood not only as a material prerequisite, but also as a processual system that changes through use and as an environment (user-technology world) [9]. Here the two linked systems as interactive system are realized.

The sociological determination of a case oriented to the application partner resulted in a first basic scenario, which is functionalized as an example for the scenarios for the different modes. With these scenarios, the flow of the assistance system is to be tested, which will be verified in the user-device usage by the iteration with the prototype. Further steps will be realized in the frontend design. This also includes the Voice Over function, which is essential for blind and visually impaired people. In further socio-scientific investigations an ideal description form of the Voice Over is to be examined. This includes the scientific foundation as well as further elaboration of the speech interaction concept and an imaginable description form, which considers the specifics of a linguistic implementation in the concept blind for blind. In a future version, a dynamic user-specific extension of the list of recurring situations should be provided.

After the latest developments, it is becoming apparent that the further work of the team at Leipzig University up to the end of the project will focus on testing a constantly evolving prototype with subjects from different cohorts. These tests will set up a permanent feedback loop, which will be used to compare the further technical development of the app with the requirements and the status of the processing of issues. In the sense of a consolidation of systems in cooperative action, the requirements and the glossary in a digital RDF based semantic web structure will also be updated. The transcripts of the test runs are also used as a source for the further development of the speech interaction concept (SIC). For this purpose, speech interaction units (SIU) are extracted as intents from the transcripts, to have a sufficiently large pool of such units, from which generalized patterns (templates) can be derived. Similar to the transcripts, a table structure for text will be developed, which can be transferred to a CSV file that is digitally processable. Parallel to this, the interaction scenarios already available from the first test runs are prepared according to this scheme and will be matched to the BIM data. In contrast to previous approaches, a co-evolution of use and existing statically considered building data is used here. Thus, information from a long-term perspective of building development can be included. A reprocessing of already existing structured data is possible. The alignment between use and user is improved by a continuous iterative process. The only thing that remains unclear is exactly which data transformations must be performed for the new purposes and how these inventory data (orientation-driven) are to be interleaved with specific user data (navigation-driven).

Accordingly, indoor navigation must take questions of location, orientation, and control seriously. The scientific evaluation and feedback to a user-oriented development is on the one side an aid to clarify the basics and on the other side an integral part for an efficient orientation of the use of the application to be created. This refers to the needs and requirements of the user group. For the clarification of this connection and for the integration of systematic innovation methods an interdisciplinary and problem-oriented view is to be won from the patterns of the development and the already existing market positions.

This will be applied to the particular subject of navigation for the blind. On the one hand, a usage-user comparison is to be made comprehensible and usable, which demands very special requirements for sensory back bindings of localization and orientation. On the other hand, navigation and especially control requires much more than a simple manual determination of points of interest can guarantee. Especially the application to the navigation of blind people in indoor areas offers insights into the sensory requirements of localization and orientation as well as into the possibilities of adaptive navigation and control. Today's developments in the field of indoor navigation must therefore focus on a mixture of technological possibilities and user adaptations as well as innovation methods. These must be embedded in a coordinated, agile, and flexible way of working to meet the iterative demands. A combination of different approaches to innovation methodology is considered promising for this purpose.

Solution

Our strategy in combining Design Thinking, TRIZ and social science leads to the following three outcomes:

a. The initial phase of TRIZ and Design Thinking were combined and extended. Design Thinking usually starts with brainstorming and empathy, which is now replaced by context modeling and functionalizing the users demands. Here the TRIZ method and mixed methods coming from social sciences lead to additional useful knowledge generation.

b. This iterative process is not only sufficient concerning starting points but also for the whole agile development process. At this point the user's requirements and the developers' technical know how come together. The entanglement results in a first prototype evaluation and iterative adaption. Regarding the use case IBN, a preparation mode for navigation was invented and introduced in the technical architecture.

c. Interpreting, evaluating and adapting the research outcomes underline the need of a constant feedback loop. Therefore, the management of the process doesn't only need content modeling but also the interconnection of a wide scale term use of resource and system.

Interdisciplinary approaches to plural process management methods are a new way of combining innovative product development and methodological use of system research. Both Design Thinking and TRIZ meet the requirements of today's work organization through their iterative approach and the interdisciplinary nature of the development work. Additionally, what both methods have in common is that they carry out technical development and innovation by closely aligning them with a broad concept of infrastructure. Although there may be arguments about incompatibility issues of these methods, a deeper analysis reveals the relatedness of the approaches rather than a competitive relationship. Only in the different design of the initial phase do the two ways of putting creativity to work for the development of comprehensive innovations differ. Design Thinking relies on the associative power of brainstorming and repeated rapid prototyping, whereas TRIZ, on the other hand, favors systematic modeling. In fact, both perspectives can have a positive effect on the identification of requirements and contexts. The specific requirements and conditions of the respective environment as well as the context of the product to be developed remain decisive. Both methods benefit from the usage of qualitative research in social science. Since a present-day requirement of the digital transformation is the close contact of prosumer, developer and device, a contextualization of the possible development trends becomes an unavoidable necessity [10]. Neither one nor the other method can claim absolute advantages for itself. User requirements are needed for a systematic modeling and for a contextualized brainstorming. The initial phase of TRIZ and Design Thinking is extended by social science research.
Initial phase is crucial and more than an intuitive brainstorming. The combination of methods is not only a possibility for a wide range perspective but also for a way to challenge the interaction of producer and consumer to a new level.

Acknowledgement: We would like to thank the Federal Ministry for Economic Affairs and Energy and the Central Innovation Program for SMEs for funding the project and for their kind support. Furthermore, we would like to express our gratitude to our partners Gräbert GmbH and AppPlant.

References

1. Mann, D. L.: *Hands-On Systematic Innovation in Business & Management*. IFC Press (2007).
2. Project Website at http://graebe.informatik.uni-leipzig.de/IBN-Web/IBN.html
3. VDI: ISO 9241-11 (2018)
4. Afflerbach, T.; Ducki, A.; Glasener, G. *Design Thinking, Digitalisierung und Diversity Management: Ein Praxisleitfaden für die Lehre*. Berlin, Toronto. (2019)
5. Altschuller, G. S.: *Creativity as exact science*. Moscow. (1979)
6. Project Website at https://wumm-project.github.io
7. Toffler, A.: *The third Wave*. New York. (1980)
8. Schumann, N.: *Zur Methodologie der Zweiten-Person-Perspektive. Kritik der experimentellen Psychologie und Neurophysiologie unter besonderer Beachtung phänomenologischer Zugangspositionen.* Würzburg. (2020)
9. Gräbe, H.-G.: *Technical Systems and Purposes*. In: Proceedings TRIZ Anwendertag 2020 (Oliver Mayer, ed.), Springer Nature 2021, S. 1-13 (2021)
10. Schumann, N.; Du, Y.: *Machines in the Triangle: a Pragmatic Interactive Approach to Information*. In: Philos. Technol. **35,** 32 (2022)