Navigating the Jungle of Assistance Systems: A Comparison of Standards for Assistance Functionality

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Abstract: Health Smart Homes offer assistance capabilities and facilitate the shift towards individual, precise health care. However, due to the variety of patient requirements and the enormous amount of existing solutions, the manual engineering of customized assistance systems becomes infeasible. By further automating this design approach, a customization of home-based assistance systems can be facilitated. In order to enable an automated design approach of assistance systems for home-based health care, a common functional vocabulary needs to be agreed upon. This paper proposes a literature-based categorization of established assistance functions and a literature comparison based on these categories to facilitate standardization of assistance functions. Therefore, we analyze standards and experience reports to identify and categorize the most common assistance use cases and functions. The results show that there is no single standard defining the most common assistance functions, which hampers communication and impedes the design process of health smart homes. To mitigate this effect, we envision a building block-based definition of a common vocabulary for assistance functions.

1 INTRODUCTION

Residential environments are becoming more and more equipped with technical devices, which renders them smart and promises support of our daily life. This also extends to the health of the residents – a specific area of research are *ambient assisted living* (AAL) systems, which aim at providing a good support for health and well-being. This is not only limited to acute health care delivery, but also includes supporting healthy living (Maeder and Williams, 2017). The patient's home as an area of health care provisioning (Haux et al., 2016) receives increasing attention, as more e-Health and telemedicine applications become available to improve the quality of care (Kruse et al., 2017) and bridge the distance between patient and health care providers using information and communication technology (ICT) (Otto et al., 2018).

In the future, a shift from one-size-fits-all healthcare approaches to customized precision health care is predicted (Maeder and Williams, 2017). In the context of patients' home environment, this is often referred to as *Health Smart Home* (HSH) (Maeder and Williams, 2017). However, in order to benefit from a tailor-made assistance system in HSHs, patients, health care providers and technicians face with complex challenges in selecting the appropriate components and products. There is a great variety and number of possible assistance technology solutions; yet they are not always compatible with each other. Furthermore, the resulting assistance systems need to be adapted to the individual requirements of the patients as much as possible, which puts major emphasis on customization (Meyer et al., 2015).

As a consequence, both patient and health care provider are tangled up in navigating the confusing jungle of assistance solutions, trying to find suitable solutions and to combine them to one working system. Professional planners often limit the selection of solutions to a small number of well-known components, which prevents the integration of new technologies or devices. To end this struggle, an automated computer-based approach might offer decision-support in selecting and connecting assistance components to a customized assistance solution for patients' homes.

We envision such a design approach that takes both the patient's requirements and needs into account and comes up with several suggestions that fulfill the individual demand for technical support of the patient. Referring back to the jungle comparison, this

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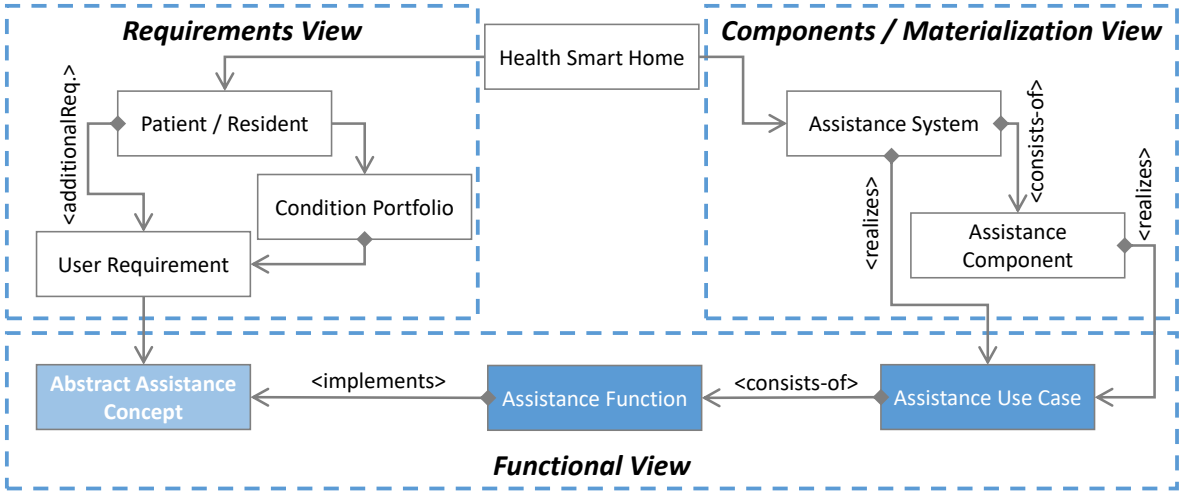

Figure 1: Assistance concepts in Health Smart Homes - context and terminology.

approach would act as a navigation system, preventing the user from getting lost in the jungle of assistance systems.

Every navigation system needs both a map and path-finding-algorithms. Therefore, an automated design approach also requires a representation of the available assistance solutions (i. e. the surrounding and world map) as well as a method on how to appropriately combine them (i. e. a path-finding-algorithm).

In this paper, we propose a categorization of assistance functions, which was derived from a literature analysis of established assistance systems and use cases. This serves as the first step in charting the existing world of assistance solutions and providing a formal documentation of component functionality to enable an automated design approach.

The goal of our research presented in this paper is to guide the consolidation of functional semantics in the field of ambient assisted living technologies in order to provide the foundation for an automated design approach for HSH systems. The main contributions of this paper are:

1. Development of a categorization of common assistance functions
2. Consolidation of different standards and guidelines for home-based assistance systems of HSHs
3. Comparison of the existing standards and guidelines by identifying their specific focus areas

The remainder of the paper is organized as follows: The next section introduces key concepts that are used by this paper in the context of HSHs and explains their relationships. Subsequently, an overview of related literature and the state of the art for model-based design approach of automation systems in the domestic environment is presented, before outlining the overall research roadmap. Section 3 describes the applied method and the analyzed literature. The results of the analyzis are presented in Section 4 and discussed in Section 5. Finally, Section 6 concludes the paper and describes further research actions.

2 BACKGROUND

2.1 Context of Health Smart Homes

Assistance systems in HSH are embedded in a special context as displayed in Figure 1.

The central concept of this paper is the *Health Smart Home* (HSH). It is an extension to the smart home concept that describes living space equipped with communicating devices to monitor the surrounding and the residents as well as controlling the physical environment. In addition, HSHs add a strong focus on the residents' health status. It needs to be managed and must therefore be measured and understood (Maeder and Williams, 2017).

HSH system deployment is based on integration of existing components (Welge et al., 2015; Haux et al., 2016). Yet, even though off-the-shelf technology can be used, there is a significant workload for system integrators (Welge et al., 2015) since HSH systems combine devices of a variety of types (telemedicine, building automation, ICT, proprietary solutions) and from different vendors.

The equipped electronic devices of HSH are *Assistance Components* that constitute an *Assistance System* in the HSH. The individual assistance components of an assistance system may exchange informa-

tion by communicating with each other. They realize specific *Assistance Use Cases*, which might be complex and specific scenarios (e. g. larger subsystems specifying an installation location). As an assistance system consists of assistance components, the assistance use case realized by the whole assistance system can also be determined.

With different prefabricated components being combined, interoperability issues need to be taken into account. *Interoperability* amongst system components is usually low and needs to be determined manually by an experimental setup for each component pair, as formal specifications of the component semantics are missing. *Integration* issues are mentioned as future challenges (Maeder and Williams, 2017). Similarly, interoperability and data integration have also been identified as one of the main technical issues in modern and future health-enabling and ambient assistive technology (Haux et al., 2016).

The *Resident* of the HSH determines the requirements the assistance system has to fulfill. On the one hand, residents may suffer from several diseases or special conditions – thus, a specific *Condition Portfolio* can be associated to each resident. This implies several *User Requirements* the assistance system should be able to fulfill. On the other hand, residents may have additional user requirements that are not related to a specific disease, but should nonetheless be fulfilled by the assistance system in the HSH.

2.2 Views on Health Smart Homes

The concepts related to the resident constitute the *Requirements View* on the HSH, while assistance system and assistance components represent the *Components / Materialization View*. A key task in HSH engineering is finding and selecting appropriate assistance components, such that the assistance system is able to fulfill the whole set of requirements.

More fine-grained *Assistance Functions* as smaller functional units of potentially complex assistance use cases are used in the mapping of assistance components and user requirements to enable detection and avoidance of unnecessary redundancy. While an assistance use case might involve complex interactions of several components (such as a fall detection system that is integrated with home care service providers via wireless communication technology), assistance functions focus on individual aspects of assistance use cases. For the introduced example, the assistance use case of the integrated fall detection system consists of several assistance functions: First, the fall detection based on measured sensor data and second, the communication with the home care provider via wireless communication technology.

The distinction of use cases and functions is as follows: Assistance use cases represent specific scenarios that may contain several interacting assistance functionality, whereas assistance functions represent individual functionality. Both assistance functions as well as assistance use cases are often described with technology-specific realization restrictions – e. g. which communication technology will be used. However, user requirements are mainly focused on providing a certain functionality, without prescribing how exactly this functionality has to be implemented by the assistance system. Thus, a technology- and manufacturer-independent model for assistance functions is needed. In order to increase reusability, the structural elements of assistance functions are defined in an abstract manner as *Abstract Assistance Concepts*. These abstract assistance concepts are modular and reusable building blocks for specifying the *Functional View* on the HSH. On a technology-neutral level, assistance functions can be described using the abstract assistance concepts and their interactions.

Consequently, the abstract assistance concepts are the missing link for a formal mapping of requirements and assistance components.

2.3 Related Literature

The functional view of HSHs is important when trying to map assistance components with user requirements, since it offers a technology-neutral formalization level for computer-based design algorithms.

There are different approaches for *specifying functional models* of automation components. For medical information technology solutions, use case-based integration profiles have been applied to model more complex scenarios (Welge et al., 2015). These profiles specify individual complex scenarios and their actors, but no modular building blocks and thus do not scale well with an increasing number of assistance solutions.

For room automation systems, a similar approach is taken by the German standard VDI 3813 (VDI 3813-2, 2011), which specifies standard room automation functions. It uses a textual as well as a function block-based representation of this common functional vocabulary of the room automation domain. For each function, the required inputs and available outputs are semantically specified. This standard is also the foundation for a semantic component repository (Dibowski and Kabitzsch, 2011), which contains functional representations of room automation com-

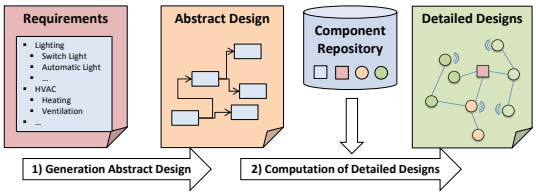

Figure 2: Automated Design Process based on (Dibowski et al., 2010).

ponents.

Using this component repository, a multi-stage *automated design approach* for room automation systems could be developed (Dibowski et al., 2010; Lehmann et al., 2016). Figure 2 depicts the different stages of the approach. It applies the functional models from the *component repository* to match the *requirements* specified by room automation planners as *abstract designs* in the common functional vocabulary the VDI 3813 offers. As a result, several design suggestions are generated (*detailed designs*).

The VDI 3813 as a common vocabulary is a vital part of the approach as it offers a standardized language for specifying both the system functionality (abstract designs) and components' semantics (component repository).

2.4 Research Roadmap

This section explains the overall context of the research and puts the contributions of this paper into perspective with regards to the bigger picture.

Since the manual design of HSHs is suffering from a high complexity, the design process needs to be automated. As the automated design approach discussed above (Dibowski et al., 2010) has proven effective for room automation, it should be investigated if its principle can be transferred to the HSH domain. This would require components of the smart home and assistance systems domains to be semantically modeled in a similar way as proposed by Dibowski and Kabitzsch (Dibowski and Kabitzsch, 2011).

Therefore, a formal and technology-neutral modeling framework for the components' functions similar to the VDI 3813 is required in order to specify the functional view on HSHs. Thus, this paper investigates if there are comparable standard functions available for assistance systems of HSHs by analyzing available literature with a strong focus on standards and guidelines.

3 METHOD

After introducing the main concepts and their relations, the method applied when analyzing existing literature of assistance systems is introduced in this section. Firstly, the literature selected for the analysis is presented before providing a detailed description of the used method of analysis.

3.1 Analyzed Literature

To identify common assistance functionality, established standards were identified and analyzed. Since the overall approach follows the general idea of the German standard VDI 3813 and the results should be compatible to the existing classification of standard functions in the room automation domain, the search for standards was focused on German standardization bodies [1]. Furthermore, restricting the analysis to German standards can be justified as AAL technology has been a major research focus in Germany. Besides several federal and state ministries, the German Federal Ministry of Education and Research (BMBF) offered the research programme "AAL – Ambient Assistive Technologies" from 2008 to 2012. In total, 54 research projects were funded (Meyer et al., 2015).

The search for relevant standards and guidelines concerning assistance functionality yielded the following results:

VDI 3812-1 "Requirements for electrical installations and building automation and control systems": This standard is focused on "supporting the selection of home automation technology and the concrete implementation" (VDI 3812-1, 2010). It lists 21 assistance functions and use cases for domestic environments.

VDI 6008-3 "Barrier-free buildings – Aspects of electrical installation and building automation": This particular standard is part of a series of standards focusing on barrier-free buildings. This part describes "ways how technical building services can reduce barriers, increase safety and enhance convenience" (VDI 6008-3, 2014). In total, 84 distinct assistance use cases are mentioned.

VDE-AR-E 2757-8 "Process support for the technical implementation of assistant systems (ambient assisted technology) in homes and residential buildings": This VDE application guide focuses on assistance functions for different components of residential buildings as well as their suitability for different user groups (VDE-AR-E 2757-

[1]The investigated standards are mostly also available in English language.

8, 2014). It lists 51 assistance functions and use cases in domestic environments.

As the literature analysis was focused on assistance systems, the standard VDI 3813 (VDI 3813-2, 2011) of standard room automation functions has not been taken into account. However, as mentioned in Section 5, it is used to assess the results of the literature analysis.

The results of the search for standards and guidelines were supplemented with an evaluation report on practical usage of assistance technology in various settings (Meyer et al., 2015). Out of 59 projects, Meyer and colleagues investigated the most relevant 17 projects in detail with regard to the used assistance systems and lessons learned from their application. A total of 45 assistance functions and use cases have been identified.

All in all, the analyzed literature offers a combination of *prescriptive* as well as *descriptive* sources. Thus, it covers both the theoretical and practical aspects of assistance solutions and indicates how relevant theoretical assistance functions are in practice.

3.2 Method of Analysis

The literature-based analysis of common assistance functions is done in two steps. The first step, *Compilation and Consolidation*, is collecting the assistance functions and more complex use cases mentioned in the literature. Afterwards, the assistance use cases need to be decomposed by deriving the assistance functions contained in the use cases. The identified functions are then added to the overall list of assistance functions. This resulting list is subsequently consolidated by eliminating duplicates and harmonizing the functions' naming.

In the second step of the analysis, *Categorization*, the functions are categorized in a mixed approach of deductive and inductive categorization. First, knowledge of the general structure of assistance systems in HSH is used to derive an initial coarse classification of assistance functions. The identified assistance functions are classified according to the initial categorization. Subsequently, they are iteratively grouped to more fine-grained categories and consolidated similar to the assistance functions from the first step. The final set of categories is then hierarchically structured.

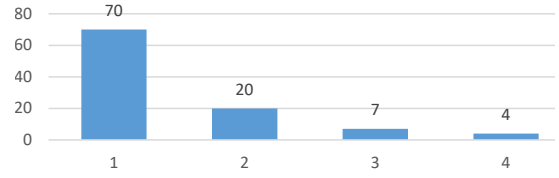

Figure 3: Histogram of the number of sources an assistance function is mentioned in.

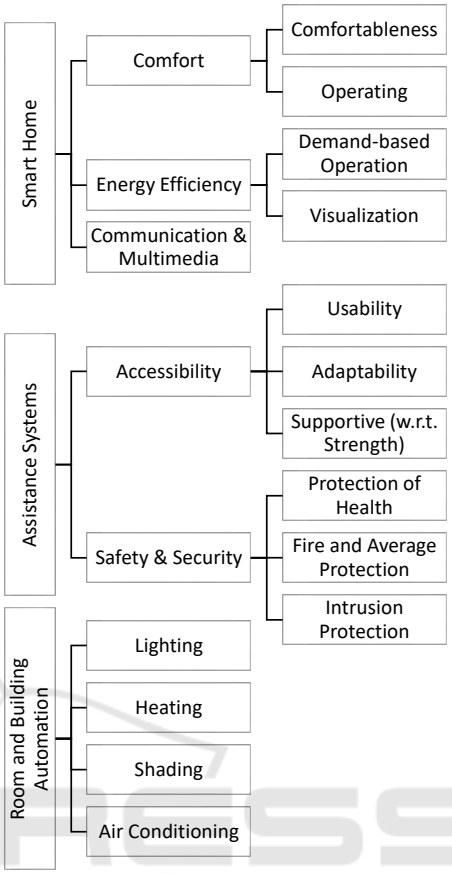

Figure 4: Resulting categorization of assistance functions.

4 RESULTS

4.1 Assistance Functions

The first step of the method presented in Section 3.2 yields a consolidated list of assistance functions mentioned in the literature. At the end of the consolidation step, 101 assistance functions were identified in total. Several assistance functions were mentioned in multiple sources, including "Automatic Light (dimmable)", "Closed-loop room temperature control", "Scene Control", "Central off", "Automatic Shutdown".

Figure 3 displays the histogram of how often functions have been mentioned. It can be seen that nearly 70 % of the identified assistance functions are mentioned in only one out of four sources. Additional 20 % of the functions are also referred to by just two sources. Given that all sources claim to focus on the

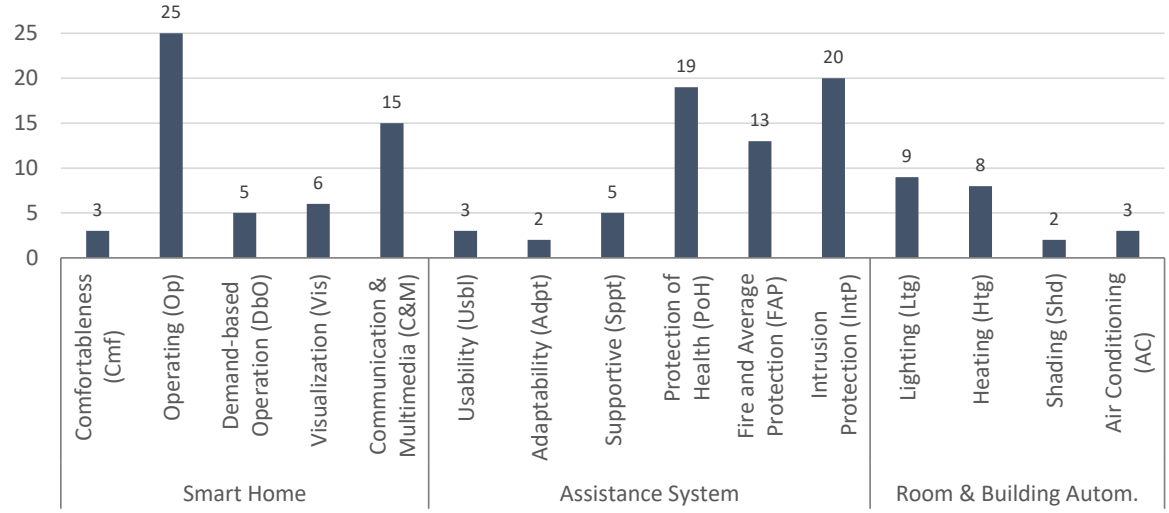

Figure 5: Resulting sizes of the function categories. The subsequently used abbreviations for the categories are shown.

same area – assistance functionality in domestic environment, but 90 % of the assistance functions are defined in up to only two literature sources, it can be concluded that the amount of overlap amongst the different literature sources is surprisingly low.

Even though the standards and guidelines target the same area, the results suggest that they might emphasize different aspects. As a consequence, neither of the standards or guidelines seems to offer a comprehensive view on assistance functions, but they all have to be considered at the same time. In this case, 30 % of overlap introduces the risk of redundancy and conflicting definitions, which hampers communication between professionals in this field [2].

4.2 Categories of Assistance Functions

Figure 4 depicts the resulting categorization of the consolidated assistance functions. It has to be noted that some assistance functions may fit into more than one category as their functionality may be reused in different application contexts.

The three closely interrelated domains *Smart Home*, *Assistance Systems* and *Room and Building Automation* represent the top level of the categorization. The categories of each domain are further divided into different groups. For smart home as well as room and building automation, these groups correspond to the different trades (i. e. "Lighting", "Heating", "Shading", "Air Conditioning", "Communication & Multimedia") or goals (i. e. "Comfort", "Energy Efficiency"). In the analyzed standards, only a small number of functions from the room and building automation domain have been identified. Therefore, these categories are not subdivided any further.

However, the smart home categories comfort and energy efficiency can be subdivided. Comfort can on the one hand be achieved by assistance functions that make residents feel comfortable or cozy ("Comfortableness"). On the other hand, comfortably "Operating" appliances and technical equipment may contribute to the overall comfort level of inhabitants. Functions for energy efficiency can be both ensuring a "Demand-based Operation" of household appliances as well as building systems and providing a "Visualization" of the energy consumption and device states.

The categories belonging to assistance systems can be divided into "Accessibility" and "Safety & Security". Accessibility contains the categories "Usability", "Adaptability", and "Supportive" functionality and aim at reducing barriers in daily life at home. Safety functions are divided into "Protection of Health" as well as "Fire and Average Protection" (e. g. in case of malfunctioning household appliances). The major application for security functions is "Protection from Intrusion".

4.3 Focus Areas of the Literature

The distribution of the 101 identified assistance functions in the different categories is shown in Figure 4. As assistance functions may be assigned to different categories, the overall amount of items in all categories adds up to 135. The cardinality of the different categories is shown in Figure 5 and depicts the focus areas of the selected literature as a whole.

The room and building automation domain is

[2]Since (Meyer et al., 2015) is a report on actual practical usage of assistance systems and it does not claim to offer a comprehensive view on assistance functionality, it is not suitable for assessing how fragmented the definition of assistance functions is.

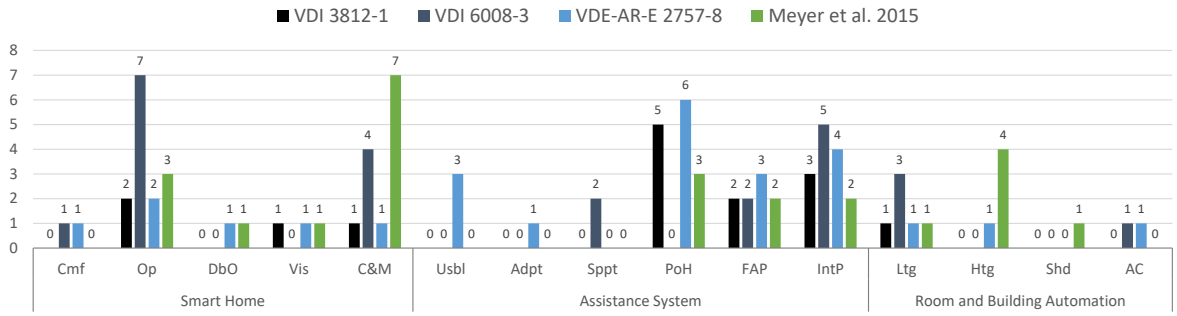

Figure 6: Profile of categories of unique assistance functions in the literature.

mentioned several times; however, it is not in focus of the assistance functions of the analyzed literature. This might be due to the focus of the literature search, which concentrated on the assistance aspects of home automation, while room and building automation are mostly concerned with providing an automation infrastructure for buildings and their technical equipment. The most important categories are "Operating" in the "Comfort" group (25 items), followed by "Intrusion Protection" (20 items) and "Protection of Health" (19 items), which both are part of the "Safety & Security" group. "Communication & Multimedia" (15 items, Smart Home domain) as well as "Fire and Average Protection" (13 items, "Safety & Security" group) are also important categories.

Specific focus areas of the different literature can be identified. Figure 6 depicts the profiles of the unique functionality for each literature source. In the smart home domain, the standard VDI 6008-3 and the experience report of Meyer and colleagues (Meyer et al., 2015) feature the most unique functions in the areas of "Operating" comfort and "Communication & Multimedia", respectively. In terms of assistance systems, each literature source contributes some unique assistance functionality to the categories of "Safety and Security".

As a summary, a focus on the domains smart home and assistance systems can be identified. Assistance functions of the assistance systems domain are most commonly used for safety and security purposes, including health care and detection of health risks, detection of safety issues related to the equipment of the apartment as well as preventing intrusion. On the other hand, smart home assistance functions focus on providing a higher usage comfort with support of operating tasks. A second focus of smart home functions is enabling communication with friends, family, neighbors, and practitioners as well as providing access to multimedia content.

5 DISCUSSION

The results presented in the previous section revealed that the domains room and building automation, smart home as well as assistance systems overlap and are closely linked. In case of room and building automation, the identified assistance functions need to be consolidated and supplemented by the already existing standard room automation functions of the VDI 3813 Part 2. As a means for aligning the standards, the different trades of room automation might be used, so that the assistance functions discussed for HSH can be mapped to the respective room automation functions.

The standard VDI 3813 is of vital importance for automated design approaches in the room automation domain, since it defines a common vocabulary of standard functions used by professionals. But, as can be seen from Figure 3 and Figure 6, for assistance systems there is no single standard that can be used as a normative reference for standard assistance functions. Each of the investigated literature sources contributed an important and unique set of assistance functions to the overall list of functions. However, this also means that, unlike in the room automation domain, there is no agreed-upon set of assistance functions that might serve as a common vocabulary for practitioners, technicians, patients, or patient advisors. Instead, they need to resort to a number of standards and guidelines when discussing assistance functions, creating the potential for misunderstandings due to redundant or contradicting definitions. These drawbacks would be overcome by a single combined standard, which however is hard to keep up-to-date.

Following the approach of the VDI 3813, the definition and standardization of modular and reusable building blocks for home-based assistance systems may be a viable approach to tackle the issue of the great variety of assistance functions, whose definition is spread over a number of different standards. The *Abstract Assistance Concepts* introduced in Sec-

tion 2.2 are such building blocks. They can be derived from the identified assistance functions.

With reference to the jungle navigation system, we have identified that there are several incomplete maps of the world, which are not yet ready to serve as an input for the path-finding-algorithms. As a consequence, we suggest consolidating the different types of objects on maps (i. e. the building blocks of world maps) as a common vocabulary for map creation. Based on this vocabulary, it will be possible for domain experts to create a consistent view of the world as input for automated path-finding-algorithms.

6 CONCLUSION

This paper investigated existing standards for assistance systems in the context of HSHs, which have the potential of facilitating precise health provisioning in the future. Since the design of such systems is complex, model-driven design automation was discussed as a promising approach to cope with the great number of possible components to select as well as the interoperability and customization requirements.

To enable such an automated design approach based on formalized functional models, a common vocabulary and categorization of assistance functions were proposed. It was identified that there is no single standard for specifying such a common vocabulary of functions, resulting in the need to align with standards of adjunct domains and to identify modular, reusable building blocks of assistance systems.

These open research topics need to be addressed in order to apply automated design approaches to HSHs and overcome the design issues hampering a successful application of assistive technology for improving quality of care.

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