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GENERAL RESEARCH

Reaching into patients' homes – participatory designed AAL services

The case of a patient-centered nutrition tracking service

Philipp Menschner · Andreas Prinz · Philip Koene · Felix Köbler · Matthias Altmann · Helmut Krcmar · Jan Marco Leimeister

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Abstract Ambient Assisted Living (AAL) offers possibilities for promising new IT-based health care services that are resulting in new challenges for its design process. We introduce a novel approach for engineering AAL services (AALSDA) which combines methods from service engineering and participatory design. We demonstrate this approach by developing and implementing an electronic data capture system, NuTrack, for self-reporting of nutrition status. The approach uses different concepts for AAL service design and delivery: service engineering for standardizing and structuring service processes, reasonable IT-support for automation of parts of services that need no person–to-person interaction, participatory design to integrate end-users in the development process, and patient integration for personalizing and improving the depth of performance of service providers' service delivery. For illustration, we present the case of chronic disease patients suffering from impaired fine motor skills. Our approach is applied in a pilot study with prototypes tested in focus groups and workshops with patients, caregivers and physicians. The results demonstrate good applicability and feasibility of the concept, and provide new insights for the future design, development and implementation of AAL services.

Keywords Participatory design · Service engineering · Customer integration · Electronic data capture · AAL · eHealth

JEL classification I10

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Introduction

Health care comprises highly complex and extremely expensive services that have a significant impact on economies and the quality of daily life of patients (Berry and Bendapudi 2007). In addition to social and economic consequences, health care is a field that continuously undergoes changes. The demographic shift in many industrialized countries has led to increased health care spending and a higher demand for care services, thus threatening existing public health and welfare systems (OECD 2009). Germany, for example, spent more than 250 billion Euro on healthcare in 2009 (OECD 2009), and costs are projected to increase by 70% by 2020 (Kartte et al. 2005).

A large proportion of the health care budget is spent on care services for chronic disease patients (OECD 2009). The predominant setting for the provision of care for the majority of patients is the home. Enabling patients to stay at home as long as possible can help to improve quality of life and is what most patients want (OECD 2005). Social policies encourage this form of care, yet the request for better quality services and the rising demand for care services are challenging to public funding systems.

A common side-effect of patients living in home care is the occurrence of malnutrition (Löser et al. 2007; Stratton et al. 2003). It emerges especially if people suffer from reduced physical ability, e.g., impaired fine motor skills (Stratton et al. 2003). Such patients are often seriously affected by an insufficient dietary intake which leads to an unnoticed reduction of weight due to malnutrition or cachexia (Löser et al. 2003). Malnutrition is associated with high morbidity and mortality, and can negatively affect the quality of life of patients as well as family members (Desport et al. 1999; Löser et al. 2003; Ludolph 2006). In the course of the diseases, supplementary nutrition or the use of percutaneous endoscopic gastrostomy (PEG) tubes for enteral nutrition becomes inevitable in many cases. This intervention significantly affects personal, logistical and financial expenditures for service providers, as well as insurance and funding agencies (Löser et al. 2007). In Germany, the total financial impact on the public health and welfare system caused by malnutrition is estimated to be 17 billion Euro, and the costs of complex care expenses result in total expenditures of 50,000 Euro per patient and year (Schauder 2006).

In order to provide optimal treatment, physicians need appropriate information regarding their patients' actual nutritional state. Yet, this implies multiple logistic challenges of capturing, archiving, analyzing and interpreting health status information (Wolfe and Pincus 1995). Especially in the case of patients being cared for at home, the major problem is that relevant contemporaneous information required to support therapeutic decision-making is often not available. Ambient Assisted Living (AAL) could be a solution to this problem, as it encompasses, amongst others services and technologies, the surveillance of individual medical status and patient behavior.

Solution idea

The recent increase in AAL technologies offers vast potential to enable new ways of health care provision at home, to improve existing health care services, and to create new services. AAL is therefore beneficial in supporting a patient's quality of life and, where implemented, could reduce the cost of delivering health care. Despite being considered medically and technically viable, few AAL innovations have, however, been put into practice (Cho et al. 2008; Essén 2009). The reasons AAL services are not seeing a widespread implementation include a lack of suitable business models, difficulties in integrating AAL into existing health care treatment processes, and usability and acceptance issues on the part of physicians and patients. Hence, methods need to be developed to systematically develop economically reasonable and user-friendly IT-enabled services and processes in health care (O'Grady et al. 2010).

In order to do this, we propose an AAL service design approach (AALSDA) that combines methods from *service engineering* and *participatory design* to enable the best possible *integration of IT and AAL technologies* into treatment processes and *integration of patients* into the design and provision of health care services to maximize usability and acceptance (Fig. 1).

We applied AALSDA to the development of a prototype system for self-reported nutrition tracking for patients

Fig. 1 The four building blocks of AALSDA

suffering from motor neuron disease by executing the following steps: After an in-depth analysis of the initial situation, we used a service engineering method (service blueprinting) to ensure optimal integration of IT and AAL technologies into treatment processes. Then, we designed a nutrition tracking system prototype (NuTrack) using a participatory development approach, evaluating and refining it through focus groups and workshops. NuTrack is currently running in a field test. The contribution of this paper is two-fold: First, we present the AALSDA for systematic design and development of AAL services and second, we propose the NuTrack prototype as a novel design artifact resulting from the AALSDA application.

The remainder of this manuscript is structured as follows. We first give an overview of related work in the four conceptual building blocks of AALSDA followed by a description of the research method and AALSDA. We then illustrate our approach by applying it to the development of NuTrack. We present our findings and close with limitations and suggestions for further research.

Related work

Ambient Assisted Living (AAL)

AAL comprises methods, concepts, (electronic) systems, devices as well as services that provide unobtrusive support for daily life based on the context and situation of the assisted person (Steg et al. 2006). It is one of the main applications of Ambient Intelligence (AmI) technologies and primarily aims at enabling people with specific health or care demands (e.g., handicapped or elderly) to live in their preferred environment, rather than being hospitalized to stationary care facilities, which, in turn, lessens the strain on public healthcare systems (Mukasa et al. 2008). In general, AAL systems are "electronic environments that are sensitive and responsive to the presence of people and provide assistive propositions for maintaining an independent lifestyle" (Naranjo et al. 2009). Many instances of AAL have the dual nature of a product, in this case a specific AmI technology or IT, and a (health-) care service that is supported or enabled by it. The area of technological advancement that acts as a driving factor for AAL systems development and enables environments to be outfitted with AmI is referred to as "Ubiquitous Computing", e.g., radio frequency identification (RFID). RFID, as all other mobile and ubiquitous computing technologies, enables a seamless and non-intrusive integration of IT applications and services into everyday life environments (Leimeister et al. 2007; Resatsch et al. 2008; Schweiger et al. 2007; Uhrich et al. 2008). Examples of research on ubiquitous computing technology as the basis of AAL systems are documented in the literature (Aarts and Wichert 2009; Mufti et al. 2009; Postolache et al. 2009; Rogers 2006).

In most cases the electronic AAL environment provides communication and information support in everyday life to enable care service provision. This paper focuses on AAL services in the medical environment which are strongly related to telemonitoring (Scanaill et al. 2006). Telemonitoring is communication and information support for patients and medical personnel, and requires the gathering of information about the patient by means of electronic data capture (EDC). An extensive body of scientific literature elaborates on the various occurrences of EDC for healthcare services and the acquisition of quantitative and qualitative data in clinical surveys (Bischoff-Ferrari et al. 2005; Blake 2008; Dale and Hagen 2007; Koene et al. 2010; Palmblad and Tiplady 2004; Richter et al. 2006). One of the advantages of EDC is that data are collected in digital form ready for an instant analysis, thus cutting costs on digitalization and improving data quality (El Emam et al. 2009; Hyde 1998). The next evolutionary step of data acquisition in clinical trial studies is the direct capture of data using barcode scanning, or most recently, Near Field Communication (NFC)[1] or RFID tags. This allows further improvement of generated data quality and enables cost-reduction (Hyde 1998; Morak et al. 2009; Smith and Offodile 2002).

Service engineering

Essential to the successful design of AAL services is that they are underlined by a reasonable service process and design. In many industries today, the main challenge in service innovation is about adoption and effective implementation of IT (Zysman 2006). Due to increased competition in many service markets, differentiation through innovative service offerings is developing into a key unique selling point (Maglio and Spohrer 2008). IT enables automation, support of processes, standardization, and new concepts for customer integration (Fitzsimmons and Fitzsimmons 2005). Regarding health care, the increase in AAL technologies over the last few years additionally offers enormous potential for improving existing health care services and creating new services.

Service engineering focuses on adopting concepts which are successfully implemented in product and software engineering to the field of services. It is defined as the systematic design and development of services by deploy-

[1] NFC is a short range high frequency wireless communication technology that allows data exchange between devices that are about 4 inches apart (ISO/IEC 2004). It is a simple extension of the ISO/IEC 14443 (ISO/IEC 2000) proximity-card standard (such as contactless card, RFID, etc.) that combines the smart card and the reader into the same device. NFC is primarily aimed for use in mobile phones.

ing engineering methods and practices, and by using tools of the engineering design field (Bullinger et al. 2003). Multiple concepts and methods have been successfully developed and deployed, and can be classified into resource, process and product models (Bullinger et al. 2003; Fähnrich and Meiren 2007). Resource models encompass development tasks which describe the provision of services. The key aspect is the planning of assets, which include human and material resources as well as the concept of technologies being used. Product models describe what a service actually does, and must be followed by process models which specify how the service is provided. However, enabling IT potentials, (e.g., by integrating AAL technologies) for health care services raises problems that existing design methods do not address (Patrício et al. 2008). This is because these services are highly individualized, knowledge demanding and generally delivered face-to-face (Berry and Bendapudi 2007; Menschner et al. 2010). Yet, efforts to realize these potential for health care services have already been successfully made (Leimeister et al. 2002; Leimeister et al. 2006) and can be expanded upon.

Participatory design

One of the central aspects of successful AAL service development, as noted by most researchers, is the inclusion of the user in the entire development process (Kleinberger et al. 2007; Naranjo et al. 2009). As the development of such innovations is computing within a user's changing environment, it is important to determine user needs at a very early stage of development (Iachello et al. 2006). Participatory design and prototyping approaches have proven to be valuable to the development of mobile or ubiquitous computing services. This also holds true for the design of AAL services. Through early involvement of stakeholders in the development process and visualization of parts of the system through prototyping, the danger of transporting wrong or inaccurate requirements to the final system can be reduced. Additionally, general requirements become more detailed and refined with progression of the development process (Resatsch et al. 2008). Participatory design is hence paramount to achieving a high acceptance of AmI technology and is thus "a key ingredient towards effective AAL systems" (Sun et al. 2010).

Recent studies also underline the potential of involving users, specifically in the process of service innovation. Involving users as innovators can result in more innovative services that have greater user value (Magnusson 2003). This is particularly true for mobile information services (van de Kar and den Hengst 2009). Additionally, as user requirements are often "sticky" information, significant costs are involved in eliciting these requirements in non-participatory design settings (Oliveira and von Hippel 2009).

Patient integration

In health care, the provision of appropriate treatment often depends on self-reported states, characteristics and behaviors of patients in order to understand disease progression or treatment outcomes. Patients therefore fulfill the role of an "external factor" in health care service provision (Fitzsimmons and Fitzsimmons 2005), and are an integral part of the service as co-creators. Integrating customers (in this case, patients) into service provision can positively impact productivity and service quality as patients take over certain parts of the service, for example, by providing accurate information about their symptoms or answering detailed questions about their state of health (Zeithaml et al. 2006).

The application of EDC for this self-reporting of patient data has been shown to increase patient compliance (Nyholm et al. 2004). The data can furthermore be made immediately available for physicians and clinical personnel, thus providing cues for possible medical interventions between medical appointments (Velikova et al. 1999).

The application of NFC technology to provide EDC for patient self-reporting is, however, comparatively novel and not widely implemented. Lahtela et al. (2008) describe a NFC-based solution for the control and distribution of medication in hospitals. Fikry et al. (2006) and Morak et al. (2009) show different ways to employ NFC technology to collect medical data in hospitals. In both of these systems, data acquisition is performed by health-care personnel within medical facilities; hence, their suitability for non-hospitalized patients is limited. Iglesias et al. (2009) describe an NFC-based health monitoring system for elderly patients as a self-management process which can be used by patients at home. The authors concentrate on the capture of vital parameters and exclude self-reported, subjective patient data. The concept developed by Morak et al. (2007) for the monitoring of heart failure patients has similar limitations.

There are a few research projects that have focused on the electronic capture of self-reported patient data on quality of life (Velikova et al. 1999), disease progression (Nyholm et al. 2004) and nutrition management (Siek et al. 2006). The results of these studies indicate increased patient compliance when EDC is compared to paper-based self-reporting and more convenient, real-time access to patient data for medical personnel. None of these research projects has focused on methodological aspects required for developing successful and commercially viable AAL services.

To summarize, the four building blocks of our approach offer the potential to address and overcome the difficulties and challenges in AAL service development, once they are reasonable combined and applied. In the following section, we propose our approach of combining these concepts.

Research approach

Research method

We used a design science approach (Hevner et al. 2004; Jones and Gregor 2007), which aims to develop solutions to organizational and business problems through design and evaluation of novel artifacts. To achieve this, design science focuses on the creation of innovative and purposeful artifacts for a specified problem domain. Such artifacts include not only new constructs or prototypes, but also new methods for the development of artifacts. The design process is thereby informed by existing theories which are applied and extended through problem-solving. The design process generally consists of analyses, design, implementation and evaluation of an artifact. It is also inherently iterative, and therefore generation/test cycles are repeatedly carried out that lead to a solution (Hevner et al. 2004; Simon 1996).

In this paper, we address design science in multiple ways. First, we combine different methods to develop and design a prototype that are generally considered to be design science methods (building on existing theories). Second, the resulting NuTrack prototype presents a novel artifact that is intended to be useful to patients and staff. Third, we derive design principles for AAL service design that go beyond the single prototype Nutrack.

AAL service design approach (AALSDA)

In developing a solution for self-reported nutrition tracking, we proceeded as follows:

The starting point of our approach was a socio-organizational problem (in our case the situation of patients suffering from malnutrition due to impaired motor control). We began with an in-depth analysis of the then-current situation of patients. Background information on the problem was obtained through a review of the literature, case studies, interviews, questionnaires, observations and document analyses (Yin 1989). In parallel, we applied service engineering by using service blueprinting (Fließ and Kleinaltenkamp 2004; Shostack 1982) to analyze current treatment processes. Service blueprinting is a process analysis method originally proposed by Shostack (1982, 1984). Creating a service blueprint requires the mapping of all key activities involved in service provision as well as the identification of the linkages between these activities (Shostack 1984). Zeithaml et al. (2006) define service blueprinting as a tool for simultaneously depicting the service process, the points of customer contact, and the evidence of the service from the customer's point of view. A service blueprint can be regarded as a two-dimensional image of a service: the horizontal axis displays the chronology of the single process steps, which can be provisioned either by the service provider or the customer, and the vertical axis separates the different stages of interaction between provider and customer.

The line of interaction separates customer action from provider action and represents direct interactions or joint activities. The line of visibility differentiates between activities visible or invisible to the customer. The line of internal interaction separates front office from back office actions and the line of implementation distinguishes between management activities and support activities (Fließ and Kleinaltenkamp 2004). Based on this analysis, process steps that do not create value to the customer can be identified, and thus eligible candidates of process steps for automation by IT or provision by the customer can be determined.

Based on the findings from the analysis, we developed a design concept and a low fidelity prototype which was then evaluated in focus groups and workshops. These were repeatedly refined after generation/test cycles. As users generally had no prior experience with AAL, we adopted the extended prototype development and evaluation approach for information systems innovations of Resatsch et al. (2008). Novel to our approach is that we also designed a target process in the form of a service blueprint, which is part of the evaluation and which was refined within the focus groups and workshops. Figure 2 depicts this approach. It is based on prototyping approaches in the ubiquitous computing field (Resatsch et al. 2008), expanded by a service engineering view.

In the following, we illustrate the approach in more detail by applying it to the development of a nutrition tracking prototype of an EDC system for people with impaired fine motor skills.

Applying AALSDA to the development of an EDC-based nutrition management system

To demonstrate the feasibility and utility of AALSDA, we applied it to the development of an AAL service for self-reported nutrition tracking that consists of an EDC system based on mobile services and an information system (IS) platform. The following section elaborately describes our development process and the results within the single steps, followed by a brief description of NuTrack. The steps undertaken to analyze and subsequently design a nutrition tracking prototype included an analysis of the current situation of patients, a service blueprint of the treatment

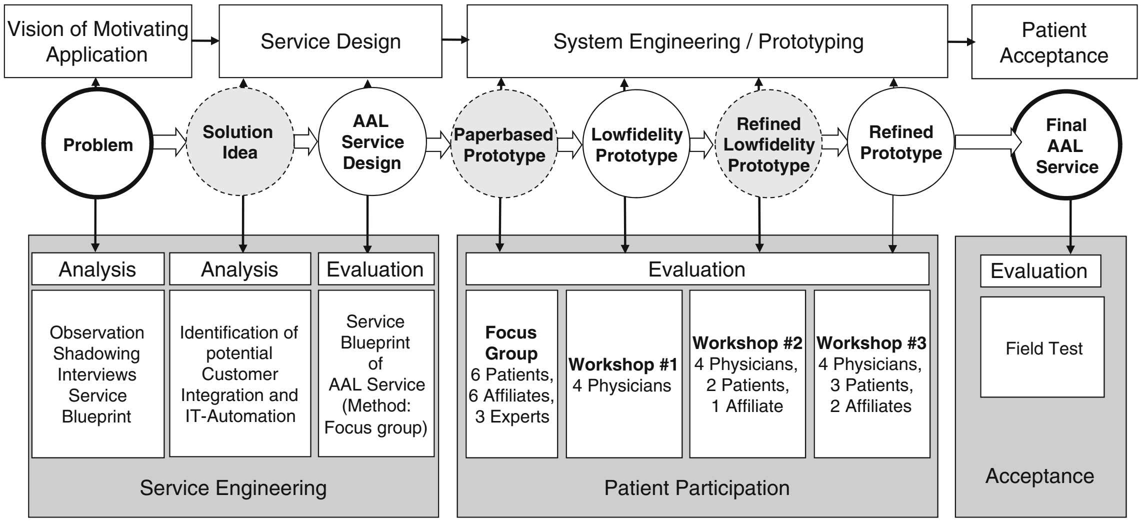

Fig. 2 AALSDA: Application of the process for AAL service development

process, and four generation/test cycles with low-fidelity prototypes and refined versions resulting in the design of the NuTrack prototype.

The observed case analyzed patients diagnosed with motor neuron disease. Patients with this diagnosis experience progressive paralysis that leads to the occurrence of malnutrition (Ludolph 2006). The complexity and difficulty of our chosen case makes it difficult to generalize our results; however, we assume that our approach could potentially produce good results for groups of patients with similar disabilities.

The first step of our approach was a fundamental analysis of the initial situation. We conducted six observations of consultations by use of shadowing (McDonald 2005), followed by interviews with the four involved physicians. The observations took place at a clinic that specialized in treatment of patients with motor neuron diseases. Apart from elevating existing treatment processes, the focus of the observations was to obtain information logistics among the stakeholders.

Underlying information logistics problem

Our observations show that there is a lack of information and interaction possibilities between patients, physicians and nursing staff. Patients have appointments every three to six months to assess the status of their disease and to adjust treatments as necessary. There is no medical follow-up of patients between visits, and physicians do not receive updates on patients from home care nurses, the family doctor or other allied health professionals. The physicians thus need to rely completely on the information presented by the patient at the assessment visit, and this has several disadvantages: First, patients may fail to give correct information (either willingly or by omission); second, information from nursing staff or the family doctor is relayed to the physician via the patient; and third, due to the progressive paralysis, patients have difficulty in verbally expressing themselves. Hence, decision-making is often based on an insufficient data set, often consisting of data from second-hand sources. Approximately 90% of consultation time is used to retrieve information. At the end of the consultation, patients are given instructions and information intended for the home care nurses and other allied health professionals involved in the patient's care. This transfer of information via the patient may be forgotten.

For ease of visualization of the initial treatment process and the facilitation of the more detailed analysis, we used the method of service blueprinting. Figure 3 shows the service blueprint of the treatment process of a patient in the clinic at the time of data capture.

The blueprint can generally be used to: identify bottlenecks or shortcomings of the initial process, highlight a critical path, and define input–output ratios or other efficiency measurement options, e.g., identifying where to potentially substitute persons by technology or move activities above or beneath certain lines (for details see Fließ and Kleinaltenkamp (2004)).

The analysis of the process depicted in Fig. 3 reveals that multiple activities reside on the line of interaction, i.e., the majority of value creating activities take place during consultation hours. Further, patient actions are mostly of a passive nature (e.g., waiting). This is a risk factor for service provision, as it does not add to creating value, and presumably also has a negative impact on patient satisfaction. It is noticeable that there are only few back office activities. Beneath the line of implementation, there are no supporting processes except for a partly digitalized health record archive. Additionally, there is no systematic or automated reconciliation of the nutritional condition of

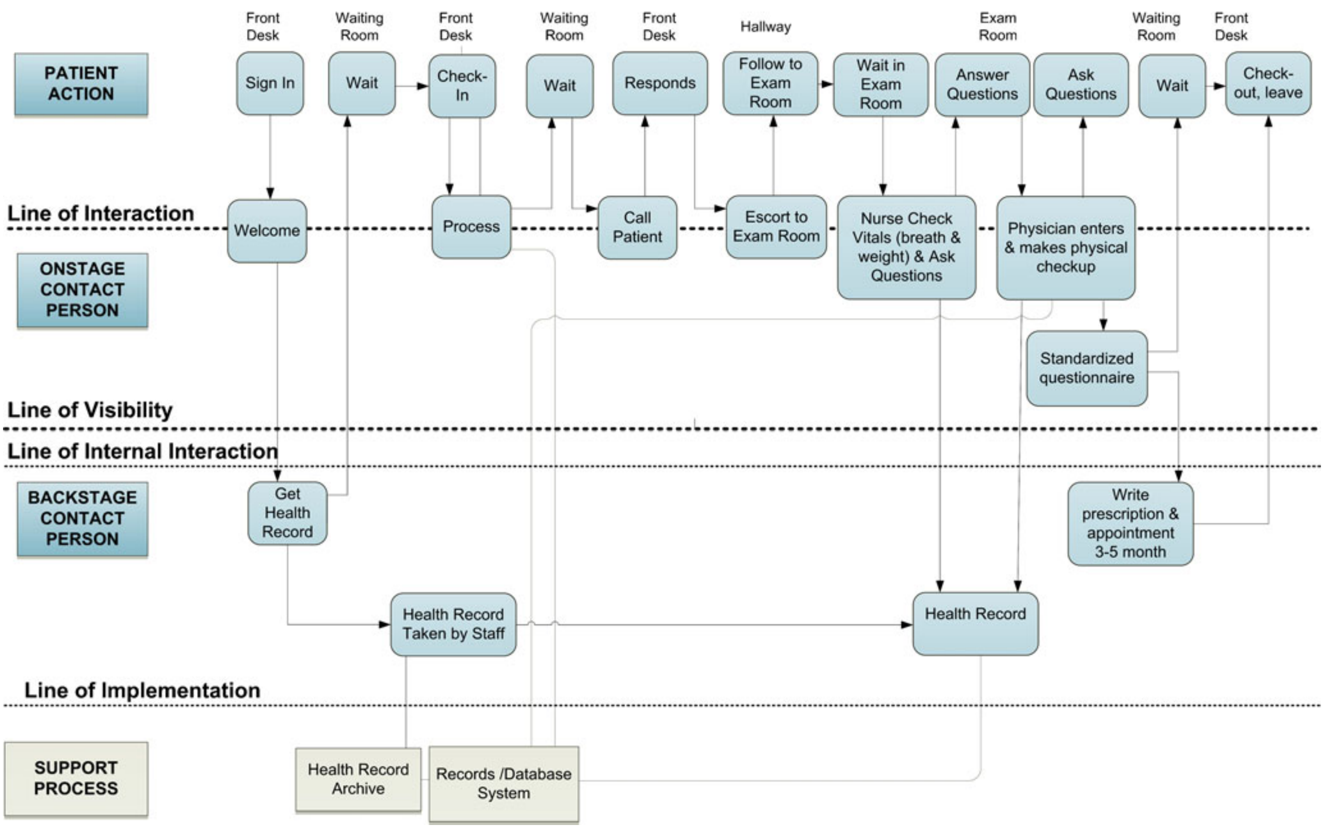

Fig. 3 Service blueprint of initial treatment process

patients. This is solely within the responsibility of the physician.

The analysis of the treatment process further reveals that no structures exist for regular collection and transmission of data on the patient's nutritional status from the home setting to the physicians. Thus, it is possible that changes in eating habits and weight could remain unnoticed during the time between assessment visits. The blueprint also clearly depicts the demand and need to improve information logistics. All data generation takes place at the line of interaction. This line presents face-to-face contacts, which are usually the most expensive encounter.

Service design and participatory development

The findings of our observations and the hints from analyzing the service blueprint formed the basis for developing the solution idea for a nutrition tracking system. In this specific case we had several challenges. To unload the line of interaction, i.e., reducing unnecessary customer contact points, decisions had to be made whether to move activities to the back office, that is, making them a candidate for automation, or to move them to the customer, allowing for active customer integration. To overcome the information logistic deficit, new process steps needed to be added, as continuous tracking and surveillance of the nutritional status did not exist thus far. Further, support processes had to be integrated into the new system. Another particularity was the progressive paralysis of patients. Due to impaired fine motor skills, it was difficult for these patients to use commonly available user interfaces.

Based on these points, we developed initial service design ideas for the intended solution. After brief discussions with two physicians, the main components of the solution were specified. In order to improve the information situation, an EDC solution at the patient's home was favored. The integration of sensors and actuators was dismissed in favor of a solution that would allow self-reporting of patients, which would be more suitable for tracking nutrition data. Additionally, in view of accounting for the patients' physical state, the NFC-based solution was preferred.

This resulted in a paper-based prototype and a service scenario which served as a starting point for the participatory development process. This paper-based prototype was first evaluated in a focus group. Focus groups are a form of group interview facilitated by a moderator, and particularly suited to obtaining different perspectives on the same topic (Gibbs 1997). In order to obtain a comprehensive spectrum of opinions, we included participants of all stakeholders into the focus group. The objective of the focus group was to discuss and evaluate the system from the patients' point of view. It consisted of six patients, six affiliates and three experts (one physician and two caregivers). For requirements elicitation and identification, we used the thinking aloud method (Nielsen 1993). Stimulated by a slide that briefly introduced the NFC-based nutrition tracking system, the group discussed the concept. Despite a generally positive reaction, concerns arouse regarding usability and data security. These issues were further discussed and negotiated, resulting in a list of requirements depicted in Table 1. This represents a common requirements elicitation approach (Kotonya and Sommerville 1998).

The focus group was followed by workshop #1 consisting of four physicians specialized in treatment of motor neuron disease. The scope of this workshop was to elevate the needs and requirements from the point of view of the clinic and the physicians. The main acceptance criteria of physicians were composed of functionalities of the backend of the solution. These included access to data and visualization of data progression to anticipate troubles. Skepticism was noticed towards data quality and efforts in monitoring several patients. A possible solution to this issue was identified by implementing automated warnings.

We next evaluated the NuTrack system through a hands-on experience in workshop #2 by using a low-fidelity prototype. The prototype essentially consisted of a Nokia 6212 classic NFC and a smart poster. The poster had images printed in front and had NFC tags glued to the back. Backend functionalities were neglected within this workshop. Four physicians, one patient and one affiliate evaluated the low-fidelity prototype. During the workshop it became obvious that success and practicability of NuTrack depended on the usability of the data capturing process. Contrary to our expectations, the NFC solution was not totally intuitive. The users needed guidance on how to touch the posters, and they also complained about the readability of the poster as well as display and voice quality of the mobile phones. However, we observed that they learned quickly and got along well once they were taught. We suspect that some of the problems were due to the NFC-enabled phones. The Nokia 6212 classic NFC is a pre-series prototype with a very small display.

During workshop #3, four physicians, three patients and three affiliates tested the refined prototype again. Only the need to be able to contact the clinic was found to be an additional requirement. Our approach is typical for participatory design in two ways: first, according to Nielsen (1994), reliable results can be obtained even with four to six persons for each iteration, and second, a "good" design is reached once there are only minor or even no further changes in requirements during an iteration.

All participating physicians and caregivers specialized in motor neuron diseases. The patients ranged in age from 29 to 70. Overall, younger patients were more attracted by the system than older ones, which was due to a higher familiarity with mobile phone usage. Table 1 shows the specific requirements for each encounter. The results had

Table 1 Identified requirements in the 4 generation/test cycles

Focus Group 6 patients, 6 affiliates, 3 experts	Workshop #1 4 physicians	Workshop #2 4 physicians, 1 patient and 1 affiliate	Workshop #3 4 physicians, 3 patients and 3 affiliates
• The system should provide an easy, intuitive and user-friendly interface for the documentation of the daily food intake.	• The system should help the physician to anticipate early trends for detecting a loss in weight or critical change in state of health.	• The font size has to be large enough to ensure readability of the smart poster.	• The system should provide easy means to directly contact the clinic, e.g., via a contact button on the poster.
• The system should send an automatic reminder to the patient if no data has been entered.	• The system should allow observation of eating habits of patients independent of time and place.	• The different tags on the smart poster (e.g., for rating or sending) have to be clearly labelled and identifiable.	
• The system should send warnings to the patient in case of insufficient food intake.	• The system should send automatic warnings to the physician or appropriate staff in case of repeated absence of data entry or insufficient daily intake by patients.	• The acoustic feedback (computer voice) needs to be audible, clearly comprehensible and not annoying.	
• The user interface must also be usable in case of progressive paralysis.	• The system should provide means for evaluation of total food intake and the possibility of a long-term analysis of the patient.	• The solution should provide instructions and guidance on how to touch the tags with the mobile phone.	
• The patient should have access to data and be able to analyze them.			
• The system should allow patients to grant third persons' access to collected data.			

consequences for both system design as well as for the service process. The refined target process for NuTrack is depicted as a service blueprint (Fig. 4). In contrast to the initial process, the system design provides more patient integration enabled through the use of information and communication technologies. The blueprint shows optimized patient contact points and a more involved integration of patients into the service provisioning process. The line of interaction, representing face-to-face encounters, could be made "free" to give room for other valuable services such as consultations.

NuTrack prototype

The NuTrack prototype and its usage are described in Fig. 5. As an easy-to-use input method for data capture for patients with impaired fine motor skills we chose the NFC technology in combination with a mobile phone. The prototype on the patients' side consists of a poster and a Nokia 6212 classic NFC. The poster has embedded NFC tags and displays nutritional images. By touching the images, the patient can record his nutritional intake. The client software on the mobile phone stores the information and transmits it to a webserver, which contains a relational database that stores all data and can be accessed by patients, relatives, care-personnel and physicians through a web interface. The transmitted and aggregated nutritional data are processed and analyzed by rules stored in the systems. Physicians and nutritionists can analyze the data and define the rules for each patient. If these thresholds are exceeded, predefined stages of an alert system are triggered:

- Stage 1: The system finds small shortfalls of the intake of calories and alerts the patient via SMS, e-mail or an automatic call.
- Stage 2: After several days of insufficient food intake, the appropriate nurses, physicians or other caretakers will be automatically notified by the system via SMS, e-mail or an automatic call.

Multimedia files for the user interface, such as photos of the food and sound data, are stored on the mobile phone. Thus, only small amounts of data between the mobile device and the server need to be transferred. This choice of a client application, rather than purely server-sided architecture, is based on the fact that, especially in rural areas, mobile communication networks are insufficiently developed for broadband connection in order to exchange data intensive multimedia files between the sever and mobile devices (BMWi 2009).

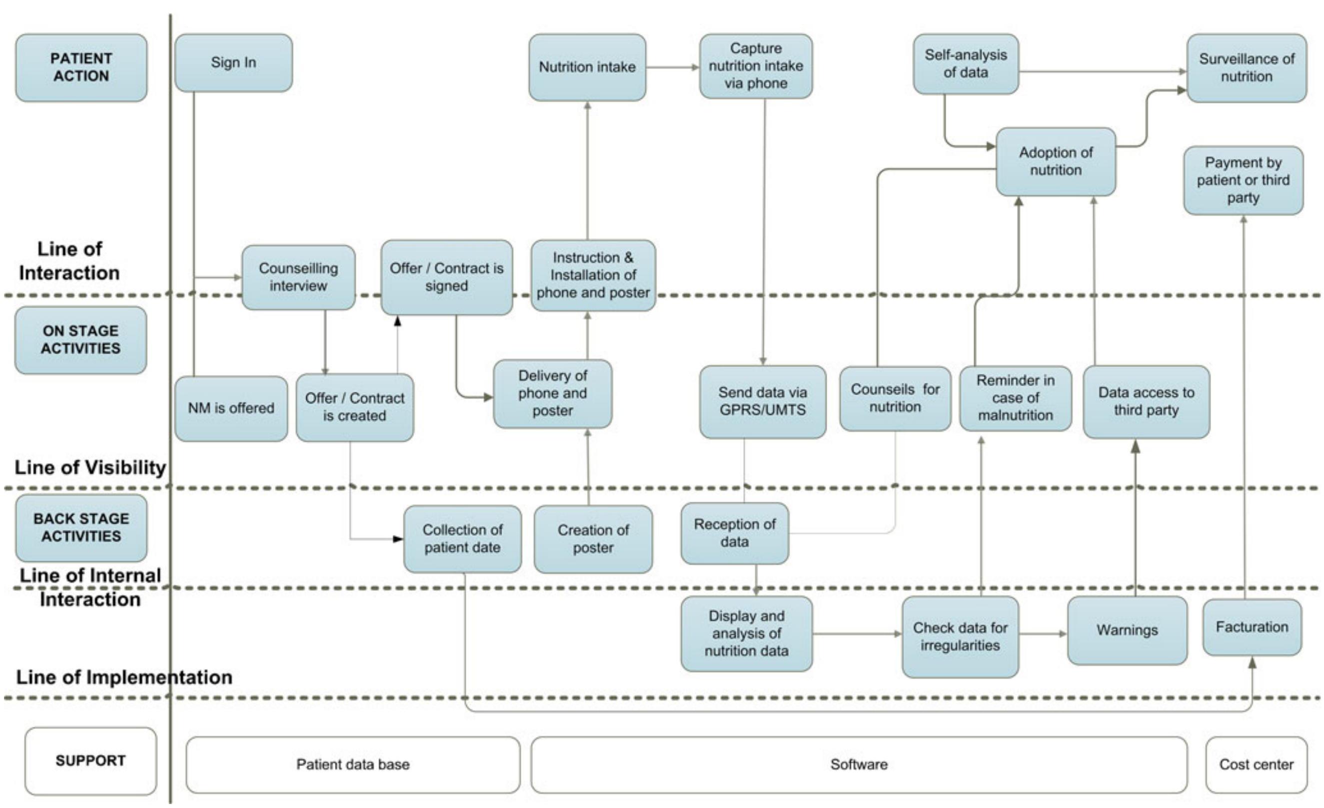

Fig. 4 Service Blueprint of process with NuTrack

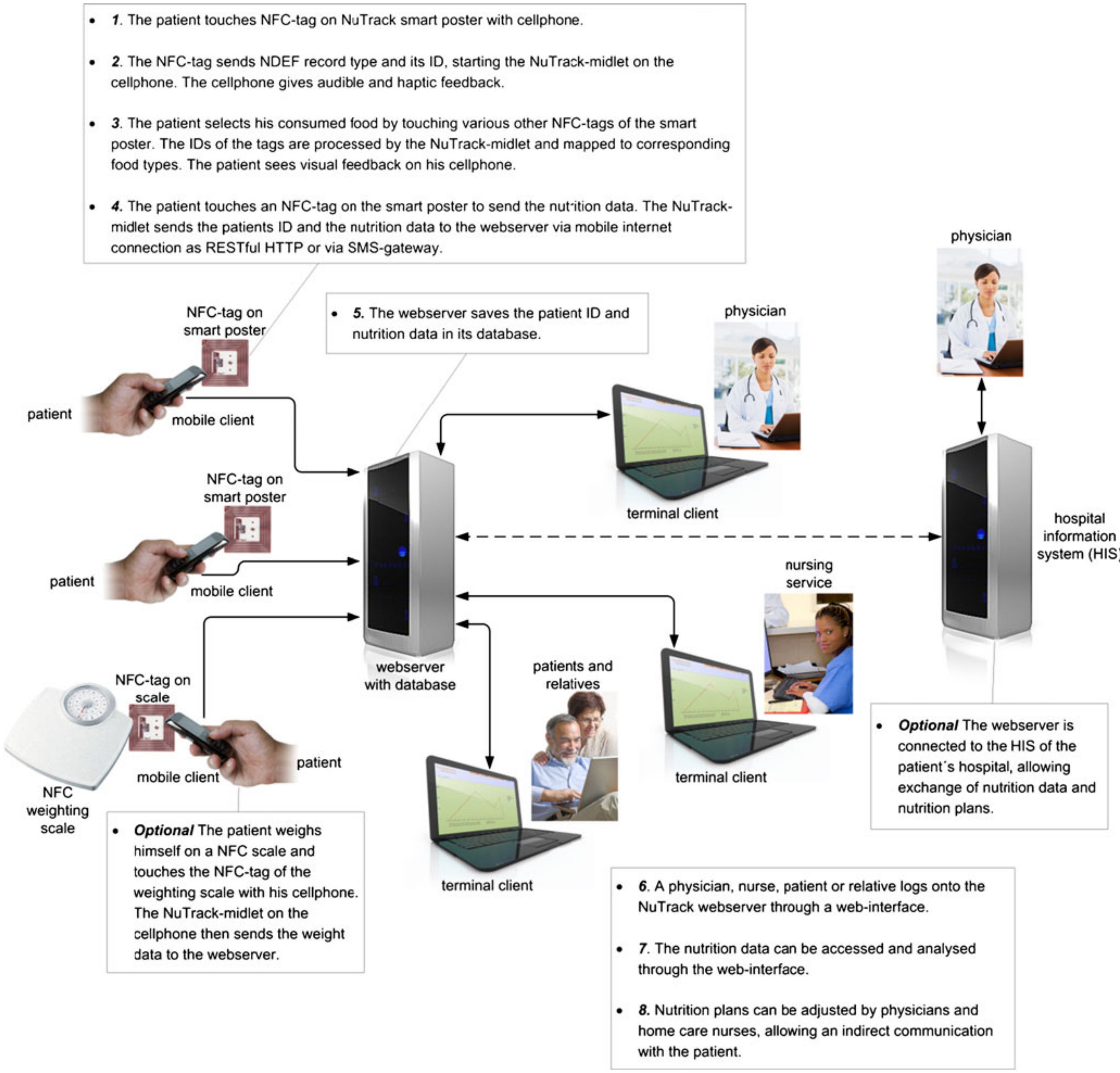

Fig. 5 Illustration of NuTrack

Conclusions and future research

Findings and implications

The first contribution of this paper is the development of a novel approach for the design and development of AAL services called AALSDA. This approach integrates and extends different methods from service engineering and participatory design. We adopt and extend the approach by Resatsch et al. (2008). In order to be able to address the specific challenges arising in AAL service design in the healthcare domain, we integrate the method of service blueprinting. AALSDA was successfully carried out for the specific case of nutrition management for patients with impaired motor control. The approach is illustrated in detail within this paper, serving as proof-of -concept and showing its applicability and feasibility. Another benefit of our approach is that it provides new insights into AAL service design.

We can confirm that involving all stakeholders early on in the service design process via participatory design is a necessity. This participatory design helps to define the requirements for the solution, and determines user-acceptance early on. Considering these in early development stages will lead to different and better solutions and also reduce the danger of project failures. For AAL service development, this is of utmost importance, as there are no prior experiences on how users interact with the different forms of AAL technologies. Few EDC prototypes have been tested in clinical environments or laboratory settings, and integration of patients in early design phases can hardly be found. Hence, the involvement of end-users in the development of NuTrack differentiates our approach from related work and makes it more likely that NuTrack will be accepted in the real-world. It did, however, become clear that involving other users than real patients in our study could have led to biased positive results.

By integrating the service blueprint into our design process, we ensure that NuTrack was supported by a reasonable treatment process in which all stakeholders were integrated. We can confirm from the discussions in our workshops that the integration into treatment processes is a critical success factor for AAL services. The blueprints were part of the iterative development process. They served as a method of communicating the solution to the different stakeholders, as well as for analysis of existing processes. Aspects for improvements are, amongst others, process steps that sit on the line of interaction, as they are candidates for patient integration and hence are a means of realizing cost savings.

Overall, we show that our approach is reasonable and depicts the potentials and possibilities that such an approach can offer to the design and development of AAL services. We believe these services will have a great impact on health care processes and services in the future.

The NuTrack prototype is the second contribution of the underlying paper. The status of NuTrack is of a fully functional proof-of-concept prototype and it is currently being used in a long-term field study in a German hospital. First evaluations show that the prototype has great potential to improve the information logistics problem between physicians, home care nurses, and patients with impairment of fine motor skills. Through the active participation and integration of patients, better documentation and an improved basis for medical treatment and nursing care are achieved. Further, through an intensified integration, patients will be enabled to better understand their medical condition and to participate more actively in the treatment and consultation processes. First observations of the field study confirm these results. If successfully realized, customer (in our case patient) integration could lead to an enhanced patient-physician relationship enabled by improved patient information and autonomy. We also surmise that NuTrack could improve productivity of medical processes not only by accounting for improved standards of medical care and quality of life, but also by being more cost efficient. Despite participants overall showing acceptance and excitement for our solution, one of the core results of the currently ongoing field tests is the challenge of bringing AAL services to continuous active usage.

The NuTrack prototype also reveals some design principles for NFC-based EDC in general. These include the importance of feedback (audible, visible and haptic), a comprehensible and coherent poster structure and measurements to ensure data security. Noted was the appreciation for the automated reminders and warnings. Responses of patients in our study included that this gave them the feeling of being cared for. We assume that the prototype system could be applied to other contexts or groups of patients in health care, such as elderly people who face similar difficulties in handling electronic devices. Further, with little modifications, NuTrack could be applied to capture other data, for example, data related to the emotional situation of a patient or the self-assessment of disease progression.

Limitations and future research

This study has several limitations. First, the early stages of the evaluations took place in a laboratory setting. Testing and evaluating the prototype in real-life-settings (e.g., patients' homes) could result in different requirements, although currently running field tests seem to support our research findings. Also, issues such as the willingness to install the poster within the apartment were not addressed. Further, we had only one prototype during the workshops. This implies that some participants started discussing the prototype while others had not yet tried it out. It is possible that they were influenced by observing other participants, which could have biased the results. Always having at least one physician in the focus groups might have resulted in patients being intimidated. Additionally, our results were verified only in focus groups, workshops and a field test. Large scale studies comprising long-term quantitative surveys and investigations, going beyond a single field test, should be performed in order to substantiate our findings.

Our next steps comprise continuing to evaluate NuTrack in more and different real life settings. Through the continued piloting of the prototype system, we hope to gain insights into the effects of frequent system use, e.g., user acceptance of technology and services by patients, family members, home care personnel, physicians and funding agencies. We also aim at assessing potential outcomes of service and technology usage such as possible increase in efficiency of treatment and medical consulting processes. Further studies need to measure the actual benefits of our prototype to patients, physicians and nurses. Questions and concerns regarding data security, privacy and trust in service provider and service quality need to be addressed as well. Additionally, future clinical studies are necessary to evaluate the effects of an improved nutritional status on underlying diseases and the progression of impaired motor skills, and therefore the medical utility of NuTrack.

Future research needs to extend, substantiate and further detail our AAL design approach. One challenge lies in its application to other AAL related health care services. Also, other methods from service engineering, as well as participatory design, need to be tested on their suitability for AAL service development, and the interplay between the methods needs to be formalized. Further research approaches could focus on how, and to what extent, EDC applications could be integrated into existing information systems (e.g., hospital information systems) and could consider technological and legal developments in telemedicine and health care. E.g., the recent integration of sensors (e.g., motion sensor) and additional technical devices (e.g., global positioning system (GPS)) in new generations of mobile phones enables the utilization of other captured data for novel AAL applications. Overall, our results confirm the relevance and impact that participatory design and service engineering can offer for the design and development of economically reasonable and socially accepted AAL services.

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