Smart Home, The Next Generation: Closing the Gap between Users and Technology

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Abstract

In this paper we discuss the gap that exists between the caregivers of older adults attempting to age-in-place and sophisticated "smart-home" systems that can sense the environment and provide assistance when needed. We argue that smart-home systems need to be customizable by end-users, and we present a general-purpose model for cognitive assistive technology that can be adapted to suit many different tasks, users and environments. Although we can provide mechanisms for engineers and designers to build and adapt smart-home systems based on this general-purpose model, these mechanisms are not easily understood by or sufficiently user-friendly for actual end users such as older adults and their caregivers. Our goal is therefore to study how to bridge the gap between the end-users and this technology. In this paper, we discuss our work on this problem from both sides: developing technology that is customizable and general-purpose, and studying user's abilities and needs when it comes to building smart-home systems to help with activities of daily living. We show how a large gap still exists, and propose ideas for how to bridge the gap.

Introduction

Due to a globally aging population, disability resulting from chronic disease is on the rise and putting tremendous social and economic pressures on our health care and social systems. In particular, the prevalence of dementia is expected to double globally by 2030 and triple by 2050. (Wimo and Prince 2010). Despite the gradual decline of cognitive abilities, older adults with dementia want to continue living independently in the community for as long as possible. As such, 'informal' care provided by family members or friends continues to be the most common, despite its unique demands and burden, which have been shown to have negative impact on the caregivers' health (Schulz and Martire 2004). Moreover, an increasing shortage or unavailability of informal caregivers due to smaller average family sizes, more common geographic separation between family members, and competing financial and economic pressures (Brodaty and Donkin 2009) further exacerbate the overall societal impacts and costs of aging and dementia.

To enable older adults to age in place and alleviate caregiver burden, smart home researchers aim to build systems that can sense, learn, and appropriately respond to the home environment and its occupants. These systems use a variety of sensors (e.g. radio-frequency identification tags, infrared motion, switches), and feed the information from these sensors through a set of classification and control mechanisms to effectors (e.g. audiovisual prompts, temperature controls, switch controls) that cause positive changes to the environment, e.g. (Hoey et al. 2010; Rantz et al. 2012; Olivier et al. 2009; Rashidi and Cook 2009; Intille 2006; Mozer 2005; Abowd et al. 2002). These intelligent pervasive computing technologies may allow older adults to take an active role in managing their own well-being, and thus hold potential to improve quality of life. For example, a person who often forgets to turn off the stove can install a set of controls in her home that will sense when she leaves the house with the stove on, and issue her a reminder to go back and turn it off. Another person who has lost the ability to cook her own meals can make use of an assistance system that will help her through the task (Tran, Calcaterra, and Mynatt 2005; Olivier et al. 2009).

Knowledge engineering techniques we have developed will allow end-users to accomplish this by giving them a portal into the specification of advanced decision-theoretic control mechanisms that can sense what they are doing and react according to the needs and requirements of the users (Grzes et al. 2012; Hoey et al. 2011). This technology will allow end-users to build and tailor specific applications for their needs, leveraging advanced computational algorithms and artificial intelligence to provide continuing assistance. These tailored solutions will facilitate activities of daily living, and allow older adults to remain independent for longer, decreasing the need for formal and informal care in the home.

To be practical for real world deployment, however, concurrent and collaborative research must also prioritize understanding the needs of the different users (Bharucha et al. 2009), and translating these needs into designs that will appropriately situate and customize technologies for diverse home environments and care situations. Specifically, there is a need to better understand how caregivers of older adults wish to introduce this technology, as these stakeholders are most likely to assume the responsibilities of procuring, customizing, and managing information exchange with such systems in the future. As such, they are arguably in the best positions to guide designers on how to close the gap between the user interfaces that enable engineers to build and adapt smart home systems and those that would allow caregivers to easily and practically customize these systems.

We open this paper by articulating our argument for smart home customizability. We will describe two ongoing streams of research into this usable smart-home problem and how they approach the problem from different ends of the research spectrum. First, from the artificial intelligence (AI) end, we develop general-purpose sensing and prompting/assistance models that can be deployed across a wide range of different tasks (Hoey et al. 2011; Grzes et al. 2012). Second, from the user research and interaction design angle, we use qualitative and design research methods to create prototypes and use them as probes to uncover various aspects of intelligent assistance systems that may need to be tailored by end-users (Hwang, Truong, and Mihailidis 2012). Our two approaches are complementary, and our long-term goal is to bring the two ends together, bridging the gap between intelligent assistive technologies and end-user customizability for smart-home systems.

The case for customizability

In this section, we argue that the potential of smart homes will only be realized if technology can be customized to specific user's needs, and that users should have control to customize these systems independently. We articulate our position based on literature from related fields and our research involving older adults with dementia and their caregivers.

Confronting assistive technology non-use

Viewing smart home systems as a class of assistive technology (AT) supporting people with disability challenges designers to confront widely reported rates of AT non-use or "abandonment", largely due to inadequate customization to individuals and their life contexts. According to a recent systematic review of AT use, selected studies showed that non-use rates varied widely from 13.5% to 65%, where dressing, hygiene, and mobility equipment were among the most commonly discarded (Steel and Gray 2009). Contributing factors can be categorized into client-related factors (e.g., age, gender, diagnosis, ethnicity, socioeconomic status, psychological expectations); environment-related factors (e.g., physical and social context); AT-related factors (e.g., reliability, cost, ease of use, aesthetics); clinical assessment-related factors; and training-related factors (i.e., how well the client was trained to use the AT) (Steel and Gray 2009). Furthermore, (Schere, Hart, and Kirsch 2005) reported about 90% of AT compensating for cognitive disabilities is abandoned after brief usage owing to psychosocial factors (e.g., lack of caregiver support).

Temporality adds another important layer of complexity to address in smart home customization. Changing medical conditions have also been known to contribute strongly to AT non-use (Verza et al. 2006), especially for degenerative conditions and declining functional abilities. Moreover, questions of when to introduce assistive technologies, and how long people can reasonably continue to use them, remain largely unaddressed (Siek and Meyer 2012).

Social factors related to self-image and social stigma also account for personal choices to abandon or not use assistive technologies that have been prescribed to people with disabilities. For example, individuals may feel that the aesthetics of the AT label them disabled, dependent, and incapable members of society. A recent study specifically examining the influence of social interactions on AT use found that individuals negotiate between feelings of self-consciousness and the need to be productive and independent. Participants tended to gravitate towards mainstream technologies (e.g., smartphones, tablet computers) because they felt they would be perceived "just like everyone else".

We view the aforementioned personal, temporal, environmental, and social factors as parameters for customizability. Within the design process, smart home designers must be able to fully understand and address such "contextual factors", as they have been defined by the International Classification for Functioning, Disability, and Health (ICF) (WHO 2012), which can describe a person's health and disability. Moreover, with a deeper, more empathetic understanding of these factors and the interactions between them, designers can start to infer which parameters should be left to end users to control and customize.

Designing the appropriate degree of user control

Related to customizability, literature from smart home user research and context-aware computing calls for a deeper understanding of how much control users desire in smart home environments. That is, what system aspects do users want to control or customize, and what aspects are they willing to entrust to system intelligence?

Related user research argues that smart homes should help users maintain a sense of control, and suggests that advancing capabilities of intelligent systems could potentially "overstep an invisible boundary" whereby people feel they have lost control of the technology and its impact on their lives (Davidoff et al. 2006). Suggested design principles propose that people should be able to create or modify behaviours quickly, as plans and routines evolve organically and may change or break down. Moreover, multiple people may need to share ownership or control of certain activities (e.g., different family members may assist with cooking). People should also maintain the ability to control and customize smart home systems to complement and not threaten their valued life roles and social identities (e.g., an older adult's daughter may choose not to have the smart home assist with cooking as she enjoys it and doing so makes her feel like a good daughter).

Customizing for older adults and caregivers

Several domain issues specific to supporting aging in place for older adults with disability further stress the need for smart home customizability. Gitlin et al. (Gitlin, Levine, and Geiger 1993) reported that family members provide 90% of the care received by older adults living in their homes, suggesting that caregivers directly affect rehabilitation outcomes, which we interpret to include assistive technology use. We take this view one step further and argue that these informal caregivers play more than social contextual roles when designing technologies for older adults with disability; rather, caregivers will arguably be the primary stakeholders to procure, set up, customize, and manage smart homes supporting older adults and, as such, should be considered a primary user group of the user interfaces that deliver smart home customizability. This view has also recently emerged from user studies of existing smart homes (Mennicken and Huang 2012). We now describe themes from our participatory design study involving six dementia caregivers (henceforth referred to as "caregiver participants") that may serve to motivate design considerations for smart home customizability (Hwang, Truong, and Mihailidis 2012).

One key issue that has yet to be thoroughly examined in the smart home literature is how to appropriately situate smart home systems that support care alongside human caregivers, most often family members. Despite significant caregiver burden, caregiver participants report taking pride in these life roles and do not believe, or want to feel, that technology can replace them. In particular, we found that caregiver participants were uncomfortable with technology providing support for any activities with safety risks associated, such as taking medications, but views on which activities of daily living were considered safe varied between caregivers. As different caregivers will undoubtedly have different preferences on how and where to situate smart home systems in their care routines, the ability to customize will be crucial to caregiver adoption and ultimate acceptance of these systems.

There is also a need for systems to be flexible to ongoing changes, both in the behaviours of the older adults they support and to the activities or routines in the home. We reported caregiver participants' concerns related to how systems would understand and respond to the characteristic fluctuations in ability, mood, and behaviours of the older adult with dementia, as well as the decline in their functional abilities over time. More relevant to their own interaction with the system, they would need to be able to make changes to the system quickly and easily. For example, if their loved one was having a "bad day", caregiver participants wanted to be able to put the system into a standby, or override the system and help directly.

The Gap

This section outlines our work on the problem of building customizable smart homes, first from the technical perspective, then from the human perspective.

Smart Homes

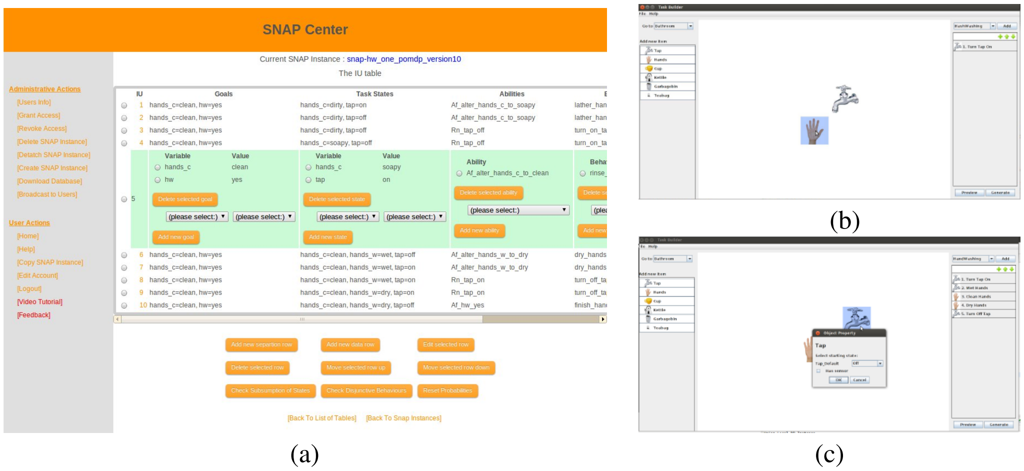
The technical challenge of developing useful interventions (e.g. prompts) and a sensing and modelling system that allows them to be delivered only at the appropriate time is difficult, due to issues such as the system needing to be able to determine the type of intervention and to recognize changes in the abilities of the person and adapt the intervention accordingly. Advanced planning and decision making approaches, such as in the COACH (Hoey et al. 2010), can make this possible. COACH uses computer vision to monitor the progress of a person with dementia washing their hands and prompts only when necessary. COACH uses a partially observable Markov decision process (POMDP), a temporal probabilistic model that represents a decision making process based on environmental observations. The POMDP framework is flexible and general in that it can be applied to different tasks, environments and users (Hoey et al. 2012). However, each new application requires substantial re-engineering and re-design to produce a working assistance system, which currently requires massive expert knowledge for generalization and broader applicability to different tasks. Engineering such systems for every possible task, home and user, is not feasible. A more scalable approach is to allow for more automation to substantially reduce the manual efforts necessary for creating assistance systems that are tailored to specific situations and tasks, and environments. In general, the use of *a-priori* knowledge in the design of assistance systems is a key unsolved research question. Researchers have looked at specifying and using ontologies (Chen et al. 2008), the Internet (Pentney, Philipose, and Bilmes 2008), Cognitive Rehabilitation Theory (Seelye et al. 2012), logical knowledge bases (Mastrogiovanni, Sgorbissa, and Zaccaria 2008), and programming interfaces for context aware human-computer interaction (Salber, Dey, and Abowd 1999).

We have developed a knowledge driven method for automatically generating POMDP activity recognition and context sensitive prompting systems (Hoey et al. 2011). The approach starts with a description of a task and the environment in which it is to be carried out that is relatively easy to generate. Interaction Unit (IU) analysis (Ryu and Monk 2009), a psychologically motivated method for transcoding interactions relevant for fulfilling a certain task, is used for obtaining a machine interpretable task description. This is then combined with a specification of the available sensors and effectors to build a working model that is capable of analysing ongoing activities and issuing prompts. We call the resulting model a SyNdetic Assistance Process or SNAP.

A SNAP is a probabilistic relational model (PRM) (Getoor and Taskar 2007) defined as a relational database that encodes a domain independent relational dynamic model and serves to mediate the translation between the IU analysis and the POMDP specification. The PRM encodes the constraints required by the POMDP in such a way that, once specified, the database can be used to generate a POMDP specification automatically that is valid according to the SNAP model. The PRM serves as a schema that can be instantiated for a particular task using a simple and intuitive specification method. The probabilistic dependencies in the PRM are boiled down to a small set of parameters that additionally need to be specified to produce a working POMDP-based assistance system.

We have demonstrated the application of the method to specify a POMDP in three examples: two are for building systems to assist persons with dementia during activities of daily living, and one is to assist persons with Down's syndrome during a factory task. We have shown how the method does not require prior knowledge of POMDPs, and how it makes specification of relatively complex tasks a matter of a few hours of work for a single coder (Grzes et al. 2012).

Although the SNAP methodology allows for the specification of a POMDP assistance system given an IU analysis, these two pieces still need to be specified manually, and



(a) (b) (c)

Figure 1: (a) Current SNAP interface showing editing of a single row of an IU table; and initial prototype of graphical version, showing user clicking on graphical representations to input knowledge fluents (b) and setting properties of fluents (c).

this process is currently only approachable by following the method in (Hoey et al. 2011). This method involves manually coding videos of persons attempting particular tasks, followed by a synthesising analysis and database entry. Currently, our interface for this process, shown in Figure 1(a), is a strictly functional view of the database itself, with limited user interface shortcuts and design[1]. The real advantage of this method will arise if we can evolve it to enable end-users, such as caregivers, to easily specify activities at a high level and appropriately situate the system to support and complement their caregiving efforts. Our initial efforts in this direction are shown in Figure 1(b,c), and our longer term vision is described later in the paper. First, we give an overview of our work on establishing user needs for this kind of system.

User needs and requirements

To approach the design of user experiences for caregivers in smart home environments (e.g., COACH), we are exploring a set of key research questions:

- Which system parameters do caregivers want to be able to control or customize? Which parameters should be "pre-programmed" or automated by the system?
- What information do caregivers want to receive from smart home systems that support their older adult care recipients?
- What interaction modalities do caregivers prefer for their interaction with smart home systems?
- What are the major design considerations that may predict acceptance of smart home systems by older adults with dementia and their caregivers?

In the following, we describe our findings to date that address each of these questions (Hwang, Truong, and Mihailidis 2012). We make an implicit assumption that caregivers of older adults are well positioned to set up, customize, and manage smart home systems, and that caregivers are ready to assume these responsibilities with the hope that these systems can improve their caregiving situations. This assumption is borne out by previous studies (Hwang, Truong, and Mihailidis 2012; Rialle et al. 2008; Rosenberg, Kottorp, and Nygård 2011; Czarnuch and Mihailidis 2011; Mennicken and Huang 2012). In fact, empowering users by providing easy-to-use tools that will enable them to create their own solutions may both motivate their involvement in research and development, and ultimately facilitate the technology adoption process (Hurst and Tobias 2011).

Desired parameters for customizability Caregiver participants felt that the COACH system would only be useful to them if they were able to customize for their unique needs, abilities and situations. In presenting participants with two iterations of a user interface prototype, the parameters they wanted within their control included the locations of COACH sensors (e.g., cameras, displays, speakers) in the home; turning assistance from COACH on and off; activity selection where they could choose from a set of "pre-programmed" activities with which COACH could assist; new custom activity creation where they could seek COACH assistance with any desired activities specific to the routines of their loved ones; prompt type, timing, personalization, and situational triggers; device and modality preferences for system control and alerts; activity and event reminder schedule management; and system initiation and standby control.

Desired information from the system Caregiver participants desired ongoing information on the status of COACH's assistance through a "constant link" that enabled them to monitor remotely, communicate with their loved ones when away from the home, and make adjustments to the system accordingly. Moreover, caregiver participants wanted to receive alerts for emergency situations, or if the system could no longer assist in the activity and their assistance was needed. Lastly, caregiver participants felt that receiving reports that displayed their loved ones' activities and performance with the COACH system would be valuable on

[1] Try the interface, or watch a video demonstration at www.cs.uwaterloo.ca/∼jhoey/research/snap/

an ad hoc, or "on demand" basis. They felt that this information could be useful in tracking their loved ones' functional abilities and alert them of declining trends, suggesting visits to health care professionals.

Preferred interaction modalities Interaction modality preferences varied widely in our study, suggesting caregivers may want to choose based on their level of experience, ease of use, and familiarity with modality types. Interestingly, our participants were generally open to the idea of interacting with COACH using a tablet device (e.g., iPad) within the home to customize and manage the system, due to its small and portable form factor, but some preferred not to bring it outside the home. Our mobile phone users liked the idea of being alerted by text message (SMS). Participants with little or no experience with computers wondered if they could use their home telephones, televisions, or simple touch-screen, wall-mounted displays. This suggests that user interfaces should be designed to work across a variety of form factors among which caregivers can select.

Key design considerations Appropriately situating smart home systems in existing home and care situations must not infringe on caregivers' valued life roles, which may provide them feelings of filial piety or enjoyment. Empowering care recipients with more autonomy in their day to day lives, however, may be in their best interests, yet at odds with caregivers' concerns related to their safety and well-being. Although caregiver participants wanted customizability, they also expressed concerns about adding to or shifting their burden from providing care to managing a complex system. The ongoing changes and unpredictability of functional abilities, moods, and routines in the home seem to burgeon system management demands. One final yet critical consideration is the validity of caregivers' self-reported needs, given these individuals have likely never experienced, or even conceptualized, the capabilities of a smart home. Smart home designers are, thus, further challenged to employ creative research methods that both introduce smart home concepts and prototypes while inquiring about, inferring, or intuiting user needs in future, real-life contexts. Together, these design considerations highlight the sizeable gap between the current state of smart home systems and future user experiences that would make them practical and accessible.

Closing the gap

We conclude with a vision of how to close the gap between technology and users, a vision we dub *D.I.Y. Smart Home*. *D.I.Y. Smart Home* connects users with developers by building a person-specific logical knowledge base of user needs, assistance dynamics, sensors, actuators and care solutions. The knowledge base will connect users with medical professionals, family members and friends, product developers and sellers, and research scientists. This connection will be structured and dynamically evolving, effectively bridging the gap between the various stakeholders. The knowledge base will also serve as a run-time processor for the provision of assistance in specific tasks: it will act as the equivalent of a 'smart home', but will be a dynamically evolving variant, customisable in real-time by end users and product developers. Thus, in *D.I.Y. Smart Home*, the smart-home emerges from the specific requirements of a user in a do-it-yourself approach that gives control to the user, while allowing them to access technological solutions. Technological interventions are integrated into the daily practice of healthy older adults, and they can build up familiarity and engagement with associated systems, enabling greater sustainability, with less disruption in later life. Thus, *D.I.Y. Smart Home* aims to provide assistance over long periods to support older adults as functional ability and health status declines.

In *D.I.Y. Smart Home*, users provide information to the knowledge base about their needs and requirements as they arise. Our intended users will be both older adults exhibiting early signs of cognitive impairment, and their family members or caregivers providing increasing support as a consequence. Our system will have a simple and intuitive interface, allowing them to quickly and easily describe a problem they are having (e.g. difficulty remembering to turn off the stove before leaving the kitchen) using the methods of IU analysis as in (Hoey et al. 2011). Their description will then be encoded as a set of fluents in the knowledge base. The knowledge base also links to technology developers and researchers by providing an interface for products in terms of their abilities and requirements in assistance tasks. Technologists provide information about their products and services by implementing this interface. This information is then also encoded in the knowledge base, and linked to the user's needs and requirements. The knowledge base therefore serves as an intelligent bridge between the users and technology developers, requiring each to only fill a particular interface describing their needs or abilities. A unique smart-home emerges for particular user through the slow process of the user's needs changing and being addressed by the knowledge base and technology developers.

The proposed system will first be used by persons who are just entering the difficult transition into dementia, and their family members and caregivers. At this stage, a person may have some mild memory deficits, and concerned caregivers may be developing coping and support strategies while their loved one is still partially independent. This time period may arguably offer a unique opportunity to involve people in building their own smart home through the use of the intelligent knowledge base, as we have learned caregivers cannot afford the additional burden of "systems administration" when they are so heavily depended upon in later disease stages. This do-it-yourself approach is key to enabling smart-homes: instead of technologists building the homes and testing them once complete, we are allowing users themselves to slowly design and build their own smart homes, addressing problems as they arise during early disease onset. The knowledge base as a marketplace will bring the pressures of the free market to bear on the problem, forcing working solutions to be developed on an as-needed basis.

Further extensions include the provision of information about dementia and assistive technology, online discussions and social networking. Collaborative filtering and user-based reviewing of products and services can allow users to better evaluate suggestions.

Encoding of Knowledge *D.I.Y. Smart Home* will encode the dynamics of assistance, user needs, sensor/technology capabilities in a logical knowledge base formulated as a probabilistic relational model (PRM) (Getoor and Taskar 2007; Grzes et al. 2012). The PRM includes the goals, action preconditions, environment states, cognitive model, client and system actions (i.e., the outcome of the SNAP analysis), as well as relevant sensor models. A ground instance of the PRM is a POMDP, which we extract from a database using an automated procedure. A hierarchical approach can be used to connect the individual task-oriented POMDPs together into a single controller (Hoey and Grzes 2011). We demonstrated the method by eliciting three assistance tasks from non-experts: handwashing, and toothbrushing for elderly persons with dementia, and a factory assembly task for persons with a cognitive disability. We validated the resulting POMDP models using case-based simulations, showed to show that they are reasonable for the domains. We also showed a complete case study of a designer specifying one database, including an evaluation in a real-life experiment with a human actor (Grzes et al. 2012).

User Interface *D.I.Y. Smart Home* will present a usable interface to end users (i.e., older adults dealing with memory issues and their concerned caregivers) allowing them to easily query the knowledge base with issues of relevance to their health needs, receiving information about products and services available to help with specific problems. The interface will also allow users to query medical information, engage in social networking, profit from collaborative filtering of assistive technologies and reviewing of products and services by others. Our initial prototype for this interface is a simple 2D graphical representation of objects in a home that are used in ADL, as shown in Figure 1(b,c). The interface provides easy-to-use and intuitive methods for specifying the elements of the SNAP knowledge base (Figure 1(a)). Users specify tasks by dragging and dropping pictorial representations of objects, and specify user behaviours and abilities by clicking on these icons. For example, to specify the single step of “turning on the water”, the user adds a tap, a hand, and clicks the hand and tap and then selects the user behaviour that is required (Figure 1(b)).

Our aim is to move to a 3D version in which the user’s home is explicitly modeled, and that can be customized by changing appliances and furniture and modifying the services these “smart” artifacts can provide. We also envision a video-game like interface where caregivers can perform an interactive care narrative, essentially telling a story about their care challenges, such as activities of daily living, date and time of day, location, affected stakeholders (i.e., family members), selected actions to to resolve problem, and feelings or ideas that arose from these problems. The idea of eliciting user preferences through narratives has been shown to a be a powerful method for eliciting detailed personal information from users (Newell et al. 2006).

Developer Interface *D.I.Y. Smart Home* will present an interface to technology providers (companies, researchers) to describe products according to abilities to fulfil assistance needs. The providers will populate the set of objects a user can access (on the left in (Figure 1(b)) by implementing an interface for each such object that defined its capabilities and requirements. Providers can also provide sensors or systems that can be retro-fit to existing devices, with which they are automatically paired. The providers will also be able to receive feedback on their products and services, search for required products and services not yet provided.

Care Needs *D.I.Y. Smart Home* will provide solutions to specific care needs as specified by end users by allowing them to directly purchase required products and services, and then linking these products and services into the care needs model developed for a specific person.

Cognitive Assistance *D.I.Y. Smart Home* will, at runtime, provide assistance to a person by acquiring sensor data, querying the knowledge base, and providing appropriate assistance as specified by the POMDP controllers.

Conclusions

This paper attempts to expose some of the key problems in making smart-home technologies usable and useful to real-world users in the long term. We described our research from the technological and user research sides of this problem, outlining a significant gap. We then proposed a method for bridging this gap using an organically evolving user and developer knowledge base that is used to implement working intelligent solutions tailored to specific users. Our approach does not simply build reactive or pre-defined smart-home systems, but rather gives control of such systems to end users, allowing them to specify the ways in which their smart-home interacts with them. This ongoing collaboration aims to both empower users and better enable smart home designers and developers to address the complex personal, temporal, environmental and social issues uncovered by our user needs analysis. Currently, our method can be used to specify a POMDP-based controller for assistance tasks quickly and easily. This takes care of only certain aspects of customizability uncovered by our needs research including the ability to build custom solutions for user-specific tasks, as well as monitoring and assessment. However, many challenges remain in addressing other key aspects required by our users, including designing useful and accessible interfaces and modalities; delivering effective prompts that will both empower older adults and alleviate their caregivers; and determining how to achieve ultimate user acceptance and integration into users life roles. Lastly, we must consider such implementation challenges as specifying common platforms for the integration of products and services and facilitating technology adoption by real-world users.

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