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WIP: Designing Smart Systems to Support @Work Caregiver Needs

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Abstract

Unpaid caregivers for persons with cognitive impairments provide a valuable medical service at a personal cost to themselves (both health and financial). Smart systems in the home can potentially ease the caregiver burden but the home is a difficult environment for smart systems to operate. This work in progress examines the design of a smart caregiver support system and how it is extended in a new system to support working caregivers. The system uses AI in a human-in-the-loop approach.

Introduction

Unpaid caregivers for persons with cognitive impairments, a subset of the total US caregiver population, number about 15 million people and the value of their care is an estimated $210.5 billion (Alzheimer's Association 2012). Many of these caregivers work outside the home and must balance work and caregiving duties. The consequences of caregiving can include workplace difficulties (excessive sick and vacation leave, irregular schedules and lost productivity) (Alzheimer's Association 2012; Covinsky et al. 2001); caregiver health problems (poorer health, high levels of stress, role conflict and depression) (Covinsky et al. 2001, Farfan-Portet et al. 2010; Wang et al. 2011); and a potentially unsafe situation when the person with cognitive impairment (the care receiver) is left home alone unsupervised (Rowe and Bennett 2003; Bourgeois, Couturier and Tyrrell 2009). Conversely, positive work experiences help ameliorate caregiver stress and enable caregivers to maintain a sense of normalcy (Edwards et al. 2002; Hasselkus and Murray 2007). *Thus, a system is needed to support working caregivers in their attempt to provide safe care while away from the home and reduce the health and work problems associated with caregiving*.

This paper's aim is to examine the use of smart sensing in the design of such a caregiving system. First, we review the CareAlert© Monitoring System as a demonstration of effective design for the caregiver. Second, this is used to discuss guidelines in the development of an in-progress product in a more complex design space, keeping the abilities and needs of caregivers and care receivers in mind. Lastly, we discuss our decision to manage errors in recognition by keeping the human-in-the-loop. *NOTE: This article does not cover the full design due to Intellectual Property reasons, instead focusing on requirements in support of caregiver needs, not AI techniques themselves.*

CareAlert© Monitoring System

The CareAlert© Monitoring System by CaregiverWatch, LLC, provides timely and reliable alerts to the caregiver when nighttime activities occur by monitoring the care receiver's bed occupancy and movements within the home. With this system the caregiver is able to awaken when needed and provide targeted assistance. CareAlert's effectiveness was demonstrated by several qualitative and quantitative studies (Rowe et al. 2009; Spring, Rowe and Kelly 2009) in which the system was strongly accepted and reliably used by caregivers; resulting in an 86% reduction in unsafe nighttime events.

This system uses several motion detectors placed strategically in the house, a bed sensor and night stand controller. The design was crafted to fit simply into caregiver homes and provide a specific and reliable feature set. Though several "smart" components are used and the state space is complex, the system appears simple enough that the caregiver can maintain a mental representation of its function and anticipate its operation. The system ignores safe activities like getting up to get a glass of water, going to the bathroom, etc.

Several features define CareAlert's function:

- *No sensor or device is placed on the care receiver*. While more and better data could be achieved by instrumenting the care receiver, these devices can be forgotten and are often not put on, fall off and are not

replaced, are taken off by the care receiver, not worn to bed and are uncomfortable (Bowen et al. 2012). Additionally, both care receivers and caregivers report wearing tags and transmitters as stigmatizing and invasive (Bruce, 2012).

- *Design for different levels of care receiver need*. Care for persons with dementia is provided over a 5-8 year span. Care receivers have different and changing health needs so the system is configurable. Fluctuations of care recipients' abilities over the years, within the week or during a day further add to the complexity. Additionally, the alerts have two severities, "informative" and "emergency", that avoid constant alarms but still increase awareness and provide a call-to-action.
- *Solve the problem needing a solution*. The literature shows caregivers need more restful sleep. Motion detectors allow the caregiver to monitor the care receiver without leaving bed or being alerted unnecessarily during normal nighttime care receiver activities.
- *Easy installation and few requirements*. Simple and robust devices are used (*even at the cost of data quality*) so installation is "do-it-yourself" capable and has no requirement on 3rd party services-- the Internet or phone.

As with good design, the simplicity might hide the design tradeoffs hidden in its development, such as:

- Motion sensors provide limited information but their low power and reliability, along with low bandwidth, means that their data is reliable and dependable.
- Many pressure sensitive bed sensors exist but care receivers that toss and turn at night can set these off prematurely. An air mattress in the bed with an air pressure sensor is a more reliable measurement.
- Pressure sensitive floor mats track care receiver activities inexpensively and reliably but are often fall hazards (Bowen et al. 2010) and battery lives are on the order of only a few days (Applegarth et al. accepted).
- Manage/restrict power, heat, bandwidth & computation.
- People understand the sensors used by their *look* (i.e. due to automatic doors and tire gauges). People assume function from form; even a semi-resemblance to a camera incurs privacy concerns (Bowen et al. 2012).

CareAlertRemote© System

Caregivers are open to using technology to assist in caregiving and a number of technologies have been successful (Smith et al. 2007; Mahoney et al. 2008). This project builds on those and CareAlert© to develop CareAlertRemote©; expanding monitoring to caregivers temporarily out of the home for errands or paid work. It is significantly more ambitious and complex than CareAlert©, needing to support remote work as well as home activities, and relies more on AI because the caregiver can not have eyes-on direct assessment of the care receiver.

It is critical that the caregiver can shift vigilance, i.e. attentional resources, to a monitoring system so they can focus on work and then assess home activities remotely as needed. These assessments take the form of peripherally awareness tools so they can "check-in" with the care receiver and investigation tools when an alert has been given and they need to decide on a course of action.

Some of the previous design ideas hold or are adapted to fit this new situation:

- *No sensor or device is placed on the care receiver*. This is even more important as the caregiver is not around to put a tag back on. If the tag comes off, the system fails.
- *Design for different levels of care receiver need*. If the care receiver has only mild cognitive deficits, alerts and constant check-ins may cause frustration and agitation. As cognition worsens, direct conversation may not successfully inform the care receiver.
- *Solve the problems needing a solution*. Caregivers need to ensure certain activities are being performed when they are at work. For example, the care receiver needs to stay in or around the home, adhere to meal times and have regular but not lengthy bathroom visits. The literature is limited on at-work caregiver needs so we currently are working with caregivers in focus groups.

Some of the previous design ideas change:

- *Easy installation and few requirements,* no longer holds due to the extra sensors and network complexities. While technically inclined caregivers could install the system, improper installation means suboptimal performance.

Some new ideas are incorporated:

- *Expect more complexity*. The design space of what is needed, compared to nighttime activity, is much larger and is unmanageable by a simple state machine. It requires new sensors and a different monitoring approach. This impacts the caregiver's understanding.
- *Keep the caregiver in-the-loop*. Because the caregiver knows their own home and they have the ability to learn to interpret sensor data, we use AI to inform the caregiver's understanding through visualizations.
- *Mobile apps and smart phones*. Smart phones have tremendous functionality needed for telecare such as alerting the device's owner, communicating via phone or instant messaging, and apps for running visualizations. *Most importantly, people keep their phones near them so alerts are immediately noticed*. While not all phones are smartphones, we can assume someone without a smartphone (or who is averse to buying one) would not be interested in automating their home anyway, i.e. the smartphone is not a barrier, but an indicator.
- *Add sensors but keep the current design requirements*. We anticipate adding magnetic switch sensors and accelerometers to monitor door and cabinet openings. As well, microphones will be added to recognize sounds. Extra sensors require additional processing, bandwidth and installation but keep within our requirements of

simplicity and robustness. These sensors provide specialized data that strengthens the feature recognition.

- *Cameras and video*. Video is invasive, has privacy concerns and requires computation and network bandwidth (leading to power consumption, cost, cooling and noise). Computer vision in a home environment is difficult, even with depth information. However, video provides for eyes-on assessment so incorporation has to be carefully considered; likely very useful in the future.

A Human-In-The-Loop System

We do not expect any current AI system to be reliable in a home context at the levels needed. Yet, we still need to provide reliable information to the remote caregiver—minimizing false positives and constant alerts that increase caregiver anxiety. Thus, important emergency alerts like door openings or loud sounds (ex. yelling, falls, breaking items, etc.) have sensors with reliable recognition and less critical activities inform the caregiver to "make the call".

We are building a visualization hierarchy supporting caregiver situational awareness, keeping them in the decision making loop and providing visualizations for different needs. There are three visualization levels: **1**) periphery (or glancible) displays to quickly view iconic activity patterns (Figure 1); **2**) journal displays showing a log of activities through the day; and **3**) heat maps of care receiver movement data. These three levels each require pattern and activity recognition techniques to classify the data. However, it avoids high-level interpretation of the data and focuses on simpler activities and events for the caregiver that can be recognized with higher reliability. Access to the raw data is also provided to the caregiver.

Figure 1. A mocked-up periphery display demonstrates iconic representations of AI sensed behaviors the caregiver can interpret to develop their home activity understanding. This keeps the human-in-the-loop. Here, we see little activity in the last hour, probably due to the care receiver sleeping.

Conclusions

This paper reviewed the design of the CareAlert© product to inform the design of the CareAlertRemote© activity recognition, a much more ambitious product operating in a more complex space. Much of the design is focused on keeping the human-in-the-loop to design around AI shortcomings in classifying behavior in a home environment.

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