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Older adults' privacy considerations for vision based recognition methods of eldercare applications

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Abstract. This study aims to explore older adults' privacy considerations for technology based monitoring applications in eldercare that use video systems. It specifically aims to introduce alternative vision based tools and identify whether distorting or "anonymizing" captured images affect older adults' privacy concerns and willingness to allow such an application to be installed in their residence. Ten residents of an independent retirement community were recruited to participate in a series of scenarios. Each scenario involved a daily activity such as sitting in the living room and having a visitor, or preparing a snack. These sessions were video-recorded using different image processing and extraction approaches. Follow-up in-depth interviews with participants were conducted after a demonstration of the captured images. Findings indicate that shape extraction can alleviate privacy concerns associated with the use of cameras. Participants expressed no privacy concerns with silhouette images and emphasized the importance of anonymity in the video sequences. They furthermore expressed the desire to control system operation by being able to turn a vision-based system off and on, and also determine who has access to the collected information.

Keywords: Privacy, monitoring, technology, independence, sensors

1. Introduction

Ubiquitous computing introduces a new era for the delivery of support and care services for older adults. Advances in information technology bring promising new approaches to monitoring older adults in their own home or residence of choice with the goal to detect or prevent emergencies, identify the onset of adverse events and ultimately increase quality of life and safety. Numerous home based technologies support physiological monitoring (such as collection of vital signs), functional monitoring (e.g. motion and activity sensors), safety monitoring (e.g. stove sensor, automatic light activation), security alarm systems, applications providing cognitive and sensory assistance (e.g., object locators, recognition aids) or promoting social interaction (e.g., portals for communication with family, smart phones) [4].

Sensors play a key role in technology applications for eldercare. Sensor-based systems can be grouped based on their installation requirements and location. One category is *on-body sensing* that includes

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sensor-based systems that are wearable and can be embedded in the person's outfit as part of clothing or an accessory [11]. A second category is *infrastructure mediated sensing* where sensor systems utilize the existing home infrastructure such as the plumbing or electrical system to mediate the transduction of events based on the premise that infrastructure activity is used as a proxy for human activities. For example, Patel et al. developed a system to detect and classify unique electrical events on the residential power line and infer residents' activities using this non-obtrusive approach [13]. Finally, the third category of sensor-based systems is *distributed direct sensing* which involves the installation of a new sensing infrastructure into the home. In this context, an associated sensor network is implanted to transfer the sensor data to a centralized monitoring system. Sensor components can include, among others, bed sensors, motion sensors or visual sensors using video capturing devices, transmitting data sets to a central server for further processing [5].

In the context of monitoring technologies that are introduced in the residence and capture data about someone's daily activities, privacy is obviously a major issue that needs to be addressed. Privacy concerns can affect the diffusion and success of such technologies. As Harper et al. [6] point out, attitudes as to what is and what is not private data vary between people in different contexts and roles. With the introduction of new technology in the home, patterns of use and social norms affect what is deemed appropriate to capture about one's life. Evolving social practices may interact with organizational policies for correct usage [6]. People are more likely to accept potentially invasive technology if they consider that its benefits outweigh potential risks [8,16].

Bellotti and Sellen [1] define privacy as a personal notion shaped by culturally determined expectations and perceptions about one's environment. The underlying premise is that the social practices and policies determining rights an individual has to privacy, interact with the functional and interface design aspects of the technology they use. Bellotti and Sellen presented a framework for addressing the design of *control* and *feedback* of information captured by ubiquitous computing environments [1]. This framework includes four dimensions that play a role in privacy perceptions, namely: capture (when and what information gets recorded), construction (what happens to the information once it gets recorded), accessibility (who has access to the information) and purposes (how will the information be used).

Applications that utilize video cameras are traditionally considered as most privacy invasive in the sense that they capture not only text based or numeric data about one's activities but they actually record a detailed reflection of all processes and interactions as if inviting an unknown observer to enter the residential setting. It is therefore, often assumed that visual sensing devices will not be welcome in one's home due to privacy concerns; yet this claim has not been systematically confirmed or even explored with older adults. Recent work indicates that older adults are often willing to compromise certain levels of privacy to gain support in remaining independent [3]. This type of conditional reasoning determines in many cases the acceptance of privacy invasive technologies, where a device that may be considered to be intrusive, is likely to be accepted if it is viewed as necessary to support a need [12].

In order to benefit from the use of video-based monitoring (including being able to identify each individual in a multi-person environment, and label events with accuracy, for example being able to accurately distinguish between a fall and someone getting on their knees to pick something up) while minimizing potential privacy intrusion, it is proposed to capture images that may still preserve one's anonymity. This could be achieved with shape extraction and thresholding where, for example, an image can have a low resolution that still highlights the recorded activities without displaying detailed features of an individual. This pertains to the element of capture in the framework by Bellotti and Sellen [1], whereby capture refers to image type and how recognizable a person's identity, environment or activity are within a captured image.

This study aims to explore older adults' privacy considerations for vision based recognition methods of technology applications in eldercare. It specifically aims to introduce alternative vision based tools and identify whether distorting or "anonymizing" captured images affect older adults' privacy concerns and willingness to allow such an application to be installed in their residence.

2. Materials and methods

The study setting was TigerPlace, an independent retirement community developed by the Sinclair School of Nursing University of Missouri in partnership with Americare. TigerPlace is designed based on the principles of aging in place, namely enabling older adults to stay at the residence of their choice independently for as long as possible rather than transfer them to a different facility every time their health care needs change [14,15].

Residents were approached by a graduate student assistant and invited to participate in the study. Once interested residents received detailed information about the study and signed the informed consent they were asked to participate in a series of scenarios. Each scenario involved a daily activity such as sitting in the living room and having a visitor, or preparing a snack. Each scenario duration was around 5 minutes, and subjects were asked to report any and all fatigue/distress throughout the taping process. Subjects were encouraged to provide feedback throughout the taping process to ensure the tasks they were asked to perform were realistic and consistent with their typical activities. The first subject performed the scenarios in his apartment. All other subjects performed scenarios in a test apartment or another room within TigerPlace. Participants reported that the chair and other props (microwave, table, coat tree, etc.) resembled furniture and appliances they have in their own apartment.

Video data was collected using two inexpensive, firewire webcams, mounted on orthogonal walls. A calibration protocol was followed to acquire the camera positions and to correct for distortion in the lens. Images were captured at five frames per second at a resolution of 640×480 pixels. To address the privacy concerns, images were anonymized by extracting only a silhouette of the resident moving around the environment. To create the silhouettes, background images were collected first to compute a background model; an algorithm was used to subtract the background, leaving only the segmented person [10]. The difference was then converted into a silhouette. An example is shown in Fig. 1. In addition, a three-dimensional representation was constructed from the silhouettes of two cameras by projecting each silhouette into voxel space and computing the intersection. An example of this "voxel person" representation is shown in Fig. 2.

At completion of these interview sessions, subjects were shown the actual video resulting from the silhouette extraction. That is, individual frames of the silhouettes images were used to create a video sequence. The graduate research assistant used a laptop to display the sequences to each subject. Subjects confirmed verbally that they were comfortable prior to audio-taping and viewing. Lights were adjusted to subjects' individual viewing preferences. Some subjects requested the lights be turned off for optimal viewing of their data. Others requested the lights to be left on or dimmed for optimal viewing.

The interview guide instrument was a semi-structured series of questions to guide the interviewer.

The questions focused on:

- Residents' initial impression of the processed images
- The extent to which this monitoring was perceived as in violation of residents' privacy
- Whether residents wanted to have control of this monitoring and how it may affect having family members or friends visit if the system were installed in their residence

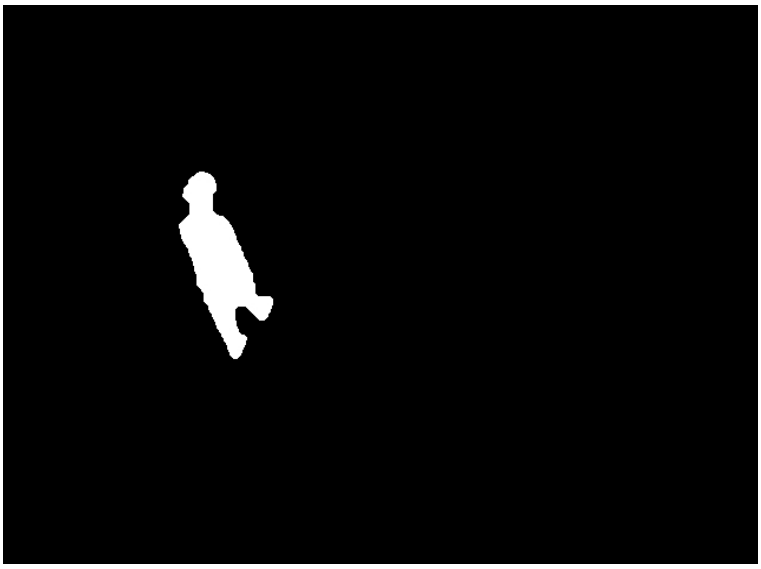

Fig. 1. An example of a silhouette image.

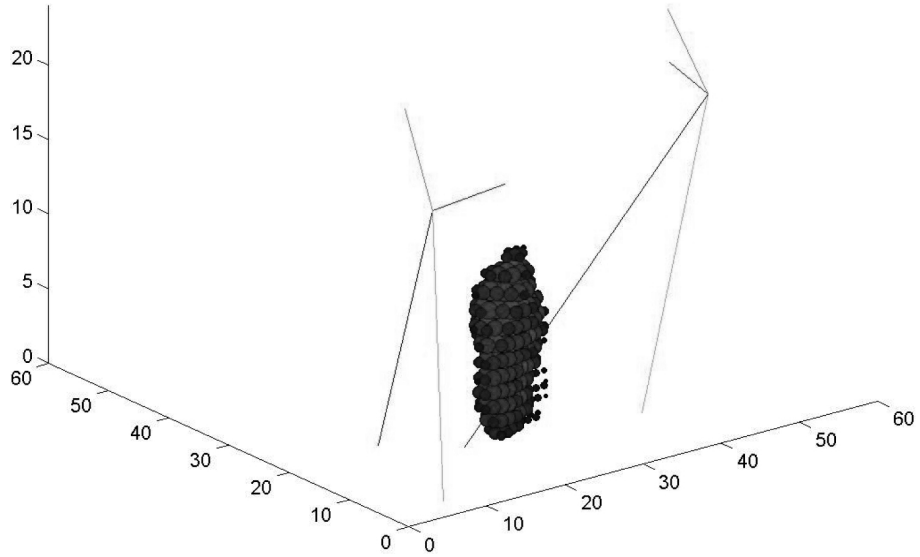

Fig. 2. An example of a voxel person image.

- Residents' willingness to permit the installation of a video sensor network in their own apartment
- Residents' preferences on image resolution and whether/how these preferences affect perceived privacy intrusion
- Overall perceived obtrusiveness and degree of usefulness of video-based monitoring

The interview protocol used descriptive cues from prior work on obtrusiveness of home based technologies [7] and dimensions of privacy in an environment enhanced by video media [2]. Furthermore, in order to explore residents' preferences on image characteristics, we integrated descriptive cues based on

the Bellotti and Sellen framework [1] for describing privacy issues in media spaces. Interviews were audiotaped. A content analysis was performed focusing on thematic coding driven by the Bellotti and Sellen framework [1]. Two authors (GD, DPO) listened to the audio tapes and separately coded resident comments using the four categories in the framework. Codes and comments were compared, differences discussed, and consensus reached resulting in the thematic classification below.

3. Results

Ten subjects were recruited to participate in the scenarios and follow-up interviews. Two subjects were male and eight were female. All participants were over the age of 65 years. The total duration of all interview tapes was 4 hours and 38 minutes. Mean interview time was 22 minutes and 18 seconds, whereas the median time was 23 minutes and 31 seconds. Interview times ranged from 10 minutes and 57 seconds to 31 minutes and 42 seconds.

Findings are grouped below using the Bellotti and Sellen framework [1] including the concepts of capture (when and what information gets recorded), construction (how is information recorded and what happens to it), accessibility (who has access to the information) and purpose (how will the information be used).

3.1. Capture

Participants found the silhouette images to be protective of their privacy. As one participant stated, "*I don't see anything threatening about it at all*." Another participant emphasized "*this is not intrusive at all-one of the reasons we live here is because we want the protection*." One participant pointed out that the featured video sequences were acceptable as they did not identify residents: "*Looking at this . . . I don't recognize me. I think this is better this way, this is plenty for my own reason, I would not object. Now if it showed who you are-that would be different*."

Participants also addressed a need for control of the frequency and location of such monitoring. One participant stated "*I would personally turn it off at times-it would be good to know you could*." Another participant made a similar point: "*yes I would like to turn it on and off, I may have, you know, some drinking buddies here sometime*."

One participant raised the issue of having the resident in control of the rooms where video sensors may be installed. "*I would not want this in the bathroom.*" That same participant also suggested that the unique preference settings may depend on gender or other characteristics: "*I think a man may not care about this as much if it is in the toilet area, you know, but a woman, I think, would . . .*."

3.2. Construction

Most participants enjoyed seeing the silhouette image sequences. They were able to identify their images and the other participants in the scenarios. One resident said "*I am fascinated by the whole thing*." Some had questions for the research assistant pertaining to how these silhouettes are created. Interestingly enough, while participants enjoyed the anonymity provided by the silhouette images, they were less enthusiastic about the voxel-display because that was eliminating all identifiable features. Most participants felt that the camera used in the scenarios was acceptable to have in their homes, and that they would not have problems with family members or friends visiting if the system was installed in their home. One respondent said "*No I would not mind having family over, I would explain to them, but friends . . . I don't know, they may think I am crazy*."

3.3. Accessibility

Nine participants emphasized that access should be limited to those who needed to process this information for the purposes of monitoring. As one participant stated "*Clearly only a few people should have access to this information.*"

Seven participants expressed the desire to be able to access their personal"anonymized" image sequences, although not on a regular basis. As one participant stated, "*I would like to see it from time to time out of curiosity.*" Another participant felt access to the video sequences would be helpful to her: "*it would be helpful to view the information-it would help me, you know, to know the general... outline of what is going on, or what I should do, you know*." Another participant stated "*It would be fun to see how I am doing.*"

Two residents emphasized that access should be additionally granted to family members. One elaborated: "*I would feel more at ease. My daughter is quite concerned about me being alone here. It would make her feel better if this was available.*"

On the other hand, another participant expressed concerns about her daughter accessing the image sequences: "*All of a sudden I would realize she was watching me. I would rather assume she was not watching me, it is like an infringement, you know ...*"

3.4. Purpose

In terms of the use of the extracted images for vision-based recognition, most respondents (N = 7) saw value for the purposes of monitoring, but felt this monitoring was not needed for them but for other older adults in a more frail status. As one respondent stated "*There are many people who would benefit a great deal from this. I don't think I need this now, you know, I am pretty independent, but I can think of others who definitely need this.*" One resident felt that the purpose of monitoring would depend on her future status: "*A lot would depend on why I was having this, why I was in danger, how impaired I was, whether it would make me feel at ease.*" One participant did not see value in the technology: "*Thank Goodness, I walk straight. I feel embarrassed, you know, kinda stupid. I don't think I want to watch this. I don't see how others having this would benefit me*."

Another participant emphasized the value of the technology for the purpose of monitoring in the context of a recent fall she had experienced in her apartment: "*Just think how important this would have been when that happened. It would have been better if we had this all the time.*"

4. Discussion

Findings indicate that shape extraction can alleviate privacy concerns associated with the use of cameras. Participants in this study expressed no privacy concerns with the silhouette images and emphasized their appreciation for not being recognizable in the video sequences. They furthermore wanted to have control of the system operation by being able to turn it off and on, and also determine who has access to the collected information. While many saw benefit in the use of video extracted silhouettes for monitoring of residents' well being, most participants felt they were independent and not needing this application just yet, a finding consistent with overall attitudes of older adults towards monitoring applications [5]. The resident who had experienced a recent fall with significant implications was the participant who saw the greatest value in the technology and the need to have it installed in

all units, perhaps giving strength to the argument that perceived need and anticipated benefits outweigh potential privacy concerns.

Most residents appreciated the distorting of images that removed specific identifying features but still portrayed their silhouette, whereas they did not see value in features such as voxel displays where the display had no resemblance to them and therefore, did not intuitively highlight how it may be useful for monitoring purposes. This does confirm the need for users to have an understanding not only of the output of the system but also its processes and purpose.

According to Bellotti and Sellen [1], systems must be technically reliable and instill confidence in users. The level of shape extraction that erases identifying features addresses privacy concerns and increases confidence in users that video-based monitoring can be useful and appropriate. The concepts of feedback and control play a great role in user acceptance, as older adults wish to control the use of monitoring features and receive information about its use, its purpose and all involved parties. As Lederer et al. [9] point out, to participate in meaningful privacy practice in the context of technical systems, people require opportunities to *understand* the extent of the systems' alignment with relevant practice and to conduct discernible social *action* through intuitive or sensible engagement with the system.

Participants varied in their desire to view the data and on whether their family should see the data. These data indicate that privacy concerns may be mitigated by allowing participants to customize the operation of the system, turning it off when desired, determining if they want to view the images, and controlling which of their family, friends or health care providers might access the data. This study provides insight into ways to improve and refine existing vision based recognition methods to address privacy considerations for older adults.

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