Perception of Human Activities
A Means to Support Connectedness Between the Elderly and Their Caregivers

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Abstract: This position paper describes a smart-phone based activity recognition system for improving social connectedness between caregivers and their elderly relatives. Sensing technologies can enable real-time monitoring to provide activity recognition in order to support health and safety among the elderly who are living independently. However, most existing activity recognition systems are focused on using sensors for unidirectional monitoring of emergency cases in particular, fall detection. Motivated by the desire to utilize bidirectional activity recognition to improve connectedness between an ageing population and their caregivers, we describe our planned approach to investigate how the perception of a caregiver's activities by a senior citizen and vice versa can aid in improving social connectedness. To investigate this perception, activity states will be transformed into an information visualization into the caregiver's home and vice versa without overt communication from participants. Findings are expected to provide further insight on the extent to which perception of human activities increase social connectedness.

1 INTRODUCTION

With the growth of demographic ageing within the European Union, formal and informal care services are increasingly becoming concerned about the fiscal burden and demands of the ageing population. Consequently, these institutions are in favour of home care solutions. As discussed in Davis et al. (2015), there are inadequate resources such as nurses, which induce cost; and consequently independent living is forced. In contrast, despite wanting to live 'separate' lives from their elderly counterparts, caregivers often experience worry or uncertainty about their elderly relative's health and well-being.

For many years, a number of scholars have associated social isolation and loneliness with old age (Sheldon et al., 1948; Halmos, 2013). In general, retirement, mobility-impairment, increased isolation, death of loved ones and kin-separation due to globalization may cause loneliness in ageing societies. Furthermore, research has found a number of health risks associated with loneliness and social isolation including high mortality risks, cardiovascular and infectious diseases, cognitive deterioration and depression (Becker et al., 1998; Stafford et al., 2011; Steptoe et al., 2013). However, epidemiological research suggests that strong social ties play a critical role in enhancing the elderly's psychological and physiological well-being (Umberson and Montez, 2010).

Social participation has been incorporated into the research and public policies of ageing societies as shown in (Landabaso and Letter, 2013). As a result, this enables social cohesion through active involvement in volunteering services, clubs and associations. In turn, this increases a sense of belongingness and also influences quality of life, which is critical for the sustainable development of ageing societies.

Human activity recognition (HAR) systems can help in reducing the challenges of supporting elderly independent living and reducing the burden of their caregivers. Moreover, HAR systems provide a plethora of opportunities for automatic recognition of activities of daily living (ALDs) in the context of health and elderly care such as fall detection (Bourke et al., 2007), classifying activities of Parkinson's disease patients (Rodriguez-Martin et al., 2013) and encouraging physical activity (Consolvo et al., 2008). However, most of the existing applications are fo-

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cused on detecting potentially dangerous situations and generating automatic alarms in the case of an emergency (Rashidi and Mihailidis, 2013).

1.1 Research Goals

Social Connectedness can be described as a sense of belongingness based on the appraisal of having enough close contacts (Van Bel et al., 2008). In this position paper, we hope to improve social connectivity through the perception of activity states generated from smart-phone sensors. This work forms part of the proposed experiment of Davis et al. (2015), which aims to induce social presence through subtle awareness of activity and emotional states between the caregivers and their elderly relatives.

The ubiquitous cell-phone provides a rich platform for human activity recognition as shown in (Anguita et al., 2012). The inclusion of sensors namely the camera, accelerometer and gyroscope, its unobtrusiveness and communication features (WIFI, 3G and Bluetooth) add to the smart-phone's appeal for enabling human activity recognition (Ustev et al., 2013). For the purposes of this research, we hope to apply the notion of abstraction (i.e. highlighting key information contained in the data and suppressing irrelevant details as discussed in (Cavaco, 2014) to investigate how the elderly and their caregivers will perceive raw activity data versus classified data.

2 RELATED WORK

In perceiving human activity, we rely on several information sources from various modalities including sensory, motor and affective processes (Blake and Shiffrar, 2007). Specifically, the human visual system seemingly plays a significant role in understanding human actions and intentions. Furthermore, it is extremely sensitive to human movement and as such it is able to extract socially relevant details (Troje, 2002). This implies that human motion could provide reliable information for discerning affect (Blake and Shiffrar, 2007). For instance, Kaye et al. (2005) confirmed that virtual intimate objects gave a sense of peripheral presence and activity awareness; thus enhancing intimacy in long distance relationships. Therefore, we believe that the perception of human activities can improve social connectedness. For instance, imagine you have an information display showing your distant elderly parent's activities in the periphery of your living room, which is placed in your living room and you suddenly discern that something is wrong and you are prompted to call your mother. Could you recognize specific patterns in the daily activities of your mother? Could you recognize that something was wrong based on the dynamics of the visualization in the absence of direct communication? Would this improve social connectedness between yourself and your elderly parent? We believe that this is possible and in this section we will explore a number of studies focused on awareness systems for elderly care.

2.1 Awareness Systems Supporting Elderly Care

Naturally, awareness of others and their activities can directly influence social connectedness by addressing social and emotional needs and possibly initiate communication through other media (Markopoulos and Mackay, 2009; Romero et al., 2007). Early conceptions of awareness systems to support ageing in place were introduced through the Digital Family Portrait (Mynatt et al., 2001) and the CareNetDisplay (Consolvo et al., 2004). The Digital Family Portrait used sensors to collect information (eg., weather and activities) to display a qualitative sense of a senior citizen's daily activities to their families over a mediated environment. The CareNetDisplay was an extension of the previous ideas of the Digital Family Portrait and consequently; the researchers amplified an older person's photograph with details about their daily life including activities, moods, medication, falls, meals and outings (Consolvo et al., 2004). Later, the Daily Activities Diarist sought to address the weaknesses of the previous awareness systems through its narrative presentation of awareness information (Metaxas et al., 2007). These earlier systems demonstrated great potential for facilitating awareness for distant family members who were worried about their elderly relatives or members of an elderly care network offering day-to-day care. However, like the Digital Family Portrait and CareNetDisplay, the Diarist reflected an unbalanced communication channel and in most cases portrayed unidirectional monitoring where the caregiver observed their elderly relatives for notification of alarming situations. Unidirectional monitoring involves the deployment of wearable devices and other intrusive sensors all around a senior's home. This is invasive and consequently violates the privacy and dignity rights of the elderly population.

More recent communication mediated systems that support peripheral awareness for connecting remote families include the following: the ASTRA - awareness system for connecting households and mobile family members Romero et al. (2007) and SoPresent - an awareness system for connecting remote households Dadlani et al. (2014). In sum, both Astra and SoPresent attempted to address the asymmetrical communication concerns of the previously discussed research by sharing moments and experiences. However, they were designed to support connectivity between families of remote households, which though related is not the specific context of this research. In our research, we are interested in understanding how the elderly and their caregivers will perceive the activity data presented in the periphery and how this acquired knowledge improves social connectivity.

3 PROPOSED ACTIVITY RECOGNITION PLAN

We have chosen an Android based platform as a means for activity recognition because of its embedded sensors such as the accelerometer and gyroscope. In addition, Android's openness provides existing resources (source modifications and open tools), which facilitate the inexpensive development of context-awareness tools. Therefore, we have developed the Accelerometer Gyrometer Logger (available on Google Play) to collect accelerometric and gyroscopic sensor readings at a frequency of 50Hz. Specific properties will be extracted (eg. mean, standard deviation, entropy etc.) from this data to detect the following activities: walking, standing, laying, sitting, walking upstairs and downstairs, running and cycling for both the elderly and their caregivers.

Several studies have shown that the Support Vector machine (SVM) is the most popular classification method in comparison to the quadratic classifier, k-nearest neighbor algorithm and artificial neural networks. For instance, Ravi et al. (2005) demonstrated that SVM gives one of the best accuracies for recognizing human activities achieving over 99.4% accuracy for boosted SVM. Moreover, Anguita et al. (2012) adapted the standard SVM to exploit fixed-point arithmetic to reduce computational complexity. This approach enabled them to deploy the smartphone inbuilt accelerometer and gyrometer sensors while maintaining normal battery lifespans for other shared resources on the phone. The adapted multi-class SVM obtained similar accuracy compared with the traditional SVM. In this position paper, we propose to adopt the multi-class SVM algorithm inspired by Anguita et al. (2012) to train and classify our data for recognizing the activities we have mentioned earlier.

3.1 Data Collection

Anguita et al. (2012) have made publicly available, a HAR training dataset (accelerometer and gyrometer) of 30 volunteers in the age range of 19-48 years. In their experiment, each volunteer was instructed to perform the following activities: sitting, standing, walking, lying, walking upstairs and walking downstairs while wearing a smart-phone on their waist. The experiments were video recorded to enable them to label the data. We will adopt a similar approach to collect additional datasets to include activities such as running and cycling. Our dataset together with the existing dataset will be used to train the multi-class SVM classifier for activity recognition. However, our study will include a larger sample space with our participants ranging between 18-90 years, who are living mostly in the Netherlands. Two sets of training data will be used, one for participants aged 18-59 years and the other for participants aged 60-90 years. We assume the elderly population will exhibit a slower speed of motion in comparison to their caregivers. The autographer wearable camera will be mounted unto the participant's bodies to capture daily activities for labelling and interpreting the data. Also, we will utilize the caregivers and their elderly relatives own homes as test-beds for our data collection. For the purposes of this experiment, we assume that the homes of the caregivers and their elderly relatives are furnished with staircases, which is typical of Dutch family homes. The selected activities include typical activities of daily living, which are commonly found in validated scales such as (Reisberg et al., 2001). Also, we used the following articles (Chavarriaga et al., 2013; Cook et al., 2009) as references for compiling our scenario.

3.1.1 Scenario Script

For our experiment, we will ask each participant to perform the following activities in sequence.

- Telephone Use (Sitting): The subject will dial a specific number listed on an instruction sheet and write down the instructions given on the recorded message. The stationary and cellular phone will be located on the dining room table.
- Cleaning (Walking): Participants will be asked to vacuum the floor of their living rooms.
- Exercising (Running and Cycling): Outside of their own homes, able bodied participants will be asked to jog on the spot for a few minutes. Moreover, those who are able to cycle will be asked to ride a bicycle for a few minutes. Note well that this scenario is more applicable to the caregivers.

- Hand Washing (Standing): Participants will be asked to wash their hands in the bathroom face basin using their own toiletries.
- Collect Ingredients (Walking Upstairs and Downstairs): Each Participant will be asked to collect some ingredients, which will be placed on the stair-head.
- Preparing a Snack (Walking and Standing): Participants will be asked to prepare a snack and beverage in accordance with the recorded instructions.
- Resting (Lying): Participants will be asked to lay on the couch in their living rooms.

Moreover, the data sets generated from the above mentioned activities will serve as ground truth for validating the perceptions of both the caregivers and their elderly relatives.

4 THE EXPERIMENT

In this paper, we will investigate the extent to which the perception of the activities of the elderly by their caregivers and vice versa help to improve bonding. Moreover, we seek to understand how much hidden information would be perceived from the unclassified accelerometer data and the classified data, which has a direct correlation between the level of activity and the jagged edges of the output graph.

4.1 Proposed Methodology

We will conduct a preliminary study applying the within subjects design to a group comprising of ten caregivers and ten elderly participants. To reduce the carry-over effects of this experimental design, we will divide the group into two groups A and B. This implies, that we will show Group A the classified activity display and subsequently show the unclassified activity display. For Group B, we will first show the unclassified activity display and then the classified activity display. Figures 1 and 2 summarize the experimental approaches.

In the classification approach, we will extract and select these features (standard deviation, mean, entropy etc), which will be used to train the multi-class SVM classifier. Signals from the both the elderly and the caregivers will be streamed to a server, which will perform feature extraction and selection, and subsequently classify the activities. The activities will be grouped into low, medium and high levels according to table one. These levels of activities will be relayed to android tablets, positioned like a photo-frame in

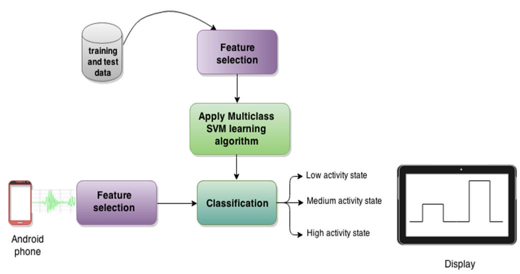

Figure 1: Set-up I showing the classification approach.

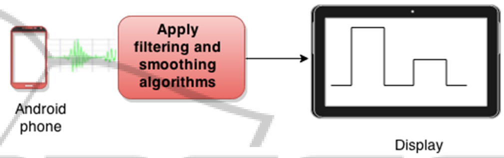

Figure 2: Set-up II showing the unclassified approach.

Table 1: Table showing activity classification levels.

Activities	Activity Levels
lying	low
sitting	low
standing	medium
walking	medium
walking downstairs	medium
running	high
cycling	high
walking upstairs	high

the homes of both the caregivers and their elderly relatives and will be rendered using simple line graphs (Figure 3).

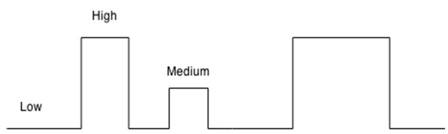

Figure 3: Line graph showing the activity levels.

The dual display of the activities of both the caregiver and their elderly relatives shows a bidirectional communication channel, which we believe is a necessary component for reducing the 'Big Brother' role of caregivers. As shown in set-up II, the experiment is repeated but this time, the original raw accelerometer data is filtered, smoothened and approximated to a similar line graph as displayed in the set-up I.

Our choice of simple line graphs to display the activities is not random. Line graphs are one of the most common means of visualizing time-series data.

They are able to easily display data, facilitate comparison and reveal trends within the data. As shown in Figure 3, we believe it will be easier to associate low, medium and high slopes with low, medium and high activity levels respectively. Therefore, this visual rendering will portray the same aesthetic quality and visual complexity for both displays.

4.2 Evaluation

To determine the usefulness of the proposed approach we hope to investigate the following:

- How does the experimental subjects perceive both displays and their preference?
- Did the elderly participants recognize certain patterns in the activities of their caregivers and vice versa?
- When they observe the display, what are their perceptions of their caregiver's activities?
- Will the application trigger social behaviour? For instance, will we see an increase in phone calls?

Furthermore, to investigate social connectedness we will utilize the validated scales such as the Inclusion of Other in the Self scale (IOS) as discussed in (Aron et al., 1992) and the IPO Social Presence questionnaire detailed in (De Greef and Ijsselsteijn, 2001).

5 CONCLUSIONS AND FUTURE WORK

We have presented our proposed approach for perception of activities from smart-phone generated data to increase bonding relations between the elderly and their caregivers. Furthermore, we have described two techniques for investigating the participants' perceptions of the activity displays and how their perceptions would support social connectivity between the generations. Firstly, we proposed the popular SVM technique for the activity classification display and secondly we proposed an abstraction of the original raw accelerometric and gyroscopic data for the unclassified display. Provided that the results of this experiment are favourable, we have a variety of activity displays in mind and we hope to implement them in the near future. Our major long term goal is to improve bonding and care by designing a system in which the elderly and their caregivers can interact through other signals (mainly physiological signals), among them unconscious signals. In subsequent experiments, we will implement a covert lighting application, which will provide contextual awareness of activity and emotional states of both the caregivers and their elderly counterparts. Therefore, we believe this subtle contextual awareness will facilitate the understanding of the affective and activity states of both parties and in turn will help them to respond with the appropriate behaviour. Consequently, this could contribute to improving social connectedness.

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