Inactivity Monitoring for People with Alzheimer's Disease Using Smartphone Technology

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Abstract. Worldwide the number of old and older people is increasing alongside the increase in average life expectancy. Due to this increase the number of age related impairments within the older society, in addition to the prevalence of chronic disease are also heightened. One of the most widespread chronic diseases is dementia, specifically Alzheimer's disease (AD). AD is a brain related condition which impairs a person's memory, thought and judgment. The aim of the current research has been to identify and alleviate a set of problems related to AD using smartphone technology. In order to determine if the level of support for those suffering from AD can be improved, our current work investigates the use of activity/inactivity monitoring using various smartphone services. Inactivity levels are being monitored in order to detect if a smartphone handset has been misplaced unintentionally, and to avoid any impact this may have on smartphone services. Specifically, GSM signal strength, Wi-Fi signal strength and accelerometer data are considered. Three smartphone applications have been developed and tested on a cohort of 8 healthy adult users as part of a pre-study investigation. Results from the pre-study indicate that the optimal approach to detect inactivity on a smartphone handset was via GSM signal strength coupled with accelerometer data.

Keywords: Alzheimer's disease, Smartphone Technology, Assistive Technologies.

1 Introduction

In 2008 the number of old people (aged 60+) worldwide was estimated at 506 million [1]. By the year 2050 this figure is expected to increase significantly and reach 2 billion [2]. Alongside the increase in the number of old people the average life expectancy has also increased, from 55 years old in the early 1990's to around 80 years old at the end of 2007 [3]. As the size of the older population continues to rise, the risk of developing age related impairments and chronic disease is also growing.

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Chronic diseases can be described as diseases of long duration and generally slow in progress [4]. Figures published by the World Health Organisation estimate that 75% of the older population have at least one chronic disease [5]. One of the most common chronic diseases within the older population is dementia [6], a term that describes a number of brain related diseases. The most prevalent form of dementia is Alzheimer's disease (AD) [7]. Symptoms of AD include changes in cognitive decline, decreased judgment and a decreased ability in thought. In 2010 the number of persons with AD (PwAD) worldwide stood at 6.5 million, with on average £25,472 being spent on care costs per person each year [8] [9]. Based on these figures it seems evident that efforts should be made in order to help further assist PwAD on a daily basis. One possible solution to this problem is the use of Information and Communication Technology (ICT) in the form of smartphones.

2 Smartphone Technology

The use of mobile phone technology has steadily become a part of everyday life within today's society. In 2009 the number of mobile phone subscriptions worldwide was estimated at 4.6 billion [10]. Modern mobile phones are now referred to as smartphones and offer a wide variety of functionality over and above traditional voice communications. Smartphones now typically include full internet access including email, short messaging service (SMS), multimedia messaging service (MMS), a build-in camera and video recorder, Wi-Fi, GPS, video conferencing and a wide range of downloadable software applications. Another major benefit of smartphone technology is the ability to send and receive a wide variety of information in real-time. Due to this level of functionality, the use of smartphone technology is now being used within a variety of domains including disease management; health monitoring and health interventions, to name but a few [11]. Clinicians regularly use smartphone to view patient test results, drug information, as a personal organiser and to keep in contact with work colleagues and patients on a daily basis [12].

The overarching aim of this research has been to alleviate a set of problems associated with AD using services deployed through smartphone technology [13]. More specifically, we investigate as part of a pre-study, solutions that may provide higher levels of support through context aware based applications. The aim of the current pre-study is to examine ways of monitoring a person's/smartphones activity in order to detect inactivity within the home environment. This is being carried out in order to eliminate the smartphone handset being misplaced and to avoid the impact this would have on the associated smartphone services. When inactivity is identified, an intervention via a reminder message alert will be triggered. This will be performed through the use of non-invasive smartphone technology via built-in services.

3 Smartphone Applications for PwAD

As part of our ongoing research based on the unmet needs of PwAD, as identified by Lauriks *et al.* [14] as the need to remember, the need for social contact, the need for safety and the need for support regarding activities of daily living (ADL), we have previously developed a suite of smartphone applications to help assist with these unmet needs [13]. These prior applications included an ADL reminder application, a picture dialing/SMS application, a geo-fencing application and a one hour reminder application. In order to test the design and functionality of the smartphone applications they were evaluated by a control group which consisted of 15 healthy adult participants. Results from this previous research had demonstrated that participants felt comfortable interacting with a smartphone [13]. Nevertheless, one problem that was identified from this phase of the work was, due to memory impairments of PwAD, there was a high probability that a participant may forget to lift the handset or misplace it, hence compromising the utility of the applications.

In order to combat this risk, an activity/inactivity monitor application has been incorporated within the set of applications. If inactivity is detected by the handset, it may be assumed that the smartphone handset is not being carried by a participant/PwAD and therefore they may need reminded to lift the device. Ideally when inactivity is detected the handset should automatically trigger an alert in order to allow participants/PwAD to avail of the smartphone services. We then decided to look at various ways of monitoring activity from the handset itself. The rationale for this was to offer the ability for the smartphone applications to be used as a standalone device, which can either be used both inside and outside of the home environment. This is also the least intrusive way of collecting data. Example systems that unitize the use of smartphone technology in order to monitor patient activity include the Context Aware Remote Monitoring Assistant (CARMA) [15], a system which uses various built in sensors including accelerometer data on a smartphone handset in order to monitor a person's daily activity levels. Likewise Zhang *et al.* [16] have developed a system to help monitor a person's activates. The system can detect whether a person is walking, standing, sitting or lying via accelerometer data collected on a smartphone handset. The aim of the current work has been to detect inactivity as opposed to activity on a smartphone handset through alternative built in services on a smartphone handset alongside accelerometer data.

4 Methods

In order to monitor activity/inactivity directly from the smartphone we decided to consider the built-in services already available within the handset. The smartphone of choice was a HTC touch HD device, running the Windows Mobile 6.1 Operating System. This handset was selected due to its rich features and large 3.8 inch touch screen interface. The smartphone applications were created using Visual Studio 2008 and developed using C#. The following three services were considered:

4.1 GSM Signal Strength

An application was created that records the phone's current signal strength directly from the handset every 5 seconds. For the purposes of the study the recordings were automatically saved to local storage on the phone handset. The motivation for this was based on the hypothesis that if the signal strength on the handset did not change over a predetermined period of time, this may indicate that the handset had been misplaced or was left in a stationary position. This could subsequently form the basis to pre-empt the triggering of an alert.

4.2 Wi-Fi Signal Strength

Wi-Fi signal strength on the handset was also considered to ascertain if the handset's inactivity could be detected. Using the same methodology as the GSM application, we created a Wi-Fi application. Wi-Fi signal strength was sampled and recorded every 5 seconds and stored on the phone.

4.3 Accelerometer Data

Thirdly and finally the accelerometer data on the smartphone was considered. The accelerometer data was sampled every 0.5 seconds as opposed to the 5 second rate with the previous measures, in order to detect any sudden movement changes.

4.4 Combination of GSM/Wi-Fi/Accelerometer data

All three smartphone applications were tested simultaneously. This was carried out in order to determine if the applications above could be used to complement each other.

In order to test the applications individually, we positioned the smartphone handset in 4 different specific marked locations. We decided to position the smartphone handset at 4 different corners within one large room (Figure 1), 2 corners by the window and 2 corners nearer the door (the room remained out of bounds during testing in order to avoid any potential disruption). Each application, after being placed within the room ran for 10 minutes.

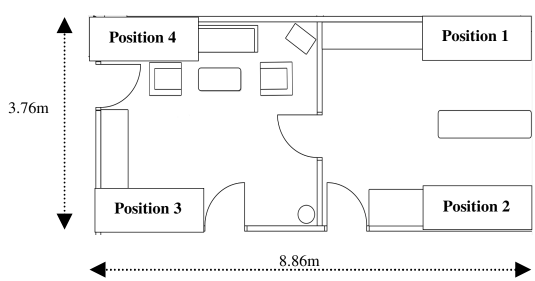


Fig. 1. Floor plan of room used to carry out testing

5 Results

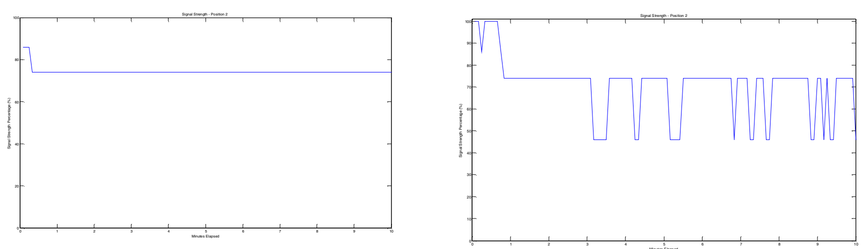
To allow comparison of results and to reduce bias the testing phase was repeated 4 times using two different HTC handsets, a HTC Touch HD and a HTC HD 2. Two different mobile phone networks were also used throughout testing, one with a frequency of 900MHz and another with a frequency of 2100MHz.

5.1 GSM Signal Strength

Results from the testing of the signal strength application demonstrated correlation with environmental surroundings (refer to Table 1). There did appear to be a pattern of little variance when the device was stationary (refer to Figure 2a). Nevertheless, this is not always the case, as in some instances there was a fluxion in recorded GSM signal strength when the phone was stationary. Examples of specific instances include when the phone was positioned at a window in an empty room with no disruptions (refer to Figure 2b).

Table 1. Average signal strength from each position for each handset and network (N)

	HTC Touch HD (N1)	HTC Touch HD (N2)	HTC HD 2 (N1)	HTC HD 2 (N2)
Position 1	85.03	99.79	64.17	100
Position 2	74.18	100	69.12	100
Position 3	79.76	75.43	73.14	100
Position 3	84.86	76.22	98.80	99.66



(a) (b)

Fig. 2. Signal strength on smartphone handset positioned by window in position 2 for 10 minutes on network 1 using (a) HTC Touch HD (b) HTC HD 2

5.2 Wi-Fi

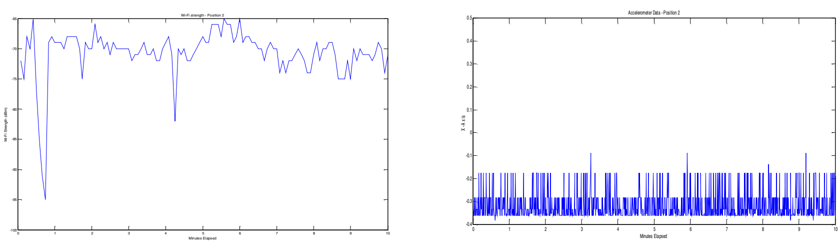
After testing the GSM signal strength application, the Wi-Fi application was then evaluated. Results from this application demonstrated that although the handset was placed in a stationary position, inside an empty room with no interruptions, the recorded Wi-Fi signal strength did fluctuate, regardless of the handset's activity. This was the case throughout all Wi-Fi evaluations, and evident throughout all data collected during the testing phase. For this stage of evaluation we tested the Wi-Fi application using 2 different HTC handsets and excluded the two different mobile phone networks, average results can be viewed below (refer to Table 2). An example of an instance is also presented in Figure 3a.

Table 2. Average Wi-Fi strength from each position, for each handset

	HTC Touch HD	HTC HD 2
Position 1	-70.62	- 68.56
Position 2	-72.05	- 71.34
Position 3	-72.82	- 69.45
Position 3	-72.57	- 71.87

5.3 Accelerometer Data

Lastly, we tested the accelerometer application created for the smartphone using the same methodology as before. Results from this phase of testing showed very accurate results regarding the handset's activity. An example of an instance is shown below (refer to Figure 3b).

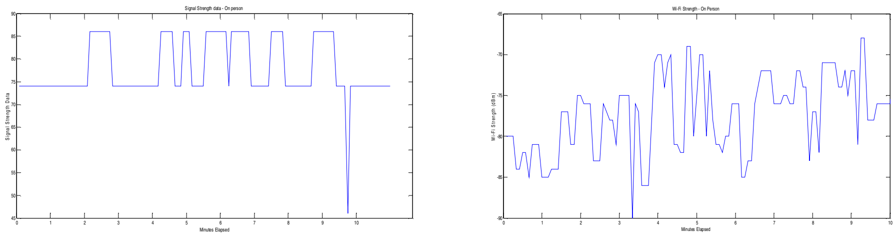


(a) (b)

Fig. 3. (a) Wi-Fi strength (b) Accelerometer data on smartphone handset while positioned by window in position 2 for 10 minutes on smartphone

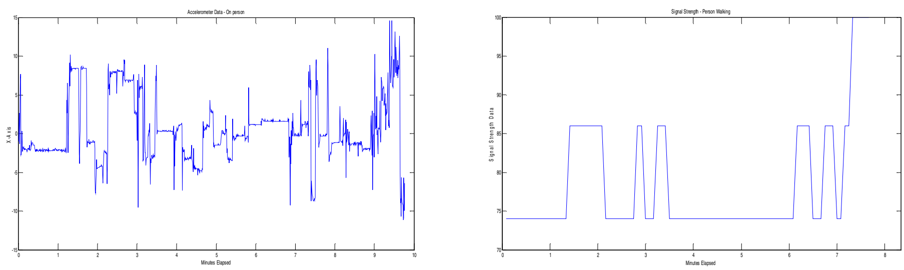
5.4 Three Services Combined (GSM/Wi-Fi/Accelerometer Data)

After the testing phase detailed above was complete, all three applications were considered together within one application. In order to do this GSM, Wi-Fi, and accelerometer data were collected concurrently. To test this application we carried out a further 8 evaluations on a control group of adult participants. Each evaluation lasted 30 minutes. Throughout the evaluation phase participants were asked to hold the smartphone on their person (place of their choice) and sit/walk around/place the phone stationary in front of them on a desk, for 10 minutes each time. Results from both the sitting phase and walking phase were as predicted varied. In order to compare results an example data set for the Wi-Fi, GSM and accelerometer data from a 10 minute sitting test for all three applications is presented in Figures 4a, 4b and 5a. A further example data set for the Wi-Fi, signal strength and accelerometer data while a person is walking around for 10 minutes is presented in Figures 5b, 6a and 6b.



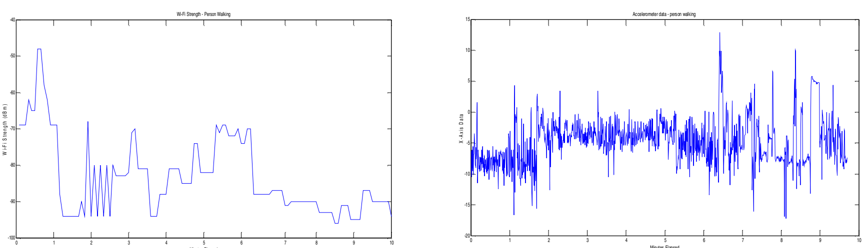
(a) (b)

Fig. 4. (a) Signal strength (b) Wi-Fi from a sitting (on person) test over a 10 minute period



(a) (b)

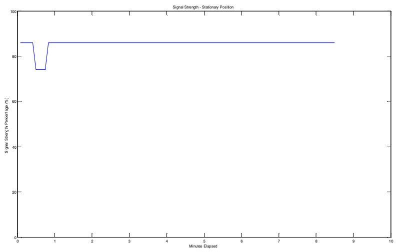
Fig. 5. (a) Accelerometer data from a sitting (on person) test over a 10 minute period (b) Signal strength data from a person walking around over a 10 minute period



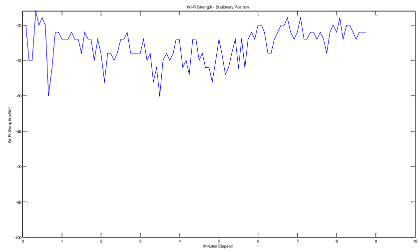
(a) (b)

Fig. 6. (a) Wi-Fi (b) Accelerometer data from a person walking over a 10 minute period

Nevertheless, results from the phone being positioned on its own proved very promising, even with disruptions in and around the environment. Example results from a 10 minute stationary test for all three applications carried out at the same time are presented in Figures 7a, 7b and 7c.



(a)



(b)

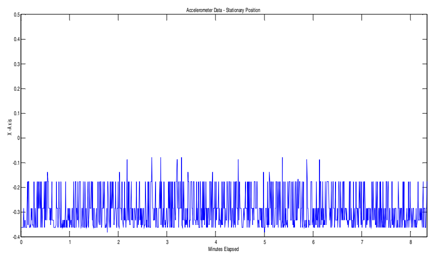


Fig. 7. (a) Signal strength (b) Wi-Fi (c) Accelerometer readings from stationary smartphone over a 10 minute period

Overall, results from this testing phase show that as before, the accelerometer data application is very accurate in detecting activity/inactivity on a smartphone handset. The signal strength tests have also shown promising results. It is therefore though that by coupling both applications, the GSM signal strength and the accelerometer application, it may be possible to detect inactivity within the home environment with an even higher degree of accuracy. The Wi-Fi application has been discounted as a reliable way of detecting inactivity, due to the high level of change in recordings.

6 Conclusion and Further Work

As the old and older society continues to grow, the increase in chronic disease will also ascend. Although there is no cure for chronic disease with the help of assistive technologies conditions such as memory impairment may be effectively managed. Not only do assistive devices provide support for PwAD, they may also relieve caregiver stress and burden. Further work focusing on the signal strength and accelerometer applications will need to be carried out in order to determine if a standalone smartphone can actually detect inactivity within with home environment, in a non-intrusive manner. We will also be incorporating the alert function within the application; this will be triggered when inactivity has been detected. We believe that through the use of ICT in the form of smartphone technology, assistive technologies such as smartphones can be incorporated easily into everyday life [17].

References

1. Kinsella, K., He, W.: An Aging world: 2008, International Population reports, US Census Bureau (June 2009)
2. United Nations Department of Economic and Social Affairs, Report Population Aging (2006)
3. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Ageing well in the Information Society – A i2010 Initiative – Action Plan on Information and Communication Technologies and Ageing {SEC(2007)811} /* COM/2007/0332 final
4. World Health Organisation, Health and Chronic disease, http://www.who.int/topics/chronic_diseases/en/
5. Busse, R., et al.: Tackling Chronic Disease in Europe, Strategies, interventions and challenges, Observatory Studies Series No. 20 (2010)
6. Alzheimer's Association, 2009 Alzheimer's disease Facts and Figures. Alzheimer's & Dementia 5(3) (February 2009)
7. Communication from the Commission to the council and the European Parliament, in a European initiative on Alzheimer's disease and other dementias, Brussels, COM (2009) 380 final, {SEC(2009) 1040}{SEC(2009) 1041} (July 22, 2009)
8. Alzheimer's Association, 2010 Alzheimer's disease Facts and Figures. Alzheimer's & Dementia 6 (February 2010)
9. Improving Dementia service in Northern Ireland: A regional strategy (September 2010)
10. World Health Organisation, Electromagnetic fields and public health: mobile phone (June 2010), http://www.who.int/mediacentre/factsheets/fs296/en/
11. Blake, H.: Innovation in practice: mobile phone technology in patient care, Professional Issues
12. Ubaydli, A., Paton, C.: The Doctors PDA and Smartphone handbook. Journal of The Royal Society of Medicine 99(3), 120–124 (2006)
13. Armstrong, N., Nugent, C.D., Moore, G., Finlay, D.: Developing Smartphone applications for people with Alzheimer's disease. In: 10th IEEE International Conference on Information Technology and Applications in Biomedicine, ITAB 2010, Corfu, November 3-5, pp. 1–5 (2010)
14. Lauriks, et al.: Review of ICT-based services for identified unmet needs of people with dementia. Aging Research Reviews 6(3), 223–246 (2007)
15. Lau, et al.: Supporting Patient Monitoring Using Activity Recognition with a smartphone. In: 7th International Symposium Wireless Communication Systems (ISWCS), York, September 19-22, pp. 810–814 (2010)
16. Zhang, et al.: Activity monitoring using a smart phones accelerometer with hierarchical classification. In: Intelligent Environments Sixth International Conference 2010, Kuala Lumpur, July 19-21, pp. 158–163 (2010)
17. Armstrong, N., Nugent, C.D., Moore, G., Finlay, D.D.: Using smartphones to address the needs of persons with Alzheimer's disease. Annals of Telecommunications 65 (2010)