Trialling a Personal Falls Monitoring System using Smart Phone

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Abstract

This paper describes a personal falls monitoring project using smart phone based tri-axial accelerometry, for surveillance of elderly people with falls risk living independently at home. The project relied on collaboration of three parties to achieve its clinical, research and technology aims. The results of data collection during the six month trial period are presented and analysed here. These results indicate a very high rate of false positives (94.7%) which would need to be addressed in future development of the system.

Keywords: falls, smart phone, personal monitoring.

1 Introduction

Falls in elderly people is a serious public health concern worldwide especially in the context of aging population (M. Tinetti et al. 1988; WHO 2007; WISQARS 2013). With the probability of about one fall each year, falling is a common phenomenon among community-dwelling elderly aged 65 and over (Campbell et al. 1981; Hausdorff et al. 2001; M. Tinetti et al. 1988; WISQARS 2013). Falling is an important source of morbidity for elderly people, causing both minor and major injuries. Up to 10% of community-dwelling elderly people who fall each year sustain a serious injury such as a fracture and head injury (Robertson et al. 2001; Sattin 1992). Fall-related serious injuries can lead to long terms hospitalization, disability, and mortality (Elkington 2002; WHO 2007). The rate of serious injuries of fall increases with age (Kingma and Ten-Duis 2000). In Australia, falling is the leading cause of deaths due to injuries; mortality from falls is more frequent than mortality from road accidents (ABS 2012; Bradley 2013). Fall injury can also be psychosocial, affecting peoples' self-confidence and capacity for independent living (Lord et al. 2007). Moreover, fall-related injuries in elderly people involve considerable cost for health care systems. A recent falls report estimated that the total annual cost of fall-related acute episodes of hospital care for elderly people was $648.2 million (ABS 2012). The lifetime costs of elderly falls in Australia were estimated to exceed $1 billion per year (Moller 2003).

2 Falls Monitoring

Different approaches have been introduced to manage falls in elderly people. Some of those approaches try to predict and prevent falls through interventional programs, for example with multifactorial intervention, exercise, and vitamin D supplementation (Gillespie et al. 2009); while other approaches focus on detecting falls during and after they happen (Day 2013). Detecting a fall after it happens is of particular importance clinically. There is direct relation between the seriousness of fall injuries and the longer time the person remains on the floor following a fall (i.e., 'long-lie') (Wild et al. 1981). Even with no direct injury from fall, about half of the elderly people who experience a long-lie die within 6 months (Wild et al. 1981). More than 20% of elderly people admitted to hospital following a fall reported a history of a long-lie (Vellas et al. 1987), and up to 47% of non-injured fallers were unable to get up from the floor without assistance (M. E. Tinetti et al. 1993). Therefore, rapid detection and management of falls in elderly people can reduce the risk of serious consequences of falls and increase the safety of independent living for this cohort (Bradley 2013).

Application of tri-axial accelerometry, either alone or in combination with other technologies such as gyroscope, has been the most favoured approach for fall detection (Bagala et al. 2012; Campo and Grangereau 2008). However, many of the studies on this technology have been done via simulation or lab based experiments. Application of this technology for detecting falls in community-dwelling elderly people is a quite innovative and challenging area in telehealth. It is challenging not only because fall detection algorithms have typically been developed and tested based on laboratory experiments and data (Kangas et al. 2012) [22], but also because using fall detection technology in real life has its own sociotechnical complexities (Bagala et al. 2012).

3 Project Description

The Telehealth Research & Innovation Laboratory (THRIL) at University of Western Sydney (UWS) was involved in a project managed by the Australian aged care support organisation Anglicare on monitoring possible falls in community-dwelling elderly people, using smart phone based tri-axial accelerometry, in 2012.

A process had been put in place by Anglicare for Aged Care Assessment Team (ACAT) reviews to be conducted for an older person when they were hospitalised due to a fall-related injury, to determine whether they needed care to help manage their falling risk and if they were frightened of the possibility of falling and sustaining a major injury. In some cases, they were referred for admission to assisted care facilities. There was no scheme for active support and assurance of their safety available at this time, so the elderly could not continue to live within their own home if the risk of falling again was high. This motivated Anglicare to initiate a six month trial to determine whether smart phones could be effective for surveillance of elderly people with falls risk living independently at home.

The main objective of this project was to provide data which could be used to prevent and minimize the occurrence of falls in the elderly by detecting movement patterns that indicate potential falls, and changes in gait that increase the risk of falling. It also alerted a call centre or carer for possible intervention, if the data indicated that a participant was becoming unsteady or apparently had sustained a fall, so that clinical support could be provided accordingly. At the same time, participants also used the technology manually to alert their carers of emergency fall situations.

4 Methodology

The architecture of the project consisted of software to detect over-acceleration from a waist-mounted device containing tri-axial accelerometer technology (installed in a smart phone), a communicating mechanisms to transfer data packets from the smart phone to the fall management and data storing systems over a network, and a call centre for monitoring recorded Possible Fall (PF) and Emergency Alarm (EA) events of the participants (see Figure1).

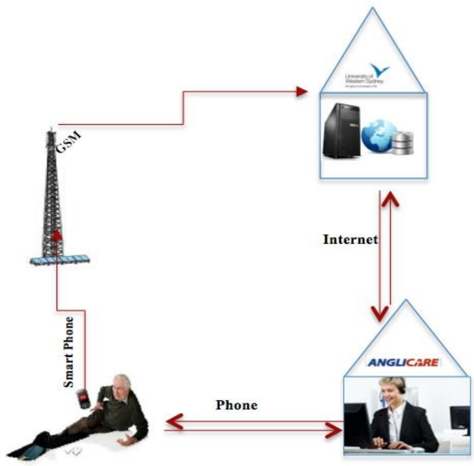

Figure 1. The project architecture.

The trial ran between May to October 2012. Elderly participants, who had a diverse range of clinical problems and disability issues, were recruited through Anglicare's 'falls community service program'. The interventions involved the use of a mobile phone to record and transmit tri-axial accelerometer readings that would provide remote falls monitoring data. Alarm thresholds could be set to alert a call centre or carer for possible assistance in case of emergencies or to identify at-risk situations. The raw falls monitoring data and event information was transmitted and stored in a central repository located at UWS that could be viewed online via a Web interface. Through this facility, clinical carers would be better informed of falls occurring in a person's home and intervene as clinically appropriate. The comparison of falls and hospitalisation occurred with a non-intervention group, mainly acquired from past hospital records for an equivalent period to the trial in the previous year (April to October 2011).

The fall detecting software (Mediiware InspectLife) was installed into a smart phone (Samsung i555) with Android 2.2 operating system and capability to detect movement using tri-axial accelerometers. The system was able to detect over-accelerations (> 27 m/s2) due to PFs and broadcast them to the fall management system over a GSM digital cellar network. The technology included an "alarm" functionality that allowed sending alert messages to the call centre either automatically in case of sustained fall, or manually through touching a red touch-button on the device's touchscreen. Following detection of PF or EA events, the system also sent SMS messages to a clinical caregiver (the project coordinator) for follow up.

A web-based fall management system (InspectLife Surveillence) was used for listing broadcasted events despatched by the smart phones (see Figure 2). Each participant had a personal profile held in the fall management system database. This profile included the elderly person's basic demographic data, important medical history (including fall history), and a record of all the sentinel events received from his/her smart phone. The project coordinator had access to this system and was in charge of monitoring the received events and handling them. Four types of sentinel events were recorded in the system: possible fall (PF), emergency alarm (EA), low battery, and lost connection. The coordinator contacted the participants to gather information about each of their events registered in the system, confirmed if a real fall had happened, collected information regarding each of the recorded events, and inserted comments on them on the subject's profile.

5 Results

The trial provided preliminary data analysis for a number of falls case studies that provide insight into the monitoring of tri-axial accelerometer signals and the detection of real falls in the home environment. 54 people completed the trial while the remaining participants discontinued the trial for various reasons.

There were 6 participants who fell and were wearing their devices at the time of the fall, but no hospitalisation was necessary as a result of these falls. Among them, 2 participants fell several times each. There were also 7 falls from 6 other participants although they were not using their devices at the particular time of the falls, and of these 2 falls resulted in hospitalization. The total number of fall was 50% lower than the proportion of participants who sustained a fall in the non-intervention group for the previous year. The hospitalisation rate of fallers during the trial was similar in proportion to the non-intervention group in 2011.

There were 51 mobile devices collecting data, 29 on a regular basis and 22 on an irregular basis (e.g. interruptions to service of varying periods). The reasons for irregular data sending and not sending at all in data storage were not discovered. One of the possible reasons

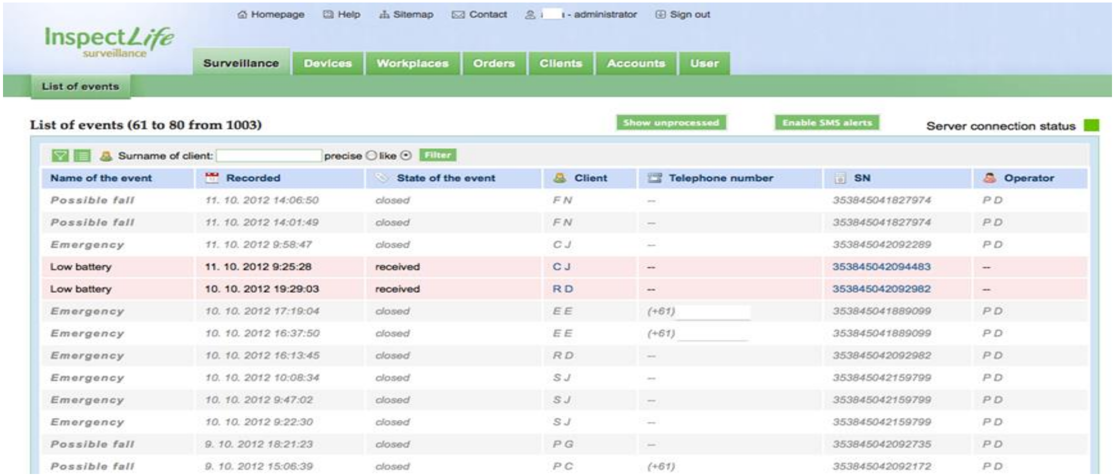

Figure 2. The web-based fall management system.

might be poor network connection due to extensive hilly area and another one might be inadvertent mobile phone setting as 'disable' for network connection.

Throughout the project a total of 769 events were detected by the devices and recorded in the web-based fall management system, of which 456 were PFs and 205 were EAs. Table 1 presents the number of recorded fall events, and their reasons. 229 PFs were created by a user who had a rigid hemiplegia. This case was a consistent user with serious gait problem and an active life that caused too many events to be recorded. In order to have more even data, this case was not considered in our calculations. Of the remaining 227 recorded PFs, only 12 were due to real falls (confirmed by the participants) and all of them were detected by the device. 7 undetected falls were reported to the project coordinator and all of them happened while the participant was not wearing the device. Therefore, the sensitivity of the device was 100% (12/12) while its specificity was 5.3% (12/227) with a false positive rate of 94.7% (215/227).

Types of fall events	# of events
PFs total	456
PFs without the hemiplegic case	227
Real detected falls	12
Real not detected falls	7
PFs without the real detected falls	215

Table 1. The types and number of fall events.

Table 2 presents the number of potential falls and their reasons. Excluding the PFs of the hemiplegic case and the real falls, the most common reason for the remaining 215 recorded PFs was 'forceful/fast movements' (such as fast bending down, sitting down fast, rushing, jumping, walking down stairs) with a frequency of 30.2%. The second most common reason (18.2%) was 'temporary ataxic/losing balance'. An interesting reason was 'external acceleration'. Such a condition happened in 6.1% of cases when a participant was in the car that hit a road bump or turned fast. Some PF categories could show predisposition to fall: these were considered 'clinically relevant' and consisted of 47% of all PFs.

	Reasons	# of events	%
Clinically relevant	Temporary ataxic/ losing balance	39	18.2
	Tipping over (stumbling)	33	15.3
	Problem with gait (e.g. due to knee-ache)	29	13.5
Clinically irrelevant	Forceful/fast movements	65	30.2
	Dropping the device	25	11.6
	External acceleration	13	6.1
	Unknown problem with the device	11	5.1
Total		215	100

Table 2. PF statistics, excluding real falls.

Table 3 presents the number of emergency alarms and their reasons. In evaluating reasons for EAs, it was found that there were 25 EAs for real emergency requests recorded in the system. Excluding these real emergency requests, the most common reason for EAs was bumping the device against something (62.8%) and then accidentally touching the touch button (28.9%).

Reasons	# of events	%
Bumping the device against something	113	62.8
Accidentally touching the emergency button	52	28.9
Unspecified problem with the device	15	8.3
Total	180	100

Table 3. EA statistics, excluding real emergency requests.

6 Discussion

The study results show too many PF events were captured due to various reasons. The falls monitoring device had one version of application software for all participants. Ideally the device should have multiple options as different elderly people suffer diverse medical conditions: for instance, impaired hearing and vision, gait anomalies. Also the fall detection device might need to be developed to be more user friendly, with design considerations particularly for the elderly. The alarm system is an important issue for healthcare monitoring as device wearers can try to contact caregivers instantly using this feature. We found from the study that the alarm is perceived as beneficial to participants but when too many false alarms are detected it produces 'alarm fatigue' for caregivers and device wearers as well. Although healthcare monitoring devices are using mainly for patient safety and quality of care, alarm fatigue is a serious issue in healthcare settings and it has been reported that >80 percent false alarm rates can occur in hospitals (George 2014, Mitka 2013). Therefore substantial improvement of this aspect is needed, for diminishing of both false 'possible falls' and false 'emergency alarm' types of events. In addition to this, the application software for falls monitoring needs to be developed specifically for elderly persons, specifically for falls detection purposes. Design issues include the need for proper labelled images with clear text and audio messages, bigger fonts with appropriate colours. Subsequently users need to receive appropriate training to use the monitoring devices most effectively.

7 Conclusion

The analysis of the data collected shows that the use of the smart phone for personal falls monitoring was subject to a number of limitations, due to both usage and technology issues. A detailed evaluation of these aspects has been reported elsewhere (Pirnejad et al. 2014), explored insight of the trial involved major factors that affect technology adoption and challenges. A number of refinements to the system, at both hardware and software level, would be necessary to ensure robustness. In particular a means of addressing the large number of false positives is needed. Additionally, revision to the human intervention aspects of the process is desirable to avoid high overhead of staff time in processing the data. This would require a more sophisticated approach for detecting falls, based on more customised characterisation of user behavioural patterns.

8 Acknowledgement

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