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Non-Contact Sensor-Based Falls Detection in Residential Aged Care Facilities: Developing a Real-Life Picture

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Abstract. ***Background***. Few studies of sensor-based falls detection devices have monitored older people in their care settings, particularly in Australia. The present investigation addressed this gap by trialling the feasibility and acceptability of a non-contact smart sensor system (NCSSS) to monitor behaviour and detect falls in an Australian residential aged care facility (RACF). ***Methods***. This study used a mixed methods approach: a) Pilot study implementation at a RACF, b) Post-pilot interviews, c) Analysis and review of results. ***Results and discussion.*** Data was collected for four RACF participants over four weeks of the NCSSS pilot. No falls were recorded during the uptime of the system. Numerous feasibility challenges were encountered, for example in the installation, configuration, and location of sensors for optimal detection, network and connectivity issues, and maintenance requirements. These factors may affect NCSSS implementation and adherence.

Keywords. Accidental falls, Aged care, Patient safety, Remote sensing technology

Introduction

Fall and fall injury rates are markedly high in RAC facilities. The Australian Institute for Health and Welfare estimated 9,226 fall injury cases per 100,000 population in RAC facilities in 2010-2011, nearly six times higher than the falls rate for people aged 65+ living at home [1,2]. The burden of injury, disability, and loss of independence caused by falls will be an escalating cost as the proportion of older people increases in Australia. One possible solution is a falls monitoring system, which operates 24x7, automatically alerting staff when either a fall or a movement indicative of potential falls risk occurs, whether the resident is conscious or inactive. This paper describes a study into the feasibility of the implementation of a non-contact smart sensor system (NCSSS) to monitor behaviour and detect falls in a RACF.

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1. Background

Falls monitoring technologies to date have largely been associated with wearable devices (e.g. accelerometers), ambient sensors or camera systems. Each of these approaches has disadvantages affecting efficacy and acceptability. The majority of these systems also focus on either simulated or laboratory activities; studies in real-life situations are less prevalent [3,4]. Multimodal approaches to falls detection and prevention have been piloted in other trials, e.g. the GAL@Home study [5] as a means to study the effectiveness of various sensor systems. Research by Potter and colleagues with acute hospital patients [6,7] found that NCSSS successfully captured true falls and pre-fall activities during the study period. An in-hospital trial of depth sensors combined with bed-exit sensors demonstrated a substantial drop in fall rates compared with the pre-sensor period, and when compared with a control unit with no bed-exit sensors. One notable field test of sensor monitoring is the University of Missouri's *TigerPlace* project, a purpose-built seniors' facility incorporating a mix of sensor types that continuously gather physiological data. These data enable detection of health status changes and trigger alerts to clinicians. A summary of two years' experience with 25 participants noted benefits including earlier detection of health deterioration and avoidance of crisis-related hospital visits [8].

Understanding feasibility, as well as acceptability, of these sensor interventions has been a characteristic of recent studies [e.g 9-10]. Related reviews have also looked specifically at acceptability to older people of activity monitoring systems in the home [11-12]. Peek [12] also found that technology acceptance changes over time, however post-implementation research is still rare.

Most of the relevant studies identified in the background research have been located overseas. Notably, three Australian trials were reported between 2004 - 2014 [10,13,14]. As a result, there is limited information on sensor use and acceptability by patients and staff in Australian RACs. The factors that influence acceptance and continued use of fall monitoring technology in Australian residential aged care can benefit from further investigation.

A principal aim of the present study was to collect and analyse practical implementation data about sensor technologies for falls detection. A secondary objective was to gain an understanding of the feasibility of NCSSS. Critically, the findings aim to explore the acceptability of this system to older Australians living in RAC facilities.

2. Methods

The project used a mixed methods approach comprising three phases: Study implementation at a RACF, using a purposive sampling approach; evaluation and post-study interviews; and analysis and review of results.

The study was conducted in a 170-place RACF with 200 staff, located in Melbourne. The facility was purpose-built less than five years before the study, and the senior management and staff were keen to participate in research activities. The study was planned to run for up to eight weeks.

The prototype NCSSS was tailored for the pilot study by Semantrix Pty Ltd, the Technology provider. System sensor features were: optical, privacy-preserving sensor, non-contact; designed for 24/7 operation; on-board cognitive processing and skeletal pose tracking suited to an indoor environment [Figure 1]. The system was calibrated to detect articulation movement patterns representing falls or other selected behaviour e.g. attempt to exit bed unaided. The sensors were modified to a) suppress system alerts (due to the system's experimental status, to reduce demands on nursing staff if alert conditions occurred); b) generate an additional depth map image for post-trial analysis.

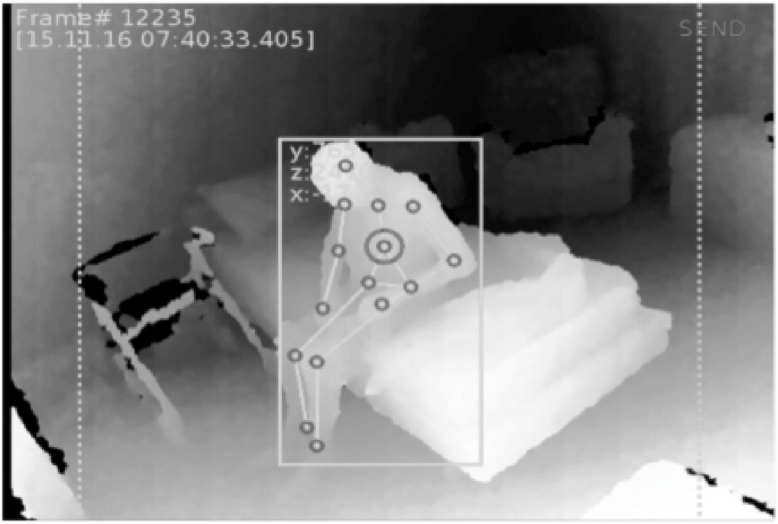

Figure 1. Example of a depth image map generated by the smart sensor system (Image courtesy of Semantrix Pty Ltd).

One bedroom in the RACF was used to test the sensor system, checking for optimal sensor placement, network connectivity, data flows and data capture to the offsite sensor database. This test highlighted a number of issues which required resolution before the roll-out. Significant customization and adjustment was needed, as the rooms had slightly different configurations. The NCSSS was configured to alert for falls, trips, or slips. A dataflow system was developed to inform infrastructure needed for sensor data generation and capture, secure storage, and retrieval for analysis. The 24/7 'movement monitoring' was enabled with approximately 18GB-25GB of data generated per day/per room. Resulting files averaged 21GB as sensor data blocks comprising high compression files (tar.gz) which were saved to a secure, dedicated server.

3. Results and Discussion

Four male residents (average age 87 years) participated in the pilot study. Each resided in a single room with *en suite* bathroom. All were assessed as high care: three used a 4-wheel walking frame as a gait aid; the fourth used a wheelchair when moving beyond his room. All patients needed staff help or supervision for mobility. Two participants were diagnosed with clinical dementia. All participants were identified as having a high falls risk: one patient had fallen 13 times during a 6-month period, another had recorded five falls in a similar period.

In total, 8 sensors were installed in the 4 residents' units: one in the bedroom, another in the bathroom. These generated data for a combined total of 122 days. The average monitoring period was 17.5 days. Disruptions to monitoring included network interference and power supply interruptions. One known patient fall incident occurred during the trial; however this was not recorded because it occurred whilst the system was still being commissioned. Unexpected technical difficulties delayed full implementation of sensors in all participants' rooms. It was discovered that some rooms did not have live connections to the facility's network; this required the Technology provider to source an alternative method for networking the devices and collecting the sensor data. This reinforces the need to perform end to end live-testing of hardware and networks in each target room during the test phase, rather than relying on a test in a demonstration room of the facility.

Placement of the sensors required adjustment to overcome radio frequency interference in some rooms. However, positioning the sensors outside the optimal 4-metre patient range caused deterioration in skeletal tracking performance. The accuracy of the pose-tracking element of the sensors is a key component in the system. However, the limitation was corrected by raising the detection level threshold resulting in the capture of a narrower range, so that the tracking was more optimised to a patient's movements within a smaller capture space of physical surroundings by the smart sensor. Clearly there is further work needed with clinicians to reach a realistic calibration for the sensors which balances sensitivity and specificity in falls and behaviour monitoring.

Post-study interviews with key staff elicited strong support for the research because of its potential to reduce falls in either RAC facilities, in hospital or at home. A selection of questions and responses is shown in Figure 2. Despite continuous problem identification with the network and work-arounds in the sensor system deployment, the facility staff retained a positive approach towards the project and willingness to participate. This might underline the importance of falls prediction and prevention methods to RACFs – i.e. aged care professionals are willing to look at innovative solutions. Relatives of the residents were also interested, supportive, and helpful throughout the trial; they too could envisage a range of benefits if the technology were proven to work.

Interview Question	***Response***
Overall what are your feelings about using a technology like this for monitoring behavior and falls detection?	*I'd strongly agree…that it's worth persisting with. When it's up and working correctly, and not falling out of the system, it will give us a good indication of the events leading up to a fall…That would be very useful.*
Do you think the installation, having the sensors in the rooms, made any difference at all to the way staff and residents interacted?	*I really don't think it had any negative impacts on anybody.*
Did you have any hesitation about the visual side, so far as the residents were concerned?	*No, they did tell us it wasn't actually… a visual of their face, it's… stick figures basically. So that's good for privacy and confidentiality, obviously.*
Can you see it having wider applicability in a place like [the RAC facility] or do you think it's more useful where people aren't able to readily communicate themselves?	*I think it would be useful in [the RAC], overall, especially for people that have dementia and can't articulate how the fall happened. It is a good measure of knowing what was leading to the fall and how they did it…*
Has being part of the sensor trial changed your view in any way about whether sensors are useful for falls detection or prediction in the RAC?	*It's exciting where the research is taking us…If it can assist us to be a bit more proactive we're all for it because we want to keep our residents safe.*

Figure 2. Post-trial interview responses by RACF staff.

3.1. Study Limitations

The complexity of providing robust device connectivity, free from interference and within the specifications of sensor device capability (distance from patient in this case), plus, secure data storage and subsequent analysis of data recordings, cannot be underestimated in terms of resource and feasibility. A particular strength of the study is the reinforcement of this complexity in an assistive technology-based pilot.

The small sample size and short duration in this study are key weaknesses. Whilst it is accepted that recruitment of older participants for any study is more difficult than younger subjects, the present low numbers and brief duration of monitoring are unreliable for drawing firm conclusions about performance of smart sensors for falls monitoring.

3.2. Recommendations for Future Work

The capacity of the smart sensor system to accurately identify fall events or activities that may place people at risk of falls, such as walking to the bed unaccompanied, in a real life setting still needs to be established. The corresponding ability of a smart sensor system to reduce time between a fall and assistance being delivered to the patient also needs to be established through future studies.

Existing monitoring at the care facility, namely pressure mat and the nurse call alert systems, was not disabled during this pilot study. However, the possibility that sensor system alerts could be integrated with alerts from existing systems is considered to be highly desirable. Vandenberg [15] argues that a coordinated communication system is essential for responding effectively to fall alerts. Development of an integration approach with an intelligent system to combine, analyse and make sense of the underlying disparate systems data would be a valuable area for further research. Such an intelligent system could learn from the detected and subsequently human verified events, such that predictive ability is enhanced over time reducing false positive or negative alerts.

The current project further highlighted the importance of multidisciplinary research teams to investigate complex real world problems. While the project team had input from researchers with a range of skills, the investigators identified the need for a data technologist to advise during implementation on managing data pathways and data tracking, and to support data correlation across the existing data systems. As the sensors generated large quantities of data, specific skills are highly desirable to organise, transfer and store the raw material and suggest appropriate analytical methods.

This study might prompt further exploration of new instruments in categorizing falls, such as the FARSEEING taxonomy [16] that allows for comparative evaluation. The authors have considered elements of the study using the FARSEEING taxonomy for the purposes of describing the approach and technologies, as well as for supporting the analysis of results. The FARSEEING repository [17] now holds data for more than 300 falls, and the Consortium is actively seeking further reports from literature and researchers in this area.

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