Utilising Wearable and Environmental Sensors to Identify the Context of Gait Performance in the Home

James Lanagan[1], Alan F. Smeaton[1], Brian Caulfield[2]
[1]CLARITY: Centre for Sensor Web Technologies and
School of Computing
Dublin City University, Dublin 9

[2]CLARITY: Centre for Sensor Web Technologies
University College Dublin
Belfield, Dublin 4
{james.lanagan,alan.smeaton}@dcu.ie, b.caulfield@ucd.ie

Abstract

In this paper we describe our work on the development of a multi-sensory deployment within the homes of elderly people prone to falling. The aim of our work is to provide both preventative guidance with regards to environmental hazards, as well as to create rich information context around gait performance, near-falls or falls that do happen so the cause can be diagnosed more thoroughly. We use a gait analysis platform developed at the TRIL Centre, coupled with a SenseCam wearable camera, to identify the activities and the location in the home during walking activities. In addition to this, and to add even more context, we use home energy-monitoring to enhance our understanding of activities and activity patterns in the home. This method could support older people in identifying a key problem and allow the participant to modify their behaviour or environment to limit or prevent future occurrences.

Introduction

Falls are a major cause of injury and fatality for older people. In our work, through the use of environmental, visual, and physical sensors we can create a clearer picture of the interactions of people with the environment around them. Our sensors provide a rich context for gait performance, allowing health professionals to re-construct the circumstances in which motor behaviours that might lead to increased risk of falling (such as increased gait variability) have occurred. Such sensors provide feedback on the movements of elderly people within their homes and information on how a home is being used. Typically a person is unable to remember the events leading up to a near fall incident such as loss of balance, but by using the aforementioned sensors we are able to provide additional context to help diagnosis. The sensors used in our study have each been used in separate and different contexts in the past, and here we unify their contributions.

Related Work

Falls are the number one cause of injury and fatality within the elderly population (O'Loughlin, Robitaille, Boivin, & Suissa, 1993) (Blake, et al., 1988). This doesn't provide the full picture however, as the effects of falls are far-reaching; a fear of falling (the “post-fall syndrome”) leads to a marked decline in the activities of daily living (ADL) (Walker & Howland, 1991). Those who have fallen in the past are more likely to fall in the future, meaning that not only is a burden created on the part of family to provide increased vigilance, but a considerable stress is placed on the victim of a fall.

Methods for reducing falls include education in the use of walking aids and risk management; exercise is seen as an important ongoing preventative measure (Sherrington, Whitney, Lord, Herbert, Cumming, & Close, 2008); *environmental modification* identifies and removes the possible causes of falls (sliding rugs, poor lighting etc.) using home intervention teams (Nikolaus & Bach, 2003) who audit a home for hazards but are expensive. Through the use of visual and environmental sensors, we create an autonomous system to collect information without altering behaviour because of observation and external observer presence.

Implementation

In our work we collect sensor data from the following sensors:

SHIMMER IMU

Shimmer (Sensing Health with Intelligence, Modularity, Mobility and Experimental Reusability) is a small wireless sensor platform that can record and transmit physiological and kinematic data in real-time. SHIMMER can incorporate wireless ECG, EMG, GSR, Accelerometer, Gyro, PIR, Tilt and Vibration sensors. This range of contact and non-sensing capabilities is reliable in clinical and in home-based usage scenarios (Burns, et al., 2010).

Figure 1. The SHIMMER platform.

The platform has been used in the past to provide measures for gait analysis (O'Donovan, Greene, McGrath, O'Neill, Burns, & Caulfield, 2009). The device itself is about the size of a wristwatch and fits on the shank of the wearer, providing data on multiple gait variables.

SenseCam

The Microsoft SenseCam is a small wearable, passive-capture camera typically hung from a lanyard around the neck designed to capture a person’s day-to-day activities as a series of photographs and readings

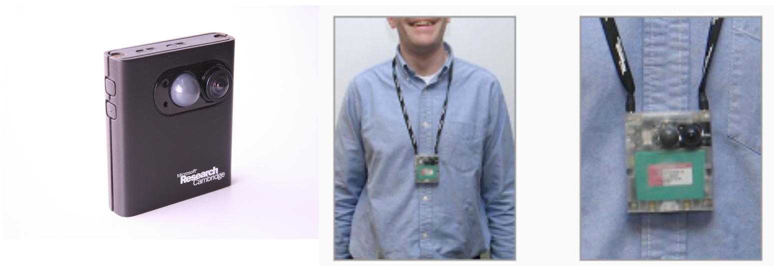

Figure 2. The SenseCam and prototype shown as worn by a user.

from in-built sensors (Hodges, et al., 2006).

The SenseCam's built-in sensors monitor the environment of the wearer and include an accelerometer, a passive infra-red sensor, a light sensor, and an ambient temperature sensor. SenseCam takes a picture every 30 seconds, or when triggered by onboard sensors. Regular viewing of one's own SenseCam images has been shown to be effective in improving short-term memory and cognitive function (Berry, et al., 2007).

By using the SenseCam in conjunction with analytic software, we can identify abnormal events that may be indicative of potential fall scenarios. The images captured by the SenseCam also provide a strong level of context to events. Additionally, we are also able to automatically identify semantic concepts appearing within the images themselves (Doherty, Ó Conaire, Blighe, Smeaton, & O'Connor, 2008) to infer activities like eating, watching television etc.

Monitoring Home Energy Usage

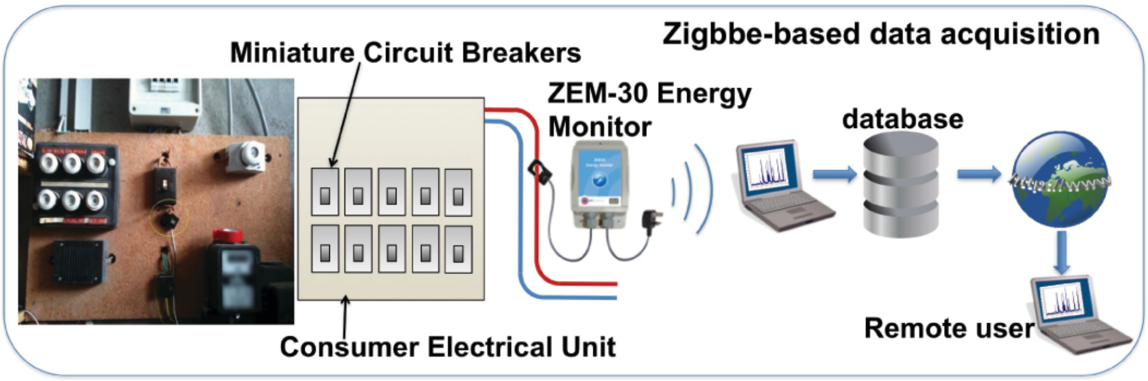

Figure 3. Overview of capturing home electricity usage data and uploading to a central server

Analysis of the electrical power usage of a home provides appliance signatures that enable identification of different types of household appliance usage (Ruzzelli, Nicolas, Schoofs, & O'Hare, 2010). This can infer additional contextual information about activities in the home that can be used to clarify or enforce classified/recognised events from other sensor platforms e.g. a kettle being switched on is a good indication of its presence within the associated SenseCam images, as well as providing a possible 'kitchen' context to SHIMMER gait data.

Methodology

Older participants – 60 years and over with no cognitive impairment and living independently – are being recruited for our study. We install energy monitoring and describe how and when the SenseCam and SHIMMER sensors are to be worn. Participants will be asked to wear the devices for 4 weeks and at the time of writing, the first of these deployments has commenced. Each week we gather the SenseCam and SHIMMER data onto a laptop.

Algorithms developed within our research group are used to automatically identify activities that the participant was doing throughout the day – walking, preparing food watching TV, etc. – from within the SenseCam images. These algorithms utilise features such as colour and shapes from within the images. Simultaneous to the SenseCam image analysis, we will analyse information from our other two sensors. Using the appliance signatures we can more accurately identify the physical context of temporally aligned SenseCam images, while information from the SHIMMER fall detector can be combined with SenseCam images to create contextual information for any events/incidents.

Discussion

Falls are the single largest cause of injury related mortality in the older population, and as the average population age increases this will become a bigger issue. Through the use of simple wearable and environmental sensing we believe we can increase independence by identifying and modifying possible environmental hazards as well as being able to *re-live* falls and near-falls through the rich context data we gather.

Acknowledgements

This work is supported by Science Foundation Ireland under grant 07/CE/I1147.

Bibliography

Walker, J., & Howland, J. (1991). Falls and Fear of Falling Among Elderly Persons Living in the Community: Occupational Therapy Interventions. *The American Journal of Occupational Therapy , 45* (2), 119.

Burns, A., Greene, B., McGrath, M., O'Shea, T., Kuris, B., Ayer, S., et al. (2010). SHIMMER™ – A Wireless Sensor Platform for Noninvasive Biomedical Research. *Sensors Journal , 10* (9), 1527-1534.

Berry, E., Kapur, N., Williams, L., Hodges, S., Watson, P., Smyth, G., et al. (2007). The Use of a Wearable Camera, SenseCam, as a Pictorial Diary to Improve Autobiographical Memory in a Patient with Limbic Encephalitis: A Preliminary Report. *Neuropsychological Rehabilitation , 4* (5), 582-6-1.

Blake, A., Morgan, K., Bendall, M., Dallosso, H., Ebrahim, S., Arie, T., et al. (1988). Falls by Elderly People at Home: Prevalence and Associated Factors. *Age and Ageing , 17* (6), 365.

Doherty, A. R., Ó Conaire, C., Blighe, M., Smeaton, A. F., & O'Connor, N. E. (2008). Combining Image Descriptors to Effectively Retrieve Events from Visual Lifelogs. *MIR '08:Proceeding of the 1st ACM International Conference on Multimedia Information Retrieval* (pp. 10-17). Vancouver: ACM.

Hodges, S., Williams, L., Berry, E., Izadi, S., Srinivasan, J., Butler, A., et al. (2006). SenseCam: A Retrospective Memory Aid. *UbiComp - 8th International Conference on Ubiquitous Computing.* California: ACM.

Nikolaus, T., & Bach, M. (2003). Preventing Falls in Community-Dwelling Frail Older People Using a Home Intervention Team (HIT): Results from the Randomized Falls-HIT Trial. *Journal of the American Geriatrics Society , 51* (3), 300-305.

O'Donovan, K., Greene, B., McGrath, D., O'Neill, R., Burns, A., & Caulfield, B. (2009). SHIMMER: A New Tool for Temporal Gait Analysis. *EMBC 2009. Annual International Conference of the IEEE* (pp. 3826-3829). Minneapolis: IEEE.

O'Loughlin, J., Robitaille, Y., Boivin, J., & Suissa, S. (1993). Incidence of and Risk Factors for Falls and Injurious Falls Among the Community-Dwelling Elderly. *American Journal of Epidemiology , 137* (3), 342.

Sherrington, C., Whitney, J., Lord, S., Herbert, R., Cumming, R., & Close, J. (2008). Effective Exercise for the Prevention of Falls: A Systematic Review and Meta-Analysis. *Journal of the American Geriatrics Society , 56* (12), 2234-2243.

Ruzzelli, A., Nicolas, C., Schoofs, A., & O'Hare, G. (2010). Real-Time Recognition and Profiling of Appliances through a Single Electricity Sensor. *SECON'10: 7th Annual IEEE Communications Society Conference on Sensor Mesh and Ad Hoc Communications and Networks* (pp. 1-9). Boston: IEEE.