Assisted Living Services for Reminding and Prompting Activities of Daily Living

A Preliminary Case Study

X Hong, C Nugent, S Devlin, M Mulvenna, J Wallace
School of Computing and Mathematics and Computer Science Research Institute

S Martin
School of Health Sciences and Health and Rehabilitation Sciences Research Institute

University of Ulster, Northern Ireland, UK
{x.hong; cd.nugent; s.devlin; md.mulvenna; jg.wallace; s.martin}@ulster.ac.uk

Abstract—**Smart Homes provide an infrastructure for implementing the 'ageing in place' paradigm. Assisted living services are essential features within a smart home. This paper presents the details of preliminary work in the development of a context-aware assistance system that can be used pervasively within smart homes. We have investigated the issues surrounding the provision of assistance in undertaking activities of daily living within a smart home and have subsequently outlined a framework to address the identified challenges. The work is currently under development and plans have been made for evaluation within a simulated living environment.**

Keywords- activities of daily living; context-aware assistance; care plan; pervasive sensing.

I. Introduction

The world has been experiencing a rapid growth of the ageing population. Though ageing itself is not the direct problem, the issues arise from the natural factors of ageing such as decreased physical and mental abilities that can result in persons being less able to perform activities of daily living (ADLs) and consequently requiring both formal and informal care support.

Challenges from the demographic change and technological advancements have witnessed the emergence of a new approach for long-term health and social care provision for the elderly. Ageing in place refers to "living where you have lived for many years, or living in a non-healthcare environment, and using products, services and conveniences to enable you to not have to move as circumstances change"[1]. This approach meets the demands of the ageing world on several accounts:

(1) The majority of the elderly prefer to remain in their own home for as long as they can [2][3][4].

(2) The use of healthcare resources can be made optimal to minimise pressures in terms of financial expenses of hospitalisation / institutionalisation and shortages of medical / care professionals [2][5].

(3) Living in familiar environments calms anxieties and reduces stress hence helps alleviate the additional burdens of being hospitalised or institutionalised [6][7].

Ageing in place can, to a certain extent, be realised through the establishment of Smart Homes, where assistive living technology enhances home environments providing services to assist the elderly to live independently, more safely and with an improved quality of life. The main aim in creating an acceptable assistive living environment is that inhabitants are provided with necessary assistive services, however, minimal intrusion is introduced into their lives.

Advances in pervasive sensing technology enable Smart Homes to automatically monitor the state change of the environment and the behaviour of the inhabitants. There are also many other sources that hold knowledge about inhabitants such as care plans and medical histories, to name but a few. This research is currently investigating different approaches to providing the elderly within smart homes efficient and effective assistance in completing ADLs by availing of four types of contextual inhabitant related information: care plan, activities, location and personal preferences.

II. Related Work

A number of studies have been conducted which address the topic of providing assistive services in the completion of ADLs within smart homes.

Autominder [8] was designed to provide adaptive, personalised reminders of ADLs through dynamic Bayesian network modelling of daily activity plans. The approach is restricted to time based reminding. The project CAMP [9] focused on the ADL of medication management. The system can monitor activities and adjust the time to deliver the reminder accordingly. A statistical reasoning system was developed to track the context of whether the user is about to leave the house. The system is therefore able to provide more efficient reminders based on contextual related information. In [10] Osmani *et al.* presented an approach to provide reminders appropriate to current contexts including the location and in particular the activity inferred from sensors monitoring interactions with everyday objects. Du *et al.* [11] adopted a planning approach to represent the constraints of reminders. The system is made aware of activity contexts and can handle conflicts between multiple reminders and between pre-planned

This research is partially funded by the Nestling Technologies project.

PervasiveHealth 2011, May 23-26, Dublin, Republic of Ireland

DOI 10.4108/icst.pervasivehealth.2011.246117

and disruptive activities. CoReDa [12] was a prototype of a computerised carer helping dementia suffers complete an ADL. The TD(λ) Q-Learning technique was deployed to create a personalised guidance system for ADL completion. The system utilised wireless sensors to follow the user's progress of completing an ADL and guided the user through the completion of the ADL. Boger *et al*. [13] developed a prompting system based on the Markov Decision Process (MDP) to assist dementia patients in completing the activity of hand washing. A video camera was used to track patient's hands whilst performing the activity of hand washing. Rather than designing a prompting system, Das and Cook [14] examined Machine Learning techniques in classifying prompting and non-prompting steps by modelling steps with relevant features.

All of the aforementioned systems endure one or more limitations in that they are: designed for a particular activity, based on only pre-planned temporal constraints and are targeted on undertaking rather than completing activities or vice versa.

III. Proposed Framework

The aim of this research is to build a context-aware assistance system to assist in overcoming the difficulties in completing the process of an ADL in addition to implementing daily plans for ADLs.

The situations where the assistance system may need to intervene, either by providing a reminder or a prompt, are listed in Table I.

TABLE I. List of Circumstances Requesting an Assistance Service

Circumstances	**Intervention**
A planned activity has been missed.	Reminding
An activity starts earlier than scheduled or too close to a previous activity.	Reminding
An activity starts later than scheduled or longer than expected from a preceding activity.	Reminding
An activity is repeated more than expected.	Reminding
An activity is carried out incorrectly.	Prompting
An activity is partially completed or stops before completion.	Prompting

We classify the levels of assistance required into two categories: reminding and prompting. Reminding services deliver feedback in the form of '*need to do*' or '*do not need to do*' at the activity events level. Prompting services provide the user with instructions of '*how to do*' at the lower level of actions within an activity.

Similar to the aforementioned context-aware reminding systems, our assistance system uses appropriate contextual information to make decisions on:

- whether or not to intervene,
- when to intervene,
- where to intervene,
- by what means to intervene and
- what details to intervene with.

In this work, we specifically investigate how care plans can be used to further support the concept of activity assistance in combination with the inhabitant's contextual information. In particular, activity contexts derived from on-going object interactions associated with ADLs are used.

A further component that has been taken into consideration is that of uncertainty. Uncertainty may be encountered whilst making decisions to provide assistance in addition to providing assistance at the appropriate time, in the correct location, by the appropriate means of user interface, and with the appropriate level of information. Sensor failure and network connectivity issues may result in inaccurate low-level sensor data, which can consequently produce inaccurate high-level activity information. High-level activity context obtained from user input, such as daily living plans and personal profiles, may not be updated. Activity context derived, extracted and deduced from different sources may be presented at coarse, medium or fine-grained levels of detail. Such context uncertainties can contribute to uncertain circumstances when making activity decisions. Availing of advanced mechanisms for handling uncertainty, our assistance system is expected to be able to continue functioning correctly when uncertain circumstances present themselves.

In summary we expect that the development of our approach will contribute to advancing concepts within the research domain through:

1) the definition of a numeric representation of care plan information on an activity being undertaken within a time interval.

2) proposing a weighting mechanism to assess credibility of activity evidence from care plans and sensors for combination when they are consistent or partially consistent.

3) proposing a method to revise activity evidence from care plans and sensors for combination when a conflict occurs.

4) modelling activities through the features of sensors and proposing a technique to discover and recognise abnormal activities.

IV. System Vision

Our system consists of the following technical components as depicted in Figure 1, each of which provides functions to facilitate specific system services.

C1 – Sensor Network: contact sensors and motion sensors are deployed to detect object interactions and track subject movements.

C2 – Knowledge Base: information about a person's care plan, profile and medical data is collectively pre-acquired and stored here.

C3 – Information Management Centre: low-level sensor data and high-level knowledge are accumulated here to accurately determine the current state of ADL performance. Imprecision, conflict and inconsistency are managed within this component.

C4 – Assistance Interface: appropriate feedback is provided to the user through different interface devices according to the user's current context.

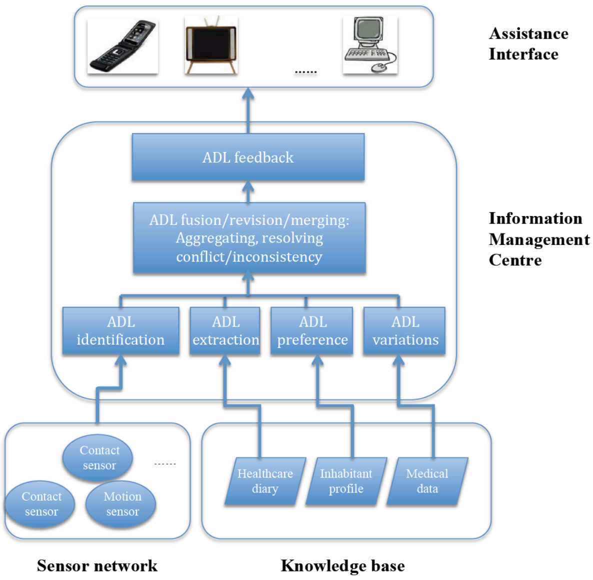

Figure 1. System vision of context-aware ADL assistance

The functionality of our system is illustrated by the following use-case scenario:

Lily is seventy-eight years old and lives alone in a detached house. She has recently developed symptoms of memory loss with which doctors have diagnosed her at the very early onset of dementia. Although she occasionally forgets things, she is perfectly fit for everyday life.

To control her dementia she has been prescribed medicine to take three times a day, to be taken shortly after meals. The time between two doses must not be longer than six hours.

Contact sensors have been installed in Lily's kitchen to monitor her interactions with household objects. For example, a contact sensor is installed on the door of the fridge to detect the opening and closing of the fridge. Motion sensors also are fitted on the ceilings throughout the house to track her movements.

At 08:00 this morning Lily took her first medicine after Breakfast. The system also detected she had tea at 10:00. Last week Lily made an arrangement with her friend Lisa to have lunch at the Ramore Restaurant in the city centre at 13:30 that afternoon and following lunch they will go shopping. At 12:30 Lily had a snack as she was a little hungry. After the snack she got ready to go out. It is impossible for her to return home to take the medicine after having lunch outside and it would be over a six hour period after her first medicine when she comes back after shopping. When she preceded to the front door the system automatically detected the possibility of her missing the medicine. The system knew that Lily had a snack a short while ago and it could be treated as a meal, so the system sent a reminding message to her mobile phone in her handbag that she was carrying. Lily heard the phone and checked the reminding message. She then went to the kitchen and took her medicine before leaving home to meet Lisa for lunch.

V. Remarks

The preliminary work of building an assistance system for the elderly undertaking daily activities has been presented. Taking into account the discussions of related research and the existing systems, the paper has highlighted the issues that our system aims to address and described the functions that can be expected to be achieved. At present, efforts are being directed towards the consolidation of all of the individual components of the system, which have been undertaken in a number of individual related research studies [15][16][17]. Plans have also been made for evaluation within a simulated living environment [18].

References

[1] *Aging in Place*. http://www.seniorresource.com/ageinpl.htm. Accessed 20 February 2011.

[2] D.J. Cook and S.K. Das, "How smart are our environments? An updated look at the state of the art", *Pervasive and Mobile Computing*, vol.3, pp. 53-73, 2007.

[3] C. Giddens and P. Higgs, *Cultures of Aging*. London: Prentice Hall, 2001.

[4] A. Walker and G. Naeghele, *The Politics of Aging in Europe*. Milton Keynes: OUP, 2000.

[5] J.L. Powell, "The power of global aging", *Ageing Int*, 35, pp. 1-14, 2010.

[6] P. Cheek, L. Nikpour, H.D. Nowlin, "Aging well with smart technology", *Nursing Administration Quarterly*, 29(4), pp. 329-338, 2005.

[7] L. Magnusson, E. Hanson, "Supporting frail older people and their family carers at home using information and communication technology: cost analysis", *Journal of Advanced Nursing*, 51(6), pp. 645-657, 2005

[8] M. Pollack, L. Brown, D. Colbry, C. McCarthy, C. Orosz, B. Peintner, S. Ramakrishnan, and I. Tsamardinos, "Autominder: an intelligent cognitive orthotic system for people with memory impairment," *Robotics and Autonomous Systems*, vol. 44, pp. 273-282, 2003.

[9] S. Vurgun, M. Philipose, and M. Pavel, "A statistical reasoning system for medication prompting," in *Proceedings of UbiComp* 2007, LNCS 4717, pp. 1-18, Springer.

[10] V. Osmani, D. Zhang, and S. Balasubramaniam, "Human activity recognition supporting context-appropriate reminders for elderly," in *Proceedings of the 3rd International Conference on Pervasive Computing Technologies for Healthcare*, pp. 1-4, London, UK, 1-3 April 2009.

[11] K. Du, D. Zhang, X. Zhou, and M. Hariz, "Handling conflicts of context-aware reminding system in sensorised home," *Cluster Comput.*, 2009, Springer.

[12] H. Si, S. Kim, N. Kawanishi, and H. Morikawa, "A context-aware reminding system for daily activities of dementia patients," in *Proceedings of the 27th International Conference on Distributed Computing Systems Workshops*, pp. 50, 2007.

[13] J. Boger, J. Hoey, P. Poupart, C. Boutilier, G. Fernie, and A. Mihailidis, "A planning system based on Markov decision processes to guide people with dementia through activities of daily living," *IEEE Trans. Inf. Technol. Biomed.* Vol. 10, no. 2, pp. 323-333, 2006.

[14] B. Das and D. Cook, "Data mining challenges in automated prompting systems,' in *Proceedings of the Workshop on Interaction with Smart Objects*, 2011.

[15] X. Hong, C.D. Nugent, M.D. Mulvenna, S.I. McClean, B.W. Scotney and S. Devlin, "Evidential fusion of sensor data for activity recognition in smart homes," *Pervasive and Mobile Computing*, 5 (3). pp. 236-252, 2009.

[16] X. Hong, C.D. Nugent, W. Liu, J. Ma, S.I. McClean, B.W. Scotney and M.D. Mulvenna, "Uncertain Information Management for ADL Monitoring in Smart Homes," in *Intelligent Patient Management*. *Studies in Computational Intelligence*, Springer, pp. 315-332, 2009.

[17] X. Hong and C.D. Nugent, "Neighbourhood Counting for Activity Detection from Time Series Sensor Data," In: *Proceedings of the 10th International Conference on Information Technology and Applications in Biomedicine*, IEEE press, 2010.

[18] C.D. Nugent, M. Mulvenna, X. Hong, and S. Devlin, "Experiences in the development of a Smart Lab", *International Journal of Biomedical Engineering and Technology*, 2 (4). pp. 319-331, 2009.