<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Towards Holistic Activity Modeling and Behavioral Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Authors(s)</strong></td>
<td>Wan, Jie; O'Grady, Michael J.; O'Hare, G. M. P. (Greg M. P.)</td>
</tr>
<tr>
<td><strong>Publication date</strong></td>
<td>2012-06-18</td>
</tr>
<tr>
<td><strong>Conference details</strong></td>
<td>6th International workshop on Ubiquitous health and wellness (UbiHealth 2012), in the Pervasive 2012 Conference, Newcastle UK</td>
</tr>
<tr>
<td><strong>Item record/more information</strong></td>
<td><a href="http://hdl.handle.net/10197/3788">http://hdl.handle.net/10197/3788</a></td>
</tr>
</tbody>
</table>

The UCD community has made this article openly available. Please share how this access benefits you. Your story matters! (@ucd_oa)

Some rights reserved. For more information, please see the item record link above.
Towards Holistic Activity Modeling and Behavioral Analyses

Jie Wan, Michael J. O’Grady, and Gregory M.P. O’Hare

CLARITY: Centre for Sensor Web Technologies,
University College Dublin, Belfield, Dublin 4, Ireland.
{Jie.Wan@ucdconnect.ie}
{michael.j.ogrady,gregory.ohare}@ucd.ie

Abstract. As the age profile of many societies continues to increase, supporting health, both mental and physical, is of increasing importance if independent living is to be maintained. Sensing and, ultimately, recognizing activities of daily living has been perceived as a prerequisite for detecting tasks that people avoid or find increasingly difficult to perform, as well as being indicators of certain illnesses. To date, extensive research efforts have been made on activity monitoring, recognition and assistance in indoor scenarios, frequently through smart home initiatives. However, the scenarios outside of the home have not received a similar degree of attention from the research community. This paper advocates a need for platforms that enable activity recognition in a range of environments, thus enabling the construction of more complex yet realistic activity models and behavior patterns. The design of a prototype supporting an integrated approach to sensor data capture and activity model construction is proposed. The application domain is that of dementia.

Keywords: Activity modeling, Ambient Assisted Living.

1 Introduction and Motivation

An aging society has significant implications from a health and economic perspective. Ambient Assisted Living (AAL) has been advocated by some as a potential remedy for many of the problems foreseen as arising. AAL is a holistic construct. It envisages enabling older adults, and indeed, those with ongoing health problems, to contribute to and participate in society in the widest possible sense. To date, research on those technologies that enable AAL has tended to be domain specific. The home itself, a controlled and well-understood environment, has naturally been the focus of much research attention. The outdoor environment is more complex and varied. In the case of dementia, the inherent dangers that arise from elopement or wandering behavior, has led some researchers to explore how pervasive technologies may be used to detect such eventualities and raise alarms with appropriate people. Yet these streams of research have tended to develop in isolation from each other. Though understandable for historical reasons, this approach is increasingly short-sighted. A more promising approach
is to develop a uniform platform for capturing salient aspects of user activity in a variety of environments. Such a development would form the basis for the construction of more holistic and encompassing models of daily activities, from which therapeutic diagnoses may be made, medical interventions monitored and quality-of-life maintained.

2 Background Research

In this section, a brief review of developments in both outdoor and indoor activity monitoring scenarios is briefly outlined.

2.1 Outdoor Scenarios

In the outdoor scenario, real time tracking has been the dominant approach for sensing and measuring human activities. The ubiquity of GPS is key. Augmented with an accurate model of the physical environment, activity modeling becomes possible, subject to ethical concerns being addressed.

One interesting example in the outdoor case is that of ComfortZone, a commercial service unveiled by the Alzheimer’s Association in the United States ([http://www.alz.org/comfortzone/index.asp](http://www.alz.org/comfortzone/index.asp)). It enables a web based application that includes a location-based mapping service, provides information of the person’s or object’s location, and supports the definition of zones, and creating alerts after the object leaves the zone. ComfortZone seeks to address two constituency of user - the person with dementia, and the caregiver. GPSshoes ([http://www.gpsshoe.com/](http://www.gpsshoe.com/)) is a wearable computing approach for tracking individuals with dementia. It places a pair of devices into the shoes, one - a GPS unit and the second - a signal transmission module to transfer the position to a central monitoring station. If the patient wanders off more than a pre-set distance, their caregiver will immediately receive a geo-fence alert on their Smartphone, with a direct link to a Google map plotting the patient’s location.

Through tracking is viable technically, the issue of making sense of what is being tracked is more problematic. One initiative [2] describes a prototype that extracts and labels a person’s activities and significant places from the traces of GPS data, using a Relational Markov Network (RMN) Model. Features are extracted considering the spatial relationship and temporal consistency between the measurements and their associations. Features include: temporal information such as time of the day, day of week or duration of the stay, 2) average speed through a segment which may be used for discriminating transportation modes. 3) geographic data, such as bus stop, restaurants and so on.

2.2 Indoor Scenarios

Smart homes for people with dementia [9], [1] are receiving increased attention by companies and researchers in order to deliver better quality and cost-effective
home care services. While such services can benefit all homes and their occupants, the needs of older and vulnerable adults can raise particular issues. The methodology is almost identical in all cases. A suite of sensors are embedded throughout the home. These record various phenomena from which patterns of activity can be gleaned. Sensors may be harnessed for a variety of purposes, for example, energy monitoring; however, it is their potential in the health domain that is of relevance to this discussion.

Many technologies for setting up a smart home are already commercially available. However, many people with dementia may experience difficulty in interacting with new technologies. As a consequence, developing a smart home that is proper for people with dementia and their caregivers is a challenging task. Therefore, smart homes should focus on monitoring behaviours as well as interactions with household objects.

3 Behavior and Situation Recognition

Human behavior and situation recognition has been studied extensively in recent years, especially, in the health care scenario. The recognition of a person’s high-level activities are extremely helpful in offering personalized high quality services, for example, tracking disease progression and responses to therapeutic interventions. In the pervasive computing area, techniques for activity recognition have been documented. Initially, such research started from specification based approaches, where expert knowledge and reasoning engines were harnessed in order to infer activity from sensor values. Techniques harnessed included logic programming [5], spatial and temporal logic [6], fuzzy logic [4], evidence theory [10], [3], and so on. However, as sensors were increasingly deployed physically in the real world, the inherent uncertainty of sensor data became a critical issue limiting the effectiveness of many techniques. Moving forward, machine learning technologies have been harnessed for activity recognition, particularly in activity recognitions systems using computer vision.

One example of sensor-based activity recognition [11] describes a prototype that recognizes activities in the home via a suite of state-change sensors. This system consists of three major components:

1. a suite of environmental state-change sensors, which are deployed to collect information about the environment and those within it;
2. a specialized context-aware experience sampling tool (ESM), designed to label users’ activities;
3. a suite of pattern recognition and classification algorithms.

Situations where there a multiple occupants in a home is far more complex. For example, [15] presents a multi-model that aims at recognizing multi-user activities, in a fully equipped smart home setting. The occupants are equipped with a set of wearable sensors, which include an audio recorder, an iMote2 with ITS400 and a RFID wristband reader. In this smart home setting, over 100 day-to-day objects are tagged and a video camera is harnessed for establishing the
ground truth. An analysis was undertaken to determine the activity features of daily living, such as brushing teeth, making coffee and so forth. For recognizing user’s activities, two temporal probabilistic models were studied and evaluated - Coupled Hidden Markov Model (CHMM), and Factorial Conditional Random Field (FCRF). Though promising, issues of background noise and scalability need further investigation. Hidden Markov Models (HMMs) is another popular algorithm for activity recognition, for example [12] harnesses HMMs for accurate activity recognition in a fully equipped smart home setting.

4 An Integrated Approach

Research on activity monitoring has been ongoing for a number of years now. Whilst undertaken in parallel in separate domains, it has nonetheless tended to focus on either indoor smart-home type domains, or on generic outdoor tracking-type services. Both domains represent two distinct islands of technologies. Increasingly, the possibility of merging these two research streams is technically realistic, and desirable in terms of what a synthesis of such research might produce. Focusing on just one aspect for activity modeling, for example, in the home, limits what insights may be gleaned when considered in light of activities and behaviors in other domains, including leisure and work.

Ubiquitous communications and sophisticated sensor platforms offer a basis for enabling a common activity monitoring infrastructure. Indeed, a generic platform could enable a number of services in a variety of domains - energy monitoring and security being two obvious examples. From a commercial perspective, it is possible that this is how such services will ultimately emerge. As well as the ubiquitous WiFi technology, a range of low-power communications technologies have been developed for sensor communications. For example, 6LoWPAN promises IPv6 compliant communications between sensors and other so-called smart objects. Such a development is fundamental to realizing the Internet-of-Things (IoTs). Along with the Sensor Web, the IoTs offers an intuitive paradigm through which networks of sensors may be deployed, accessed and visualized. Developments in sensor platforms have resulted in a new generation of mote-type platforms. Such platforms supports significant onboard processing, similar to conventional smart phones in many respects. Indeed, just as many conventional Smartphones support a common environment based on a Java or Java-type platform, a common platform for sensors may emerge over time.

Ultimately, the issue of standardization is crucial if an integrated approach to activity modeling is to be realized, and interoperability is be ensured. In the case of the Sensor Web, this issue of interoperability is still outstanding [13] even though both standards for the Web itself as well for certain sensor categories are quite mature. Yet in terms of sensors for the home, and for AAL services, standards and interoperability issues demand further research. Pertinent initiatives in this area include that of the FP7 UniversAAL project (http://universaal.org/) and the AAL Open Association (AAALOA) (http://www.aaloa.org/).
Ongoing Developments

Recently, a project has commenced in our laboratory that seeks to realize a uniform platform for enabling activity recognition in both indoor and outdoor scenarios, with an emphasis on dementia situations. Such people may function normally for extended periods of time but certain activity traits will inevitably emerge as the disease progresses that will require management strategies and, ultimately, therapeutic intervention. The outdoor component of this system is hosted on a GPS enabled Smartphone device, and is based partially on the existing OutCare service [14]. The indoor component harnesses part of a 100 node sensor network. Fig. 1 demonstrates the general architecture. Initial research focused in the issue of sensor discovery; in the longer term, a generic approach to activity modeling will be developed. Finally, issues of visualization and in-situ decision making for delivering assistance will be addressed.

Two basic issues arose that compromised the integrated approach. In the first instance, as alluded to, a lack of appropriate standards became painfully obvious. SensorML, approved by the Open Geospatial Consortium, has been adopted, and though encapsulating a rich suite of sensor functionality, its efficiency for lightweight sensor devices is compromised. Secondly, the lack of a robust generic software solution for heterogeneous sensor networks suggested significant effort be expended on customized ad-hoc solutions. To minimize the difficulties encountered, we harnessed an agile agent approach [8] realized through

Fig. 1. Architecture for a unified approach to indoor and outdoor activity recognition
the SIXTH middleware platform [7]. This offered suitable abstractions for managing the heterogeneity of platform and protocol. However, further refinement is needed to enable a robust enabling platform.

Acknowledgements

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

References