Toward Information Systems for Ambient-Assisted Living

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Abstract—**This paper introduces the paradigm of Ambient Assisted Living (AAL) and lays the foundations for developing AAL systems in the socio-economical context. A brief review of the state-of-the-art is proposed to illustrate recent advances in academia and grey literature, R&D and industry. AAL approaches increase feelings of well-being, comfort and ambient sensing and address the area of smart homes to support independent living for elders and disabled people. Selected projects and systems are described and compared to make appear common and emerging trends in the AAL domain.**

I. Introduction

THE potential of new technologies to enhance quality of life and support the independent living of older persons at home has rapidly progressed in recent years. In particular, recent R&D has aimed at conceiving and developing supportive environments for older people based on the concept of "ambient assisted living" using pervasive Information and Communication Technologies (ICTs) to enable older people to live independently in their own homes. AAL systems include activity monitoring which implies a multi-sensor data acquisition in the home [1] to monitor a person's movements and behaviors as well as the processing of this raw sensor data in order to make higher-order inferences about the person's activities and daily life patterns. In-home activity monitoring is essential in a whole range of potential applications, such as falls monitoring and the development of a new generation of smart environments to support frail and disabled people living at home. The paper is structured as follows. Sections 2 and 3 respectively outline the socio-economic drivers issues in the development of AAL systems. Section 4 gives a short state-of-the-art in the area of AAL systems and in-home activity monitoring as well as the methodology employed. Section 5 presents a software for analyzing Circadian Activity Rhythms (CARs) illustrating current research in the area. Section 6 highlights emerging trends and common approaches for developing such systems, and section 6 summarizes the paper.

II. Social, economic implications for developing commercial AAL systems

With the growing aging population in countries worldwide, monitoring physical activity and health conditions of the elders as well as people with chronic impairments at home, has become a priority to alleviate social consequences of this public health issue common in many countries. Medical and social care services can quickly become overburdened if no preventive solutions are carried out to preserve autonomy and quality of life of the older adults at home. ICT has opened up the possibility to change the future of the landscape of care and support in response to demographic change. Assistive technology for "Aging in Place" is an efficient method to reduce hospital or nursing home placements by stimulating physical activity reducing the risk of diseases, and improving the level of safety and security in the home. Alerting emergency services in case of sudden accidents such as falls or preventing aggravated health deterioration on the long term leading eventually to expensive hospitalizations are the major concerns to increase feeling security, comfort and well-being at-home, while maintaining an economic stability for the healthcare budget. It is clear that more efficient health and social care services supported by ambient technologies will change the organizational climate. The use of these products as well as the skills or education required to use them in a medico-social context will affect attitudes and approaches to the delivery of services. There is a need to select the right product derived from the ICT which will deliver the most appropriate service for AAL stakeholders and customers in accordance to their current needs. Better care, diagnostics and medical interventions operated in timely manners are the health benefits for older adults, disabled people and finally for society as a whole. In industry, success of IT systems depends on a team of specialists possessing multiple backgrounds such as engineering, ergonomists, marketers, behavioral science. In academia, challenges are often more oriented around "proof-of-concepts" demonstrating novel capabilities of information systems or embedded devices built in the field of expertise of the research labs developing them. One major issue concerning ambient intelligence is the ethical problem due to the multitude and heterogeneous personal information continuously collected in the home. AAL systems must provide the sensation that the technology is here for assistance rather than for controlling what people are doing.

III. Key points for developing commercial AAL systems

First, a user-centered method is often the most efficient way to approach AAL designs. When goals are carefully defined according to the wishes and preferences of individual, based on user research, developing a new technology or integrating existent technologies "on the shelf" can be envisioned. Proposing the right technology to the right person may be challenging if the monitored

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person's physical or cognitive abilities are not well pre-determined. Second, the technology must be adapted, and accepted by targeted "clients". For example a sophisticated technology requiring special skills is unlikely to be used by frail older people in everyday life. The technology must remain easy to install and use, proposing intuitive multi-sensorial user interfaces. In-home activity monitoring should remain passive and unobtrusive. Video cameras or microphones for example may give the impression of spying and watching every move of the person entailing privacy issues. Pendants can provoke feelings of loss of dignity. Wearable devices can also be constraining and may not be able to trigger alerts if the user forgets or chooses not to wear them. Costs of in-home monitoring systems or sensor devices must remain affordable without compromising reliability and robustness. At the functional and technical level, AAL systems must be easy to manage with plug & play modules reacting dynamically to the real-world situation. Re-configurable sensor networks, automatic reboot or back-up, self-healing and low-power consumption are services expected in such systems. Pitfalls and difficulties for deploying ALL systems include poor data quality and a lack of knowledge concerning the user life habits, for example: do the data belong to the right person being monitored? Was a physiological alert raised due to a physical activity or a medical problem? These are some questions which would need to be ultimately interpreted by AAL information systems and confirmed by stakeholders. Tailoring threshold levels to the individual taking into account the familiar environment, is one challenge to reduce false alerts. AAL systems also get advantages to exploit data monitored on the long-term. This reduces the number of medical visits less profitable for patients due to disrupted medical records, and also avoids at the stress associated with medical routines that may influence physiological measurements.

IV. A FEW EXAMPLES OF ACADEMIC STUDIES AND COMMERCIAL SYSTEMS

This section describes academic research and commercial systems in the AAL context. Techniques and approaches promoting ambient sensing considerably vary and can be implemented in various ways. This review involves a search of the Medline database with the terms "activity monitoring" and "home" and a search in the IEEE *Xplore* resource with the terms "activity monitoring" and "elderly" from 2005 to present. Also, as this is a relatively new and rapid changing area, much of the current research activity is accessible only within the "grey literature" or within the commercial sector. The review therefore included a number of key R&D projects and systems known to the authors that are representative of R&D.

A. Academic research – Grey literature

Developing original approaches for in-home monitoring activity are everyday challenges of academic scientists conceiving AAL systems. Investigations are various and interactive within a multi-disciplinary research area. A large-scale AAL system for example, called "Virtual Human Interface", uses virtual reality and animation technologies to support rehabilitation, physical and cognitive science [2]. Identifying movements and tracking activities using appropriate and advanced theoretical models, eventually embedded in hardware devices, are key tasks, part of AAL. Wavelets, Hidden Markov models [3], and signal processing methods [4], have been applied to accelerometer data to identify human activity and detect falls in various conditions. In [5], authors have developed a Bayesian classifier processing video sequences to extract dynamic human movement features. The continuous recording of such movements and activities on the long-term enables extraction of lifestyle patterns, trends and life rhythms whose irregularities may indicate a worrisome situation. Statistics applied to motion data are one way to learn habitual activity profiles, predict behaviors and detect irregularities in behavioral trends or rhythms [6]–[8]. Other methods include machine learning [9] or image processing. Researchers in [10] have developed a toolbox permitting to elaborate activity patterns based on vision information using 3D cameras. Body networks sensing physical signals and communicating wirelessly to base stations are also designed in this perspective to monitor rhythms of daily living [11].

A UK-based project "Care in the Community" [12] developed a system for monitoring the social well-being of older people at home, generating alerts in respect to social participation (trips out of the house and visits from others) and patterns of meaningful activities (e.g. leisure). Another UK project SAPHE [13] aims to monitor the activity patterns of people with chronic diseases, such as COPD (chronic obstructive pulmonary disease), so that community nurses can use this information to manage these cases more effectively.

B. R&D – Industry

Due to a healthcare industry moving quickly, challenges in R&D and industry are often more commercially oriented rather than theoretical. Products rush everyday on the market place with new designs, features and technology. This business driven approach leads to competitions among firms and companies, often creating gaps between IT communities and the needs of users [14]. Today, approaches change and including user requirements and informal caregivers in the loop is more and more usual. International groups have their own range of ambient products for home and medical environment. Philips proposes "Ambient Experience", an innovative living space supporting patient and family in the hospital context. This comprehensive solution generates special effects based on lighting, sound and spatial technologies to enforce feelings of comfort and well-being. The design reduces patient anxiety and increase the effectiveness of cares for medical staff [15]. The research community at INTEL in healthcare explores innovative mobile technologies in collaboration with research labs to improve quality of life and healthcare services in a proactive manner [16]. Projects include for example the development of a Mobile Clinical Assistant to enhance

accessibility for patient care records, a mobile sensing platform running Linux in collaboration with the University of Washington, or a sensor-based system using RFID tags attached to everyday objects to infer activities of daily living (ADLs). A number of AAL projects are currently being funded by the European Commission. For example, SOPRANO [17] is using pervasive ICTs (sensors, actuators and smart interfaces, such as avatars) to enable older Europeans to live independently in their own homes. SOPRANO not only addresses the "problems" of old age (e.g. falls, health problems) but will focus on positively enhancing the quality of life of older people, for example by encouraging and promoting healthy lifestyles and activities.

V. A SOFTWARE APPLICATION FOR MONITORING HOME-BASED BEHAVIORS AND HABITS

This paragraph introduces a software application developed for AAL systems illustrating current research in the area of in-home activity monitoring and context awareness in AAL [18]. The software program (Fig. 1) runs a pattern mining algorithm modeling Circadian Activity Rhythms (CARs) for predicting activities, evaluating the behavioral activity periodic upon 24 hour periods (circadian), and inferring potential decline in the person's health or functional status. The main objective of the application is to alert caregivers for eventually preventative assistance.

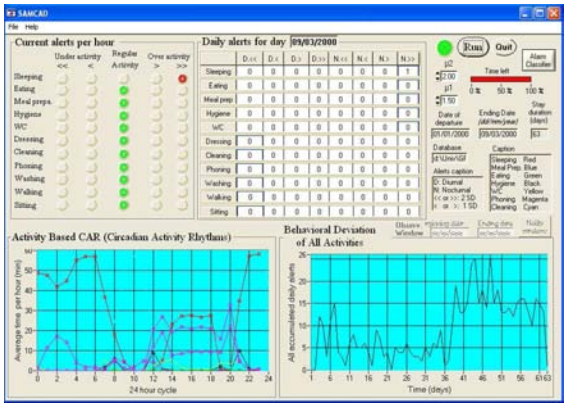

Fig. 1. GUI of the software application showing mainly CAR at the bottom left hand corner and their deviations on the right for detecting atypical situations.

CARs may concern the user presence and activity levels generated in every room, as well as activities or tasks specific of everyday life such as the ADLs. CAR of sleeping or eating for example can be some indicators of well-being and quality of life, and their disruptions occurring subtly over time may be useful to detect for instance early signs of depression or malnutrition.

The model has been applied to a dozen of older persons selected in Assisted Living [19]. Figure 2 stereotypes for example their habits in term of presence in every room for every hour of the day. This study demonstrated as well as that an approximate learning period of three weeks depending on the user behavior, was necessary to observe stabilized CAR activity patterns.

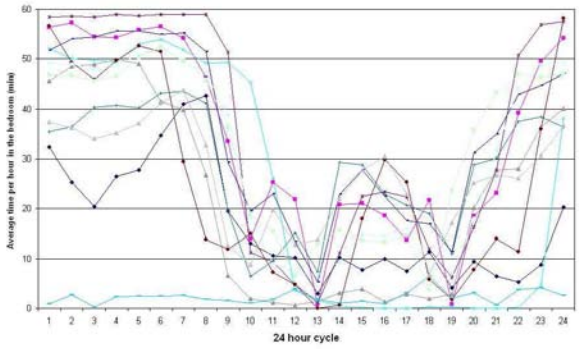

Fig. 2. A dozen of CAR activity patterns captured in Assisted Living.

Other benefits of the software application include the assessment of rehabilitation treatments or the detection of side effects of medication .

VI. EMERGING TRENDS AND COMMON APPROACHES

This section deals with emerging trends, common approaches or techniques highlighting differences between AAL developments. AAL mainly focuses on the challenges involved in motion tracking, data association to identify who owns data, activity detection and classification using various system architectures with a wide range of techniques and applications. With today's progress in pervasive technology, continuous monitoring has become accessible allowing long-term behavioral trends and life rhythms to be detected, followed and analyzed for a better knowledge of daily life patterns. Behavioral recognition and inference of pathologies, are more and more integrated in AAL systems. Behavioral anomalies or changes in activity patterns, reflecting abnormal health status, can thus be early detected and investigated [20]. This has tremendous implications for the healthcare industry for responding to medical problems before they require placements in medical institutions. Caregiver assistance and nursing interventions can be better adapted to the specific needs of the patient. Populations expressing different characteristics (e.g. in own homes, Assisted Living residences, independent living, and even intensive care units) are more and more targeted with various techniques and models more responsive to these specific activity patterns. The rapid developments within ambient technology and its potential for long-term monitoring is consequently opening research opportunities in various areas such as gerontechnology, wireless sensor networks, behavioral and social science, data mining, nursing. On the reverse side, a better understanding of people's daily routines is required to better estimate user needs which is a crucial factor for building AAL systems and to evaluate prototypes. A particular effort is given today to include the informal caregivers (domestics, friends, and neighbours) closing the loop of AAL systems to reduce the vulnerability of the housebound patients.

VII. CONCLUSION

This paper has presented the concepts and challenges of ambient assisted living. A growing aging population is the main reason to enable new ambient technological solutions for increasing lifetime expectancy at home limiting hospitalization and thus medical costs. In the industry, these solutions are often associated with improved social care services making the job of the caregivers easier and more efficient. These systems also imply responsibilities by informal social support such as the family and friend network which need some training or "education" to use these systems. The technology may however not be accepted if not intuitive or too expensive. The fast changing healthcare industry, responding to new user demands and needs, constantly redesigns its products for better managing healthcare at-home. Team working among multidisciplinary researchers, IT engineers and social scientists is essential in order to build systems based on a better understanding of the people being monitored. Emerging research topics are numerous. A key component is the monitoring of activity patterns based on in-home life rhythms. AAL systems are evolving towards the measurement of long-term behavioral trends and rhythms in order to better estimate physical activity and health and detect abnormal activity patterns reflecting potentially early signs of changes in behaviors which could be related to changes in cognitive and health status. The objectives are to detect, better evaluate, and offset chronic disease progression such as dementia linked with physical activity by prompting timely preventative interventions. Consequently, new AAL technologies need to include new modules enabling activity pattern extraction, and this technology must be acceptable by the users to increase quality of life, while at the same time respecting their privacy.

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