Holistic Monitoring To Support Integrated Care Provision

Experiences from Telecare Trials and an Introduction to SAPHE

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Abstract—**This paper provides an overview of the benefits that may be obtained by health care providers from the deployment of a social care oriented Telecare system focused on the non-invasive, ambient monitoring of individuals' activity within their homes. The paper reports findings from Telecare deployments within Liverpool UK and discusses the benefits of a holistic monitoring approach, combining ambient and wearable monitoring, to support the provision of integrated care. This approach is currently being undertaken within a UK Government supported collaborative research project SAPHE which is introduced.**

Keywords—telecare; remote monitoring; integrated care; ambient sensing; wearable sensing

I. INTRODUCTION

Chronic disease will be the leading cause of disability by 2020 [1]. Consequently, the use of preventative care and effective chronic disease management to reduce the dependence of individuals on health and social care services is a priority across the developed world.

The UK SAPHE[1] (Smart and Aware Pervasive Healthcare Environment) project was initiated to develop and trial a novel pervasive computing architecture for supporting the provision of care to individuals with chronic diseases. The work builds on previous Telecare trials [2, 3] undertaken in Liverpool UK and, through the unobtrusive sensing and linking together of physiological parameters and lifestyle patterns, will examine the opportunity for better well-being monitoring and the early detection of changes in diseases.

II. BACKGROUND

Telecare may be defined as the use of Information and Communication Technology (ICT) to support independent living for the frail, elderly and disabled. Typically this involves some form of remote monitoring of the individual within their home environment. To date both commercial products and research projects and trials have generally been allied to a particular care domain, either health or social care, and focused on one of two differing aspects of remote monitoring:

A. Activity monitoring for social care

Telecare systems are traditionally associated with social care provision for older people with the majority of commercial systems being simple panic alarm devices. More advanced systems that monitor the activity of the individual have entered the market and have been the focus of significant research effort [4, 5]. The typical design of these systems is to use non-invasive motion sensors (Passive Infrared sensors, PIRs) to detect the individual's activity within their home and to raise alarms in the case of detected exceptions such as periods of excessive inactivity. More advanced systems move into trend analysis for long term well-being monitoring. The output of such systems is targeted towards social care provision and maintaining the safety of the individual within their home.

B. Physiological monitoring for health care

The alternative approach, typically taken for health care purposes, is to focus on the remote monitoring of physiological parameters particularly through the use of body sensor networks [6]. Here the desire is to provide better support for those with long term conditions and/or those recovering from an acute episode or surgery. These systems are commercially available and facilitate the measurement and upload of physiological parameters to health care professionals who can then respond to threshold exceptions and/or view physiological trends.

C. A Holistic Approach

The above separation in approach is often a result of segregated care provision services and policies; social care provided by local authorities and health care by national health services. Previous work under taken by the SAPHE project partners has focused in both these areas. However a holistic integration of both of these approaches potentially offers greater benefits such as the provision of contextual information to supplement physiological measurement; and the use of activity level changes to give early indication of health changes. As the care provision landscape changes, with the

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[1] SAPHE: www.saphe.info

growing integration of social and health care services [7, 8], such a holistic approach also has organizational and efficiency benefits such as facilitating information sharing across stakeholder groups.

III. SOCIAL CARE MONITORING BENEFIT ANALYSIS

Evaluation and experiences with social care trials undertaken in Liverpool UK, focused on **non-invasive** activity and behavioral monitoring, have highlighted a number of areas where significant benefits can accrue beyond social care provision to the providers of health care. These benefits have been solicited both through independent evaluation, undertaken by Lancaster University UK, and interviews with Community Matrons (CMs) and Occupational Therapists (OTs) across the UK. Examples of these benefits, which are universal in their applicability, are given below.

A. Reduction in anxiety and fear of falling

Exacerbations in chronic conditions are often linked to increases in a service user's anxiety levels. For example panic attacks can lead to restricted breathing in COPD sufferers and a resultant call to emergency services, *"I can't breathe!"*. Overall wellbeing is influenced by one's feelings of security and confidence. The support and reassurance offered by a Telecare system, and the knowledge that if a problem was to occur help will be summoned, has been shown to increase feelings of security and confidence.

The independent evaluation of the Liverpool Pilot highlighted the positive increase in feelings of security and confidence provided by the installed telecare system; most importantly for the service users themselves but also for their informal carers. CMs interviewed in Liverpool have cited anxiety as a very significant factor in the wellbeing of COPD sufferers and a major cause of emergency calls.

B. Timely response to emergency situations

The provision of a timely alarm and response to emergency situations such as a fall has significant benefits in terms of the likely outcome of such an event. Such benefits may be:

- Avoidance of an emergency admission
- Avoidance of subsequent hospitalization
- Reduced stay in hospital
- Reduced stress and anxiety
- Reduced fear of recurrence

Such benefits may arise from a reduction of clinical and/or mental complications that may arise from a prolonged period of incapacitation.

For instance, left undetected a night-time fall may result in a service user lying on the floor for several hours before being found by a visiting carer the next morning or even later. A timely alarm can provide significant improvement in response delay in such a situation through lack of activity or lack of room change detection.

An example from the Liverpool Pilot: Mrs. M is put to bed by a carer at around 21:00 and is not meant to leave bed during the night until a carer arrives the next morning to get her up. One night Mrs. M got out of bed at midnight, fell and was unable to get up again. An alarm was raised and Mrs. M was in hospital within the hour. Mrs. M's OT believes this rapid response probably saved Mrs. M's life.

C. Reduced acute care stay - reducing the risk of cross infection

One of the greatest risks associated with acute care admission of an elderly or frail person is cross infection. Telecare provides the ability to minimize the length of stay on two grounds:

- Earlier diagnosis / timely response to problems reduces the risk of complication pre-admission.
- A supportive home environment with the reassurance of 24-hour monitoring reduces risks associated with early discharge.

Within the Liverpool Pilot there were several instances where it was felt safe to return a service user to their home sooner following an admission due to them having the telecare system installed. This was often supported by the provision of daily activity summary emails to a professional carer.

D. Indication of infection

Activity data may provide early indication that a service user is suffering from an infection. This may manifest itself in clear changes in behavior, such as an increase in toilet visits (indicative of a Urinary Tract Infection, UTI), or more subtle declines in general activity levels or abnormal (confused) behavior resulting from raised temperature.

Early diagnosis of infection can help to prevent falls and minimize hospital admissions.

A case study from Building Telecare in England [6]: A few weeks after [the telecare system] was installed it was noticed at the control centre that Mrs. B's nocturnal visits to the bathroom had increased significantly over a three day period. They alerted a care professional and Mrs. B was diagnosed with a urinary tract infection which was then quickly treated enabling a full and quick recovery.

E. Sleep patterns

Fluctuations and trends in an individual's sleep patterns provide a very good indication of wellbeing. Activity monitoring can provide information on the timing of sleep periods as well as sleep disturbances which are indicative of quality of sleep.

During the Liverpool pilot the OT looked at factors such as:

- Is the person still going to bed?
- Are the timings of sleep periods changing?
- Are there disturbances in the sleep periods?

An increase in the lateness of going to bed or not going to bed at all may indicate a difficulty with climbing stairs to the bedroom or mental anxiety such as:

- Aversion to bed through fear of death—*"people die in bed"*

- Delusion—thinking there is someone upstairs

Similarly getting up later may be indicative of depression, *"what have I got to get up for?"*

A shift in sleep timings may indicate an inability to distinguish time of day.

Increased disturbances in sleep may indicate clinical problems such as a UTI (increased toilet visits) or breathing problems (e.g. a COPD exacerbation).

F. *Identification of a reduction in level of activity*

Reduction in the activity levels of a service user may be indicative of the following problems:

- Physical ailment/handicap

- Increased fear of falling

- Depression

An example from the Liverpool Pilot: Mr. H showed reduced activity over two or more days and was not leaving the house. On investigation he complained of sore feet. A single referral to a chiropodist who treated several bunions and ingrown toenails led to a swift resumption in Mr. H's activity levels.

G. *Identification of toilet related problems*

Indirect (and non-invasive) monitoring of toilet usage, through monitoring flushing, provides additional information beyond merely monitoring activity in the bathroom/toilet. Increased toilet usage may be indicative of a UTI, as already mentioned, whilst reduced toilet usage may indicate constipation or a decline in personal hygiene as a result of mental problems (going to the toilet but not flushing).

H. *Reduced risk of hypothermia*

A variety of factors (e.g. respiratory problems, poor housing quality, financial concerns etc.) make elderly and frail people more susceptible to problems with cold weather. To reduce the risk of respiratory problems all living spaces within a home should be maintained above 16°C.

Statistics from Age Concern[2], UK: In 2005, in England and Wales, the deaths of 69 people aged 65 and over involved hypothermia as the underlying cause, according to their death certificates. In the winter of 2005–2006 there were 23,200 more deaths in England and Wales amongst people over the age of 65 compared to levels in the non-winter period. (Excess winter deaths are the difference between the number of deaths during the four winter months, compared to the average number of deaths during the preceding autumn and following summer. The number of additional deaths in winter varies depending on temperature and the level of disease in the population, as well as other factors).

I. *Evidence of effects of medication changes*

As a result of continuous monitoring it is possible to observe changes in behavior that may occur following a change in medication. In particular, adverse reactions to medication can be detected that manifest themselves in reduced activity levels, reduced or disturbed sleep, or changes in toileting etc. This is especially pertinent to dementia suffers who may not be able to recognize or report such changes for themselves.

This has been cited as a potential benefit by interviewed CMs in Essex, UK, as General Practitioners (GPs) currently have no ability to directly evaluate the effect of medication changes and are reliant on ill-effects being reported.

J. *Evidence based Care Assessments*

In essence, most of the examples given above relate to the ability of a social care oriented Telecare system to continuously monitor the actual activities being performed by a service user within their home without interference to them or interaction by them. This provides a true evidential basis for assessment by care professionals and overcomes problems associated with interview based assessment where feedback from service users and/or their informal carers may be incorrectly reported.

IV. FURTHER RESEARCH

The current UK Government supported research project SAPHE was established to develop a novel Telecare system which more fully addresses the needs of integrated health and social care providers. The research builds on the results presented in Section III and is being undertaken by a collaboration of university and commercial partners. At the present time the project is reaching the end of an initial, exploratory stage, focused on working with Community Matrons and community Social Workers to gain a deeper understanding of the needs which future Telecare systems should address. The project is focused on looking at the most complex cases, often referred to as the 'challenging' or 'difficult-to-manage' cases, seen by community based care professionals. Initial findings from the research show that while there may be one or two key factors in any case, these are likely to be directly or indirectly influenced by a wide range of contributory factors which are both health and social care related. Early work conducted by a social gerontologist from Liverpool University UK identified the following key factors which made patients 'difficult-to-manage':

A. *Clinical Conditions*

A number of different clinical conditions were identified as the underlying clinical problems, but these in isolation did not make the patients 'difficult-to-manage'. In addition to the underlying conditions, other clinical factors included: management problems associated with dementia, decreasing mobility and nutritional deficiencies.

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[2] Age Concern: www.ageconcern.org.uk

B. Falls

Over the course of the research falls were often mentioned as risk factors and that they may be associated with either medical or contextual/situational conditions.

C. Contextual/Situational

Physical factors in the homes of the service users as well as changes to their support network or family problems were also recorded as creating issues.

D. Personal/Psychological

A range of problem factors were identified in this category, these were: coping with long term conditions, the attitudes of service users to receiving care, negative habits, self-neglect and attitudes to situation.

V. SAPHE SYSTEM DESIGN

In order to develop a holistic monitoring solution to support integrated care provision the SAPHE project has adopted a top-level architecture, Fig. 1, which combines systems for monitoring service users and their homes together with a network-based platform providing data analysis and management capabilities linked to care providers' existing ICT infrastructure. The technical research focus within SAPHE is in three main areas: ambient sensing, wearable sensing, and inferencing/decision support.

Data from both wearable and ambient sensors are received wirelessly by a SAPHE home hub within the Service User's home. A store and forward approach provides a continuum of monitoring and data capture by the wearable sensors beyond the home. Data upload to the SAPHE Platform is secured via the use of a Virtual Private Network (VPN).

The implementation of a network platform to collate monitored data simplifies the development of complex data analysis tools and visualization components for different stakeholder groups and facilitates wider system integration.

A. Ambient Sensing

Ambient sensing (e.g. vibration, pressure, temperature, movement or video-based sensors) provides generic behavior profiling and activity recognition. It is disease independent and captures information such as activity level, sleeping pattern, room occupancy, and gait and posture changes. A variety of non-invasive sensors will be deployed throughout the home to provide continuous activity and environmental monitoring of the individual within their dwelling.

B. Wearable Sensing

Wearable sensing (e.g. ECG, SpO_2, motion sensors) provides patient-specific monitoring of key physiological indices as well as contextual information. SAPHE is developing a novel low power common node architecture that can be used to connect almost any physiological or biochemical sensors to the system. By using wireless sensors wherever possible, the system has been designed to help keep patients mobile and unrestricted.
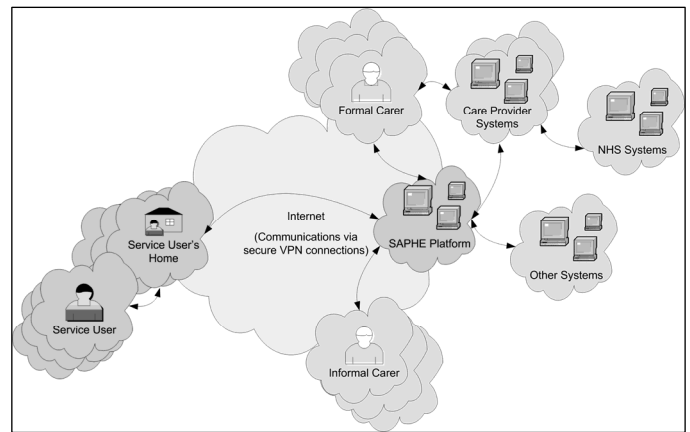

Figure 1. SAPHE Top-Level Architecture.

C. Inferencing and Decision Support

The SAPHE system will combine on-node processing and off-node long term trend analysis. This configuration uses two tiers for the more computationally intensive trend analysis. Local inferencing will be carried out by the SAPHE home hub, which coordinates communication with a wireless network linking both ambient and wearable sensors; and remote data servers and existing healthcare ICT infrastructure where long-term trend analysis will be performed based on individual and pooled population data.

The SAPHE project commenced in March 2006 and will run through to February 2009 with a 20 service user trial in 2008 with Liverpool Primary Care Trust.

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