Pervasive Technology to Facilitate Wellness

PJ McCullagh
Computer Science Research Institute
School of Computing & Mathematics
University of Ulster
Shore Road, Co. Antrim
BT37 0QB, Northern Ireland
pj.mccullagh@ulster.ac.uk

M Beattie
School of Computing & Mathematics
University of Ulster
Shore Road, Co. Antrim
BT37 0QB, Northern Ireland
beattie-M3@email.ulster.ac.uk

CD Nugent
Computer Science Research Institute
School of Computing & Mathematics
University of Ulster
Shore Road, Co. Antrim
BT37 0QB, Northern Ireland
cd.nugent@ulster.ac.uk

ABSTRACT
In this paper we evaluate the state of the art in systems with the ability to monitor health and wellness. We report on three categories of system: home telehealth monitoring, accelerometer based systems for classifying movement and state, and systems designed to provide feedback for athletes and sports enthusiasts. As these latter two approaches become pervasive, they can find application as systems that promote wellness in the general population. This can be particularly appropriate to the ageing population, if the systems can be tuned to their requirements, with particular reference to usability.

Categories and Subject Descriptors
J.3 [**Computer Applications**]: Life and Medical Sciences – *health, medical information system.*

General Terms
Measurement, Performance, Standardization

Keywords
Wellness, home monitoring, mobile monitoring, feedback

1. INTRODUCTION
The early part of the 21st century has witnessed a change in demographics for the population in most developed countries. People are living longer [1] and as a result this is providing extra demands on Health and Social care delivery. New paradigms for the delivery of care are required, one of which being that care needs to be handled in the community [2]. ,The demographic change is exacerbated by changes in diet and exercise, which has yielded an increase in the prevalence of diabetes. As an example, the World Health Organization (WHO) predicts that diabetic related deaths will double between 2005 and 2030 [3]. Healthy diet, regular physical activity, maintaining a normal body weight and avoiding tobacco use can prevent or delay the onset of diabetes [4]. Other chronic diseases such as chronic heart failure, hypertension and chest disease are all increasing. Many older people have more than one chronic condition [5]. The care required to support these conditions is complex and hospital care is becoming increasingly expensive, as new therapeutic treatments become available.

Treatments yield large amounts of data which can exist in 'islands', providing further difficulties for health care professionals to interpret and influence treatment. For chronic conditions, monitoring should be convenient, frequent and there should be ongoing remote clinical support. Nevertheless, this is at variance with the time constrains, under which most health systems provide care. Fortunately advances in technology are beginning to assist with the 'self management' of long term conditions [6, 7]. Improved sensor and information and communications technologies now provide the opportunity for solutions that may become both ambient and pervasive.

Telehealth and telecare offer the potential for home based monitoring, in which the patient and doctor collaborate on the care plan. The patient collects information in their own home, such as weight, blood pressure, or blood glucose level, using 'point of care' recording technology. The doctor can then remotely view the data and provide appropriate advice. Thus technology can act as a filter, enabling the doctor to attend to the most appropriate cases. According to Charles B. Corbin of Arizona State University [8], "Wellness is a multidimensional state of being describing the existence of positive health in an individual as exemplified by quality of life and a sense of well-being." Wellness has many dimensions which include physical, mental, intellectual, emotional and spiritual attributes. Technology can facilitate choices and processes to promote awareness towards physical wellness, and hence influence the less tangible aspects, as cite above.

Advances in mobile technology provides the opportunity for new solutions to manage 'wellness', and hence could potentially assist with the strategy to manage and even prevent long term conditions. Information on health status can be easily monitored with mobile technology and also could be used as the mechanism to feed back to a person about potential required changes in their daily activity. People are, however, demanding and desire unobtrusive, convenient, even fashionable solutions, which do not constrain their lifestyle. This is particularly true of the target population, the 'baby boomer' fashion conscious generation, who are now reaching their 'sixties'.

PETRA'10, June 23 - 25, 2010, Samos, Greece.

2. TECHNOLOGY REVIEW

In recent years a number of platforms have emerged that can be used to support long-term medical conditions without impacting dramatically on the user's day to day life.

2.1 Home telehealth

Figure 1 illustrates the general architecture of home based telehealth systems. They comprise sensors (for weight, blood pressure, heart rate, oxygen saturation etc.), a home hub (computer), a remote server and a number of communications links. The prevalence of broadband communication has provided the possibility to offer increased functionality such that it is possible for synchronous tele-consultation with a remote doctor. Telecare extends this paradigm with the use of sensors (such as Passive Infra Red devices, door and window switches, and enabled devices such as cookers, fridges etc), around the home to build up patterns of peoples' behaviour and provide information to the person, for self-management, or possibly to a remote carer. Self report of health status, mood, diet, exercise and medication provides more complete data, but requires user interaction with the computer system.

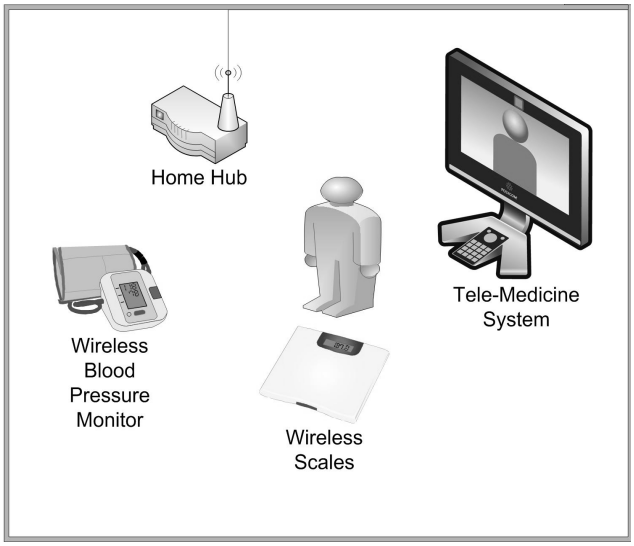

Figure 1 Internet based architecture for Telehealth system

With such an architecture, measurements may be recorded on a daily basis and this avoids the need for people to travel to primary or secondary healthcare facilities. The data can then be viewed over time and trends noted by both patient and healthcare professional. An asynchronous communication channel (for example web based email) may be used. It is also possible within such a model to include patient education on management of long term conditions. For more sophisticated systems, this can be personalised and sensitive to context [9]. Nevertheless, it is important to note that the use of such systems on a regular basis is required so that relevant trends or deviations can be identified.

These systems, utilize lightweight computers on the client side, which are unobtrusive. These include Docobo www.docobo.co.uk,, Health Buddy www.healthbuddy.com, Intel Health PHS6000 http://download.intel.com/healthcare/. Scientific trials are still in an early stage. For example, the Intel system has been used by the Lothian National Health Trust (NHS), as part of a large scale, 400-unit telehealth pilot. A randomised control trial, conducted by Edinburgh University, is monitoring 200 chronic obstructive pulmonary disease (COPD) patients and will later include patients with other chronic conditions (cardiac diseases and diabetes) [10].

2.2 Ambulatory monitoring of lifestyle data

For people suffering from chronic conditions, it is important to obtain lifestyle information. A key component of this is information on movement and activity. Data can be provided by an accelerometer, which is now in widespread use in high end smart phones. Devices that can be used to measure activity include sensors comprising accelerometers and gyroscopes (Xsens MTx, www.xsens.com, Intel shimmer http://shimmer-research.com/wordpress/home, and Sunspot, http://www.sunspotworld.com); accelerometers embedded in mobile phones (Apple iPhone, HTC, http://www.htc.com/uk/), and subscription services such as MiLife. The latter are Internet based systems, providing devices for recording and upload, coaching tips and motivational feedback. ActivPAL provides an accelerometer but adds bespoke classification software. The classification of movement into different activities (lying, sitting, standing, stepping) can be used to infer and annotate overall activity. In this example, during the daytime period (9.00 am – 5 pm), activity is classified as standing, stepping or sitting, as appropriate to an office job. During the evening (5pm – 11pm) period, Figure 2, it is clear that at 7.15pm the participant went on a run for 30 minutes (as indicated by the continuous block, colored orange in the feedback).

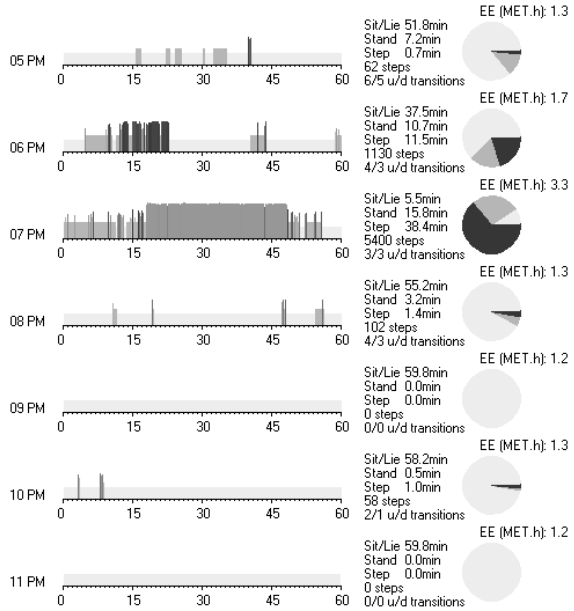

Figure 2 Time sequence example of activity classification using ActivPAL.

2.3 Technology for everyday wellness

Weisner indicated that "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday

life until they are indistinguishable from it." [11]. The Nike+ and iPod is a system which measures a runner's distance, pace, speed and calories burned during workouts, as well as giving real time audio feedback on progress being made. At the end of the workout all recorded data can be uploaded to the Nike+ website. The website displays all uploaded data regarding previous workouts and allows comparisons to be made. Data is generated during a workout through the use of a piezoelectric sensor, built into the sole of a Nike+ compliant running shoe. The data is passed from the user's shoe wirelessly using a 2.4GHz transmitter to a receiver in an Apple iPod Nano (a ubiquitous MP3 music player). ANT+ is the wireless networking protocol with lower power requirements than Bluetooth. Figure 3 indicates the data provided by the web based system. The top graph indicates the sequence of runs uploaded to the web site. Any individual run can then be assessed by click upon the graph. The bottom graph for example indicated the latest uploaded run (6th April 2010). The figure indicates a run of 6.09 miles taking 49 minutes 45 seconds, at 8minutes 10 seconds per mile, with a calorie expenditure of 771. Although the information is not entirely accurate, it provides sufficient accuracy for its purpose. The feed back is motivating, and there is an element of social networking built-in.

On August 31 2008 Nike organized the "Human Race". Thousands of runners lined up for 'physical' races in Taipei, Melbourne, Munich, Paris, New York and Austin. Anyone could participate, simply by running 10Kilometers in their own region, alone if appropriate. In total, 779,275 people participated running a total of 4 million miles [12]. Feedback and pervasive low cost technology is the key to such success. Of course the success of Nike and Apple hasn't gone unnoticed and Adidas have recently rolled out a similar product with web support, Adidas Mi Coach [13].

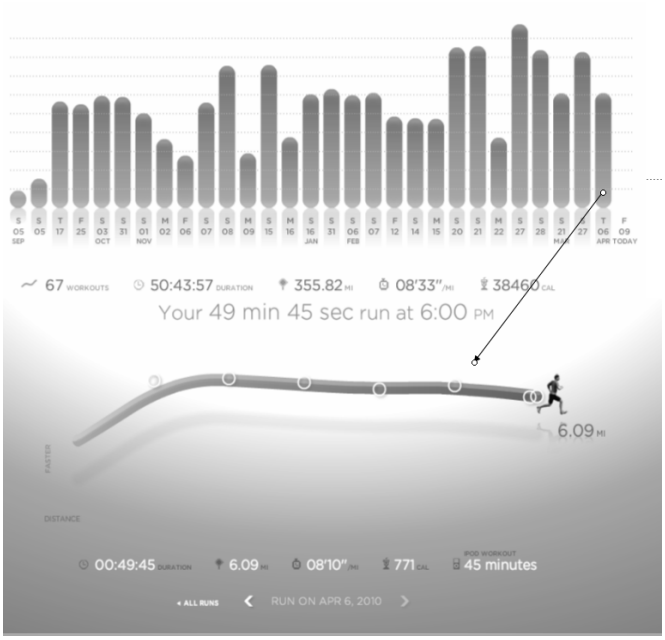

Figure 3 Feedback from the Nike+ platform for motivating running enthusiasts.

The Garmin Forerunner is targeted at runners, tri-athletes, walkers and cyclists. Global Positioning System (GPS) accurately measures distance, speed, time, altitude, and pace, all of which can be important to athletes in training for races [14]. The GPS sensor is built into a watch, which is slightly bulky but usable by the athlete. This measures position and pace. A chest strap is worn by the athlete if they also wish to measure heart rate. Electrodes make contact just below the breast bone. All that is required is that the electrodes are dampened to make good contact with the skin. Figure 4 illustrates heart rate (for part of the run only), pace and the route of a run undertaken using this device.

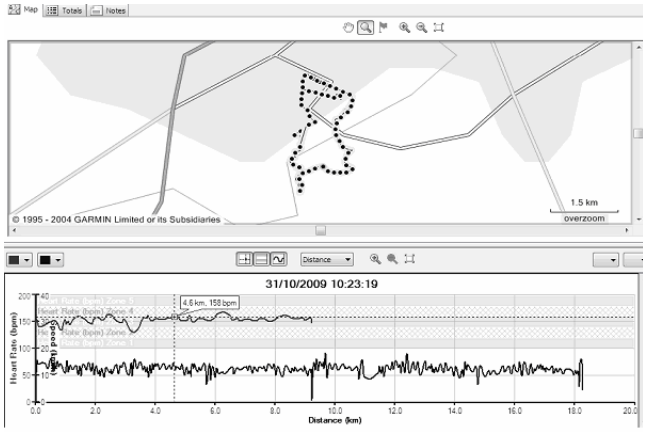

Figure 4 Garmin data: upper figure indicates the location; lower figure indicates heart rate (partial), and pace.

This provides interesting data which can be assimilated into a training programme to determine if goals are being achieved. Technology built into garments can also provide wellness management [15]. Despite significant progress, there are technology challenges associated with power management, signal recognition, increased artifact due to movement and interference, and connectivity issues from the garment. Cost is of course a big issue for bespoke garments, manufactured in very small numbers.

3. DISCUSSION

Technology can be used to promote wellness, by recording data and providing feedback to motivate the individual. The sensors necessary for recording pertinent information need to be unobtrusive for every day living. Possibilities include sensors in garments, sensors in footwear and sensors in mobile devices (e.g. phones). Feedback can be through text messaging or auditory information, using a mobile device such as a smart phone. This paradigm has received acceptance by athletes and sports enthusiasts, as evidenced by the number of users for Nike and Adidas training systems. Could this technology be used by the ageing population, for which significant health and wellbeing improvements could be achieved?

The main obstacle is acceptance and usability. This of course is more difficult in the age group we are targeting, due to lack of dexterity and visual acuity. In addition older users have less experience with using mobile devices, although this may change over time. The economic argument for addressing wellness in the older population is compelling. Within the context of an aging population there is an increased demand for supply of

care. Financial viability of care is recognized as an imperative across the world; indeed, the European Union (2001) stated that care for the elderly was dependent upon "…guaranteeing accessibility, quality and financial viability." [16]. There are also ethical issues associated with recording and storing of 'wellness' data. It can identify forensic information such as 'where' the individual was and 'when'. This information is normally benign, but it does take us closer to the surveillance society [17]. In the longer term, data can often have unanticipated 'secondary' use. How long will it be before health insurance companies look for 'proof' of a healthy lifestyle, if such technology is widely accepted? A smart shirt which is technology enabled at reasonable cost, but is also serviceable and easily maintained is an important goal to assist the ageing in the wellness paradigm.

4. CONCLUSION

Due to the population demographics, there is a need for researchers to promote the wellness paradigm. Technology has become available in homes for self management, with remote support from the healthcare professional. For people who are experiencing a long term condition, there is an obvious incentive to interact with the technology and hence the healthcare providers.

Promoting wellness in a healthy but ageing population provides a greater challenge, but this could reduce the prevalence of chronic diseases. This approach requires multidisciplinary teams including engineers, computer scientists, clothing, technologists and designers. The underlying technology to support wellness is generally available but needs to be tuned into a solution which can become pervasive in society. Some technological challenges exist, such as dealing with artifact, the need for a long lasting power supply given that network connectivity is required. Acceptance is the key issue, with the main question from the community being: *will this help*?

5. ACKNOWLEDGMENTS

Our thanks to funding form the following sources: Cross-border Centre for Intelligent Point of Care Sensors; ESRC New Dynamics of Ageing: Design for Ageing Well team, http://www.newdynamics.group.shef.ac.uk/projects/36.

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