Journal of Universal Computer Science, vol. 12, no. 1 (2006), 6-14
submitted: 6/5/05, accepted: 13/12/05, appeared: 28/1/06 © J.UCS

Pervasive Health Management and Health Management Utilizing Pervasive Technologies: Synergy and Issues

Jean Roberts
(Health Informatics Unit, University of Central Lancashire, UK
JRoberts1@uclan.ac.uk)

Abstract: Much development work is ongoing addressing technologies and their application in the health domain, in order to achieve solutions that are non-invasive to every day life and work. As with many previous phases of informatics to support health, currently the developments are in islands and there is considerable untapped potential for synergy. Much research development is happening in other domains and show potential for health reversioning and deployment once proven. This paper explores some of the technological, societal and domain-specific issues surrounding this emerging concept of pervasiveness. It concludes that pervasive support to care is emerging but further work on minimizing risk and marketing the concept to professionals and laypeople is necessary to ensure an effective deployment.

Keywords: Health, pervasive technology, human information processing, societal issues, portable devices, expert systems

Categories: C.5.3, H.1.2, I.1.2, J.3, K.4.m

1 Introduction

Pervasiveness is applied to things that either move within themselves or change status relative to the environment; everyday examples are traffic lights and paternoster elevators (both of which should operate without intervention, to a set of complex rules ad infinituum). In computing terms, technologies should be integrated to the point of disappearing, only being detectable on an 'as and when' basis.

In seeking a contemporary definition of pervasiveness as applied in an informatics context I found it means 'all things to all men', a bit like eHealth or health informatics itself. For the purpose of this paper I will use consider two key criteria :

- Appropriate computing technologies everywhere and always there when needed
- Technology-enabled information available on a 'just in time' basis

The line between pervasiveness and ubiquity is very fine; around the premise of using it 'because it is there' or taking for granted that it is always' there for use if needed' respectively. Satyanarayanan of Carnegie Mellon [Satyanarayanan, 01] reminds us that ten years before he outlined a vision and challenges, in 1991 Weiser's seminal paper [Weiser, 91] referred to ubiquitous computing as a synonym for what we now call pervasive. By 1999 the terms had not yet stabilized – and 'calm technologies' : those residing in the background of a situation until and unless needed - was an accepted term in the UK literature, cited in the 'Grand Challenges in Computer Science The Sentient Building' document from Cambridge University

[Harle, 99]. As we move into an era of minaturisation, ambient technologies, agent-based solutions and embedded chips, the platform for non-invasive therapeutic technologies gets more viable. I am using the term 'technologies' in the broader sense as used in health technologies assessment – which covers the evaluation of drugs, interventions and procedures not just IT 'black boxes and string' as encompassed within informatics. Distributed systems were precursive to pervasive computing; covering remote communication, built-in fault tolerance, robust sustained availability, remote information access and security issues. All these factors remain considerations within development of pervasive solutions now.

Pervasive healthcare addresses the technologies and concepts that integrate healthcare more seamlessly into day to day activities; covering operational care in many settings, the facilitation of independent living, monitoring of disease status and lifestyle management. Under pervasiveness I would include a range from the self-initiated panic alarm button to the autonomous wireless signal alert which indicates vital signs have become critical and sends a third party message and/or induces an emergency action [Lymberis, 04]. Within a hospital, the monitoring and alarm initiators become more critical – whether applied to a patient directly or the life support services they need, such as anaesthesia or pain control. The European project ARTIST [ARTIST, 04] recognizes that until recently such technologies, whether in health or, for example, aeronautics, the technology would have been 'small or simple, or the composition of almost non-interacting imported and assembled components'. Things have moved on considerably, such that in future technologies will also put monitors into the body during operations or diagnostic interventions.

Convergence of health, social care and lifestyle management is still a strategic goal in the UK, but is now emerging on the radar screen. In other countries, the development may be seen a little more clearly; for example, the independent Finnish Technology Research Centre [VTT, 05] actually go so far as to define a health domain to include self care, health maintenance and wellness management; into which technologies are totally integrated if pervasive healthcare is achieved. For the UK, the prime focus for current cross-sectoral development is holistic records and 24/7 access to their contents for decision support by authorized, authenticated professionals. It is only in selected specialist areas and for certain interventions that non-invasive technologies are contemplated in routine working.

According to a recent document issued by the UK Parliamentary Office of Science and Technology [POST, 05] 'pervasive computing will enable intuitive, mobile, and even passive (i.e. more natural) interactions between 'users' and information technology (IT). Pervasive computing hardware does not take the form of personal computers (PCs) that we know today. Instead, the devices are tiny, even invisible, and will soon be embedded within almost any object in our homes, offices or vehicles. Increasingly, wireless networks will allow large numbers of such devices to communicate and interact free from human input. It is thought that this technology will bring great benefits to individuals, business and governmental systems with added convenience, time and cost savings, and greater safety and security. Wearable computers embedded in items of clothing, will, for example, be able to monitor an individual's medical wellbeing. The wearer and relevant medical service could be automatically alerted to any problems detected. Such potential benefits, however, have to be measured alongside concerns over personal & civil liberties, information

security and data protection'. The above statement presents a non-technical synthesis on the subject but covers all the main areas of potential and concern, indicating that the technology is not yet generally understood but is sufficiently likely to appear on the national (research and development funding) agendas that our elected representatives require to understand its components.

2 Technologies

Current pervasive technologies in the health domain can be utilized by both professional and the layperson, thereby raising serious challenges in the areas of liability, privacy and informed usage. In addition, there are tensions where a monitor may indicate a situation is escalating out of the anticipated normal range, but the actions necessary to intervene successfully will take time to put in place. Items like smart clothing that can detect critical situations in diabetes support and administer trans-dermal insulin as a holding response are to be welcomed. A sophisticated monitoring device fashioned in the guise of an every day item may appear more non-threatening to the patient. Compliance with necessary monitoring can be achieved, say for an older patient who otherwise may heighten their clinical condition through stress and anxiety at being 'wired up', but is quite happy wearing a new watch!

An international scoring indicator [Open Research Network, 99] can be used to show that we definitely have pervasive informatics in the UK health domain. Pervasiveness is indicated by a ratio of Internet users per capita of 1 in ten upwards; *embryonic* use being less than 1 in a thousand, *established* is 1 in a thousand and *common* is 1 in a hundred. National Opinion Poll research (NOP) states that GB has 28.1 million users (in 2005 - approximately 60% of the population, up from 54% a year ago) [NOP, 05]; and as health is in the top three of the most frequently accessed topics on the Internet, the use of the Internet for health is unarguably 'pervasive'.

The emerging technology increasingly carries a reduced stigma too, viz the relatively invasive plug socket visible in the 1995 film 'Johnny Mnemonic' that has been superceded by subcutaneous sensors for wireless / RFID (radio-frequency identification) monitoring, for example, of electrocardiograms (ECG / EKG) from Finland. The technology has to cope with internal flexibility and also mobility of users and devices, to the point where it operates transparently in a 'smart space', whether internal, close to a physical body or in a closed or wider open environment.

The complexity of pervasive solutions increasingly relies on interworking components that were developed separately from the solution in which they are finally deployed. Some challenges are raised by the collective synergy of the components working together that may have been addressed in the subsidiarity of the elements working stand-alone or in different situations. The combinatorial effects must be tested as rigorously as in the individual parts. An ongoing problem is the longevity of the power sources of pervasive devices and developers are becoming less 'precious' about the identity of their tools, adopting a hybrid technique which is referred to as 'cyber foraging' whereby wireless links are enhanced, where available, with grounded connections. This will be increasingly delivered on a slightly more formal and proactive basis than delegates wandering around conference locations to pick up a 'hot spot'!

3 Societal Issues

Pervasive computing applications should present the user with minimal distraction to their day-to-day life or work. In order to achieve this - issues of size, invasiveness, robustness, intermittent support to their performance in a real world environment and their overall power requirements have been addressed. As with the relatively simplistic mobile phone, developments to address these issues are ongoing, not least in the areas of low signal coverage. With some developments in health, the challenges of abreaction between devices in a 'confined' space or where other technologies may be affected are inhibiting. How many hospitals still bar use of mobile phones completely rather than just limiting communication to silent texting which does not have any effects on other patients or technologies such as ultrasound machines and current loop hearing enhancers?

It is claimed that the Internet and similarly tele-health applications 'make geography history'. Good product and service design of pervasive solutions has to achieve scalability by reducing the negative interactions between different applications and amongst the user base, especially when the user population increases and wireless operation prevails. There are already concerns about the robustness of data transfer over fixed lines between hospitals and family physicians. Much demonstration and testing will be necessary to allay fears in areas where the technologies are less tangible.

A parallel deployment of the same life-enhancing technologies that can support, for example those with diabetes, is at risk of inhibiting roll-out in the health domain [DoH, 02a]. Marketing companies are initiating photos of the buyers of certain products in retail outlets for purchase profiling [Spy, 05], transmitting the images captured by wireless links when the product is picked up off the shelf; innocuous if you are buying teabags but with other possible connotations if you are purchasing tobacco or alcohol.

Technology is also supporting flexibility in the management of care caseloads [e-Envoy, 02] – telehealth clinics in relatively remote/ inaccessible locations can now monitor cancer patients, check progress with burns and wound care, support patients with mental health challenges, or triage accident victims without necessitating logistically traumatic travel that could make clinical situations worse for the patient and more resource-intensive for care practitioners and their organizations. Whilst the wilder areas of Scotland may spring to mind for these scenarios, it must also be acknowledged that similar 'isolation' could happen in an urban area with traffic gridlock or for an older person without personal transport available!

If a member of the public with a chronic diabetic condition decides to buy an off-the-shelf diffusion pump or smart shirt that can react in the light of vital signs if their usually stable condition goes outside normal range and requires immediate intervention to avoid a crisis; then who is in overall control of their condition … and more importantly whose responsibility is it if the device malfunctions? The impact of interventions initiated by a set of rules that is not readily visualized could be difficult to understand, and a challenge on which to carry out audit trails. Will a care practitioner take 'on faith' the calibration of such a device, or will a protracted verification process be interjected, similar to the Portable Appliance Testing (PAT) that a laptop computer may be subjected to at each organizational site on which you

wish to use it? When such innovative technologies are to be deployed operationally, it is recommended that much effort be put into communicating with potential users and recipients so that a general concern does not become a very real objection to its use.

An interesting development from Wearable Futures [Newport, 05] is the transition from health maintenance to wellbeing activities. Not only will the health domain be interacting frequently with the social care sector for patient / client interventions within a holistic programme. The citizen could, before too long be using similar technologies to de-stress themselves of their own volition. How then do you (or should you) record these alternative therapies that can demonstrably already have an effect on hypertension and related areas? In addition, if such self-management techniques do not have the desired effect but the citizen is reluctant to give them up, will 'chill-out chips' become a treatment stopper in the way smoking cigarettes is viewed in cancer cases? Consideration of the allowable contents of and access to holistic 'womb to tomb' records is already scoping the mechanism for a record subject to be able to input their own file as an adjunct to clinical input from professionals.

Pervasive technologies will have to overcome a number of societal issues before becoming generally accepted. These will include proving probity and engendering trust in the operation of the devices; ensuring robust interworking between components in all situations, confirming that any proactive tasks address patient safety and that decision support functionality is proven, understandable and acceptable to all domain users, expert and lay.

4 Patient / Client Benefits

It has been well-researched that patient/client quality of life frequently improves in rehabilitation and recovery terms as well as in coping with chronic conditions if they can live in a well-known homely environment. A doctor can discharge a patient home or to another non-hospital location if they feel that the clinical condition can be adequately managed in that situation; how much more beneficial if the patient leaves hospital with an implanted technology that the doctor is confident has been programmed to react to the same signs they would professionally react to and in the same way? The cardiac pacemaker, once a technology to be wondered at, now is taken as a tool of the trade and those receiving one are just told to 'make sure your mobile phone is in a pocket on the other side of your shirt' rather than being subjected to very detailed lifestyle management!

As the home space of patients / clients becomes diffused in the future with pervasive applications, a residual challenge is ensuring these can co-exist happily and without fault. Concerns about a hiccup and its related involuntary nerve / muscle movements causing an inappropriate dosage from a proactive pain control infuser have to be removed. The proactive nature of pervasive computing tools for patients must encompass determination of ultimate actions subject to location, physical, psychological and emotional state; in a similar way that a clinician makes a judgement on confirming intravenous fluid regimes based on a patient assessment of anxiety, consciousness and the like AFTER a computed calculation based on tests and vital signs.

5 Strategic Plans in Place

The European Commission Information Society Technologies work programme for 2003/04 identified an eHealth focus on 'biosensors, secure communication and their integration into wearable or implantable systems for … ubiquitous management of health status' [European Commission, 03]. In looking at the state of the art and future challenges intended as 'by 2004', wearable personal eHealth systems are not just available, but professionals are now looking to their effective production, affordability, usability, invisibility and autonomous power requirements. Systems for vital signs monitoring, diagnostic investigation and smart treatment are already in the market, albeit not yet generically available. The ARTIST project (www.artist-embedded.org) touches on future health deployments in its strategic roadmap. These include remote manipulators in surgery, micro-electromechanical systems (MEMS) that can explore blood vessels and embedded safety critical vital sign monitors.

The English Connecting for Health / National Programme for IT [CfH, 05] aims to deliver 24/7 access to electronic patient records for all authorized authenticated professionals as described in the Information for Health strategy [NHS, 98] and Delivering 21st Century IT Support for the NHS in July 2002 [DoH, 02a] which follows the Department of Health plan [DoH, 02b]. That goal, if/when achieved will certainly ensure informatics support is pervasive for NHS professionals. However there are certain risk areas in the plans when seen from across the home countries, in an e-government environment and from a lay perspective, extending healthcare beyond conventional clinical settings to individuals in the community.

6 Risks to Pervasiveness

If technology is enabling everything from anywhere, the question is raised as to where can you, as a professional, 'get away from it all'? 24/7 access is excellent on an as required basis, but when it becomes impossible to block off quality time for the family and non-work activities then we must revisit work-life balance and recognize the legitimacy and include functionality which readily inserts 'Normal service will be resumed in due course' responses to professional and client approaches. Early email was lauded as providing the ability to send messages at your convenience and process them asynchronously on a similar as convenient basis, but have hand-held devices and 3G phones have taken that a step too far?? What price the risk from an ill-considered, badly spelled message open to mis-interpretation that was typed from a personal data assistant device (PDA) whilst on a train journey, or the challenge to prove probity of process when such a device is used? As pervasive technologies are applied and invoked in more situations, the devices themselves can build up complex pictures of an individual, their lifestyle, travel patterns, medication and their clinical status. Such a rich picture could provide an unauthorised but clear view of activities of daily living to a third party. For example the technologies must be able to demonstrate that they can operate in a trusted manner and not release information unless authorized so to do. As Satyanarayanan [Satyanarayanan, 01] questions 'How does one strike the right balance between seamless system behaviour and the need to alert users to a potential

loss of privacy?' The public sensitivities surrounding any aspect of personal health means that this topic is very important in our domain.

Stanford [Stanford, 02] raised concerns, in early 2002, about the security of PDAs being used for clinical person-identifiable records and the use of such devices has increased considerably both formally and informally since. In fact his statement that 'organisations apply the principle of benign neglect to PDAs at their peril' is still very pertinent. It is not difficult to identify developments in the UK where clinical trials data is captured and collated on such mobile devices and members of the clinical team use the devices for patient reference, activity logging in addition to clinical calculations and agile (flexible and mobile) access to guidance information and sensitive emails. The devices are becoming ubiquitous so how often do they get left in the back of taxis and on buses like laptops are frequently?

There may be concerns about the technology per se, but a further area of scrutiny is that, once accessibility is enabled by the technologies, the content that becomes pervasive too. This article is not the place to rehearse all the arguments about how to identify 'good' quality information; just to state that an example of international activity relating to the quality of content is to be found in eEurope 2002 command 667[European Commission, 02].

Using pervasiveness in its wider sense, a concern from the USA [Wallace, 05] is that as the Internet can be accessed from almost anywhere, its content too could become subject to official sanction, with the requirements for validity and decency, the '9pm watershed' for children's access and similar issues being *imposed* from governmental agencies rather than through a parental or individual's right to choose what they bring into their own home domain. Could certain data be subverted 'for the public good' even though the technology was available to access it?

7 Home Countries Activities

All the home countries have some activities in the planned deployment of pervasive technology that could be extended or reversioned in the health domain. For example in Scotland [SHE, 01] the Digital Advantage initiatives are looking at adaptation of education materials for wider usage, the experiences of which could benefit the need to develop informatics competencies by care professionals. The Welsh have long deployed tele-health to address wide area service provision and best use of scarce experts in dermatology. There are also groups in Northern Ireland who are leading the way in research and production of smart textiles [Newport, 05].

The e-Government Interoperability Framework (e-GIF) is putting in place the environment for better public services tailored to the needs of the citizen and business for a seamless flow of information across government. It realistically recognizes that 'the aims of e-Gov will not be achieved overnight … that e-GIF must remain up to date and aligned to the requirements of all stakeholders and able to embrace the potential of new technology and market developments'. As part of the public sector, health is mandated to comply with, input to and benefit from these strategic developments. E-GIF also informs the Open Source Software policy [e-Gov, 04] which adds further depth to a pervasive capacity.

The European Union is funding a Sixth Framework project to promote the development of a roadmap for the next ten years suggesting how agent-based

computing could develop; called AgentLink III [Luck, 2005] it has a number of UK Universities involved including Liverpool and Southampton. The project briefing outline [European Commission, 05] describes the current agent-like systems in the areas of pervasive computing, the Semantic Web and peer-to-peer (P2P) networks, and predicts that 'industrial developments of infrastructures for building highly scalable applications comprising pre-existing agents must be organized or orchestrated', stressing the need for both exploitation and further research to be business case based. The focus is on usefulness and targeting application domains where agent-based solutions can bring about the highest impact, whilst ensuring the continued viability of traditional component-based methods where appropriate. From other areas noted in the AgentLink III outline where pervasive technologies are being developed or deployed, many of the future instantiations will also be in the health domain, requiring the concomitant sensitivity issues to be raised.

The UK Parliamentary Office of Science and Technology (www.parliament.uk/post/) has recently issued a call for expertise to input to a 'POSTnote' to provide MPs and Peers with an overview covering, for example core technologies behind pervasive computing, in particular ubiquitous communication, and intelligent user interfaces; the current position, recent applications and obstacles to more widespread/large-scale implementation; potential future applications and the potential benefits that pervasive computing may bring in the future; and issues such as privacy and security arising from increased data collection/transmission through 'hidden' technologies embedded in the environment & wireless networks. The report will be made publically available through the website in early 2006.

8 Conclusions

Discounting the Alice in Wonderland notion that 'words can mean what I want them to mean', closely related synonyms such as embedded, ubiquitous, pervasive, ambient, assistive, agent-based to list but a few, will all become satisfactorily delineated over time. There is no question that many developments will deliver *pervasive support* to a wide spectrum of health care maintenance and management situations in the very near future. However much coordinated research into minimizing the risks of the concept is required. The effective communication of what the technology covers and what benefits it may offer to both public and professionals is needed. This has to be in parallel to actual developments. In the same way as an individual in the developed world expects to be able to buy a household electrical device and use it on a 'plug and go' basis, much effort must be focused on making pervasive technologies robust and safe for professionals, patients and clients in day-to-day situations.

References

(All web sites accessed October/November 2005 unless otherwise noted)

[ARTIST, 04] Project ARTIST IST-2001-34820 Advanced Real-Time Systems Embedded Systems design : Roadmaps for Research, CEC, 2004

[CfH, 05] NHS National Programme for IT, Connecting for Health, www.connectingforhealth.nhs.uk

[DoH, 02a] Department of Health, Delivering 21st Century It Support for the NHS, July 2002

[DoH, 02b] Department of Health, Delivering the NHS Plan, April 2002

[e-Envoy, 02] UK e-envoy, UK online annual reports, archive.cabinetoffice.gov.uk/e-envoy/

[e-Gov, 04] UK Government, www.govtalk.gov.uk/policydocs/consult_subject_document.asp?docnum=780

[European Commission, 02] European Commission, eEurope 2000: Quality Criteria for Health-related websites, COM(2002)667 Final , November 2002

[European Commission, 03] www.cordis.lu/ist/workprogramme/en/2_3_1_11.htm

[European Commission, 05] www.cordis.lu EU funded project launches technology roadmap for agent-based computing

[Harle, 99] R Harle and G Coulouris, Grand Challenges in Computer Science The Sentient Building', Cambridge University, 1999

[Luck, 05] M Luck, EU funded project AgentLink III www.agentlink.org/roadmap/index.html

[Lymberis, 04] A Lymberis and D de Rossi (Eds), Wearable eHealth Systems for Personalised Health Management, IOS Press, August 2004

[Newport, 05] Wearable Futures : Hybrid Culture in the design and development of soft technology artschool.Newport.ac.uk/smartclothes/wearablefutures_keynote.html September 2005

[NHS, 98] NHS Executive, Information for Health : An Information Strategy for the Modern NHS www.dh.gov.uk

[NOP, 05] www.NOP.co.uk

[Open Research Network, 99] www.science-arts.org/internet

[Satyanarayanan, 01] M Satyanarayanan, Pervasive Computing : Vision and Challenges, IEEE Personal Communication, 2001

[Stanford, 02] V Stanford, PERVASIVE computing journal, http:/computer.org/pervasive April-June 2002

[POST, 05] Parliamentary Office of Science and Technology www.parliament.uk/post.

[SHE, 05] Scottish HE Funding Council HE/39/01 ICT Pervasiveness – update circular

[Spy, 05] www.spychips.com

[VTT, 05] VTT, Technical Research Centre of Finland, www.vtt.fi/indexe.htm

[Wallace, 05] JD Wallace, The specter of pervasiveness, www.spectacle.org

[Weiser, 91] M Weiser, The Computer for the 21st Century, Scientific American, September 1991