This is the pre-print version. The final version is available at: Kitsios, F., Papadopoulos, T. and Angelopoulos, S. (2010). A roadmap to the introduction of pervasive Information Systems in healthcare, *International Journal of Advanced Pervasive and Ubiquitous Computing*, 2 (3), pp. 21-32. [see: https://www.igi-global.com/article/roadmap-introduction-pervasive-information-systems/51664]

A roadmap to the introduction of pervasive Information Systems in healthcare

Fotis Kitsios, Thanos Papadopoulos and Spyros Angelopoulos

Abstract

Pervasive healthcare is an emerging research discipline, which focuses on the development of pervasive and ubiquitous computing technology for healthcare environments. Information and Communication Technologies have dramatically evolved during the last decade, laying a solid foundation for the future generation of Ubiquitous Internet access. As a result, current efforts in research and development in the areas of pervasive healthcare, promote the formation of inter-disciplinary international teams of experts, scientists, researchers and engineers to create a new generation of applications and technologies that will facilitate the fully-automated information cyberspace systems. The authors discuss the current state-of-the-art in the world of Telecommunications and Internet Technologies as well as new technological trends in the Internet and Automation Industries, while promoting research and development in the interdisciplinary projects conducted by multinational teams world-wide.

Introduction

Over the last years, Information Technology (IT) has been implemented as a means to achieve competitive advantage for private firms, and provide better quality services to customers. The IT artefacts have started to embrace all activities of human beings. They are embedded in more places than a desktop computer and provide innovative services in ways that have not been imagined in the past.

The paradigm shift (Kuhn, 1967) in the use of IT and Information Systems (IS) is usually referred to as ubiquitous or pervasive computing (Weiser, 2002). Ubiquitous Internet and pervasive IS are active research areas that have recently started to mature. Literature suggests many applications and systems on futuristic and pervasive computing for the 21st century, and discusses possible scenarios of adoption and implementation (Angelopoulos *et al.*, 2008).

In the healthcare context pervasive computing is used widely, for instance through blood pressure cuffs and glucose meters that can upload data to a personal computer for collection and dissemination to professional caregivers (Borriello *et al.*, 2007). However, there is still research to be done in terms of its implementation and the role of stakeholders in the construction of such tools. Literature has not explored thoroughly the necessity of adopting and implementing pervasive IT/IS.

Aiming to address this gap, the chapter aims to shed light upon the complex configurations of stakeholders that construct Pervasive Information Systems (PIS). The structure of the chapter is as follows: after a brief introduction to pervasive computing, the introduction of PIS to the healthcare is examined and in particular literature regarding the implementation of PIS to the specific context. Additionally, issues regarding the role of stakeholders during the implementation process are highlighted. The chapter concludes by an overview of the PIS and their application in healthcare and suggests further research avenues.

Pervasive computing

This is the pre-print version. The final version is available at: Kitsios, F., Papadopoulos, T. and Angelopoulos, S. (2010). A roadmap to the introduction of pervasive Information Systems in healthcare, *International Journal of Advanced Pervasive and Ubiquitous Computing*, 2 (3), pp. 21-32. [see: https://www.igi-global.com/article/roadmap-introduction-pervasive-information-systems/51664]

Omnipresence is the ability to be everywhere at a certain point in time. Ubiquity postulates the omnipresence of networking; an unbounded and universal network (Angelopoulos *et al.*, 2008). The widely used definition of ubiquitous computing is the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user (Wang et al, 2007). Pervasive computing integrates computation into the environment, rather than having computers, which are distinct objects. Ubiquitous activities are not so task-centric while the majority of usability techniques are. It is not at all clear how to apply task-centric techniques to informal everyday computing situations (Abowd & Mynat 2000).

There is no clear definition of pervasive computing in the current literature (Orwat et al., 2008). Pervasive computing is considered roughly as the opposite of virtual reality. Where virtual reality puts people inside a computer-generated world, pervasive computing forces the computer to live out there in the world with people. Visualisation and interaction of pervasive services can be implemented using context-aware augmented reality (Van de Kar, 2005). Thus, pervasive computing is considered a very difficult integration of human factors, computer science, engineering, and social sciences (Weiser, 1991). On the other hand, augmented reality (AR), another type of virtual reality, is considered as an excellent user interface for pervasive computing applications, because it allows intuitive information browsing of location-referenced information (Lee et al., 2006; Schmalstieg and Reitmayr, 2005). Moreover, pervasive computing is also different from traditional general purpose computers. This is because IT is not in the foreground, triggered and manipulated by humans; instead, IS resides in the background, monitoring the activities of humans and processing this information to other sources (Kourouthanassis et al., 2008).

The vision of pervasive computing consists of unobtrusively integrating computers with people’s everyday lives at home and at work (Chen et al., 2007) and has inspired many researchers to work on new hardware, networking protocols, human-computer interactions, security and privacy, applications, and social implications (Weiser, 1991; Satyanarayanan, 2001). In the last decade, a number of researcher articles presented the vision and illustrated the scenarios of futuristic computing systems in the year 2005 (Babulak, 2005). Much of the research on Ubiquitous Computing has been dominated by a focus upon the office environment since when Mark Weiser articulated the notion of Ubiquitous Computing back in 1994, the office has been the default domain. However, today, much of the foreseen technology is already implemented and fully integrated in industry, military, businesses, education and home. Mark Weiser in his article which was written back in 1996 wrote about futuristic computer technologies applied in “Smart House in the year 2005” (Weiser, 1996). Mark Weiser’s vision did indeed materialise and some of his concepts are currently part of ongoing research and implementation projects (Babulak, 2005).

Pervasive computing as well as the ubiquitous Internet technologies, include the potentials to make our everyday life more comfortable. As a distinguished Professor of Computer Science quite aptly once said: “Computer technology today has influenced almost every aspect of our lives, industry, business, and education. However, most unfortunately computer technology have mechanised the relationship between people due to e-mail and Internet technologies. It is important that the research, academic and industrial community work together to reverse that equation, whereby computer technology will be a tool that will improve human lives and mutual interaction." (Babulak, 2005b). The authors encourage reader to reflect on that statement.

Literature has focused on the differences of PIS with the old paradigm of Desktop Information Systems (DIS) (Kourouthanassis et al., 2008; Lyytinen & Yoo, 2002; Saha & Mukherjee, 2003; Satyanarayanan, 2001). PIS steps back from the original interaction of humans with the IS and views computing devices as seamlessly merging into the physical environment; the DIS is viewed as another access device. PIS also incorporates the interaction of devices with each other in a natural and unobtrusive manner (Maes, 2005; Quek et al., 2002). Therefore, PIS "enable the provision of more human-like communication capabilities, while at the same time effectively treating implicit actions as meaningful system inputs" (Abowd, Mynatt, & Rodden, 2002; cited in Kourouthanassis et al., 2008: p.). The PIS extend the paradigm of DIS under six examination dimensions depicted in table 1.

Table 1: PIS and DIS differentiating elements (adopted from Kourouthanassis *et al.*, 2008)

DIS and PIS differentiating elements

	Desktop information systems	Pervasive information systems
User	Committed Known Trained Role model: office clerk	Opportunistic Unknown Untrained Role model: citizen
Task	Generic Focused on utility and productivity	Specific Focused on service delivery and experience
Medium	Localised Homogeneous 'Point and click' paradigm	Constant presence Heterogeneous Natural interaction and multimodal paradigm
Space	Cybernetic	Physical
Product	Virtual	Tangible and virtual
Time	Reactive	Proactive

The most important benefit deriving from the deployment of the ubiquitous computing systems is the creation of new experiences for the end user. This is particularly important in the regional development, where the provision of complimentary consuming schemes and the urbanization of today's society have created the model of the new consumer who is more knowledgeable about comparable product costs, more changeable in retail and brand preferences, showing little loyalty to brands, self-sufficient, yet demanding more information, who holds high expectations of service and personal attention and is driven by three new currencies: time, value, and information (Kourouthanassis *et al.*, 2007).

Let us imagine a scenario where a person lives in the "Smart House 2015" (Tolmie et al., 2002). It is already 8:00 am and the alarm clock wakes Alice up while half opening the blinds to let the morning light enter her bedroom. The soundtrack of her favourite music station plays on the home cinema set while she takes her bath and a cup of fresh coffee waits for her at the kitchen. She dresses up and leaves home on time while pressing the button "exit" on the touch panel. The door closes behind her and immediately, all unnecessary lights as well as the toaster that she forgot switched

This is the pre-print version. The final version is available at: Kitsios, F., Papadopoulos, T. and Angelopoulos, S. (2010). A roadmap to the introduction of pervasive Information Systems in healthcare, *International Journal of Advanced Pervasive and Ubiquitous Computing*, 2 (3), pp. 21-32. [see: https://www.igi-global.com/article/roadmap-introduction-pervasive-information-systems/51664]

on, turn off. The security alarm sets on and waits for Alice to get back. As soon as Alice arrives from work, she gets in her house using the fingerprint reader at the front door. At the very same time, the in-house lighting is set in the "welcome mode" and the air-conditioning system is set to suit her preferences. While she is entering the living room, TV switches on her favourite news station in order to inform her about the current affairs. She takes a look at the remote control, in order to check that everything is perfect and she initializes the multi-zone entertainment system. Her favourite music plays on the home cinema set and she is now ready to enjoy her bath, since the water is ready at the desired temperature. The ventilation works silently in order not to disturb the music listening, and it maximizes its power only when Alice gets out of the bathroom. She has not had the time to cook and the delivery boy rings the bell to deliver her favourite Chinese food. Immediately, the monitor that can be found closer to her location, shows the view of the man smiling at the front door and with the touch of a button, she opens the door and the front lighting to facilitate his entrance into the house. This example explicates in detail the pervasiveness of IT in a home environment, and the subsequent benefits that stem out of the implementation of PIS.

Therefore, ubiquity represents the concept of having a network connection everywhere (Watson, 2004) with all consumer devices, with the intelligence and information widely dispersed and always accessible, as well as smart entities including appliances, buildings, signs, street smart communities, etc. The main focus is to enable one global network that would be available 24 hours a day, seven days a week, whole year round, and will provide best quality of services to anyone, anywhere and anytime (Babulak, 2005a).

PIS projects are yet to be implemented. The aforementioned challenges reveal that there is more work to be done in respect to the way the PIS is implemented and evaluated. In the implementation of such a system implementation, issues regarding the disclosure of information, as well as in the relationships between different actors entailed in the process, and their views and agendas. There is a burgeoning population of 'effectively invisible' computers around us, embedded in the fabric of our homes, shops, vehicles, farms and some even in our bodies. They are invisible in that they are part of the environment and we can interact with them as we go about our normal activities. However, they can range in size from large plasma displays on the walls of buildings to microchips implanted in the human body. They help us command, control, communicate, do business, travel and entertain ourselves, and these "invisible" computers are far more numerous than their desktop counterparts.

However, pervasive computing brings to the foreground new security threats, ranging from loss of privacy and financial damages, to bodily injuries. For instance, PIS are vulnerable to security threats, known from conventional IT systems, but new threats may come to existence due to the unique nature of the pervasiveness of the devices. At the same time, strong security in pervasive applications, for example, fee-based feature activation in products, offers new opportunities for businesses as well as for users. Therefore, security in pervasive computing and PIS stems out as an emerging research theme, since there is an active academic and industrial community working on strong security solutions (Paar & Weimerskirch 2007). Several approaches are developed to protect information for pervasive environments against malicious users. Nonetheless, ad hoc mechanisms or protocols are typically added in the approaches by compromising disorganized policies or additional components to protect from unauthorized access (Wang et al., 2007).

Pervasive Information Systems in the healthcare context

A system is context-aware if it can extract, interpret, and use context information and adapt its functionality to the current context of use (Korkea-aho, 2000). In particular, context-awareness is also considered as one of the most important issues in pervasive computing, which is used to provide relevant services and information to users by exploiting contexts. By contexts, we mean information about locations, software agents, users, devices, and their relationships (Daftari et al, 2003; Gu et al, 2004). Recently, several researches have been in progress for developing flexible middlewares, which can supply context-aware service infrastructure such as Context Toolkit (Dey et al, 2001), Reconfigurable Context-Sensitive Middleware for Pervasive Computing (Yau et al, 2003), SOCAM (Service-oriented Context-aware Middleware) (Gu et al, 2004), and GAIA (Biegel & Cahill, 2004).

There are three main reasons why context is important (Hong et al, 2005). First, context reduces the input cost. Second, context may provide an exciting user experience without much effort on the users' part. Third, users benefit through context sharing. User preferences and security may vary depending on the device capabilities and other context conditions. Therefore, the context adaptability should provide for means to express conditions and reason them applicable to adaptable ubiquitous services (Gandon and Sadeh, 2004; Held *et al.*, 2002). One particular important issue is to combine context awareness with more natural and intuitive interfaces like AR for providing more human-oriented visualization, interaction and collaboration of various pervasive services (Lee *et al.*, 2006). Further, in a dynamic heterogeneous environment, context adaptation for user-oriented services is a key concept to meet the varying requirements of different clients. In order to enable context-aware adaptation, context information must be gathered and eventually presented to the application performing the adaptation (Held *et al.*, 2002).

Pervasive healthcare seeks to respond to a variety of pressures on healthcare systems, including the increased incidence of life-style related and chronic diseases, emerging consumerism in healthcare, need for empowering patients and relatives for self-care and management of their health, and need to provide seamless access for health care services, independent of time and place. PIS and ubiquitous Internet increasingly influences health care and medicine (Orwat *et al.*, 2008). According to Kohn and Corrigan (2000), thousands of patients die each year in hospitals due to medical errors caused by inefficient patient pathways and care procedures. In the U.S., such errors are estimated to account for 7000 deaths annually and are often due to bad handwriting and similar problems (Menezes *et al.*, 1997). This indicates that there exists high potential in applying PIS to process improvement. For example, medication errors could be largely eliminated through better auditing capabilities, introduced by pervasive computing technology, such as RFID. Therefore, PIS can contribute to the elimination of errors since it improves the improvement or procedures through which care is provided.

PIS assists in the improvement of other hospital processes (Bohn *et al.*, 2003). Decisions are based upon information about the physical location of a person or object. For instance, if the health condition of a patient deteriorates and needs to be taken to the Emergency Unit, the system could locate the nearest doctor and call

This is the pre-print version. The final version is available at: Kitsios, F., Papadopoulos, T. and Angelopoulos, S. (2010). A roadmap to the introduction of pervasive Information Systems in healthcare, *International Journal of Advanced Pervasive and Ubiquitous Computing*, 2 (3), pp. 21-32. [see: https://www.igi-global.com/article/roadmap-introduction-pervasive-information-systems/51664]

him/her to the scene so that (s)he can take further actions. Moreover, PIS can facilitate the exchange of information to authorised users at any time and any place and secure the confidentiality of medical data. This means that doctors do not need to be accompanied with a large folder of diagnostic files, since all written information as well as X-ray images and other data are accessible on touchpads in the patient's rooms, the offices, on handheld devices, through headsets and wherever else they are needed. Consequently, healthcare personnel focus on their work and do not need to be worried about access to information.

Pervasive computing is mentioned in the context of improving healthcare (Borriello *et al.*, 2007). In the specific context, applications include psychotherapy (Sa *et al.*, 2007); autism and children with special needs (Kientz et al., 2007); simultaneous assessment of multiple individuals (Hayes et al., 2007); continuous measurement of physiological signals such as limb motion, respiration, and skin temperature (Wade and Asada, 2007). Arguably, then, PIS are actually starting to be deployed. For instance, telesurgery is becoming a practical reality, with remote surgeons taking part in a surgical procedure, or are able to consult on the condition of a patient (Borriello *et al.*, 2007). These researchers advocate towards the use of PIS, as it benefits healthcare organisations in three ways: firstly, PIS lower costs since they enable faster and more appropriate care to patients; secondly, care is made accessible to more people and the scale at which healthcare can be applied is increased; and thirdly, healthcare is becoming more personalised, enabling thereby individuals to be more responsible for maintaining their health.

In a not-so-imaginary example, Black *et al.* (2004) describe the use of PIS in healthcare environments: "Patients are instrumented with vital-sign monitors and with a means of determining their location. Physicians and nurses have wireless PDAs, also instrumented with a means of determining their location. Context-aware applications help optimize physician rounds, support nurse triage, simplify the user interface to pervasive devices, provide additional data for billing reconciliation, and provide clinical communications." Fully automated environments will require sophisticated MIMO antenna systems and small smart devices that will be able to communicate within themselves all the time. These devices will have self healing capabilities to make sure that they are recharged regularly and will be operational without any interruption. In contrast to humans who have breakfast, lunch, dinner and snack on accession to make sure that they are able to do their job, and yet they sleep anywhere from 6 to 14 hours each day, the devices creating the fully automated space can not sleep, perhaps they may wait or be on pause mode, but as soldiers they must be in full operational readiness at any time and anywhere.

PIS may improve productivity, but it also introduces costs, for instance in deployment, administration, and maintenance. Healthcare may be an area on which people are willing to spend a significant part of their income, but, however, the amount of money that can be actually invested by governments on new treatment methods, the benefit of which is mostly marginal, is certainly limited. Considering though the prospective proliferation of pervasive computing technology, we can conclude that the cost might as well drop below the level where its application in the healthcare domain becomes economically attractive (Bohn *et al.*, 2003).

This is the pre-print version. The final version is available at: Kitsios, F., Papadopoulos, T. and Angelopoulos, S. (2010). A roadmap to the introduction of pervasive Information Systems in healthcare, *International Journal of Advanced Pervasive and Ubiquitous Computing*, 2 (3), pp. 21-32. [see: https://www.igi-global.com/article/roadmap-introduction-pervasive-information-systems/51664]

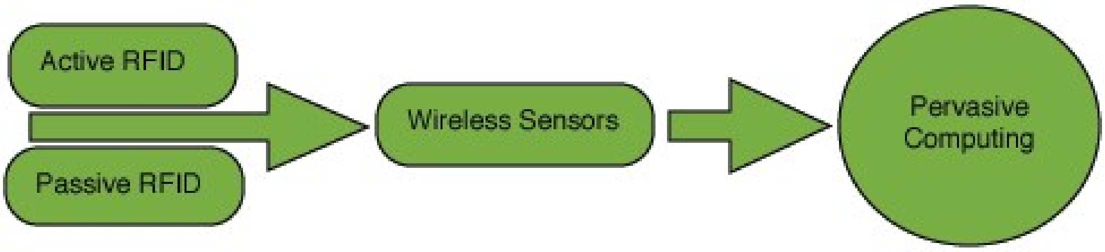

Figure 1. PIS roadmap

Research is yet to be conducted to shift from design to actual implementation (Tolmie *et al.*, 2002). Apart from benefits related to the implementation of PIS in healthcare, there are also challenges to researchers in several ways. For instance, clinical staff needs to deal with large volumes of shared data, such as patient records and x-rays. Additionally, the work of clinical staff is team-oriented and requires collaboration in order to solve complex problems; it is also nomadic, as it requires them to attend conferences and exchange views with colleagues. The working environment is filled with disruptions, and hence they should be able to memorise parallel pending activities during the treatment process. They also need quick access to relevant data, while at the same time, keeping sensitive medical data private (Borriello *et al.*, 2007). To assist with these issues, PIS suggests an integration platform between different artefacts, which come together to suggest improvements in the way health is provided to citizens.

Taking into account the aforementioned challenges in the implementation of PIS in healthcare, we suggest that two issues should be addressed in order to successfully implement PIS, namely technical factors, such as interoperability, battery capacity, (data) security and connectivity, and social and organisational factors and in particular the focus on stakeholders and their acceptance of the new technology (Newell, 2007). This is because the healthcare context is peculiar in terms of the multiplicity of stakeholders and users of PIS –e.g. doctors, nurses, managers, administrative staff– and the diverse settings, that is, accident settings, intensive care and adapted domestic environments; there is also the 'patient' factor, people who are suffering and need to be treated as soon as possible.

The aforementioned stakeholders should accept the new PIS; acceptance is defined as the adoption and use of objects by persons (Scheermesser *et al.*, 2008) and can be studied using the Technology Acceptance Model (TAM) (Davis *et al.*, 1989; Davis, 1989), and the Theory of Planned Behaviour (TPB) (Ajzen and Fishbein, 1980; Ajzen, 1991). TAM refers to a model that aims to reveal the user acceptance of IS. It postulates that perceived ease of use and perceived usefulness should be considered for the acceptance of IS. The former factor can be translated as the degree to which a person believes that using the system will enhance his/her job performance, whereas the latter medical or therapeutical use (Davis *et al.*, 1989; Scheermesser *et al.*, 2008). The TPB model, stemming from social psychology, is concerned with intended behaviour and the factors that determine it, that is, intended attitudes, subjective norms and perceived behaviour control (Scheermesser *et al.*, 2008). These factors are concerned mainly with the fit of the PIS to the social norms and "the person's perception that most people who are important to him think he should or should not perform the behaviour in question" (Fishbein and Ajzen, 1975; Scheermesser *et al.*, 2008).

Using TAM and TPB models, Scheermesser *et al.* (2008) explore the implementation of pervasive computing in healthcare, using two case studies in pre- and post-clinical healthcare, namely the treatment of acute cardiovascular diseases, and the potential for the treatment of multiple sclerosis. Using a qualitative user acceptance analysis of the two studies, the researchers suggest that the main factor of user acceptance is the perceived medical usefulness; usability is a decisive factor of acceptance if the perceived usefulness is reduced by problems with usability. Moreover, acceptance is inhibited if data privacy or if subjective norms are violated. Finally, the successful implementation of PIS depends on the active integration of different stakeholders, physicians, medical staff and patients, each with their specific agendas, priorities and needs (ibid).

The integration of the views of different stakeholders brings to the foreground issues of power and politics, which are inherent in every IT innovation implementation process. As stakeholders have different views regarding the PIS and its implementation due to their different agendas, they many associate in order to influence the outcome of the process. Stakeholders, their associations, and their dynamics are the starting point for implementation, shaping the process depending on their vested interests and agendas (Harrisson and Laberge, 2002; Swan and Scarbrough, 2005).

To address the politics and dynamics inherent in the implementation of IT innovation –and in our case PIS– Harrisson and Laberge (2002), in their study of diffusion amongst workers of a large microelectronics firm, use Actor-Network Theory (ANT) and its uniqueness in treating artefacts and technologies as well as people and organisations as members of a network (Callon, 1986; Latour, 1987/2005; Latour and Woolgar, 1986). In particular, they regard innovation as a network, constructed through the associations of actors, shaped by pre-existing ideologies and workers' perceptions regarding collective relationships, and based on the translation of identities of actors who participate in the implementation.

In the case of PIS implementation, ANT focuses on the chains of actions and events which have to do with the implementation and more specifically to the actors involved in the spread of ideas, objects or artefacts that may modify it, deflect it, betray it, add to it, or appropriate it (Sarker *et al.*, 2006). The emphasis lies in how actors not only react towards PIS, but how their actions create and appropriated PIS. Secondly, ANT considers the different identities and meanings constructed by different actors during the implementation process. Latour (1987) suggests that the identity of innovation and technological change depend on how actors enact and enrol them. Therefore, it studies how actors can attribute different meanings of PIS as they seek to achieve their own goals.

ANT may constitute a useful theoretical lens for understanding socio-political phenomena such as PIS implementation, especially where technology plays a critical role, since firstly it does not exclude non-human actors (e.g. technologies) from the analysis, allowing thereby for a more explicit examination of the enabling or restricting role of IT in the implementation process; and secondly, it acknowledges the inherently unstable nature of actors, as they can change their associations with others, depending on their different agendas and views of the PIS in question; and thirdly, it suggests that IT –PIS in this case– when it is introduced into an organization, it has to be 'translated', that is, adjusted to local conditions (localised) (Czarniawska and

Sevon, 2006). Therefore, ANT brings to the fore a political analysis which is important in the implementation of IT innovations, and in this case the PIS.

Conclusion

In this research we aimed to provide an overview pervasive concerning from a healthcare point of view. IT/IS did inspire a number of outstanding scientists and engineers in the past centuries to find new solutions to make life easier for all mankind. The emergence and accessibility of advanced data and telecommunications technologies combined with the convergence of industry standards, as well as the convergence of data and telecommunications industries contribute towards the ubiquitous access to information resources via the Internet.

The automated environment and cyberspace systems for the 21st century entered a new era of innovation and technological advancements. The world's industry and commerce are becoming increasingly dependent on web-based solutions, with regards to a global vision for the future. With increased benefits and improvements in overall information technology, the benefit-to-cost ratio has never been higher. It is essential to continue the development of industry standards and the application of information technologies in order to increase the automation and ultimate success of modern logistics, the E-Commerce and E-manufacturing industries (Kropft, 2002; Shade, 2001).

The advancement of current technologies in the fields of data and telecommunications, ubiquitous Internet access and sensor technologies combined with the new revolutionary explorations and concepts in biotechnology and nanotechnology, computer human interface-interaction, etc., present a great challenge for the research community not only as a result of mathematical complexity, but most of all as a result of the user's perception (Babulak, 2005).

Future efforts should be focused on designing a communication language and transmission media that will allow for instantaneous communication transfer and control between smart devices and humans. Additionally, despite the benefits of PIS, it is important to shed light upon the evaluation of such technologies and the cost-benefit ratio of PIS in healthcare. Finally, since their implementation is challenging and the user acceptance is a crucial factor in the process, research should shed more light upon the role of actors and their emerging associations during the implementation, focusing on the way in which PIS is introduced, interpreted, defined, and modified in healthcare context.

References

Abel, D. J., Taylor, K., Ackland, R. and Hungerford, S., (1998) 'An exploration of GIS architectures for Internet environments', Computers, Environment and Urban Systems, Vol. 22, No.1, pp. 7-23.

Abowd, D. and Mynat, D., (2000) 'Charting past, present and future research in Ubiquitous computing', AC Transactions on Computer-Human Interaction, Vol. 7, No. 1, pp. 29-58.

Ajzen, I. (1991). 'The theory of planned behavior'. *Organizational Behavior and Human Decision Processes*, 50, 179-211.

Ajzen, I., and Fishbein, M. (1980). '*Understanding attitudes and predicting social behaviour*'. Englewood Cliffs: Prentice-Hall.

Angelopoulos, S., Kitsios, F. and Babulak, E., (2008) 'From e to u: Towards an innovative digital era'. Accepted for publication in: *Heterogeneous Next Generation Networking: Innovations and Platform*.

Babulak, E., (2005a) 'Automated Environment via Cyberspace', Proceedings of the International Conference on Applied Computing (IADIS), Algarve, Portugal.

Babulak, E., (2005b) 'Quality of Service Provision Assessment in the Healthcare Information and Telecommunications Infrastructures'. Accepted for publication in the *International Journal of Medical Informatics*, Elsevier.

Biegel, G. and Cahill, V., (2004) 'A Framework for Developing Mobile, Context-aware Applications', Proceedings of the Second IEEE International Conference on Pervasive Computing and Communications (PerCom'04), IEEE Computer Society.

Black, J. P., Segmuller, W., Cohen, N., Leiba, B., Misra, A., Ebling, M. R. and Stern E., (2004) 'Pervasive Computing in Health Care: Smart Spaces and Enterprise Information Systems'. In: MobiSys Workshop on Context, Boston Massachusetts, USA.

Bohn, J., Gaertner, F., and Vogt, H. (2003). 'Dependability Issues of Pervasive Computing in a Healthcare Environment'. Proceedings of the First International Conference on Security in Pervasive Computing.

Borriello, G., Stanford, V., Naranayaswami, C., and Menning, W. (2007). Pervasive Computing in Healthcare. Editorial. *IEEE Pervasive Computing*, 6(1), 17-19.

Callon, M. (1986). Some elements in sociology of translation: domestication of the scallops and fishermen of St. Brieuc Bay, in: J. Law (Ed.) *Power, action and belief* (London, Routledge), pp. 196–233.

Chen, G. and Kotz, D., (2000) 'A survey of context-aware mobile computing research', Technical Report TR2000-381, Department of Computer Science, Dartmouth College.

Czarniawska, B., and Sévon, G. (Eds.). (2005). *Global Ideas: How Ideas, Objects and Practices Travel in the Global Economy*. Malmö: Liber & Copenhagen Business School Press.

Daftari, A., Mehta, N., Bakre, S. and Sun, X.H., (2003) 'On design framework of context aware embedded systems,' Monterey Workshop, Chicago, Illinois.

Davis, F., Bagozzi, R. P., and Warshaw, P. R. (1989). 'User Acceptance of computer technology – A comparison of two theoretical models'. *Management Science*, 35, 982-1003.

Davis, F. (1989). 'Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology,' *MIS Quarterly*, 13, 319-340.

Dey, A. K., Abowd, G. D. and Salber, D., (2001) 'A conceptual framework and a toolkit for supporting the rapid prototyping of context-aware applications', Human-Computer Interaction, Vol. 16, pp. 97–166.

De Sa, M., Carrico, L., and Antunes, P. (2007). 'Ubiquitous Psychotherapy'. *IEEE Pervasive Computing*, 6(1), 20-27.

Dickson K. Chiu, W. and Leung, H., (2005) 'Towards ubiquitous tourist service coordination and integration: a multi-agent and semantic web approach', Proceedings of the 7th international conference on Electronic commerce ICEC '05. ACM Press

Dix, A., Finlay, J., Abowd G. D. and Beale, R., (2004) 'Human- Computer Interaction', Prentice Hall, Harlow, England, third edition.

Fishbein, M., and Ajzen, I. (1975). *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Reading, Massachusetts: Addison-Wesley.

Funk, J. L., (1998) 'Competition between regional standards and the success and failure of firms in the world-wide mobile communication market', *Telecommunications Policy*, 22(4/5), 419-441.

Gandon, F. and Sadeh, N., (2004) 'Semantic Web Technologies to Reconcile Privacy and Context Awareness', *Web Semantics Journal*. 1(3).

Garlan, D., Siewiorek, D., Smailagic, A. and Steenkiste, P., (2002) 'Project Aura: Towards Distraction-Free Pervasive Computing', *IEEE Pervasive Computing*, 1(2), 22–31.

Gu, T, Wang, X. H., Pung, H. K. and Zhang, D. Q., (2004) 'An Ontology-based Context Model in Intelligent Environments', in Proceedings of Communication Networks and Distributed Systems Modeling and Simulation Conference, San Diego, California, USA.

Harrisson, D., and Laberge, M. (2002). 'Innovation, identities and resistence: The social construction of innovation'. *Journal of Management Studies,* 39(4): 497-521.

Hayes, T.L., Pavel, M., Larimer, N., Tsay. I.A., and Nutt, J. (2007). 'Simultaneous assessment of multiple individuals'. *IEEE Pervasive Computing*, 6(1), 36-43.

Held, A., Buchholz, S. and Schill, A., (2002) 'Modelling of Context Information for Pervasive Computing Applications', in Proceedings of the 6th World Multiconference on Systemics, Cybernetics and Informatics, Orlando, FL, USA.

Hong, D., Chiu, D. K. W. and Shen V. Y., (2005) 'Requirements elicitation for the design of context-aware applications in a ubiquitous environment', Proceedings of the 7th international conference on Electronic commerce ICEC '05. ACM Press.

Jackson, J. and Murphy, P., (2006) 'Clusters in regional tourism: An Australian case', *Annals of Tourism Research*, 33(4), 1018-1035.

Jennings, N. R., Faratin, P., Lomuscio, A. R., Parsons, S., Sierra, C. and Wooldridge, M., (2002) 'Automated negotiation: prospects, methods and challenges', *International Journal of Group Decision and Negotiation*, 10(2), 199–215.

Kientz, J.A., Hayes, G.R., Westeyn, T.L., Starner, T., and Abowd, G. D. (2007). "Pervasive computing and autism: assisting caregivers of children with special needs'. *IEEE Pervasive Computing* 6(1): 28-35.

Kitsios, F., Angelopoulos, S. and Zannetopoulos, I., (2008) 'Innovation and e-government: an in depth overview on e-services', *Heterogeneous Next Generation Networking: Innovations and Platform*.

Kohn, L.T., and Corrigan, J. (2000) (eds). *To Err Is Human: Building a Safer Health System*. National Academy Press, 2000. Available at:

http://books.nap.edu/books/0309068371/html/index.html

Korkea-aho, M., (2000) 'Context-aware application surveys', available at: http://users.tkk.fi/~mkorkeaa/doc/context-aware.html

Kourouthanassis, E., P., Giaglis, M., G. and Vrechopoulos, A. P., (2007) 'Enhancing user experience through pervasive information systems: The case of pervasive retailing', International Journal of Information Management, Vol. 27, pp. 319–335.

Kraus, S., (2001) 'Strategic Negotiation in Multiagent Environments'. The MIT Press, Cambridge, MA.

Kropft, P., (2002) 'What is Pervasive Computing'. Series of Lecture notes.

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers through Society.* Milton Keynes: Open University Press.

Latour, B. (2005). *Reassembling the Social: An Introduction to Actor-Network-Theory*. Oxford: Oxford University Press.

Latour, B. and Woolgar, S. (1986). *Laboratory Life: The Construction of Scientific Facts* Chichester: Princeton University Press.

Lee, K. J. and Seo Y. H., (2006) ' A pervasive comparison shopping business model for integrating offline and online marketplace', Proceedings of the 8th international conference on Electronic commerce: The new e-commerce: innovations for conquering current barriers, obstacles and limitations to conducting successful business on the internet ICEC '06. ACM Press.

Lee, K. J., Ju, J. and Jeong, J. M., (2006) 'Mobile and pervasive commerce track: A payment & receipt business model in U-commerce environment', Proceedings of the 8th international conference on Electronic commerce: The new e-commerce: innovations for conquering current barriers, obstacles and limitations to conducting successful business on the internet ICEC '06. ACM Press.

This is the pre-print version. The final version is available at: Kitsios, F., Papadopoulos, T. and Angelopoulos, S. (2010). A roadmap to the introduction of pervasive Information Systems in healthcare, *International Journal of Advanced Pervasive and Ubiquitous Computing*, 2 (3), pp. 21-32. [see: https://www.igi-global.com/article/roadmap-introduction-pervasive-information-systems/51664]

Lukkari, J., Korhonen, J. and Ojala, T., (2004) 'SmartRestaurant: mobile payments in context-aware environment', Proceedings of the 6th international conference on Electronic commerce ICEC '04. ACM Press.

Mark Weiser's Vision, retrieved February 3, 2005, from Ubiq Website: http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html

Menezes, A.J., van Oorschot, P.C., and Vanstone, S.A. (1997). *Handbook of Applied*

Cryptography. CRC Press, Boca Raton.

Noble, B., Satyanarayanan, M., Narayanan, D., Tilton, T., Flinn, J. and Walker, K., (1997) 'Agile application-aware adaptation for mobility', in: Proceedings of the 16th ACM SOSP.

Norman, D. A., (1999) 'The Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution', The MIT Press.

Orwat, C., Graefe, A. and Faulwasser, T., (2008) 'Towards pervasive computing in health care – A literature review', *BMC Medical Informatics and Decision Making*, 8(26).

Pike, R., Presotto, D., Dorward, S., Flandrena, B., Thompson, K., Trickey, H. and Winterbottom, P., (1995) 'Plan 9 from Bell Labs', *Computing Systems*, 8(3), 221–254.

Roussos, G., (2003) 'Appliance design for pervasive computing', *IEEE Pervasive Computing*, 2(4), 75–77.

Ruta, M., Noia, T. D., Sciascio, E. D., Piscitelli, G. and Scioscia, F., (2007) 'Session M5: e-business systems and applications: RFID meets bluetooth in a semantic based u-commerce environment', Proceedings of the ninth international conference on Electronic commerce ICEC '07. ACM Press.

Salvi, A. B. and Sahai, S., (2002) 'Dial m for money', Proceedings of the 2nd international workshop on Mobile commerce WMC '02. ACM Press.

Sarker, S., Sarker, S., and Sidirova, A. (2006). 'Understanding business process change failure: an actor-network perspective.' *Journal of Management Information Systems* 23(1), 51-86.

Scheermesser, M., Kosow, H., Rashid, A., and Holtmann, C. (2008). 'User acceptance of pervasive computing in healthcare: Main findings of two case studies'. Second International Conference on Pervasive Computing.

Schilit, B. N., Adams, N. and Want, R., (1994) 'Context-aware computing applications', In IEEE Workshop on Mobile Computing Systems and Applications, pp. 85-90, Santa Cruz, CA, US.

Schmalstieg, D. and Reitmayr, G., (2005) 'The World as a User Interface: Augmented Reality for Ubiquitous Computing'. Central European Multimedia and Virtual Reality Conference 2005 (CEMVRC 2005), Prague, Czech Republic.

Shade, B., (2001) 'Increased Productivity Through E-Manufacturing', by Cahners Business Information.

Shafer, S., Krumm, J., Brumitt, B., Meyers, B., Czerwinski, M. and Robbins, D., (1998) 'The new easyliving project at microsoft research', In DARPA / NIST Smart Spaces Workshop, Gaithersburg, Maryland.

Stajano, F. (2002) 'Security for Ubiquitous Computing', Wiley press.

Sun, S., Su, C. and Ju, T., (2005) 'A study of consumer value-added services in mobile commerce: focusing on domestic cellular phone companies in Taiwan, China', Proceedings of the 7th international conference on Electronic commerce ICEC '05. ACM Press.

Swan J., and Scarbrough H. (2005). *The politics of networked innovation*. *Human Relations*, 58: 913-943.

Tolmie, P., Pycock, J., Diggins, T., MacLean A. and Karsenty, A., (2002) 'Unremarkable Computing', Xerox Research Centre Europe.

van de Kar, E. (2005) 'The design of a mobile information and entertainment service on a UMTS testbed', Proceedings of the 7th international conference on Electronic commerce ICEC '05. ACM Press.

Wang, H., Cao, J. and Zhang, Y., (2006) 'Ubiquitous computing environments and its usage access control', in: Proceedings of the First International Conference on Scalable Information Systems, INFOSCALE, ACM Press, Hong Kong.

Wade, E., and Asada, H. (2007). 'Conductive-Fabric Garment for a Cable-Free Body Area Network.' *IEEE Pervasive Computing*, 6(1), 52-58.

Wang, H., Cao, J. and Zhang, Y., (2007) 'Access control management for ubiquitous computing. Future Generation Computer Systems', accepted for publication in Future Generation Computer Systems journal.

Wang, Y., van de Kar, E. and Meijer, G., (2005) 'Designing mobile solutions for mobile workers: lessons learned from a case study', Proceedings of the 7th international conference on Electronic commerce ICEC '05. ACM Press.

Watson, R. T., (2004) 'Data management: Databases and Organizations' 4th edition, Willey press.

Watson, R. T., (2000) 'U-commerce: the ultimate', Ubiquity, Vol.1 No. 33. ACM Press.

Weiser, M., (1991) 'The computer for the 21st century', Scientific American, Vol. 265, No. 3, pp. 66–75.

Weiser, M. (1996) 'Open House', Web magazine of the Interactive Telecommunications Program of New York University. Appeared in March, 1996 ITP, Review 2.0. http://www.itp.tsoa.nyu.edu/~review/

Wohlwend, H., (2001) 'An E-Factory Vision', 2nd European Advanced Equipment Control/Advance Process Control Conf., April 18-20.

Yau, S. S., Gupta, S. K. S., Karim, F., Ahamed, S. I., Wang, Y. and Wang, B., (2003) 'Smart Classroom: Enhancing Collaborative Learning Using Pervasive Computing Technology', in Proceedings of the 6th WFEO World Congress on Engineering Education and the 2nd ASEE International Colloquium on Engineering Education (ASEE 2003).