Requirements and Barriers to Pervasive Health Adoption

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Abstract. An increasingly significant characteristic that has emerged through the use of eHealth applications is the rise in consumer empowerment. The latest advances in sensor technology, sensors implementation, improved wireless telecommunications capabilities, open networks, continued increases in computing power, improved battery technology, and the emergence of flexible software architecture has led to an increased accessibility to healthcare providers, more efficient tasks and processes, and a higher overall quality of healthcare services. Intelligent infrastructures have provided the layers for contextual information gathering, knowledge processing as well as adaptation and optimization mechanisms. Pervasive health monitoring and care (PHMC) would shift the paradigm of healthcare from the traditional reactive, event-driven model, to one were subjects proactively manage their health in a patient centered healthcare system. The objective of this work was to identify requirements and barriers to adoption of pervasive sensing and computing in healthcare. To do so, the authors systematically reviewed published works on health information technology, eHealth, and pervasive health care, since 2005. We found technological, financial, psychological, logistic and liability issues related with requirements and barriers to PHMC adoption. We identified as potential requirements related with adoption of PHMC: optimization of hardware and software for remote, unobtrusive health monitoring; better evaluation of the implemented systems; better coordination of the involved stakeholders; respect and improvement of existing standards for eHealth or new standards realization; collaboration and team work of all stakeholders that may benefits from pervasive health implementation; training in using new technology; training for searching library and information sciences related with health technology and information communication technology; training in thoughtfully analysis of added value associated with new health technology; promotion of healthier lifestyle using health information technology; analysis of social and organizational change process in order to design flexible, adaptive systems for health monitoring and care; adequate policy support for quality improvement of pervasive health systems; transparency with regard to the goal, business plan and process

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implementation of pervasive healthcare; consideration of patients' perception as well as healthy individuals perception and patient-physician relationship as a core organizational operational system for PHMC; healthcare equity through improved data collection; education for technology literacy; and education for lifestyle management using new technologies. Barriers to implementation are associated with: financial constraints; privacy policy and related issues; poor transparency towards work plans and with regard to the implementation of health information technology; underestimation of complexity of the technological, clinical process and organizational problem; less or even lack of collaboration and team work of all stakeholders - patients, doctors, therapists, sociologists, engineers, computer technicians, etc.; fragmented or lack of responsibility in management of health information system implementation; low effective, persistent and consistent management of system implementation for more closely coordinated forms of health and social care provision; lack of quality audits of health information technology implementation in some healthcare systems; health professionals perception related mainly with less evidences on added value of some implemented eHealth approaches; aspect of culture associated with all stakeholders involved in health information communication technology. For the future it would be desirable to set up a comprehensive method that provides support in implementing PHMC taking into account quantitative measurements of variable identified in this work and potentially supplemented by others standardized surveys.

Keywords: pervasive health monitoring, pervasive healthcare, health information technology adoption.

1 A Short Story. Information Technology in Healthcare

"*I sighed as I flipped again through the paperwork sent with my first admission of the night. All I found was a partially legible discharge summary. The patient, a young man who was ventilator dependent and in a vegetative state since receiving a gunshot injury 6 months previously, had been transferred from a nursing home after a workup revealed a new deep venous thrombosis in his leg. From the limited notes provided by the nursing home, I ascertained that the gunshot had initially caused a subarachnoid hemorrhage. It was my job, as a night-float admitting resident, to determine whether it was safe to start anticoagulation for his thrombosis. I rummaged through his papers again. All I could find regarding his brain hemorrhage was the handwritten statement "Recent head CT stable." I was angry that physicians had sent this patient without adequate documentation. In the corporate world, a business transaction would not be finalized if crucial information were missing, but transfers like this are commonplace in medicine. I called the nursing home and reached a doctor who had never heard of my patient. He agreed to look up the record and call me back. A few minutes later, someone else from the nursing home paged me and said he couldn't find any mention of a previous head CT. I pressed him for more information. After a second perusal of the record, he discovered that a "brain" CT had been performed a few days earlier. My spirits rose as I waited for the report. "Oh," he said, "we don't have a report.*

We're not an acute care facility, so it takes several days for us to receive reports." Defeated, I hung up. Half an hour later, I was wheeling my ventilated patient to the CT scanner for new views of his brain. These days, we can find the answer to almost any question immediately by doing a Google search, but unfathomably, it is still not possible for a physician in Manhattan to obtain a timely report of a study performed in another New York borough. I waited for a corrections officer to open the gates to the prison floor of the hospital so I could see my next admission — a prisoner from Rikers Island who had been sent to a different hospital for stabilization and was being transferred here for treatment. The nurse warned me, "There's not much there," as I looked through the chart. The discharge summary from the transferring hospital was one of the briefest I had ever seen: "Admitted for altered mental status, s/p respiratory distress, and intubated. Treated with broad-spectrum antibiotics, extubated 2 days ago and now stable for transfer." A set of basic laboratory tests from a couple of days earlier was included with the paperwork, but there were no culture reports, no mention of which antibiotics had been used, and no chest radiography reports. A 10-day course of critical care had been summed up in three sentence fragments and one set of lab tests. I spent another 20 minutes drawing labs and cultures and then ran back to the emergency room to see another new admission, still without a clear plan for the patient I had just left. Later that night, I looked over the chart for my sixth admission. A 72-year-old patient with schizophrenia who spoke only Cantonese had been referred from a Chinatown clinic for admission. Because only the words "PPD positive" had been written on the referral sheet, he had been isolated in the emergency room. I wasn't sure whether the tuberculosis positivity was a new finding, and the patient appeared comfortable on the stretcher. He was not coughing, and his lungs were clear. Without any family members present to provide clarification, I tied a mask on him and walked him outside his isolation room to a translator phone. Even through the translator, I could barely get a history. I looked for evidence of a recent skin test on his forearms but found nothing. He was a febrile, and his chest radiograph was normal. I couldn't understand why his primary care doctor had thought he needed to be admitted. Once again, I felt as though I were practicing medicine in the dark" (Litvin CB, 2007).

Litvin [1] story published, in 2007, in The New England Journal of Medicine, the most widely read, cited, and influential general medical periodical in the world, underscores common communication breakdowns among patients, clinical, and administrative staff (e.g., distribution of patient information), related mainly with accessing meaningful data in real time. This is the common perception of healthcare professionals related with eHealth in many countries that currently use eHealth technologies. The term eHealth or e-Health encompasses a range of services or systems that are at the edge of medicine/healthcare, information technology and engineering, including: telemedicine, telerehabilitation, telehealth, telegenetics, electronic health records (EHRs), electronic medical records (EMRs), personal health records (PHRs), patient-centered medical home (PCMH or Medical Home), e-Patient, m-Health, connected health, consumer health informatics, health knowledge management, virtual healthcare teams, medical research using distributed sensors networks, health information system (HIS) or health information technology (HIT), information communication technology (ICT) for healthcare, pervasive health monitoring and pervasive healthcare. In recent years, interest in both eHealth and innovation in pervasive health monitoring and care (PHMC) has grown tremendously, and there has been increasing recognition of the importance of medical devices and other non-pharmaceutical health related technologies to all aspects of healthcare. The World Health Organization (WHO) issued the first global directive on medical devices in 2007, recognizing that, like medicines, many health technologies are indispensable. In Europe, taking into account the financial burdens associated with the ageing of the population and the parallel rise in chronic diseases, the overriding concern of Europe's healthcare sector is to find ways to balance budgets and restrain spending. According to World Bank figures, public expenditure on healthcare in the EU could jump from 8% of GDP in 2000 to 14% in 2030 and continue to grow beyond that date. For Europe, eHealth adoption is one of solution to reduce cost and improve healthcare as was emphasized to the High Level eHealth Conference 2006 in Malaga, Spain: *"Europe can benefit from eHealth that focuses on ensuring better: prevention disease, prediction of disease, personalization of healthcare, participation of Europe's citizens in their own healthcare improvement, increased patient safety throughout all stages of the healthcare process, productivity and performance of Europe's healthcare systems, and of Europe's third healthcare industrial pillar, monitoring of indicators and productions of regular data and reports on health status"* [2]. In many European countries, the health and social-care system is looking at the potential of eHealth to serve as a complementary support structure for quality care that is coordinated, comprehensive, and cost-effective. Moreover, research on pervasive computing technologies for healthcare, which does not aim to replace traditional healthcare, is directed towards paving the way for a pervasive, user-centered, preventive healthcare model [3] at lower cost. PHMC has the potential to significantly improve health outcomes over the long term and thereby reduce direct and indirect costs, given the much greater opportunities for continuous monitoring and adjustment of treatment. The pervasive health monitoring enables to build sensing and computing systems that allow long-term subjects' health assessment and health critical events signaling.

Pervasive healthcare may be defined from two perspectives: i) as the application of pervasive computing technologies for healthcare, and ii) as making healthcare available everywhere, anytime and to anyone [4]. The pervasive healthcare applications include pervasive health monitoring, intelligent emergency management system, pervasive healthcare data access, and ubiquitous mobile telemedicine. Pervasive healthcare is closely related to biomedical engineering (BME), medical informatics (MI), and ubiquitous computing (UbiComp). BME combines engineering skills with medical and biological science to improve diagnostics, treatment, and follow-up. Using technology related MI large sets of medical data are processed to optimize healthcare management. A main objective of UbiComp is physical integration and embedding of computing and communication technology into environments. While BME and MI mostly focus on technology to improve the existing health delivery model, pervasive healthcare in contrast tries to change the health care delivery model: from doctor-centric to patient-centric, from acute reactive to continuous preventive, from sampling to monitoring [5]. Additionally, while the term "pervasive" stands for the tendency to expand or permeate, "ubiquity" is the property of being omnipresent. In this sense, the ultimate goal of pervasive healthcare is to become a mean for achieving ubiquitous health.

Efficient pervasive healthcare architectures, mechanisms and systems could alleviate the problem of supporting and caring for people with a long term condition and less mobility. Some of the problems that initially was thought to be solved by using ICT in healthcare delivery systems were the incorrect recording of diagnoses, unavailability of patient information, delays in accessing the information, space limitations for record-keeping and insufficient personnel for patient monitoring. The paradigm shift in BME and MI has enabled a reduction in these hurdles and a more personalized service to be delivered.

In the last years, worldwide politicians have been supporting greater investments in health information technology and expect it to significantly decrease costs and improve health outcomes. For instance, Barack Obama's campaign Web site proclaimed that his health plan would *"lower costs through investment in electronic health information technology systems" (Obama 2008)*. An economic stimulus package was passed by the USA Congress including $19 billion for investments in healthcare ICT (Kaiser Family Foundation 2009), together with the Health Information Technology for Economic and Clinical Health (HITECH) Act, approved in 2009. Under the HITECH Act, every hospital in the United States has been eligible for a minimum of $2 million — and many millions more for larger hospitals - to buy and use "electronic health records". Similarly, physicians have been eligible for payments ranging from $44,000 to $63,000 to begin to use such health electronic records. And, more critically, the federal government conditions all these investments on the ability of all these electronic health records to be shared, or interoperable, through local, regional, state, and, eventually, a national "health information exchange" [6]. HITECH includes a set of standards that allow senders to push health information securely to known receivers, to market based health information exchange solutions that can be used to create an exchange network. Providers must purchase technology and comply with metrics related to implementation, and that compliance is defined as meaningful use [7]. To achieve the intent and sustainability of meaningful use, technology first needs to show value at the front lines of healthcare delivery [8]. From that perspective, the American policy has made several assumptions as: i. technology is a strategic tool; ii. technology will continuously improve quality; iii. technology will work better if it is comprehensively implemented. The current policy takes a top-down strategy and assumes that there is uniform and solid evidence for use of technology in all types of provider settings, a view that is inconsistent with existing evidence [8]. As Funtowicz and Ravez [9,10] noted, *"The traditional distinction between 'hard', objective scientific facts and 'soft', subjective value-judgments is now inverted. All too often, we must make hard policy decisions where our only* *scientific inputs are irremediably soft. The requirement for the "sound science" that is frequently invoked as necessary for rational policy decisions may affectively conceal value-loadings that determine research conclusions and policy recommendations. In these new circumstances, invoking 'truth' as the goal of science is a distraction, or even a diversion from real tasks. A more relevant and robust guiding principle is quality, understood as a contextual property of scientific information".* The complex issue of introduction eHealth in our society should be recognized as a *post-normal problem* [11] that can be solved by "bringing 'facts' and 'values' into a unified conception of problem solving in these areas, and by replacing 'truth' by 'quality' as its core evaluative concept" [11]. The idea that quality differences should be measured by accounting for differences in services to the contribution to outcome has increasingly been recommended by some, and some possibilities would in fact exist to account for difference in the marginal benefit for the consumer that result of differences in the quality of the service [12]. Perhaps most prominently, this was shown in one of the recommendations from the Atkinson report from 2005 for strategies to improve price and productivity measurement in the UK: *"An output measure should be adjusted for the attributable incremental contribution of the activity to individual or collective welfare. This should include capturing any change in outcomes which is attributable to the use of the inputs. A basic count of activities does not measure the quality of the output such as change in quality of patient experience or clinical effectiveness. This is a continued weakness of the current method"* [13].

Given the reality of financial crisis in Europe, balancing rising cost pressures against limited resources is a concern across countries. As was emphasized in WHO publications, in 2009 [14]: *"Technological innovation is the most important driver of health care costs, estimated to account for between a half and three quarters of all growth in health care spending* [15,16]. *However, the role played by technological change is complex. New technologies can reduce costs through efficiency gains or through health improvements that reduce the need for further and perhaps more costly care. But they can also lead to higher costs: by increasing utilization; by extending the scope and range of possible treatments available; by extending treatment to a wider set of indications and to more people (expansion); by replacing an existing and cheaper technology (substitution)* [17]; *and, even if not more expensive, by being applied more widely within the relevant patient population than the existing technology (a combination of substitution and expansion)"* [14].

The requirements for adoption of PHMC should be analyzed from a sociotechnical perspective, that combines the social aspects of system development and technical solutions which address how PHMC may enhance the delivery of care.

2 Methodology and Scope of Study

Our objective was to identify requirements and barriers to adoption of pervasive sensing and computing in healthcare. To do so, the authors systematically reviewed guidelines, technical research work, declarations, recommendations, position papers, and social or psychological implication of health information technology published since January 2005 on the clinical and scientific databases: USA NIH repository for peer-reviewed primary research reports in the life sciences PubMed NCBI, Excerpta Medica Database (EMBASE), and IEEE Xplore. IEEE that stands for Institute of Electrical and Electronics Engineers publishes in IEEE Xplore leading journals, transactions and magazines in technology, including electrical engineering, computing, biotechnology, power and energy, telecommunications and dozens of other essential fields. A search of the 'grey' literature, citable material not indexed in NCBI Pub Med, EMBASE or IEEE Xplore, was also conducted. We systematically reviewed English language literature on human research related to the adoption and use of eHealth in the world. To obtain articles on eHealrh implementation and utilization, we required that one or more of the following keywords or phrases appear in the article: eHealth, health information technology, health information technology costs, electronic health records, electronic medical records, personal health records, patient-centered home medical records. All of the abstracts were examined manually to identify whether the publications should be retrieved in full text for further review. We excluded from our analysis the specific field of medical therapeutic research. This research allowed us to select 82 articles with issues relevant for description of requirements and barriers to pervasive healthcare adoption. We limited our analysis to papers related with technical research work on health information technology and pervasive healthcare, guidelines and position papers related with factors that facilitate or barriers to adoption of information communication technology. The scope of our review encompassed the benefits and associated barriers of eHealth for description of presently state of pervasive healthcare implementation and to call for future research on effective implementation and adoption.

3 Hand Fan Model – Framework for Analysis of Determinants for PHMC Adoption

Medical informatics research units began to appear during the 1970s mainly in USA and Poland [18]. Since then, despite the interest and significant investments in promoting medical informatics and health information technology solutions, there remains a major gap between the promise and reality of delivery. The NHS Future Forum [19] recognized that: *"There has been too much focus on different parts of the system - GPs, hospitals, public health - and insufficient attention to how they all join up to provide the integrated care that patients need"*.

In many countries, the information technology systems associated with social and economic infrastructure are enterprise-level systems with the following characteristics [20]: - they are able to run large-scale applications exceeding several million steps, including complicated on-line and batch processing; - frequent interactions with the system are possible, creating the potential for human operation faults; - dependability of the IT service is affected by environmental changes (such as a sudden peak of traffic). Defects in information technology services may have greater negative impacts on social and economic activities in the future, since the risks of such defects are increasing due to their wider applications and the growth of information technology systems' complexity and scale [20]. A meta-analysis of the impact of HIT implementation (i.e., CPOE - computerized physician order entry, EHRs - electronic medical records) across hospitals and ambulatory care organizations in seven countries identified implementation risk factors that included: implementation, and opportunity costs; staff anxiety and resistance to changing long-established processes; concerns about affecting provider - patient relationships; training [21,22]. Costs represent a significant barrier to HIT implementation for both small and large health care organizations [21,22,23,24,25]. The expenditures include acquisition costs (i.e., upfront capital required for purchase), ongoing maintenance costs (i.e. staff training, software upgrades), and infrastructure costs (i.e., cost on system implementation or maintenance; cost of computer upgrades or networking) [26,27].

From a sociotechnical perspective, the adoption of HIT implementation needs to combine the social aspects of system development (i.e., recognizing the skills and work of health care professionals) with technical system functioning (i.e., technology and tasks) to address how health IT fits within the organizational, operational, and cultural processes to enhance the delivery of care [28]. Furthermore, increased implementation and use of electronic records will require changes to workflows, increased emphasis on preventive care, retraining or hiring staff, and increased financial incentives to report and improve performance [29].

Based on the above discussions, we think that the key to further development and improvement in PHMC is *Post-Normal Scientific* analysis and management [11] of complexity of the factors that facilitate or limit PHMC implementation. We identified technological, financial, psychological, logistic and liability issues related with requirements and barriers to PHMC adoption (see Table 1). All these factors are interrelated and focus on one or several issues can improve adoption. However, sustainable health care using pervasive sensing and computing should be achieved by adopting a strategy in which the role of each variable is appreciated in its full context of complexity and uncertainty, taking into account the relevance of human commitments and values.

In the last decades, in problem solving, outline/framework design or for structural/ relationship representations, the graphical representations of relationships between ideas, words, tasks or other items in personal, familiar, educational or business context, the Mindmap is used. Mindmaps are used to generate, visualize, structure, and classify ideas, and as an aid to studying and organizing information, solving problems, making decisions, and writing. We choose to use a hand fan representation (see Figure 1) of interrelation between issues related with requirements and barriers to PHMC adoption for three reasons. First, history of use of hand fan is chronologically and socially correlated with history of using instruments in medicine. The oldest evidence of the use of instruments in medicine is from the Edwin Smith Papyrus, a textbook on surgery, that give details on anatomical observations, and the "examination, diagnosis, treatment, and prognosis" of numerous ailments. It was probably written around 1600 BC, but is regarded as a copy of several earlier texts. Medical information in it dates from as early as 3000 BC [30]. The earliest hand held fan, originated in Egypt in 3000 BC [31]. Ancient Egyptians used hand fans for cooling themselves, winnowing, or for

Table 1. Requirements and Barriers associated with PHMC adoption

	Requirements	Reference	Barriers	Reference
Technological	Sensors and Actuators	45,47,48,49,50	Sensors and Actuators	55,77
	Power management	51	Power Management	51
	Communication Network	45,47,52	Communication network	47,52, 77
	Autonomic Decision Making System	45,47,48,52, 53,54,55,56,57, 58	Interface with the User	95
	Security	46	Security	46,55
	Interoperability	55, 58	Interoperability	55,77
			Defects Management	20,27
Financial	Incentive	49,59,60	Costs	55,78,97, 98
Logistic	Quality Audit	27,69,70,71	Quality Audit	27,69,70 71
	Coordination	27,49,72,	Coordination	27,49,72
	Standard	55,59	Maintenance	48
	Team based care	56,74,75,76	Team based care	49
	Training	76,77,78,79	Training	76,77,96
	Lifestyle incentive management	45,50	Productivity	77
Liability	Policy	49,77,82	Policy	49,59,77, 87
	Transparency	49	Transparency	49,69,71
Psychological	Perception	59,83,84	Perception	73,77, 85,86,87, 99
	Culture	100,102,103	Culture	49,77,99, 100,102, 103
	Education	102,103	Education	99,102, 103

religious ceremonies. Elaborate hand fans symbolized power, royalty and status in the society. We used this graphical representation because we think that it may symbolize PHMC as a tool or instrument to maintain physiological and psychological health. Nowadays, one of the goals of PHMC, as in early beginning of the use of fans, is to be an instrument to maintain health, strengthening users' ability to manage their own care. Moreover, the currently technology related with PHMC is mainly afforded by countries with better socio-economic development and higher income population. Continuing the history, the Chinese made some innovations on the long shafted Egyptian hand fans by mounting it on a much shorter handle, which allowed the user to carry it around. They also popularized the half-moon shape hand fan by using bamboo, wood, ivory and silk. The artistic ability and creativity of the Chinese were displayed as the surface of their hand fans were ornamented with feathers or hand painted with various Chinese designs. Aside from being used to cool people, swat insects, and as a kung fu weapon, the hand fan symbolized various things including beauty, feminism, royalty, and social status. Japan made another innovation on the hand fan by coming up with the first folding fan in the 8th century BC. Like the Chinese and Egyptians, the Japanese recognized that hand fans symbolized prestige, royalty and other social standings. Soon after, hand fans gradually spread to Europe and other western countries [31]. What was happening with medicine in that time? The most ancient Chines medical text, *Huangdi Neijing* also known as *The Inner Canon of Huangdi* or *Yellow Emperor's Inner Canon*, discusses the use of needles for therapy (acupuncture) [32]. Are presented, in this text, concepts which have been developed in China from more than 2000 years, including various forms of herbal medicine, acupuncture, massage (Tui na), exercise (qigong), and dietary therapy. According to the *Huangdi Neijing*, the forces of universe can be understood via rational means and man can stay in balance or return to balance and health by understanding the laws of these natural forces. Man is a microcosm that mirrors the larger macrocosm and the reason of disease development is natural effects of diet, lifestyle, emotions, age and environment [32]. Ancient Chinese thought recognized also that *chaos* and *order* are related. Ying and Yang, emerged from chaos and retain the qualities of chaos. *Too much of either brings back chaos.* As we known, nowadays a significant part of research work on engineering and informatics adopts the new and exciting field of scientific inquiry – the *chaos theory* – to better understand transient changes in economics (Benoit Mandelbrot), communication of information through telephone line (Cantor Set), fractal presented in turbulence, blood vessels, lung, etc. The new *chaos*-based understanding of nature requires a new notion of the appropriate form of scientific practice. This new practice of science is called "*post-normal*" science. The *Post-Normal Science* (PNS) is a new conception of the management of complex science-related issues. It focuses on aspects of problem solving that tend to be neglected in traditional accounts of scientific practice: uncertainty, value loading, and a plurality of legitimate perspectives [11]. *"In pre-chaos days, it was assumed that values were irrelevant to scientific inference, and that all uncertainties could be tamed. That was the "normal science" in which almost all research, engineering and monitoring was done. Of course, there was always a special class of "professional consultants" who used science, but who confronted special uncertainties and value-choices in their work. Such would be senior surgeons and engineers, for whom every case was unique, and whose skill was crucial for the welfare (or even lives) of their clients*" [10]. We observed this tendency of thought on involved stakeholders in the implementation of e-Patient, eHealth Collaborative telehealth, mHealth, electronic health records (EHRs), electronic medical records (EMRs), personal health records (PHRs), patient-centered medical home (PCMH).

e-Patient (Also known as Internet patient), is a health consumer who uses the Internet to gather information about a medical condition of particular interest to him, and who uses electronic communication tools (including Web 2.0 tools) in coping with medical conditions. The term encompasses both those who seek on-line guidance for their own ailments and the friends and family members (e-Caregivers) who go online on their behalf. e-Patients report two effects of their online health research: "*better health information and services, and different (but not always better) relationships with their doctors*." As the use of the term e-Patient has evolved, there has been less emphasis on Internet access and technology, and a contention that the "e" in "e-patient" stands for "*empowered, engaged, equipped, enabled*" [33];

mHealth or m-Health: Includes the use of mobile devices in collecting aggregate and patient level health data, providing healthcare information to practitioners, researchers, and patients, real-time monitoring of patient vital signs, and direct provision of care, via mobile telemedicine [34];

EHRs: An electronic record of health-related information on an individual that conforms to nationally recognized interoperability standards and that can be created, managed, and consulted by authorized clinicians and staff across more than one healthcare organization [35]. While EHRs are a critical aspect of health IT, the term embodies a much wider array of technologies, including PHRs, m-Health, telehealth (including telemedicine), and the use of technology for physical fitness (e.g., Kinect, Nintendo's Wii Fit), as well as cognitive stimulation (e.g., online Solitaire or memory games). In Hong Kong, a computerized patient record system called the Clinical Management System (CMS) has been developed by the Hospital Authority since 1994. This system has been deployed at all the sites of the Authority (40 hospitals and 120 clinics), and is used by all 30,000 clinical staff on a daily basis, with a daily transaction of up to 2 million. The comprehensive records of 7 million patients are available on-line in the Electronic Patient Record (ePR), with data integrated from all sites. Since 2004, radiology image viewing has been added to the ePR, with radiography images from any HA site being available as part of the ePR [36]. The countries with higher adoption of health information technology (more than 90%), particularly EHRs, are Netherlands, New Zeeland, Norway, United Kingdom, Austria, Sweden, and Italia [see 37]. Nearly all primary care physician in Denmark have EHRs with full clinical functionality [38];

EMRs: An electronic record of health-related information on an individual that can be created, gathered, managed, and consulted by authorized clinicians and staff within one health care organization. The main difference between EHRs and EMRs is that EMRs are used by and within a single organization (such as an ambulatory practice), and EHR applies when it contains data from or is accessed by multiple organizations [35];

PHRs: Health records where health data and information related to the care of a patient is maintained by the patient. This stands in contrast with the more widely used EHRs or EMRs, which are operated by institutions (such as a hospital) and contains data entered by clinicians or billing data to support insurance claims [39]. PHRs can be broadly described as a set of electronic tools that allow consumers to access, coordinate, and control appropriate parts of their health information. PHRs combine not only data, but knowledge and software tools, which motivate patients to become more involved in their healthcare [40,41]. A PHR should typically present a comprehensive and precise review of the health and medical history of the individual patient through the collection of information from a variety of sources. Since it is retained, maintained and controlled by the consumer, the PHR positions the consumer at the core of the healthcare process, potentially fostering personal empowerment and facilitating self-management, shared decision making and better clinical outcomes [40,41]. The health data on PHRs might include patient-reported outcome data, lab results, data from devices such as wireless electronic weighing scales or collected passively from a smartphone. PHRs intersect with connected health in that they attempt to increase the involvement of consumers in their care. PHRs, whether through patient portals, electronic downloads onto a personal USB drive, or through a company sponsored Web site (e.g. MyAlert, Microsof HealthVault), allow patients timely access to their medical information.

PCMH or Medical Home: A team of people embedded in the community who seek to improve the health and healing of the people in that community. They work to optimize the fundamental attributes of primary care combined with evolving new ideas about organizing and developing practice and changing the larger health care and reimbursement systems [42]. Unlike more narrowly focused ways of organizing the delivery of commodities of healthcare, the PCMH aims to personalize, prioritize and integrate care to improve the health of whole people, families, communities and populations. Thus, the PCMH consists of the following: 1) the fundamental tenets of primary care: access, comprehensiveness, integration and relationship; 2) new ways of organizing practice; 3) development of practices' internal capabilities; 4) health care system and reimbursement changes. The PCMH concept links new approaches to health care organization with the well-established primary care function for improving the health of people and populations [42].

The above comparison of history of hand held fans and the use of instruments in medicine underscores our first reason for hand fan symbolic representation of determinants to PHMC adoption. The second reason for choosing the hand fan model in the representation of variables associated with PHMC adoption is its architecture and functionality. The number of pieces that commonly are part of a folding fan, in our model are the determinants (variable associated with requirements and barriers) of PHMC. Links between fan pieces can be associated in our models with statistical correlation between different variable encompassed by PHMC adoption. Low correlation between the determinants that undermine and the determinants that facilitate PHMC may be represented in the open top part of hand fan where may be possible to better observe and analyze the complexity of the factors associated with PHMC adoption, while in the bottom part of the fan, more rigid, less flexible and not much useful for cooling, may be represented in our models the variables with high correlation between barriers and facilitators that reduce the possibility of adoption of PHMC, because of the high risk and lower probability for implementation and functioning.

Fig. 1. Hand fan model of determinants in pervasive healthcare adoption

The third reason for adopting the hand fan model of PHMC is that hand fan is an example of human created instruments where the processes and results are all time different in comparison with the instruments created by other instruments (e.g. machine created objects). When designing PHMC, this model may suggest that it is necessary to analyze the complexity of human perception, thinking, behavior, human relationship with objects and society. For instance, amidst the advent of countless technologies, hand fans by their functionality, usability and associated human values did not become obsolete. Hand fans persisted to exude their value. They are still a useful instrument in our society. Aside from being functional, hand fans have being used for various purposes: gifts or wedding favors during weddings; home decor or office decor; promotional products [31]. Hand fan graphical representation as a model for the determinants to PHMC adoption may symbolize also the potential changes along the time in fabrication, use and perception of the PHMC technology in society - pervasive (ubiquitous) computing "*the third wave in computing, just now beginning. First were mainframes, each shared by lots of people. Now we are in the personal computing era, person and machine staring uneasily at each other across the desktop. Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives"* [43]. Ultimately, computers would "vanish into the background" *weaving "themselves into the fabric of everyday life until they are indistinguishable from it*" [43].

Today's health information systems are far from perfect and an attitude of openness and willingness to help to improve the health system is crucial. There is a need for a decision support tool for PHMC implementation that asks the 'right' questions, but does not restrict answers to a pre-defined, context-free set. Responses to questions may serve to identify information needs (including value assumptions), the expertise required and appropriate criteria to be used. Processes incorporating multiple opportunities for stakeholders' involvement at multiple points, and transparent, explicit approaches that incorporate social values or equity arguments into decisions on the development, implementation and funding of pervasive health monitoring and pervasive healthcare, should be considered in the framework of PHMC technologies. The framework should be considered as a checklist of the necessary elements for improving the acceptability of processes and, in turn, decisions.

4 Requirements for PHMC Adoption

Pervasive technology has been identified as a strong asset for achieving the vision of user-centered preventive healthcare. In order to make this vision a reality, new strategies for design, development and evaluation of technology have to find a common denominator and consequently interoperate [3]. As Kreps and Neuhauser [44] so elegantly stated: *"eHealth information that is interactive, interoperable, personally engaging, contextually tailored, with the ability to be delivered to mass audiences can really make a difference in enhancing the quality of healthcare and health promotion efforts. It can reach diverse audiences with information that matches their health needs and communication orientations. Health information can be easily updated and adapted to changing health conditions. It can foster greater participation between interdependent healthcare providers and consumers and insure that all crucial stakeholders in the healthcare enterprise have access to timely and accurate information to guide their decisions"*.

Requirements with regard to the technology of pervasive monitoring systems point foremost to the use of sensors that are: non-wearable; unobtrusive (embedded sensors networks, nanosensors, etc.); compact; lightweight; with long battery life; simple to operate - that is, intuitive and thus requiring little training; relatively easy to customize for different approaches; feasible devices supporting teleassistance. Moreover, monitoring should be ubiquitous. The interface with the user should be not very complex but also not very simple, clinically intuitive with all the features necessary to allow clinicians to deliver high-quality care or to be used for self-management of therapeutic processes. The comprehensive information on the important technological requirements for pervasive healthcare aplications and various solutions for optimization of usability of existing technology for pervasive sensing and pervasive health was presented by Varshney [45].

Many important issues are currently related with sensors and actuators for unobtrusive health monitoring (e.g. improve reliability of non-contact electrocardiogram, ballistocardiogram, unobtrusive plethysmogram or unobtrusive motor activity monitoring) as well as software architecture aiming to provide means for applications running on pervasive sensing devices to make use of a wide range of mobile devices, short-range and long-range wireless communication. In a pervasive health context, the system should integrate heterogeneous devices, to support a multimodal interaction and user interface migration, and also to manage context information. The user should have access to expert fuzzy systems which may provide a "prognosis" in the form of predicted outcomes - with each outcome presented as a curve that is a function of time, and the possibility to explore different intervention plans. In addition to decision support, tools that provide motivation and assist with compliance with treatment or instructions for healthier lifestyle should be available. Virtual reality and augmented reality may contribute to increase accessibility to more comprehensive and efficient health care. For instance, "mediated immersion" (pervasive experiences within a digitally enhanced context) may allow that a patient consult remotely, in real time a physician, and that consultation and diagnosis may be based on using a 3D functional model of patient body or body part, by accessing data from sensors that monitor physiological and biochemical changes in the patient, as well as patient health database (comorbidity, allergy, treatments, etc.).

There are now open issues and technological challenges in pervasive health monitoring related with access to health information, power management, lack of comprehensive coverage of wireless and mobile networks, reliability of wireless infrastructure, privacy and security, representation of data, autonomic decision making, and interoperability. Although several technologies are developed to improve security and privacy (see [46]), more work is needed in order to ensure the integrity and confidentiality of the information, mainly transmitted through wireless and mobile networks where security is still seen as insufficient. We list several references related with important requirements and barriers for pervasive health care. Although the selected literature mainly discusses issues related with HIT, architecture for sensor-enhanced health information systems and for information communication technology for effective PHMC could be design by thoughtful analysis of selected papers.

Requirements – Technology

Technology – Sensors and Actuators

"Design requirements for these types of sensors and actuators are strict, especially for those addressing the medical needs. The acceptance of such devices by the inhabitants is only possible if they are easy to install or to wear and configure. Also, the device should introduce as little inconvenience as possible to the patient."

[47] Agoulmine N et al, (2011), IEEE Nanotechnology Magazine

Technology – Sensors and Actuators

"An important aspect of improved usability will be to make health IT an increasingly invisible contributor to value-added care processes in much the same way that computers in cars provide invisible support for such critical functions as antilock brakes and electronic stability systems."

[48] Walker JM & Carayon P, (2009), Health Affairs

Technology – Sensors and Actuators

""Tailored interventions (e.g. those that afford participants access to interactive facilities for self monitoring, monitoring by health practitioners, individualized feedback, and telephone communication) may be more effective in engaging participants, building their self-efficacy, and improving their adherence with recommended health behaviours than programmes that present only generic educational information."

[50] Laakso EL & Tandy J, (2011), Physical Therapy Reviews

Technology – Sensors and Actuators

"The inclusion of appropriate interactive components for engaging patients within cyberspace may contribute to improved intervention efficacy, as would the inclusion of remote/wireless applications for monitoring and tracking outcomes."

[50] Laakso EL & Tandy J, (2011), Physical Therapy Reviews

Technology – Sensors and Actuators

"The need to have technology that can be responsive and adaptive to local needs appears as a common thread in successful implementation strategies, both in health care and in other sectors".

[49] Rozemblum R et al, (2011), Canadian Medical Association Journal

Requirements – Technology

Technology – Power Management

"[....] the *implemented energy-efficient application-specific integrated circuit (ASIC) has two standby modes. In the active standby mode, only an ultra-lowpower (ULP) timer with a low-frequency clock generator is active, and it periodically power ups the sensor node. In the passive standby mode, the whole sensor node is power silent, and a secondary passive radio frequency (RF) receiver works as the supervisor circuit. The specifically designed passive RF receiver can harvest energy from the RF signals in the space (transmitted by the master node which is not power critical), and hence, the passive standby mode consumes zero power ideally.* "

[51] Zhang X et al, (2010), IEEE Transactions on Biomedical Circuits and Systems

Technology – Communication Network

"A "multi-modal" telehealth system can include various channels of patient-to system communication: via a traditional telehealth hub device, web (PC or tablet) mobile phone, interactive TV, or interactive voice response (IVR).[...] In addition, despite the availability of multiple patient 'modalities', the care coordinator should have a single interface for managing data and assessments that flow from multiple channels of patient interaction."

[52] Gosh R & Schellhorn H, (2011), PervasiveHealth Conference

Technology – Communication Network

"Deployed sensors and actuators transmit their data either through wireless communication technologies using protocols such as ZigBee, Bluetooth, or wired communication technologies such as Ethernet or power line communications.[...] The wireless body area network (WBAN) allows the medical sensors and actuators to communicate with a control on short range to receive or send data."

[47] Agoulmine N et al, (2011), IEEE Nanotechnology Magazine

Technology – Communication Network

"The potentially spotty coverage of existing infrastructure-oriented wireless networks will significantly affect the delivery of monitoring messages [...] health monitoring can be achieved by using ad hoc wireless networks, formed among patients' devices that can transmit vital signs over a short range."

[45] Varshney U, (2007), Mobile Network Application

Requirements – Technology

Technology – Autonomic Decision Making System

"Some intelligence in the form of context awareness can be built in pervasive services to avoid "False-positive" alerts."

[45] Varshney U, (2007), Mobile Network Application

Technology – Autonomic Decision Making System

"The ADMS collects, filters, and analyzes the data and then saves it in a local database. The goal of ADMS is to build a model of the inabitant's environment and maintain their medical profile. All the received data is transformed into knowledge to feed the embedded decision system. Based on the generated knowledge and as a set of predefined policy rules, ADMS may be able to understand the situation of the inhabitant and make appropriate decisions about his/her safety and health care in an autonomic manner. These decision can be either new knowledge in the system, actions to enforce in the smart home components (e.g., switching on a light and opening a window), or actions on the medical sensors (e.g. delivering a drug and changing the sampling frequency). ADMS is also responsible for keeping the third party medical and safety institutions (e.g., hospital and police) fully appraised of the situation of the inhabitant."

[47] Agoulmine N et al, (2011), IEEE Nanotechnology Magazine

Technology – Autonomic Decision Making System

"Context can consist of both implicit and explicit information and can even be further divided among low level (such as time, temperature, and bandwitdth) and high level contexts (complex user activity). The primary context types are location, identity, time, and activity. In healthcare environment, the context types may also include current medications, handicaps, and current environment and may relate with person's identity and/or location, but likely to change with time."

[45] Varshney U, (2007), Mobile Network Applications

Technology – Autonomic Decision Making System

"Simply providing patients with access to their information online and enabling them to share it with others is inadequate; useful technologies for patients need to be 'integrated into the patient's…existing health and psychosocial support infra-structure'"

[48] Walker JM & Carayon P, (2009), Health Affairs

Requirements – Technology

Technology – Autonomic Decision Making System

"The interviews reveal that the information need of volunteers aids concerns foremost safe, relating to cases of falling incidents, fire, wandering, and intruder alert. [...] *Open interview with the residents (in assisted living residence) indicate that they may accept monitoring to the extent that it is used for the purpose of detecting and responding to emergencies."*

[52] Bakkes S et al, (2011), PervasiveHealth Conference

Technology – Autonomic Decision Making System

"Health Information Technology can also provide tools to help inform decision making with regard to diagnosis (with clinical prediction rules) prevention (reminders), disease management (registries), and treatment (electronic prescribing tools)."

[54] Bates DW & Bitton A, (2010), Health Affairs

Technology – Autonomic Decision Making System

"In addition, patients who may benefit greatly from information technology (ICT) adoption, in particular those with chronic diseases, are older on average, raising requirements for user friendliness. Their needs for ICT are also disease specific, necessitating different types of ICT. As a consequence, changes to the operating platform of health care ICT could require changes to many disease-specific

[55] Christensen MC & Remler D, (2011), Journal of Health Politics, Policy and Law

Technology – Autonomic Decision Making System

For chronically ill patient "[....] *using preventive interventions that are driven by predictive analytics, that can be automatically personalized for patients, and which empower patients to participate as a partner in the care delivery process."*

[52] Ghosh R & Schellhorn, (2011), PervasiveHealth Conference

Technology – Autonomic Decision Making System

"Sorting and searching of lists and linking of listed problems to relevant portions of progress notes, assessments, and treatment plans."

[56] O 'Malley AS, (2011), The New England Journal of Medicine

Requirements – Technology

Technology – Autonomic Decision Making System

"Barriers seen in practice to date with automated feedback systems include varying degrees of computer literacy, lack of technical support, and patient-related factors. These barriers emphasize that to be successful a computerized decision support system must be easy to use and feasible for use in real-world practice settings."

[57] Trivedi MH & Daly E, (2007), Drug Alcohol Dependence

Technology – Security

"[…] *it is suggested that implementation of digital watermarking should be complemented with data encryption mechanisms to improve the assurance and integrity of the data stored, retrieved or transmitted across electronic devices. It is vital that both patients and healthcare workers have confidence in the confidentiality and integrity of the information and data, and the security of the transmission channels.*"

[46] Adesina AO et al, (2011), South African Journal of Science

Technology – Interoperability

"Homer, a home system designed and developed at the University of Stirling, can communicate with any device within the home and then expose the functionality to a range of different interfaces on different platform. […] *Homer components are lightweight, loosely-coupled modules that can be installed, modified and removed from Homer at run-time.* […] *It is important to develop a home system which can dynamically install and uninstall devices within the home as they become available and unavailable, without interfering or restarting the home system."*

[58] Maternaghan C & Turner KJ, (2011), PervasiveHealth Conference

Technology – Interoperability

"[…] *to prevent losing the value of existing information communication technology, the ability to integrate old and new information communication technology (i.e., backward compatibility) may be critical for adoption. For example, long after the development of superior CD and USB flash drive storage technologies, many computers continued to have floppy disk drive readers. Backward compatibility is also important, as it lowers switching costs.* […] *However, backward compatibility can reduce the performance standard of the new technology below its potential; for example, a word processing program that accepts documents in old formats will not run as quickly.*"

[55] Christensen MC & Remler D, (2011), Journal of Health Politics, Policy and Law

Incentive for adopting pervasive health monitoring and coverage of some services may support development of health delivery models that are more efficient and of a higher quality, with reduced healthcare labor and at a low-cost healthcare platform for patients and healthcare professionals.

Requirements – Financial

Financial

"A national organization was viewed as a way to help establish a coordinated approach to lobbying for political support. The release of funds in accordance with performance benchmarks (gated funding) was also a feature of the Canada Health Infoway plan that was seen as an enabler of provincial buy-in and commitment."

[49] Rozemblum R et al, (2011), Canadian Medical Association Journal

Financial

"Until we place financial value on the kind of high-quality patient care that can only be achieved with information sharing, there is little reason to believe that the adoption of standards will progress at anything other than the current slow pace."

[59] Diamon C & Shirky C, (2008), Health Affairs

Financial

"[…] *a revised payment model that would provide financial incentives based on patient outcomes that can be achieved with the use of electronic health records."*

[49] Rozemblum R et al, (2011), Canadian Medical Association Journal

Financial

"The Patient-Centered Medical Home (PCMH) is a primary care model that aims to provide quality care that is coordinated, comprehensive, and cost-effective. PCMH is hinged upon building a strong patient-provider relationship and using a team-based approach to care to increase continuity and access. It is anticipated that PCMH can curb the growth of health care costs through better preventive medicine and lower utilization of services."

[60] Marshall RC et al, (2011), Military Medicine

In the study of Coye at al [62] is underscored that remote health monitoring should reduce health expenditure by: (1) early intervention - to detect deterioration and intervene before unscheduled and preventable services are needed; (2) integration of care - exchange of data and communication across multiple comorbidities, multiple providers, and complex disease states; (3) coaching - motivational interviewing and other techniques to encourage patient behavioral change and self-care; (4) increased trust - patients' satisfaction and feelings of "connectedness" with providers; (5) workforce changes - shifts to lower-cost and more plentiful health care workers, including medical assistants, community health workers, and social workers; and (6) increased productivity - decreased home visit travel time and automated documentation. In Europe, Denmark and Netherlands are the countries with higher adoption of health information technology [61,62,63]. In 2006, 98% of the Danish GPs, all 73 hospital and all 331 pharmacies shared data over the network, and about 80% of the totally exchanged healthcare information was sent electronically [60]. The Danish Centre for Health Telematics rates as significant factors for EHRs implementation: a) national, regional and local commitment, b) the cost-effectiveness of the program, c) close cooperation between clinicians and developers, efficient project management, c) testing and certification of software solutions and operators, and f) an intensive information and promotion policy. In our analysis, we find that in addition to optimization hardware and software for remote, unobtrusive health monitoring, more work should be done in order to allow PHMC adoption: 1) better evaluation of the implemented system; 2) better coordination of involved stakeholders; 3) respect and improvement of existing eHealth standards, or introduction of new standards for various aspects of PHMC; 4) collaboration and team work of all stakeholders that might benefit from pervasive health implementation; 5) training in using new technologies; 6) training for searching library and information sciences related with health technology and information communication technology; 7) training in thoughtfully analysis of added value associated with new health technology; 8) promotion of healthier lifestyle; 9) analysis of social organizational change process when is designed PHMC; 10) adequate policy support for quality improvement of pervasive health systems; 11) transparency with regard to the goal, business plan and process implementation of pervasive healthcare; 12) consideration of perception of patients, as well as perception of healthy individuals and patient - health professional relationship as a core organizational operational system for pervasive health monitoring; 13) healthcare equity through improved data collection; 14) education for technology literacy, and 15) education for lifestyle management using new technologies.

A number of publications cite the importance of involving the expertise and knowledge of healthcare professionals to ensure that emerging technologies are appropriate for clinical use [64,65]. Physicians, doctors, nurses, occupational therapists, nutritionists, physiotherapists must be involved in pervasive healthcare, they providing important skills and knowledge for promoting healthier lifestyle and for lowering negative impact of chronic diseases on patients and healthcare expenditure. Stevens [66] suggested that nurse involvement in system's design can yield positive results because they understand the context in which the system will be used and can link it with issues such as patient safety and user acceptance. Huryk [67] reported that nurses are more likely to be satisfied with a system if they have been involved in its design. Excluding healthcare professionals from the development of pervasive health monitoring systems is likely to be detrimental to their design.

Requirements – Logistic

Logistic – Quality Audit

"As explained by Kieran Walshe, theory driven evaluation would start with a theory about how implementation might work, and then design an evaluation to test the theory. The study evaluating implementation in the Swedish hospital [...] is an example of a theory-driven evaluation. Many more studies like this are needed, examining implementations at large and at small hospitals, rural and urban sites, and so forth, to build a useful evidence base about the factors important for health IT implementation."

[27] Goldzweig CL et al, (2009), Health Affairs

Logistic – Quality Audit

"To facilitate diffusion of technology necessary for improving patient safety and quality, others need to learn what are the determinants of a successful implementation and which IT applications do in fact have an impact. Therefore, it is important for these health IT projects to monitor and evaluate their implementation processes and effects. [....] Evaluating the value of health IT was hampered by the absence of validated instruments and measures, organizational demands that competed with data collection, and lack of evaluation expertise among health IT implementers."

[69] Damberg CL et al, (2009), Health Services Research

Logistic – Quality Audit

"The electronic records industry will find more enthusiastic adoption when they ask concerned clinicians about what their software and hardware fails to do properly and when they fix those problems."

[68] Kaufman JL, (2008), The New England Journal of Medicine

Logistic – Quality Audit

" The use of organized quality improvement efforts such as participation in a quality improvement demonstration program may be associated with increased delivery of recommended care processes, which in the context of this study translated into better performance on the clinical measures that were rewarded in the pay-for-performance program."

[69] Damberg CL et al, (2010), The American Journal of Managed Care

Requirements – Logistic

Logistic – Coordination

"There was consensus among the participants that a process is needed to update the architecture and standards of the e-Health plan on a continual, timely basis, and to provide guidelines and tools to manage this evolution. In addition, effective strategies for closing the gap between national standards and existing legacy systems were identified as a challenge in implementing the e-health system by our participants."

[49] Rozemblum R et al, (2011), Canadian Medical Association Journal

Logistic – Coordination

"System Flexibility: allowing for flexibility in the functionalities and use of systems rather than expecting and roles to reconfigures around new technology.

Organizational Flexibility: allowing for flexible redefinition of roles and responsibilities around new technology.

Local context: allowing for specificity and tailoring of services according to local policies and context."

[72] Bouamrane M-M et al, (2011), PervasiveHealth Conference

Logistic – Coordination

"Set up an appropriate balance between central coordination and local management. [...] The Danish Centre for Health Telematics rates the following as significant factors: a) national, regional and local commitment, b) the cost-effectiveness of the program, c) close cooperation between clinicians and developers, d) efficient project management, e) testing and certification of software solutions and operators, and f) an intensive information and promotion policy."

[73] Deutsch E et al, (2010), International Journal of Medical Informatics

Logistic – Coordination

"[...] *the stakeholders reported that the Canada Health Infoway blueprint needed to be less top-down, and more flexible and adaptive to accommodate changes in technology and feedback from implementation experiences."*

[27] Goldzweig CL et al, (2009), Health Affairs

Logistic – Standard

"[...] *the standard-setting process should account for the diverse interests in health care. This could be facilitated by a common operating platform and communication standards that maximally accommodate diversity."*

[55] Christensen MC & Remler D, (2011), Journal of Health Politics, Policy and Law

Requirements – Logistic

Logistic – Standard

"[…] *standards for moving data across the network are more important than standards expressing the content of that data. Put another way, it is better to share important but uncodified information between Doctor A and Doctor B so that an informed clinical decision can be made, than to have perfectly formatted data that never leaves Doctor A's office.*"

[59] Diamond C & Shirky C, (2008), Health Affairs

Logistic – Team based care

"*Impairments is individual and varied and as such what works for one person does not work for another, therefore it is even more crucial that people with special needs be consulted in what enables their independence in their home.*"

[74] Jarrold D & Boumrane N, (2011), PervasiveHealth Conference

Logistic – Team based care

"*Ideally, there needs to be a set of clinicians, managers, and informaticians looking constantly at ways questions can be asked of the data in order to improve care quality, outcomes, and work processes from the perspectives of all key stakeholders.*"

[77] Detmer DE, (2009), Information Knowledge and Systems Management

Logistic – Team based care

"*HIT can support team-based care with tools enabling team members to identify patient care goals and document and monitor progress using a shared care plan.*"

[56] O´Malley AS, (2011), The New England Journal of Medicine

Logistic – Team based care

"*It is important to see health information technology less as an alternative means of documentation and more as a new information system that offers clinicians an opportunity to transform the way in which they deliver.*"

[74] Maxson E et al, (2010), Annals of Internal Medicine

Requirements – Logistic

Logistic – Training

"[...] *organizations successful in utilizing e-prescribing software reported greater familiarity with the capabilities and purpose of the system.*"

[77] Police RL et al, (2011), Informatics in Primary Care

Logistic – Training

"*The experts will use their experience with EHR implementations and the subject matter to help physicians and administrators select an EHR system that meets their needs.*"

[76] Maxson E et al, (2010), Annals of Internal of Medicine

Logistic – Training

"*Other facilitators of adoption included the availability of technical support for the implementation of information technology (47%) and objective third-party evaluations of electronic health record products (35%).*"

[78] Jha AK et al, (2009), The New England Journal of Medicine

Logistic – Training

"*Education for health information professionals must be based upon a solid founda-tion of the changing paradigms and trends in health care and health information, as well as technological advances, to produce a well-prepared information workforce to meet the demands of health-related environments. Educational programs should begin with the core principles of library and information sciences and expand in interdisciplinary collaborations.*"

[79] Cleveland AD, (2011), Journal of Medical Library Association

Logistic – Life Style Incentive Management

"*Micro-payment to a user device every time the user exercises or eats healthy food. This mobile money can then be used for paying wireless monthly charges, for donating to a charity of user's choice, or for paying healthcare expenses.*"

[45] Varshney U, (2007), Mobile Network Application

Requirements – Logistic

Logiic – Life Style Incentive Management

"*Computer-based interventions that afford patients timely access to educational and interactive tools are indicated for use with behaviours that require regular input to elicit and maintain selfregulation such as dietary and physical activity*."

[50] Laakso EL & Tandy J, (2011), Physical Therapy Reviews

The liability issue is very important for future adoption of PHMC. Lack of clear regulation and fair penalty related with the cost of lawsuit abuse and fraudulent lawsuits undermine the use and large scale adoption of IT in health care. For instance, the contract for realization of Romanian national health information system - the SIUI (Sistemul Informatic Unic Integrat), was assigned without compliance with requirements of policy related to the type of the contract and without written responsibility of providers for not respecting deadlines and for losses produced by errors in the system. After 6 years and more than 120 million euros for deployment and optimization, the system was blocked in January 2011 because of "some errors in software". A prejudice of 1, 400 000 euro was made by the "errors" of SIUI. The evidences on the value of prejudice and those associated with errors in SIUI were not followed by any criminal responsibility.

Requirements – Liability

Liability

"*The lack of a national policy or harmonized provincial policy to guide investment and adoption was seen as a problem.*"

[49] Rozemblum R et al, (2011), Canadian Medical Association Journal

Liability

"[....] *50% of respondents to the survey of Massachusetts medical providers identified political and structural issues within their practice groups as the most important factors influencing electronic medical records adoption.*"

[77] Police RL et al, (2011), Informatics in Primary Care

Requirements – Liability

Liability

"Health On the Net (HON) is an organization that reviews and accredits Web sites. […] The Top 100 List: Websites You Can Trust (Medical Library Association, Consumer and Patient Health Information Section, 2008) lists Web sites that have been evaluated for quality and content by the Consumer and Patient Health Information Section (CAPHIS), a section of the Medical Library Association […]The National Library of Medicine offers an online tutorial, Evaluating Internet Health Information: A Tutorial from the National Library of Medicine (U.S. National Library of Medicine and the National Institutes of Health, 2007) and a MedlinePlus Guide to Healthy Web Surfing (MedlinePlus, 2010)."

[82] Golterman L & Banasiak NC, (2011), Pediatric Nursing

Well-designed electronic medical records based on pervasive sensing and computing should ensure that providers have appropriate client information at the right time and in the right format to make decisions about client care before, during, and after clinical encounters. Patients' empowerment may contribute greatly to acceptance, and by their implication in the design of the system, an increase in the effectiveness in practice of pervasive health systems may also be achieved.

Pervasive healthcare require changes to workflows, increased emphasis on preventive care, retraining or hiring staff, and increased financial incentives to report and improve performance. The key to maintain partnerships between stakeholders should be honest, open, with frequent communication that builds trust, understanding of other partners' priorities, grasping organizational and operational environments and constraints.

Requirements – Psychological

Psychological

"Family and friends are the main source of information on specific technologies, but a personal physician is identified as the most trusted source when Americans consider potential risks and benefits of using a new technology."

[83] Schur CL & Berk ML, (2008), Health Affairs

Psychological

"Physicians' perceptions of medical care quality improved as the number of health information technology (HIT) types used increased. This study supports more extensive use of HIT in physician practices."

[84] Fang H et al, (2011), American Journal of Management Care

Requirements – Psychological

Psychological

> *"Pushing the "send" button requires that the people who need to share information trust each other, understand and implement the necessary protections for the information they hold, and know that the information policies in place across a network will be upheld and enforced in the event of a breach."*
>
> [59] Diamond C & Shirky C, (2008), Health Affairs

Motivation, greater availability of reliable devices for self-monitoring, measurements for the practitioner between appointments, and a better selection of treatments based on individual response, are all aspects that contribute to the more frequent use and popularity of self-monitoring [80,81,103]. Web based software that may enhance motivation for healthier lifestyle increases compliance with the treatment. Moreover, personalized health monitoring and personalized care may enhance adoption of pervasive health systems. Already, there are many health information applications based on the Internet. However, in 2002, a systematic review [68] has shown that quality of health information available to consumers via the Internet is problematic. A total of 79 studies were included in the review, which assessed 5,941 health related websites, 1,329 web pages and 408 evaluation results for 86 distinct quality criteria. The authors reported that 70% of the studies found that the quality of information on the Internet was problematic, 22% of studies remained impartial, and only 9% of studies achieved a positive assessment regarding quality. In our opinion, more meaningful information related with health may be obtained through the Internet by reinforcing the patient-health professional relationship in the designing of mobile technology and Web 2.0. based systems. This opinion is based on evidences that health professionals are identified by patients as the most trusted sources of information on the potential risks and benefits of using a new technology [103].

5 Barriers to Adoption of PHMC

Deutsh et al [71] analyzing the problem documented during implementation of EHRs in five countries – Denmark, England, Germany, Canada and Australia – have suggest that equal attention needs to be devoted to acceptance, change management, health-policy related goals and implementation strategy, basic legal conditions, data protection as well as technological aspect.

In our analysis, local and regional funding [60] was identified as important problems in the implementation of eHealth. Initial start-up challenges for implementation of PHMC encompass constraints on funding but these costs may be diminished by adapting, where is possible, the existing PHRs, PCMH, EHRs, EMRs to ubiquity and unobtrusiveness in health monitoring. An open issue remains identifying how, when, and by whom this technology and services will be funded. The pertinent issues also involve questions about willingness to pay more for health care on a collective basis and the value and distribution of the benefits gained from higher spending on health care [14]. The decision to fund should take into consideration the implications, the extent to which the transformation will cause shifts in the quality of the process of care, and cost-effectiveness of the pervasive health monitoring implementation, by using social management models and financial results. To deliver better health care at a lower cost, health technology should be redesigned to support improved, patient-centered care and not the isolated tasks of physicians and clinicians [46]. If policy-makers are able to take a more discerning approach to reducing coverage, with a focus on enhancing value and avoiding harmful effects on equity, they may be more successful in alleviating pressure on the public budget. This in turn would contribute to achieving a higher level of attainment of health system goals (or at least prevent them from being further undermined) [14].

Barriers – Financial

Financial

"Most hospitals that had adopted electronic records systems identified financial factors as having a major positive effect on the likelihood of adoption: additional reimbursement for electronic health record use (82%) and financial incentives for adoption (75%)".

[78] Jha AK et al, (2009), The New England Journal of Medicine

Financial

"The need for interoperability can raise switching costs from training and translation if switching one technology changes how another technology is used.[….] switching costs may be so high that users are effectively locked into a specific form of ICT, either at the system or the vendor level, and as a consequence new technologies may never be adopted. Depending on the industry, the risk of system disruption or breakdown makes the risk of using a new vendor or technology, especially an unproven one, potentially huge. Such breakdown may imply irreversible damage to the company or individual user."

[55] Christensen MC & Remler D, (2011), Journal of Health Politics, Policy and Law

Barriers – Financial

Financial

"Funding was the primary barrier. With their up-front costs for hardware, software, training, and transition and their ongoing operational costs, IT systems were beyond the reach of some smaller agencies. Other funding barriers included program reluctance to give up reimbursable staff time for researching, learning, and implementing new systems or to allocate funds to improve slow internet access and infrastructure of current IT systems. One agency supervisor stated that funding was a barrier to improving information management at the agency: 'Money is always an issue - there's never enough.'"

[97] Wisdom JP et al, (2010), Contemporary Drug Problems

Financial

"If a large incentive is applied to one type of output, other outputs might be neglected, and overall care might worsen. Thus, a large financial incentive based on a narrowly focused set of measures may lead to the unintended consequence of having a physician "teach to the test," devoting resources to those things being measured and neglecting other important outputs that are not being measured. Teaching to the test is why few private-sector corporations put a large fraction of employee income at risk with incentives."

[98] Siva I, (2010), American Journal of Managed Care

We found out that less successful implementation of health information technology is associated with financial constraints but also with : privacy policy and related issues; poor transparency towards work plans and with regard to the business project for HIT implementation; underestimation of complexity of the technological, clinical process and organizational problem; fragmented or lack of responsibility in management of health information system implementation; low effective, persistent and consistent management of system implementation for more closely coordinated forms of health and social care provision; lack of quality audit of the implemented health information technology in some healthcare systems; health professionals perception related mainly with less evidences on added value of some implemented eHealth approaches; less or even lack of collaboration and team work of all stakeholders - patients, doctors, therapists, sociologists, engineers, computer technicians, etc.; aspects of psychological perception and culture associated with all stakeholders involved in health information communication technology.

Barriers – Logistic

Logistic - Team based care

"Moreover, inadequate attention to clinicians, the key users of electronic health records, was viewed as a critical ingredient missing from the e-Health vision."

[49] Rozemblum R et al, (2011), Canadian Medical Association Journal

Logistic - Productivity

"Three recent provider surveys indicate that many physicians cited the upfront, and possibly continued, loss of productivity associated with the transition from a paper-based to electronic system of data management as a barrier to HIT adoption."

[77] Police RL et al, (2011), Informatics in Primary Care

Logistic - Maintanance

"Finally, health IT project budgets (even in the most robust organizations) rarely provide the resources that would be needed before and after initial implementation to do the complex work of analyzing existing care processes; designing value added processes; specifying, programming, deploying, and maintaining health IT to support those processes; and training care teams to execute them effectively."

[48] Walker JM & Carayon P, (2011), Health Affairs

Logistic - Training

"Staff experienced barriers in technology-related training, logistical challenges in integrating the technology, and sustaining the technology."

[96] Wisdom J et al, (2008), Journal of Behavioral Health Services & Research

Standards can improve but can also be a barrier for pervasive health monitoring and care adoption. There are a lot of important standards for sensors development, biosignal acquisition and processing, wireless communication, data networking, eHealth (i.e. HL7). However, as was shown for EHRs [27], many of the applications do not respect these standards. Furthermore, the history of failed standards efforts is filled with vendor approved standards that never passed the crucial test, which is clear utility for the user. Many very well-designed data-networking standards, whether designed by individual vendors or international consortia, were largely unable to compete on a global scale with the Internet's simple but evolving standards [27]. Diamond and Shirky [59] discussed the issue associated with standards in eHealth. They suggest that health information technology should use a minimal set of standards at first, mainly focusing on standard for sharing information, standards guided by a clear policy framework

Barriers – Technology

Technology

"Some authors have speculated that the significant variability in HIT adoption across practice specialties may stem from the fact that existing EMRsystems do not meet the clinical needs of certain physician organizations."

[77] Police RL et al, (2011), Informatics in Primary Care

Technology

"Clinicians frequently comment that "I work for my EHR instead of my HER working for me." Poor usability can result in errors that threaten patient safety, loss of productivity, and the failure to realize the quality and efficiency benefits of health information technology."

[95] Blumenthal D et al, (2011),The New England Journal of Medicine

Technology

"The EMR is currently considered an immature technology which staff have described as 'clunky' and which currently interfaces poorly with other ICT systems. Many staff have given up using it 'until it works better'. [...] An annual software upgrade in the Veterans Association in August of 2008 resulted in faulty displays of medical records and consequently incorrect doses of drugs, unimplemented treatment cessations, and delays in treatments (Associated Press 2009)."

[55] Christensen MC & Remler D, (2011), Journal of Health Politics, Policy and Law

Technology

"The types of phone the (elderly) participants have are older phones with very limited screen, as the phone seem to be passed on to them by their children."

[55] Christensen MC & Remler D, (2011), Journal of Health Politics, Policy and Law

Technology

"Connectivity and interoperability problems were cited as barriers to effective utilization in two recent studies. A cross-sectional survey of primary care providers reported that 52% of physicians had connectivity issues with their EMR during patient visits. Although it is optimal for HIT systems to be able to directly exchange information, true system interoperability has yet to be achieved."

[77] Police RL et al, (2011), Informatics in Primary Care

Furthermore, the pattern of a high degree of technical design but a low degree of trust or incentive to share describes a number of prominent failures [89] in health information technology. Considering that, in many cases health care practitioners fail to assist and/or oversee the nature and content of HIT, creating opportunities for the development of imprecise, dangerous or erroneous medical information [90,91]. For instance, Hardey [92] describes incidents where unidentified online sources have inadvertently or advertently become creators of untrustworthy health information and unregulated distributors of healthcare. Scheidt [93] underlines this fact, stating that technology has a nested context and needs to be considered in relation to such contextual community factors as place, systems, re-structuring strategies, and socio-economic patterns. Failing to account for the variety of ways in which information communication technology is embedded in practice settings, compromises our overall understanding of how people perceive and choose to engage with technology [94].

Barriers – Liability

Liability

The United States and Europe "[…] *shows that both systems are facing problems requiring policy changes. Much attention has been focused on the time to approval and regulatory barriers in the United States, but we found numerous examples of high-risk devices that were first approved in the European Union but showed no benefit or demonstrated substantial safety risk in subsequent testing.* […] *The few studies that have evaluated the performance of regulatory systems have relied on unconvincing outcomes such as recall rates. Because recalls require a number of unpredictable steps (including device-malfunction recognition, reporting, aggregation with other events, and regulatory action), low rates of recalls do not show an optimally functioning system, and high rates do not necessarily translate into patient harm or identify regulatory flaws.* [...] *Key problems in the European Union are the near-total lack of empirical evidence regarding the performance of its system and the lack of public access to either premarket or postmarket data. Data transparency also promotes improved knowledge about device performance and would facilitate more precise comparisons of regulatory decisions among regions.*"

[88] Kramer DB et al, (2012), The New England Journal of Medicine

Moreover, an overly "top-down" approach and insufficient engagement of clinicians were aspects considered to lower the adoption rates of EHRs in Canada [49]. The study suggests that although a "top-down, technical, architecture-first" approach may eventually lead to the same outcome as a "bottom-up, clinical needs-first" approach, the "top-down approach" could be too slow, expensive and inefficient.

Privacy and security are the great concern among physicians and patients. The news are often filled with stories of lost data files or system breaches that threaten the security of consumer information. The PHMC implementation should establish a level of confidence in the data communication in order to avoid disclosure to those to whom it should not be, whether the disclosure is accidental or malicious. Protection of the data should take into account integrity of data - ensure that the recorded information is correct and is not in any way corrupted. A corrupted patient record is a serious problem and could lead to errors in medications, treatment and even to the death of a patient.

Barriers – Psychological

Psychological - Perception

"Privacy and security remains a great concern among the American population these days. The news is often filled with stories of lost data files or system breaches that threaten the security of consumer information. Fears of patient information getting into the wrong hands are a very real concern."

[73] Deutsch E et al, (2010), International Journal of Medical

Psychological - Perception

"Among caregivers, there may be resistance to using unfamiliar products and devices. [....] At home, families are resistant to working with technology as they fear it will compromise the autonomy or dignity of their loved one [....] The elderly individual may also have reservations. Anything atypical is often looked at with skepticism, and interoperable nursing facilities or assisted living facilities are the anomaly—not the norm - at this point in time, although over the next decade it is likely that the use of this technology in these settings will grow exponentially. A senior may feel more comfortable speaking with a nurse or physician about their health, and may feel intimidated by the technology and find it unusable. Residents may fear that provider's use of computers creates an artificial barrier between themselves and those caring for them. In the home setting, people's fears about reliance on technology often relates to a fear of dehumanizing the individual or invasion of privacy."

[85] Goldwater J & Harris J, (2011), Ageing International

Psychological - Perception

"[...] acceptance problems or even resistance from doctors resulting from the impression that the primary purposes are to save costs and achieve greater control."

[73] Deutsch E et al, (2010), International Journal of Medical

Barriers – Psychological

Psychological - Perception

"A crucial part of technological literacy is recognizing that all technologies bring with them both positive and negative consequences. Most students find it easy in their ExploraVision entries to list the positive impact of their innovation. More difficult is recognizing the negative impact."

[86] Eisenkraft A, (2011), Technology and Engineering Teacher

Psychological - Perception

"[...] *'organizational trust' and 'adaptive practice culture' are two factors that positively influence the utilization of e-prescription technology within a physician organization."*

[77] Police RL et al, (2011), Informatics in Primary Care

Psychological - Perception

"Generally the participants (29/34) were willing to accept such a technology and felt it would be a great addition for their future healthcare. However, some the participants would prefer to talk to the physician rather than use video conferencing (19/34)."

[87] Dhukaram AV et al, (2011), PervasiveHealth Conference

Pervasive health monitoring and care may be beneficial by improving the health system ability to effectively coordinate care between multiple providers from different health disciplines, in order to assure better access to healthcare for patients located in a wide geographic area. However, presently there are few solutions on interconnectivity/interoperability that allow monitoring and computing everywhere, any time through mobile network, cloud computing, etc. Moreover, a paucity of studies exists with evidences on the added values that PHMC may bring to healthcare systems and to clinician-patient relation. These may reinforce entrenched psychological and cultural barriers related with pervasive health monitoring and care implementation (e.g. perception that healthcare professionals and patients are less prepared to learn to use information technology; resistance to change of the relationship between healthcare professionals and patients; less perception of many engineers and computer technicians on their limited knowledge on bioethics, standards use in healthcare and biomedical measurements; ethnical and racial disparities in access to health care in some countries; communication proficiency between providers and patients; culture, in some countries, that prevent mandatory of quality audits, etc.). For efficient PHMC implementation researches and evidences on healthcare provider differences in communication proficiency, including varied listening skills and different views from their patients of symptoms and treatment effectiveness [99] may be carried out. In the design of PHMC systems should be address also factors influencing patient centeredness and provider-patient communication that include: language barriers; racial and ethnic concordance between the patient and provider; effects of disabilities on patients' health care experiences; providers' cultural competency [100]. Efforts to remove these possible impediments to patient centeredness are carried out in many countries. For instance, in the USA, the Office of Minority Health has developed a set of Cultural Competency Curriculum Modules that aim to equip providers with cultural and linguistic competencies to help promote patient-centered care [101]. These modules are based on the National Standards on Culturally and Linguistically Appropriate Services. The standards are directed at healthcare organizations and aim to improve the patient centeredness of care for people with *Limited English Proficiency* (LEP). Another example, which is being administered by the Health Resources and Services Administration, is *Unified Health Communication*, a Web-based course for providers that integrates concepts related to health literacy with cultural competency and LEP [100].

Health literacy and health information technology literacy are important barriers to adoption of pervasive health monitoring and care. Patients with limited health literacy are more likely to have difficulty understanding instructions and taking medication properly [100], incur higher medical costs and are more likely to have an inefficient mix of service use compared with those with adequate health literacy [102]. They may also experience many difficulties, including: less frequent preventive care; poorer understanding of their conditions and care; higher use of emergency and inpatient services and higher rates of rehospitalization; lower adherence to medication schedules; less participation in medical decision making [100].

It is understood today that there are many good reasons to believe that healthcare professionals education on HIT, that includes content on knowledge, skills, and attitude related to public HIT processing will improve healthcare quality. In addition, training in public health and biomedicine standards and ethics is needed for computer technicians and engineers involved in the development of HIT in order to foster the development of PHMC.

Furthermore, policy measures need to ensure that consumers and service providers are discerning and critical in their use of eHealth services. Such policies should also highlight the necessity to educate consumers. Policy initiatives will need to provide a comprehensive framework, which will ensure that broad-ranging consumer eHealth services can be effectively, efficiently, and safely accessed [103].

6 Conclusions

At the present pace of innovation in technology, medicine practice will change profoundly in the next decades. An increasingly significant characteristic that has emerged through the use of eHealth applications is the rise in consumer empowerment. The patients will not only take a more active and self-managing role, but will be also able to manage parts of their healthcare remotely.

In this work we present our analysis on requirements and barriers to PHMC development and adoption. More work are necessary to be carried out on: optimization of hardware and software for remote, unobtrusive health monitoring; better evaluation of the implemented systems; better coordination of the involved stakeholders; respect and improvement of existing standards and introduction of new standards for various aspects of eHealth system; collaboration and team work of all stakeholders benefiting from pervasive health implementation; training in using new technologies; training for searching library and information sciences related with health technology and information communication technology; training in thoughtfully analysis of the added value associated with new health technologies; promotion of healthier lifestyle using health information technologies; more attention and analysis on social and organizational change process when designing PHMC; adequate policy support for quality improvement of pervasive health systems; transparency with regard to the goal, business plan and process implementation of pervasive health care; perception of patients, healthy individuals and patient-physician relationship as a core organizational operational system for PHMC; healthcare equity through improved data collection; education for technology literacy; and education for lifestyle management using the new technologies.

Barriers to implementation are associated with: financial constraints; privacy policy and related issues; poor transparency towards work plans and with regard to the implementation of health information technology; underestimation of the complexity of the technological, clinical process and organizational problem; low effective, persistent and consistent management of health information technology implementation in health care systems; less or even lack of collaboration and team work of all stakeholders; fragmented or lack of responsibility related with defects and failure in some implemented projects of health information technology; lack, in many countries, of quality audits of eHealth implemented systems; perception and culture associated with all stakeholders involved in health information communication technology.

As a future step, the results of our analysis may be crosschecked and used to mathematically model the cost effectiveness of implementation and adoption of PHMC using quantitative measurement of factors identified in our work and potentially supplemented by others standardized surveys. The new knowledge acquired using these type of evaluation may allow to find solutions for building a sustainable health care system through a flexible environment that adaptively responds to all instability and all unpredictability in the next future, where our life and all business are extremely interconnected in chaotic patterns.

We imagine a world where embedded sensors in our houses or work environment (furniture, wall, floor, toilet, etc.) or inside our body (nanosensors, smart nanorobots, etc.) may send, on demand, reports on health changes during the last hours, or during a day, a month or a year. The reports may be based on measured physiological parameters (heart rate, blood pressure, physiological stress reactivity, weight, temperature, glycemia, cholesterolemia, metabolic equivalent for task, etc.) or on psychological and behavioral data (e.g. meaningful analysis of speech, mood, gesture, muscle force, daily motor activity, etc.). The reports may also suggest personalized healthier lifestyle instructions. We imagine a world where using virtual reality, or "mediated immersion" or augmented reality, we can consult, sitting in our house or in our work place, a health professional that we can choose by consulting data associated with their performance on quality of care measurements. We imagine a world where the quality of life for people with chronic diseases is improved by real time monitoring of health parameters, medication, treatments, etc., through cognitive sensors network that should constantly self-adapt based on the dynamic context of the environment, individual stakeholders, and even more, compelling the interactions and relations between them.

Think about it. The present survey shows that there are people working to build such a world.

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