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Consideration the Relationship between ICT and Ehealth

Sadr, Seyed Mohammad Hossein *
Ph.D student in Management Information Technology, Department of Management and accounting, University of Allame Tabataba'I (ATU), Tehran, Iran.
* E-mail of the corresponding author: sadr.mba@gmail.com.

Abstract
Information and communication technologies (ICTs) are potentially powerful instruments to strengthen health systems, with innovations ranging from electronic health records to transmission of clinical data. Information and communication technologies have already become inseparable part of healthcare sector activities. In the paper we present existing solutions of ehealth and ambient assisted living systems developed by researchers of the Faculty of management and economics University in allame Tabatabae. We also touch the issue of interoperability that is crucial for correct interconnection of medical and other devices and information systems. We propose a high level functional architecture of a system that can satisfy the requirements of interoperability.
Keywords: information technology; communication technology; eHealth; mHealth; interoperability; healthcare.

1. Introduction

Health concerns all of us. Information and communication technologies (ICTs) are increasingly providing us with the tools and knowledge that we need to improve health care, enabling solutions that benefit patients as well as healthcare professionals and institutions in both the private and public sectors worldwide. E-health can serve as a vehicle for the transformation of health conditions in the developing world, particularly for those living in rural and remote areas. Improving access to health care services in developing countries through ICTs has been receiving particular attention since the first World Telecommunication Development Conference (WTDC) in 1994. Disseminating information on successful e-health experiences helps our partner countries to gain a better perspective on why these have succeeded, and thus supports them in decision-making on how to develop and improve their own programmes in this key area.

In 2005, the World Health Assembly recognized e-health as the way to achieve cost effective and secure use of ICTs for health and related fields, and urged its Member States to consider drawing up long-term strategic plans for developing and implementing e-health services and infrastructure in their health sectors. To successfully prepare these so-called “e-health Master Plans”, close cooperation between both healthcare and telecommunication professionals is essential. Amongst the strategic issues to consider are how to share infrastructure to reduce costs and how to integrate security and privacy aspects into planning activities (Lhotska, et al, 2011).

This concise document is intended for decision-makers in the health, telecommunications and information technology sectors, particularly in developing countries. It aims to increase awareness of the opportunities that information and communication technologies (ICT) can bring to the health sector (in the form of e-health), thereby opening the way for the development and implementation of useful and sustainable products and services in their respective countries.

This document, while modest and clearly in need of ongoing review, correction and expansion, is intended to serve as a point of departure for international discussion. The goal is to accelerate the assimilation of ICT in the health and medical sectors with a view to the rapid, effective, quality-based and sustainable transformation of health systems themselves.

The many differences that exist in terms of health conditions and healthcare systems make it impossible to define a universal methodology. However, just as in the case of individual medicines, our experience over time enables us to determine "what works" and "what does not work".

The present and the future are already – and will be increasingly – characterized by rapid technological change, ever more affordable prices and increasingly user-friendly solutions. But these positive trends will be genuinely beneficial and sustainable only to the extent that a framework for action, at the political, health, technological, economic and social levels, is up and running within each country. Our intention here has been to outline the initial main strands of this framework so that stakeholders from the sectors concerned can take the first steps, and then systematically take the plan forward in greater detail, tailoring its various aspects in accordance with their specific requirements.

This progressive approach is essential if our shared aspiration is to rise to a key challenge of the Millennium and "connect the unconnected". Where health is concerned, the connectivity targets support meeting the legitimate and achievable objective of "e-health for all by 2015" to realize the broader 2015 United Nations Millennium Development Goals in health, education, employment and poverty reduction.

2. Brief history and definition of e-health

The term "e-health", coined in the latter part of the twentieth century, can already be found in around 4,000,000 Web pages. In the latter part of the nineteenth and early part of the twentieth century, medical applications were quick to derive benefit from the progress being made in the field of analogue telephony. The technology enabled not only individuals to call the doctor but also hospitals to transmit electrocardiograms over telephone lines. These were the early days of "tele"-medicine, or medical care delivered remotely. However, bandwidth limitations and the consequent low rate of data transfer over the copper wires then in use, coupled with interference and various types of noise, put a brake on the expansion of these analogue techniques (Lhotska, et al, 2011).

Since then, the boom in data digitization, computerization and digital networks witnessed since the mid-twentieth century has moved beyond telemedicine and has led to a multiplicity of e-health applications. These have emerged from academic research laboratories and have increasingly become part of people's everyday lives.

Digital telemedicine has experienced tremendous growth over the past 25 years and is now a major component of e-health. It enables, among other things, the exchange of healthcare and administrative data and the transfer of medical images and laboratory results. Improvement in these processes has gone hand-in-hand with the technological progress that is generating ever higher bandwidths, greater storage and processing capacities, smaller and smaller components and higher levels of security. This has occurred in the context of decreasing costs and increasingly user-friendly features. It is now reasonable to expect that by 2015 every inhabitant of our planet will, from any location and at any time, be able to access the medical information necessary to maintain his or her health or seek a cure for his or her illness.

To take up WHO's famous "Health for all in 2000" declaration, made in Alma Ata, we may now speak of "e-health for all in 2015" as being a credible and realistic objective – and one which it is our shared responsibility to achieve.

Different definitions have been used over time to designate ICT applications in the service of health.

Around 1970, the term "medical informatics", considered at the time to be state-of-the-art technology, was used to refer to the processing of medical data by computers. However, the importance of "information processing" was to be rapidly superseded by that of "information communication", as seen in the extremely rapid development of the Internet. Health applications then became known as "health telematics" or "telemedicine", and now "e health".

The acceleration of transfer rates over networks of interconnected computers (currently in the order of several gigabytes per second) has removed all barriers to the exchange of medical data, physiological signals and medical imagery between computers. The standardization of exchange protocols between computers, such as the Internet Protocol for example, in addition to the improved structuring of medical data and data security rules, is increasingly making it possible for health professionals in different locations to understand one another and work together, despite differences in languages. It is now clear that the value of these applications lies not in the technology itself, or even in the exchange of data, but in the ability to develop human networks of competence and expertise in the field of health. In short, this new way of working – networking all those involved in the health enterprise – is rapidly expanding thanks to technological progress.

The common denominator in all of these technologies is data digitization, without which data could not have been processed and exchanged in the manner to which we have become accustomed. This is why, rather than proposing a series of more or less restrictive academic definitions for the use of ICT in healthcare, the consensus approach is to bring all of these applications together under the term "ehealth".

The prefix "e-", standing for "electronic", is similarly used in numerous other applications such as "elearning", "e-governance" and "e-transport", to convey the notion of digital data (as opposed to conventional analogue data such as paper medical records, electrocardiogram printouts and x-ray film). Without digitization there would be no automatic processing and no instantaneous exchange via the network (Lhotska, et al, 2011).

The term "health" is used broadly and does not refer solely to medicine, disease, healthcare or hospitals. The scope of e-health is health in general, with its two major facets, namely public health which is the responsibility of States and is geared towards preventing and responding to disease in populations – and healthcare, which is geared towards individual patients and the treatment of disease.

Although healthcare accounts for over 95 per cent of health expenditure in the majority of countries, it should not be forgotten that public health (including diseases relating to the environment, ageing, predictive medicine, and so on) is, and will continue to be, at the heart of sustainable health systems in both rich and developing countries alike.

The notion of e-health thus covers all aspects of health, not only healthcare. The term is gradually evolving to refer to the skeletal structure for all health systems' functions. It is not simply a matter of improving the body of epidemiological data or exchanging files between public health institutions, but increasingly with using e-health technologies to bring about necessary reforms in health systems and thereby move towards the overall

improvement of health on a global scale. Examples range from individually-tailored health promotion measures in the context of the home, workplace or school to the customized delivery of healthcare to individual patients in many settings. One of the errors that are often made at the outset is to circumscribe developments in the field of e-health solely to the healthcare sector, as it is here that the developments are perceived to be more spectacular and more immediately beneficial.

3. Literature review

This section provides a detailed review of analytical frameworks that can be used to analyze the policy issues listed in Section 1.

3.1 Health

Health is a component of human capital, which in some recent literature is referred to as health human capital to distinguish it from education human capital (see Schultz, 1999; Lopez- Casasnovas, 2005). This is in contrast to other literatures (see e.g., Mankiw, et al., 1992; Barro and Sala-i-Martin, 1995), where the term human capital is used to mean education.

Human capital is part and parcel of human beings and is not easily measurable (T.W. Schultz, 1961; Mushkin, 1962; Becker, 1964; Lucas, 1988). The World Health Organization=s definition of health clearly illustrates the conceptual nature of health, and the implied difficulty involved in measuring it: Ahealth is a state of complete physical and mental well-being and not merely the absence of disease or infirmity (Lhotska, et al, 2011).

A further characteristic of health human capital is that it is positively correlated with other forms of human capital. Healthy individuals, for instance, are on average better nourished and better educated than individuals in poor health (Fuchs, 1996, 2004). However, although both health and education increase labor productivity, health has the additional feature that by reducing the time spent in sickness, it increases the total amount of time available to produce money earnings and commodities, as well as the time available for leisure (Grossman, 1972a,b).

As an asset, health is accumulated at the individual- or household level. To paraphrase Grossman (1972a,b; 2000), individuals must use their own time and transportation services to seek health maintenance care. The same idea has been echoed elsewhere: AHealth is produced by households not doctors or hospitals “(Dowie, p. 4). However, this does not deny the importance of hospitals and doctors as inputs into health production, as serious illnesses cannot be effectively treated without these inputs. The quotation emphasizes the role of individuals in choosing hospitals and doctors for treatment or in complying with treatment regimen. Moreover, households and doctors may, and often emphasize different dimensions of health. Many variables are used to summarize health status of households (Strauss and Thomas, 1998), and each captures only some facets of health and ignores others, and they generally measure even these emphasized facets with error and possible bias, adding to the econometrician's problems of estimating the effects of health capital on worker productivity or on consumer benefits.

3.2 Health care

The most important difference between health and health care is that health care is tradable in markets while health is not. However, health care markets are highly imperfect. The imperfection arises from the special characteristics of health care. These characteristics were introduced into the health economics literature by Mushkin (1962), Arrow (1963) and Klarman (1963). In the opening part of his paper, Arrow stressed that its subject matter was health care and not health. AIt should be noted that the subject is the medical-care industry, not health@ (Arrow, 1963, p. 94; emphasis in the original). The distinction is important because in the real world only markets for health care are observed. Although individuals trade health against other commodities over time (Claxton, et al., 2006), there are no markets in which sellers and buyers can exchange health.

Although individually, the health care attributes discussed below are not unique to health care markets, when Ataken together, they establish a special place for health care in economic analysis “(Arrow, 1963, p. 948). Following Arrow (1963), we illustratively discuss these characteristics with respect to a few categories of economic theory, as they relate to health care, namely: demand and supply, uncertainty, information asymmetry, and health care pricing practices.

Germano Mwabu (2007) shows that Good health is a determinant of economic growth and a component of well-being. His paper discusses and synthesizes economic models of individual and household behavior, showing how they may be used to illuminate health policy making in low-income countries. He show that there are large returns to health improvements in low-income countries. Moreover, health improvements in poor nations can be achieved through implementation of simple interventions such as dietary supplements, control of parasitic diseases, and pro-poor social expenditures. The paper concludes with a discussion of these policy options.

Information and communication technologies have become inevitable and almost inseparable parts of our lives. They have also penetrated many application areas, including medicine. In that way new term “eHealth” has

appeared. It represents those activities in healthcare practice that are supported by electronic processes and communication. There is no generally accepted definition – in literature we can find more than 20 characteristics. However, we can say that the term encompasses rather wide range of systems being at the edge of healthcare and information technology. The systems include electronic health records; telemedicine; consumer health informatics; health knowledge management; medical decision support systems; mHealth (use of mobile devices for different applications in healthcare). With boom of smart phones, iPhones and similar devices, mHealth has become an attractive application area. The mobile devices can be used for many different functions in healthcare. Let us mention the most frequently cited: collecting health data; delivery of healthcare information to clinicians, researchers and patients; real-time monitoring of patient vital signs; and direct provision of care (using tools of telemedicine). This technology obviously provides greater access to medical information, larger segments of population in developing countries, improving the capacity of health systems in such countries to provide quality healthcare. Many above mentioned functions of mHealth can contribute to better awareness of care for one own health, teleconsultancy, sending data about one's health to the doctor, informing people e.g. about air pollution and warning them of the situation. In [1] following application fields of mHealth were identified: diagnostic and treatment support; remote monitoring; remote data collection; education and awareness; helpline; communication and training for healthcare professionals. Gradually there appear new areas of interest in mHealth: emergency response systems (e.g., road traffic accidents, emergency obstetric care); human resources coordination, management, and supervision (e.g. natural disasters); mobile synchronous (voice) and asynchronous (SMS) telemedicine diagnostic and decision support to remote clinicians; clinicianfocused, evidence-based formulary, database and decision support information available at the point-of-care; pharmaceutical supply chain integrity & patient safety systems; clinical care and remote patient monitoring; health extension services; health services monitoring and reporting; training and continuing professional development for health care workers; health promotion and community mobilization. Recently there have appeared additional application areas on the edge of medicine, social care, and technology, namely assistive technologies and ambient assisted living.

In the next sections we present existing solutions in information technologies that can be advantageously applied to healthcare domain and projects already applied to healthcare, emergency medical care, and assistive technology domains.

A vast and exciting field of research and international action covering the various types of evaluation is due to come into being in the coming years, in which context the role of international organizations such as WHO and ITU will be decisive.

4. The main players in the field of e-health

In contrast to the traditional health sectors, e-health solutions require coordination with new players whose cultures, objectives and traditions are different.

In the first instance, we may identify the following groups of players:

· United Nations agencies and other international bodies dealing with health, telecommunications and trade
· Government authorities, health and telecommunication decision-makers at the national and regional levels, as well as the regional bodies to which they belong
· Academic and research institutions
· Local health professionals and their associations
· Consumers, patients and their associations
· Donors
· Non-governmental organizations
· The private sector, including foundations and industries related to health and ICTs
· The media.

Each of these groups has a different educational background and tradition, as well as differing responsibilities and constraints, all of which has to be respected, mobilized and coordinated.

United Nations and other international bodies

The all-embracing mandate of the United Nations agencies is to show the way and assist countries in the ultimate interests of bringing about peace and prosperity in the world through development. Each player (e.g. the different agencies) has its own specific mandate and means. Their responsibilities in the short term have to do with implementing the action plans and programmes approved by their general assemblies and, in the long term, with contributing to the various mandates of the United Nations approved during annual plenary meetings. The e-health sector is one component in the development process since there is no health without development, no development without health.

All of the United Nations agencies are therefore concerned to differing degrees, some more directly than others.

In 2000, the United Nations General Assembly adopted a vast plan of action – known as the Millennium Development Goals (MDGs) – for the new millennium with the aim of reducing poverty throughout the world and supporting development by 2015. Among the means proposed for pursuing such action, explicit mention is made of the use of information technologies and collaboration between the public and private sectors.

World Health Organization

The World Health Organization (WHO) is the United Nations agency with a mandate in global public health. Its working tools are both legal (recommendations, resolutions, expert information, health standards and regulations) and technical (action programmes, technical assistance upon request) in nature. WHO is particularly active in the effort to control or eradicate infectious diseases such as malaria, HIV/AIDS and tuberculosis, while at the same time drawing up guidelines for numerous other areas of public health including nutrition, reproduction, hygiene, use of medicines, and others.

In pursuance of its role in providing assistance to States, WHO published, in 2005, a general report on the subject of e-health, in the interests of drawing the attention of decision-makers to the need for the rapid development of strategies in this area. This initiative led to the approval by the World Health Assembly, meeting in Geneva in May 2005, of a resolution on e-health (WHA58/28), which invites each State to define its national strategy, develop regional cooperation and public/private partnerships, make the greatest possible use of technical and semantic (classification of diseases, for example) standards to facilitate cost reductions and system interoperability, and incorporate these solutions within their existing health systems.

The Resolution was later supplemented by a list of the specific contributions that WHO was proposing to make to States in such areas of common interest as deontological and ethical rules, and the publication of an annual report on the e-health situation worldwide. This WHO resolution – the first such reference document inviting States to take action – demonstrates the awareness on the part of this key United Nations agency, whose credibility is acknowledged by all, of the importance of the matter.

Whereas the number of States with the beginnings of an e-health strategy in 2005 amounted to some 20, it is now (in 2008) estimated that over 120 States have adopted a strategic outlook in that regard.

Each of WHO's six regions are invited to tailor the agency's resolution to their own environment health situation and priorities, requests from States and so on), and several regions have already produced strategic documents and outlined country plans.

Since the approval of the Resolution, an annual report based on the responses to questionnaires distributed to all Member States has been compiled by the WHO Global Observatory for eHealth for the annual assembly. In addition, factual data concerning e-health are regularly posted and updated on the WHO website.

Finally, WHO is able to provide ad hoc assistance on a case-by-case basis, to which end numerous meetings are regularly organized at the national or regional levels (e.g. the WHO Eastern Mediterranean Region).

Several ad hoc initiatives are worthy of mention:

· Handling the aftermath of the tsunami in Indonesia in December 2004 was coordinated by the United Nations, with WHO being responsible for the health issues. Using the ICT facilities available in WHO's "situation room", geographic and health data were immediately brought together in order to optimize coordination of the rescue and relief effort. The necessary international cooperation including access to communication satellites, images and networks worked very well, making it possible to avoid health catastrophes (epidemics) over and above the initial catastrophe.

· WHO's pioneering HINARI programme makes available the world's electronic health and medical literature to health institutions in developing countries, for free or at low cost. This partnership between WHO and over 50 biomedical publishers was begun under the then UN Secretary General Kofi Annan to help bridge the digital divide in health. With institutions and universities in over 100 countries participating, the programme is a major component in the effort to combat digital exclusion in the health domain. WHO has also developed the "ePortugese" web portal to deliver health information, facilitate capacity building and improve collaboration in the eight Portuguese-speaking WHO Member States.

· The fundamental work being carried out in the area of medical and healthcare terminology is essential to the discussion and communication process. WHO's research work within the framework of international consortia should result in semantic standards that are acceptable to all, and we may now look forward to the automatic translation of medical texts as a universallyavailable and affordable service.

· In the technical domains, WHO is collaborating with the telemedicine reference centre in Tromso, Norway and is developing partnerships with numerous NGOs, such as RAFT (University of Geneva), in support of health education and disease control programmes in rural areas.

· WHO's epidemiological data collection units are second to none when it comes to the gathering and analysis of health data. In cooperation with the relevant international bodies (including the United States Centers for Disease Control and Prevention in Atlanta, and the European Agency Centre for Disease Prevention and Control in Stockholm), this work enables emerging global health threats to be met with early detection, an appropriate

alerting mechanism and rapid response.

These examples provide a good illustration of the diversity and henceforth essential nature of e-health solutions, as well as the need for ever greater cooperation between a diverse set of stakeholders: doctors, telecommunication engineers, economists, intellectual property specialists to name a few.

UNAIDS

UNAIDS is the UN agency established to coordinate the multidisciplinary resources necessary to mount an effective campaign against the global HIV/AIDS epidemic. Its e-health initiatives focus on using ICTs for data collection, analysis and exchange, patient monitoring and management, and sharing results of therapeutical trials. In addition it uses ICTs in its prevention and education campaigns, including in isolated areas. In collaboration with numerous academic research centres, UNAIDS has accumulated a wealth of experience in the use of e-health technologies in disadvantaged areas, and in the expert use of state-of-the-art technologies in rural areas.

International Telecommunication Union

The International Telecommunication Union (ITU) has from the outset played a pioneering role by supporting, for over 25 years now, telemedicine pilot projects in developing countries, in order to test the technical feasibility of advanced technologies in the local healthcare context. The initiatives pursued have been most effective in those cases where the participation of local players could be counted on.

Following these pilot phases and with the recent worldwide boom in mobile telephony (for example, from five million mobile telephones in Africa in 2002 to 120 million today), the priorities are now shifting towards support for regional broadband infrastructures and associated services, for which significant investment and regional coordination are necessary. This essential mission is in the process of becoming a reality, judging by the success of the "Connect Africa" conference coordinated by the ITU in Kigali in October 2007. The meeting resulted in political agreement among the 54 countries represented and a financial commitment of several billion dollars on the part of various players such as the World Bank, the African Development Bank and the European Union. In the e-health field, the

ITU has for a long time now been establishing important policy initiatives and supporting relevant resolutions (see WTDC-06 Resolution 54 on information and communication technologies). This includes related matters such as data security, confidentiality and protection, and respect for diversity.

A working group on telemedicine regularly publishes a report on the areas of experimentation currently being pursued.

In what represented a major leadership initiative, ITU organized the World Summit on the Information Society (WSIS), which held its first phase in Geneva in 2003 and its second in Tunis in 2005. Both phases of the Summit led to the approval by the representatives of over 140 countries of resolutions and action plans identifying the strategic priorities for combating the digital divide.

Together with education, e-health was recognized as a major strategic goal. The outcomes have been widely disseminated and, together with the above-mentioned WHO resolution, constitute a key political point of departure for the development of sectoral, national and regional policies.

The roles of the different entities are clear: ITU must point out the technological opportunities, coordinate the technical discussions among States and foster norms and standards; WHO must be the guarantor of health content and of the integration of the corresponding approaches in health systems; while specific agencies such as UNAIDS are invited to make the best possible use of these instruments, in a coordinated manner, in pursuing their respective mandates.

UN Global Alliance for ICT and Development

The New York-based Global Alliance for ICT and Development (UNGAID) was set up in 2006 by the United Nations Secretary-General to combat the digital divide and foster cooperation between the public and private sectors. This entity grew out of the UN ICT Task Force, which brought together diverse stakeholders, including governments, foundations, academics, industry, NGOs and UN agencies. It is financed by voluntary contributions, which are used to promote and encourage ICT initiatives and advocate investing in ICTs for development.

Their advocacy approach emphasizes the need to develop ICT applications and secure infrastructure in line with local requirements and human capacity using the "bottom up" and not only the "top down" approach. Respecting local languages, culture, customs and locations is a key factor in ensuring the long-term viability of the applications. In addition it is necessary from the outset to have appropriate training plans for local experts including technicians and engineers if implementation plans are to meet with success. This investment in training, which must be seen as long term, is often underestimated or underfinanced despite being the underpinning for future success. Cooperation, particularly via the Internet, with external training centres is extremely useful, mutually beneficial and relatively easy to implement. This is true whether the centres are academic or otherwise,

foreign or domestic. Such collaboration can extend as far as the recognition of diplomas and student participation in research programmes. Numerous developing countries have demonstrated the technical and economic viability of this joint approach.

Generally speaking we can say that any project that lacks an associated training plan with solid foundations has little chance of surviving in the long term. This is particularly true in the field of e health, where the operational constraints are more burdensome than in other sectors.

Integration of ICT into health systems

Numerous telemedicine projects in the developing countries have been developed with aid from wealthy countries in collaboration with local health professionals (doctors, for example) and local authorities, with the general idea being to "cut and paste" solutions already having proved to be effective elsewhere in the originating country in question.

This "top-down" approach is almost bound to fail in the medium term, even if the solutions may function at a technical level in the short term, since the procedures and systems will be different. By way of evidence: the 27 countries of the European Union, with closely related conditions, cultures and economies, developed 27 different health systems that are only minimally – and in some cases not at all – compatible with one another.

By contrast, where the overall approach is defined by common accord, a key factor in the future success of any given application is the appropriation of the corresponding solutions by local operatives.

There are two consequences to all this:

· Systematic and regular collaboration with the local authorities and leaders is essential. What is the problem? Where are the difficulties? What do you propose? E-health solutions must not be solutions that are brought in from outside and grafted onto the health system. Instead they must be components desired by stakeholders for incorporation into their system. Such solutions also serve as instruments for enhancing the social cohesion of the professional group.

· A comprehensive programme of education and training for the partners is essential. Education and training call for a great deal of time and money. Most project-bearers have a tendency to underestimate this item, to which some 40 per cent of the available time and total budget should be allocated. Moreover it must be put in place at the outset of the project and not at the end as a mere afterthought. This educational component may be developed together with academic bodies which could recognize the required competencies and award diplomas to successful students.

Indeed, public acknowledgment of such training is an essential part of the picture. International cooperation in this area is welcome.

5. Multi-Agent Systems

The multi-agent technology has already proven that it is suitable for creating open, flexible environment able to integrate software pieces of diverse nature written in different languages and running on different types of computers. It enables to design, develop and implement a comparatively open multi-agent environment suitable for efficient creating of complex knowledge-based or decision support systems. Such an environment is able to integrate geographically distributed knowledge sources or problem solving units. Multi-agent systems have useful properties, such as parallelism, robustness, and scalability. Therefore they are applicable in many domains which cannot be handled by centralized systems, in particular, they are well suited for domains which require, for example, resolution of interest and goal conflicts, integration of multiple knowledge sources and other resources, time-bounded processing of very large data sets, or on-line interpretation of data arising in different geographical locations. Here we will present several examples of multi-agent solutions that might be efficiently used in different tasks in the healthcare domain ranging from coordination of rescue operations over logistic operations up to process evaluation and control.

A. Coordination of Rescue Operations

There exist situations, in which search-and-rescue operation performed by a group of cooperating robots and unmanned aerial vehicles can be utilized. The cooperation of units as well as data and social knowledge sharing is necessary not only for the purposes of efficient exploration of an unknown area but also for establishing virtual communication bridges, over which video streams are transmitted to a human-operated base.

B. Air Traffic Control

Decentralized air traffic control of both manned and unmanned aerial vehicles (UAVs) is another challenging task for multi-agent systems. No fixed flight corridors are present and all detected possible future collisions are addressed locally using distributed re-planning of flight plans with no central element involved. The developed system supports both cooperative and non-cooperative behavior of UAVs, definition of both static and dynamic no-flight zones and real-world data integration. All the planned and successively performed operations must be safe from the collision avoidance perspective.

C. Vehicle Routing Problem

Vehicle Routing Problem belongs to optimization problems and falls into category of the NP-hard problems. The problem is defined as routing of a fleet of gasoline delivery trucks between a terminal and a number of service stations. The trucks have load capacity limitations and deliveries have to be accomplished at minimum total cost. Similar problem arises when it is necessary to deliver material, food, etc. after a natural disaster, for example. It has been shown that agents can provide a feasible solution in polynomial time with reasonable time complexity. That is an important feature when the solution is required very quickly.
All three presented examples of multi-agent systems have been implemented and the software solutions are used.

6- Multi-Agent Systems in eHealth

Modern health care is highly specialized. Complex examination of a single patient involves many expert consultations and laboratory tests. Medical knowledge, examinations and treatment are distributed functionally, geographically, and also temporally. There is a need for reliable and consistent information flow among all participating subjects with the aim to satisfy the global goal – improved health of a patient. Of course, the necessary information flow is not predictable in extent and structure, but it develops and changes in time due to new knowledge and reactions. To satisfy these requirements and provide adequate decision support, the use of flexible intelligent software support is becoming increasingly desirable. Distributed problem solving and agent technology offer efficient and natural solutions, because they correspond to the main properties of the medical domain, namely distribution of information, problem solving capabilities, resources, and responsibilities, decision making with incomplete information, iterative refinement of plans. In this section we present two different applications utilizing multi-agent approach.

A. Agent-Based Simulation of Processes in Medicine

Agent-based simulation of processes allows integrating procedural knowledge in the form of organizational processes and formalized medical guidelines in medical decision support systems. The process-based multi-agent system is able not only simulate and evaluate the processes, but also control and monitor their abidance in practice. An application example is a critiquing decision support system that can monitor the progress of patients' treatment and alert a physician in case of inconsistencies.

B. K4Care - Knowledge-Based Home-Care eServices for an Ageing Europe

An integrated knowledge-based intelligent technology has been developed to help in the management and provision of health care services to chronically ill patients anytime and anywhere through the Web [6]. Efficient and quality health care management is achieved with a model that not only organises health care according to national and international standards, but also allows the adaptation of the model to specific health care systems, the extension of the model with new services, and the update and upgrade of services already provided. According to the users' demands the whole range of mobile devices can be used: laptops, tablet PCs, or personal digital assistants (PDAs). The system was developed in an EU consortium (www.K4care.net).

The care of chronically ill patients involves lifelong treatment under continuous expert supervision. Admission to hospital and residential facilities can be unnecessary and even counterproductive, and could saturate national health services and increase health care costs.

The health care model is organised at the level of actors, by defining the actions allowed to each actor, and at the level of services, by defining the procedures that implement each service as a combination of actions and document accesses.

The result is a formal model evaluated in eight EU countries (i.e., Czech Republic, Finland, France, Hungary, Italy, Romania, Spain, and UK); which is modular, incremental, scalable, adaptable, updateable, standard-driven, knowledge-based, and computable with ICT.

All the documents (e.g., requests, authorisations, prescriptions, scales, laboratory results, etc.) in the health care model are XML files, which are managed by a sophisticated relational database that also stores information about the actors (i.e., health care professionals, patients, relatives, etc.), roles, groups (e.g., evaluation units) and relations between actors (e.g., who the family doctor for a particular patient is). Each sort of document in the Health Record is formalised by a XML Schema that prevents the system from incorporating wrong documents, and a couple of XSL files allowing the documents to be shown or filled through the Web.

An Agent Profile Ontology (APO) formalises all the concepts and constraints of the health care model so that any modification of the APO represents a change in the model and an automatic and immediate adaptation of the ICT system operation. The APO knowledge about actors, services, etc. is complemented with a formalisation of the procedures that implement the health care services of the model (e.g., comprehensive assessment, nursing care, follow-up, etc.), represented as health care algorithms with the SDA notation.

The medical knowledge related to fifteen common chronic diseases was distributed between the Case Profile Ontology (CPO) and a library of Formal Intervention Plans (FIPs). The CPO gathers all the concepts and interactions of these diseases at the levels of signs and symptoms, syndromes, means of assessment, social issues, and interventions.

The system implements three different sorts of personalisation: user, patient, and treatment.

The users of the system are: health care professionals, patients, and citizens in general. Professionals can be of several sorts (defined as a hierarchy in the APO): physician in charge, family doctor, head nurse, nurse, social worker, etc. Each user in the system has a modifiable default profile obtained by automatic personalization of the APO that avoids a nurse for example starting a service or accessing a document not allowed to nurses.

The services provided, are accessible by web browsers and wireless devices, such as mobile telephones or PDAs. Most of the services in home care are performed either by nurses or social workers. Thus we developed an application for PDAs that provides these care givers with all necessary data and information they need at the patient's home and allows them to enter new data about the patient's health state. The family doctor can check the patient's health state remotely. In the designed system the patient history is stored, which allows checking trends in monitored values, visual checking of development of injuries or varicose ulcers, for example. The application also marks, which data was not filled so far, so the nurse cannot forget to fill the required data. We considered important to have a proof-of-concept of our approach so we performed tests in real environment and nurses as users. The device is equipped as a regular PC and not far from it with its computing power, yet still a lot more portable than a notebook. The key advantages are various connectivity possibilities: cable, Wi-Fi, Bluetooth, and GSM. Another advantage is weight and size, which is around or slightly above regular GSM phone. The possibility to acquire photo-documentation was found especially helpful.

7. ICT helping disabled and elderly

A. Control of Technical Devices through Eyes

An experimental I4Control® system enables control of home appliances or medical assistive tools through movement of eyes. The system was awarded the European IST Prize in 2006, and launched in production and on the market in 2008 by the Medicton group company. The system is original and low cost. Special attention is devoted to experiments with its application for text entry, in entertainment applications for making the life of the users more enjoyable and more equal, in mobility control and in the control of environment.

B. OLDES – Older People's e-Services at Home

OLDES (http://www.oldes.eu/), an IST EU Program, started in 2007. It planned to offer and test new technological solutions for improving quality of life of seniors and challenged persons, through the development of a very low cost and easy to use entertainment and health care platform, designed to support their independence when living on their own at their homes with tele-assistence e.g. of local public services. To achieve this goal OLDES decided to combine tele-medicine, tele-assistance, tele-entertainment and telecompany into a federated internet based system intended for 3 very different and complementary groups of users: the customers (elderly persons who need some sort of support), their care givers (e.g. organized in public or non-for-profit services) and health professionals (medical doctors and nurses). Each of these groups requires/ensures specific type of services and consequently the OLDES platform provides them by group specific access rights.

OLDES was designed as an easy-to-use, plug-and-play system which can be easily customized towards the needs of the individual user by modifying the set of ensured services for three types of application scenarios. The simplest base level scenario is intended for a vivacious elderly who requires no extra services but who can benefit from more social contacts – this level includes communication and telecompany through a low-cost PC and open-source internet based software. The intermediate level is complemented by simple sensors (e.g. to measure the ambient temperature) for the management of generic monitoring situations (e.g. very hot periods in the summer). Finally, an upper and tailored level scenario expects that there will be engaged healthmonitoring sensors depending on the health profile of the user.

Moreover, this most complex level has to be ready to create, send and handle an alarm signal generated automatically in the case the monitored signals of the considered patient meet certain predefined condition.

When designing the OLDES platform special attention has been given to the design of communication interface for the customers who are not expected to be accustomed to using computer and internet. That is why it was decided to hide the technology from its elderly users and ensure all communication through a television screen controlled by a remote controller customized for that purpose. This solution called for innovative approach and special attention had to be devoted to a user-centred design of an easy to use GUI.

In 2010, the final year of the project, the OLDES solution was successfully tested at two different locations: in Italy (Bologna) with the involvement of a group of 100 elderly people (including 10 senior citizens suffering from heart disease) and in the Czech Republic (in Prague) with the involvement of a group of 10 diabetic patients. In this way it was possible to confirm that the OLDES platform ensures the intended flexibility and configurability as it works well for all the three types of user scenarios customized to the needs of the target application by different types of sensors (heart versus diabetes monitoring). The acceptance study conducted among all the users confirmed that our easy to use "plug and play" system was very well accepted by the patients involved in the project. After peer review evaluation, the OLDES project has een selected as one of the 25 nominees for the IT @ 2011.

The suggested OLDES approach proved to be an effective solution for municipalities, hospitals and their contact centres for the provision of health and social services. That is why the project partners decided to proceed in further development of the second generation of the system called SPES. The newproject SPES (Support to Patients through E-service Solutions) starting in April 2011 aims at transferring the original approach and results achieved in the implementation of the OLDES platform into 4 new geographical contexts (Ferrara, Vienna, Brno and Kosice), focusing on new target diseases: dementia, mobility challenged persons, respiratory problems and social exclusion).

C. NETCARITY

European project "NETCARITY", (Information Society Technologies, Ambient Assisted Living, IST-2006-045508) (www.netcarity.org) has been focused on research and testing of technologies which help older people to improve their wellbeing, independence, safety and health at home. Netcarity offers several groups of functions aiming at supporting older people at home, namely inclusion, assistance, protection, and health. Inclusion is focused on new ways of communication so that the users keep in touch with friends and family. Assistance means support of everyday tasks, e.g. cooking and shopping.

Protection is focused on security and safety issues, e.g. alerting family members or caregivers in case of dangerous situations (falls, no sign of user activity). Health is intended for provision of long term, proactive, medical support to look after physical, emotional and social wellbeing.

D. e-Scribe

The goal of the project (www.escribe.cz) is to design and set up an online voice transcription centre for the hearingimpaired. The transcription will initially be carried out by professional human quick-writers, while our future goal is to automate the transcription. The project is a collaboration of RDC/CTU and the Czech Union of the Hearing-Impaired (CUN).

E. Localization and Navigation of Visually Impaired People GPS/GSM navigation system for visually impaired people allows immediate localization and navigation of the person in case of orientation loss. It uses combination of GPS navigation technology and possibilities of GSM/GPRS mobile networks.

A visually impaired person can be easily navigated based on his/her detected position. In case of need he/she can call the specially created phone line that acquires the information about the position from the GPS device. Mobile transmission of voice and data using GPS and GPRS technologies is utilized for communication of the visually impaired person with the navigation call centre. The system was developed by CTU students (navigace.sons.cz/en/). It is necessary to note that the system is determined for open space where the GPS signal is sufficient. And it does not provide information about obstacles on the path.

F. Out of Darkness

The project is focused on development of a new kind of an aid for visually impaired people. The aid consists of the sensor for obstacle detection and a tactile display integrated in a shirt. The tactile display has 7 x 3 vibrating actuators. The position of an obstacle in front of the user determines which actuator is activated. Obstacles are detected by a stereo camera (www.venzetmy.cz/english.html). The device enables to detect obstacles within the profile of the whole body, is supplied with GPS module for global orientation, it does not use acoustic information thus it does not block ears for perceiving other sounds from the environment.

G. ENABLE - A wearable system supporting services to "enable" elderly people to live well, independently and at ease The project ENABLE (www.enable-project.eu) has developed a personal, user-centered enabling system, with services, for use by an elderly person in or out of the home, to mitigate the effects of any disability and to increase quality of life: independence, autonomy, mobility, communications, care and safety. The system is based on a distributed open platform, enabling other services to be added by third parties, by "plugging" into defined interfaces. The platform includes a mobile phone, enabling the user to get out and about, for visiting, shopping, recreation, etc, whilst maintaining contact for help and services. The prototype developed in the frame of the project has the following functions: communication and alarm service from anywhere; falls prevention and monitoring; location service; environmental control; diary service; vital signs, lifestyle and symptom monitoring services.

8. Conclusion

In the paper we have tried to present several ICT solutions directly applicable to healthcare domain, either as part of information systems, systems supporting rescue and logistic operations, assistive systems, or home care support systems.

The most challenging tasks are integration tasks for applications, such as management and logistics in case of natural disaster; organization of help, multilingual support in information systems. We can utilize results from planning and scheduling systems, coalition formation, distributed decision support and use of mobile technologies. In addition, several presented solutions have been already introduced to routine practice. Solutions developed in EU projects were successfully verified in pilot tests.

Presented projects showed that successful applications need coherent approach of experts from many

different disciplines, i.e. information technology, electronics, communication technology, medicine. Standardization can make the way from an idea to an application much easier and faster. Thus acceleration of standardization process represents a key issue.

It is important that involved companies, researchers, and standardization bodies agree and cooperate towards the ultimate goal – defined standards. There already exists one example of successful agreement on defined standard DICOM. DICOM is now widely accepted as standard for medical imaging data and nobody uses another data format. Similarly we should reach such agreement for other data types.

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