PERSONALIZED HEALTHCARE COMMUNICATION IN INTERNET OF THINGS

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Abstract

Personalized healthcare is a challenge because supports the sustainability of care. Internet of Things is a paradigm promising to manage the digital identity, so the personalization of care services. Different equipment is used in extra-wall healthcare and assistive services, requiring different sorts of objects to communicate and to make the ubiquitous system-of-system. Extended entities and mixed roles are becoming inter-operable. We present how adaptative care might exploit the broadband communication over powerline, with the link to the digital energy.

1. Introduction

Different communicating objects have penetrated our lives and many more are to come. Pervasive technologies exploit interactions between human beings and their environment, and those between non-human entities themselves. The integration, inter-operability, low cost and low consumption aspects are challenging issues. The efficient communication of objects needs a global system approach, marrying energetics, electronics, cognition and networking, complementing multi-sensor setup. Let us start from a concrete domain.

Personalized Healthcare is the integrated practice of well-being, healthcare and patient support, based on an individual's unique biological, behavioral, social and cultural characteristics. Service tailored proactively for each patient at several levels empowers the individual by "the right care for the right person at the right time", leads to better outcomes, improves satisfaction, and keep the cost-effectiveness. Sustainable services focus the prevention, early pathology detection, and homecare rather than expensive clinical one, move beyond alert systems, but check the overall well-being anticipating needs and ensuring compliance to care plans.

Telemedicine is the delivery of clinical **care at distance** using electronic communications and information technologies practiced on the basis of real-time (synchronous), and store-and-forward (asynchronous) interaction [1]. It enables the retrieval of patient data from the medical equipment and remote change settings of device parameters, exchanging medical and context-related information objects among sites. Real-time telemedicine ranges from a simple telephone call to a robotic surgery, requires the presence of both parties at the same time and a real-time **communication link** between them. Video-conferencing with attached medical peripheral equipment, or home monitoring employing remote devices (otoscope, stethoscope, ECG) allow a remote physician to inspect inside a patient, to hear the heartbeat and much more. Store-and-forward telemedicine acquires medical images and bio-signals, transmits multimedia objects for an offline, delayed assessment, affecting Dermatology, Radiology, and Patho-anathomy specialties. A doctor consulting a specialist, or a specialist releasing second opinion, home monitoring by devices, like blood pressure monitors, and transferring data to a caregiver grow emerging personalized services at no extra effort for caregiver. Telemedicine services exchange information, multimedia objects, patient data and context: medical records, recent and past examinations, treatments, and other data of interest [2] protected by law, acquiring and transmitting them to remote elaboration. Information processing elicits facts by formalized knowledge. Much data is 2D or 3D, X-ray, ECG, mammography annotated by text (physician remarks), notes, and referrals to other information, implying both ethical and confidentiality issues.

Physicians work in interacting virtual and ubiquitous environments [3], where various hospitals in geographically dispersed areas are linked and data objects are accessible via personal web objects/pages, one for each patient. Unlike other areas information objects are not just viewed. Doctors use web to interact with data, to annotate images, to add medical knowledge, to navigate inside 3D objects. ICT supports a variety of operations: image display, segmentation, multi-modal registration, fusion, and anatomic object visualization.

Humans act in several roles (Fig. 1): a doctor produces health during business hours, but consumes personalized services in evening time. Clinical work is nomadic and ubiquitous: even outside hospitals a doctor keeps his role. For example a road accident with an injured requires doctor's intervention. The same individual might be ill, becoming a patient for a while. Doctors are typically responsible for several patients; they often do research, teaching, and have some administrative duties. The globalised life counts extended enterprises interlinked with extended homes. A hospital adopting early de-hospitalization and tele-monitoring is an example of a globalised entity: producers and consumers loose the distance. Let us denote as "Prosumer" such mixed role and use "EE2EH" for the mixed virtualized environment. The role carries some ambiguity, requiring Prosumer to identify himself to restrict possible operations, to qualify him properly before generating or consuming personalized services.

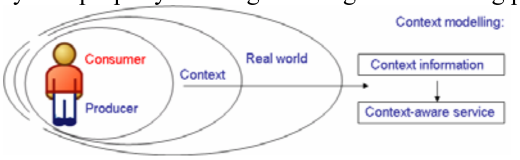

Fig.1. Extended entities and actors in real world.

Better-personalized diagnostics [4] considers the patient with the context, and the clinical history altogether. Description and Situation design patterns models acquired by sensors data, enabling to detect, measure, and mine among different parameters and conditions. The location of patient in emergency situations enables service provision. Patient behavior is a treasure enabling adaptive capability and referencing future decisions, but patient decisions are forgotten in the state-of-the-art. The personalization tool captures and stores relevant information about the patient, the situation, the transaction and the content offered, to avoid saturating users with repetitive messages and enabling based on patient choices and behavioral patterns customized content.

2. Discussion

Digital Hospital might be seen as the free flow of real-time information exchanged between healthcare professionals and patients: digital need of care, digital multimedia objects characterizing the human being and related processes, digital care service, and digital money. The process of healthcare digitization starts exploiting the always-on broadband, mainly Internet connections, public-private synergies, the rise of merchant assistive services, and ubiquitous trading of services. The Digital Hospital, like any abstraction, falls into the Internet of Things sphere because of similar implications. We can ubiquitously manage on-line bank accounts, digital meters, industrial automation equipment, intelligent home, so it is timely to speak also about the tele-medicine and assistive services. Digital Hospital will be the abstraction working in background fully automatically, which will be invisible to the user, but such system-of-systems will be able to manage the digital multimedia objects worldwide. Internet of Things (IOT hereafter) is a new vision of the technological ubiquity in communication era radically transforming the society, corporate, communities, and personal spheres. Early forms were represented by the widespread use of mobile phones, little gadgets becoming an integral part of everyday life. Second step is the embedding of short-range mobile transceivers into a wide array of additional devices/appliances, enabling new forms of communication between People and Things (P2T), and between Things (T2T). A new dimension has been added to the world of Information and Communication Technologies: from anytime, anywhere connectivity for anyone, to anything, e.g. between PCs, Human to Human (H2H), Human to Thing (H2T), and Thing to Thing (T2T). Multiple connections creates an entirely new dynamic network of networks – an Internet of Things, based on solid technological advances and visions of network ubiquity, computing, communications, and dynamic technical innovation in a number of domains, ranging from wireless sensors to nanotechnology. Embedded intelligence, advances in miniaturization and nanotechnology, and a combination of all above-mentioned developments makes the IOT. It connects the world's objects in both a sensory and an intelligent manner mapping them into the digital representation of physical objects.

Personalized healthcare might be seen as an abstraction layer of IOT. Documents (laboratory exams, X-rays) represent the lowest one. Services, such as medical records, X-ray imaging, blood test results management, medical applications, represent the middle abstraction layer, while a disease treatment, e.g. "Anaemia treatment", illustrates the higher abstraction layer. A collection of highest possible layers becomes the PHS entity of IOT. Modern PHS systems use Internet connection to link the remote home and the caregiver. The reliability of the link should be considered because of the nature of the care service. Any tele-medical equipment is alimented by electrical power, so twisted pair wired setup is an asset to exploit. The powerline communication and fieldbus enabled systems transforms the electrical energy distributions networks into the valuable components of the IOT, where the embedded chips and RFID items grant the identification capability: Digital Hospital depends on reliable communications. Wireless sensors gather real-world data, body- and ambient- sensor network services generate both behavioral and biological data. Unobtrusive service delivery through computers and consumer electronic devices with various interfaces distributed throughout the home, and proactive human-machine interfaces (HMI) with context-aware sensing, motivate health-conscious behavior.

Several sensors are available for tele-monitoring services. By combining RFID cell phones and RFID sensors with cellular networks or the Internet, the patient becomes empowered to read RFID sensor tags anywhere for almost any application. RFID tag is a smart device equipped with an electronic chip and a smart antenna. RFID reader interacts with the tag and sends a signal to someone for further elaboration (Fig. 2).

Fig. 2. RFID transformation from skin patch.

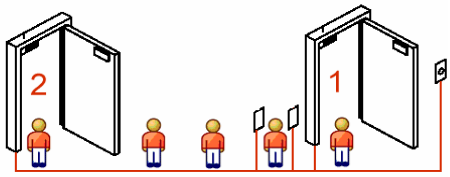

Fig. 3. Process mapping – clean room entry

RFID tag is a physical object, applied to a real world object in order to identify it, but it enable to gather additional knowledge about it. Recent examples include glucose monitoring, cardiac monitoring, UV monitoring, and biomarker skin test patches. RFID-enabled system [5] interprets the data about the physical objects and takes decisions locally or remotely, after communicating digital objects. The above-said transforming might be used to move **physical objects** vs. the Internet of Things. Processes might become digital objects too. An example might be a system composed by two RFID readers (Fig. 3). Real world includes physical and non-physical objects. The interoperable business deals with both of them. The digital things in the digital world are collections of objects to exchange and to make them interoperable. To interact with a process, the actor (human) should use a tag, which might be embedded into a mobile phone, wristwatch, or plastic badge. All different interaction forms, human interacting with the real world objects, human interacting with the digital world objects, human interacting with the real world process, human interacting with the digitized process, might be represented by digital items. An object becomes a data element, while a process becomes a collection of data element with appropriate timing. To discover the direction of the movement, the timestamp is analyzed. It is important hence the synchronization of clocks among the RFID network. The synchronization is the ubiquitous service as well, and it might be performed over the Internet or over the fieldbus topology. The final vision of the Internet of Thing is reported on the Fig. 4, where enabling technologies are shown as (B) and (C), and the traditional “old” world is shown as (A) with industries, extended and de-localized enterprises, ubiquitous workers, homes, energy utilities [6], TLC, services, and all other realities.

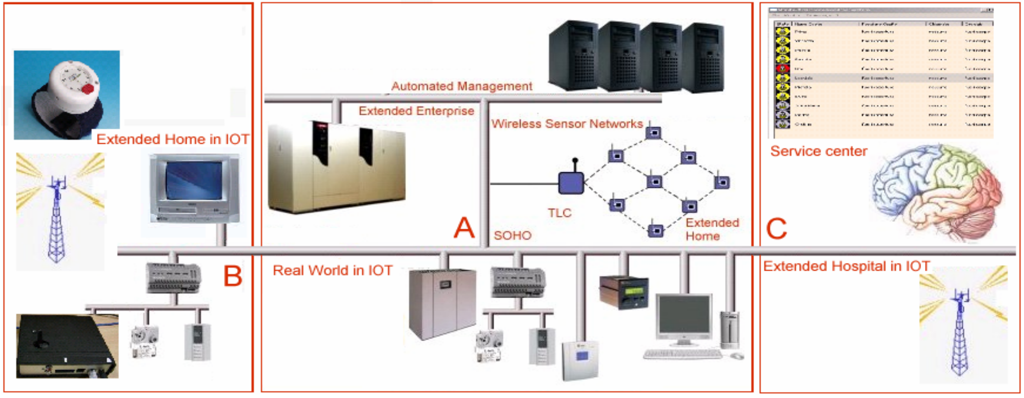

Fig. 4. Personalized Healthcare in Internet of Things

The extension of the above-mentioned reality by new enabling and emergent technologies is represented by the component (C), including the formalization of cognitive processes, machine-reasoning, semantic web, automated decision support, and whatsoever. This is the wireless extension worldwide enabling the future human-less scenario, in which the automated intelligence might govern things: physical objects and non-physical entities (processes), parts of the real world or of the digital one. The (B) component shows the missing element, making possible such scenario, which might be the RFID, a part of the Radio Science and the Technology, transforming real life members into digital things, ready to enter into the Internet of Things.

3. Information and Knowledge

Healthcare is one of the most information-driven industries: primary data collected from a series of discrete observations bear imminent information but overload, so the knowledge is typically derived by systematic interpretation of the essential structured information, exploiting classification models in the medical field. Medical history, nurse notes, description of pathways, protocols of care (information about treatments and diagnosis) are unstructured multimedia, a proper classification of the underlying concepts is needed. NLP and Ontology-driven clinical DSS mining facts on a particular patient, and guidelines and protocols' triggering enable classification, because a systematised taxonomy of medical terminology and concepts identify instances in available corpus.

Diagnostics look for the person's condition change between examinations, rather than the current snapshot at the time being status, requiring evolving pattern detection in dynamics. Some parallelism with the representation of digitised processes is envisaged. A current mammogram has clinical value, but its true significance stay in relation to the past one: two objects should be recovered, transmitted, and elaborated. Something that appears suspicious but unchanged is less relevant than the situation evolved radically in the last 6 months. However the previous mammogram is frequently unavailable because other facility visited and interoperability lacking: each of us should leave a distributed multimedia library behind allowing PHS brings all the information together to the point of need on time. Healthcare adopts also uncertainty reasoning and needs the context-related information.

Multi-sensor fusion approaching holistically multiple information sources relies on sensors reducing both systematic and random errors. In cardiac sensing both ECG and haemo-dynamic signals, such as the impedance cardiograph or blood pressure, give mutually correlated information, being physiologically coupled mechanical and electrical functions. Whenever an ECG signal is degraded either due to poor electrode connection or patient movement, joint analysis of complementary sensors, such as the ventricular pressure, sustain cardiac monitoring resolving some intrinsic ambiguities in rhythm disturbance assessed by ECG alone. Whilst error-minimisation by multiple identical sensors appears intuitive, the reliance on different sensors in terms of both sensing type and location exploit general principles of pattern recognition and machine learning. Further challenge is the redundancy introduced by the adoption of the powerline communication together with the traditional one (medical equipment is alimented by energy) exploiting the multiple parallel communication channels offering the better resilience.

4. Conclusions

Professional work in healthcare is highly collaborative, because of tight interaction between different expertises to set specialized treatment. It is nomadic, because involves speaking with patients/families/colleagues, attending conferences. The environment is hectic and filled with disruptions, requiring keeping in mind several parallel activities pending. Professionals need quick access to relevant data for alternating work situations, but usually have no fixed desks. Sensitive medical data is strictly private, but knowledge is distributed among different professionals and care assistants, who need to collaborate across time, space, and organizational boundaries. Innovative devices for clinicians include large X-ray wall displays, bulky information networked with PDA. Healthcare is challenging extended communication and is representative of the Internet of Things [7]. Activity-centered computing principle suggests representing computational activities as first-class objects in the computing environment along with files and applications. We have tried to map the personalized healthcare on Internet of Things. We have analyzed healthcare processes leading to the combined use of the RFID, ubiquitous technology and machine reasoning.

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