Recent Advances in e-Health and Perspectives

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Abstract. We propose in this paper some considerations above the advances in e-health technology based on the papers presented in the present special issue, as well as some perspectives about prototypes in achievement, discussing their acceptability in the framework of a mutual benefit both for elderly people and for the society, depending on the sensorimotor abilities as well as cognitive and decisional autonomy kept during the longevity. Symmetrising with the infancy, the society has, for helping dependent people, to identify helpers with carefully specifying their role and planning their financial support. Thereafter invasive and intrusive aspects of new micro-nanotechnologies are discussed and then we study the complexity of the data recorded on elderly subjects in their environment: it comes essentially from interactions between numerous elements regulating their spatiotemporal rhythms. Taking into account these interactions, we can describe emergent invariant structures like signatures of the global behaviour allowing alarms triggered when the activity becomes uncommon with respect to a canonical profile characteristic of subjects in their environment. We conclude by proposing a coherent future research program whose aim is to consider dependent elderly persons in their in his own, biological and sociological whole for ensuring their integrity and comfort.

Keywords: e-health
1. Introduction

The last eighteen years [Cou96, Tam98] have seen the rapid development of the monitoring for elderly at home using NTIC (New Technologies of Information and Communication), i.e., smart cameras, position sensors, fall detectors, and actimetric tools as radar, infrared until the recent Wisee® and uTrack® magnetic devices [Pu13, Chen13]. The recorded data are intended to define a quantitative framework, in view of significant deviations from normal behaviour means to identify the entry in a pathology (e.g., neurodegenerative, such as Alzheimer’s disease) or the occurrence of an acute episode (dyspnea, fall,...) requiring intervention at home. The interest of such alarms is twofold, namely i) to allow for maintenance as long as possible at home, for an effective longevity in a familiar living environment, and ii) to argue for a return at home if the behaviour in an institution (hospital or seniors residence) will detect any abnormal deviation.

In the second section, we present rapidly the papers of the present issue, which give examples of prototypes using new e-health technologies. In a third section, we present the problem of complexity of surveillance at home, focusing on issues related to their acceptability by the elderly and their maintenance by caregivers, which requires the identification of interactions between physical and human elements authorizing or otherwise limiting the use of ICT in gerontechnology. Finally, we conclude by presenting a future research agenda, which would combine the interests of ethics and take into account the totality of both the surveillance and the therapeutic education.

2. Advances in e-health technologies

The present issue contains papers presenting advances on a very broad spectrum of the e-health technologies:

– in [FMC], authors describe the recent technologies for the detection and alert in case of fall,

– in [OPK+], a computer medical support systems are used in monitoring and diagnosis is presented for non-invasive liver fibrosis recognition,
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– in [MLD], web-scraping techniques are proposed to process data sources on the Polish medical market,
– in [NBAY+], exploratory data analysis tools are used for studying insulin therapy in the elderly type 2 diabetic patients,
– in [CABA+], a monitoring system based on different types of sensors and a powerful self-learning decision tool serves to monitor elderly and dependent people in nursing homes,
– in [PBK+], a living lab approach is studied for testing the development, assessment and provision of assistive technologies for supporting older adults with cognitive disorders,
– in [VD], authors propose a living lab solution for developing home-based social and healthcare solutions for the elderly using participatory design,
– in [Dan], artificial intelligence techniques are presented in order to efficiently personalize speech therapy,
– in [WWBD], Twitter discussions are used to predict the spread of the seasonal epidemics (Chickenpox) in France,
– in [MIWW+], a triage support algorithm is developed for patients classification at urgency care area in a hospital,
– in [DM], authors describe the chronotherapy techniques needed for accompanying patient in a “domomedicine” experiment,
– in [GBI+], a supervision system which exploits information generated by binary sensors is presented useful for security systems watching motion at home.

3. Ethical implications of gerontechnology

3.1. Acceptability of the technology

By 2020, people over 75 will account for 10% of the French population, that is to say, a crucial socio-medical and economic challenge for our society. ICT will be represented by multiple sensors taking information on the dependent person or in its immediate environment. These sensors are usually equipped with a GPS, allowing the location where the alarm could trigger. This latter facility increases the chances of ac-
ceptance because it allows the movement of the subject out of the flat monitored. Miniaturization does not require installation of an invasive network of deep sensors (in particular at the mucosa level) in order to avoid inflammation, allergy or infection, and must be "forgotten" during the information capture and quickly "perceived" (through vibration, ring, visualization) if necessary (as the pain as alarm symptom) which is all the better tolerated if it incorporates the usual clothes or current devices (like clock or smart phone). The three items conditioning acceptability are:

1) an easy maintenance, especially if external source of energy is required, or better in the future, made from a renewable energy: solar cell, movement electric transducer, osmotic glucose biofuel cell [ZGG+13],...

2) a clear return information, in summary form, given by the usual channels (audio and video, e.g., using the home TV screen), or new channels like epidermal or lingual stimulation [APD03] upon request (e.g., via the touch of a remote control device) or regularly automatically. In the latter case, the feedback can be done via the digital clone of a caregiver (cf. Figure 1) delivering a familiar message initially written using a text processor like Word®.

3) the possibility for dialogue with the surveillance system, if desired and if possible, at least in case of proved alarm. This dialogue could take place through a web server or exploiting the cloud facilities giving access to the individual and community public health knowledge [LJD99b, LJD99a, PBC+99].

3.2. Identification of carers

Identification of technological caregivers in the environment of the dependent subject is a crucial step in the implementation of monitoring technology. Between 1990 and 2013, the French Ministers and Secretaries of State in charge of the family and the elderly have defined a decisive political new paradigm of family solidarity, identifying and organizing the caregivers help [Min04]. To do this, we must identify these in the human environment of the dependent person, namely relatives, friends (members of the "Agape" network), doctors and paramedics, as
The three points above require an accurate identification of the person watched and/or its caregivers and imply at least partially the conservation or their own both sensory (new technologies being able to compensate sensory impairments like presbyopia or presbycusis), and cognitive (especially mnemonic) abilities.

well as social workers. Most having only occasional contact with the subject, the caregiver should if possible be from family or immediate social vicinity. An interesting attempt to identify and help caregiver neighbourhood was developed at London, in the Griffin House [PH01]: 32 seniors and 24 students in medicine or dentistry live together since 1998 in the same building, and companionship was established, for the mutual benefit of the two age classes: "Both students and the older residents benefit from living together and sharing their experiences" (cf. http://www.mds.qmw.ac.uk/students/accommodation.shtml). This pilot seems to be of major interest and resumes that conducted thirty years ago by the pioneer R. Hugonot at Grenoble. Family carers must be designed and subsidized as symmetrical with the beginning of life (parent or guardian) [Min04]. More than financial assistance, caregiver must receive a minimum technological training, allowing him to anticipate failures of surveillance system, checking at fixed schedule its power supply and consulting periodically the information return at home for the elderly, to verify its integrity, precision and understanding.
3.3. *Invasiveness, intrusion and micro-nano-technologies*

Contrary to the general opinion, the use of nano-technologies are not necessarily accompanied by an additional comfort nor a risk minimization. To take advantage of the small size of the sensor, it should be placed in situ, closer to the production of the signal, which increases its intrusiveness, especially in the nervous or mucosal tissue. There may also be invasive: the tissue or the cell involved may be the subject of:

1) an immune rejection reaction, or
2) a non-specific inflammatory reaction, or alternatively
3) a torpid chronic infection responsible distant pathologic reactions (e.g., a cardiac valvulitis, as peripheral infection from a dental granuloma). The micrometric sensors placed on the skin outside of the subject outside are less intrusive and invasive.

The other argument against the nano-sensors is their very local and low intake of information, generating a noise difficult to estimate, so to extract, making necessary to increase the number of nano-sensors, for getting an average information assigned to Gaussian noise: this is the case, for example, of immuno-adsorbent sensors made of antibody proteins attached to a piezoelectric substrate, or endoluminal micro-cameras, which do not replace less-limiting endoscopy devices, but more comprehensive. The local information taken at the molecular level is also very disturbing for signal transmission and Heisenberg principle could drastically limit the use of nano-sensors, if they are found growing too the signal/noise ratio. The latter objection is the local supplying power, even if the miniaturization reduces considerably the need of energy inputs. Sustainable local energy (like biofuel cells cited above) could compensate for this. An additional argument to make to the debate is philosophical and must be carefully weighed. As noted by J.P. Dupuy [Dup03], a group of European research centers has recently used the “NanoToLife” name - short for "Bringing Nanotechnology to Life." The ambivalence of the expression is a masterpiece of doublespeak... It can mean modestly an attitude of withdrawal, "Bringing nanotechnology to exist", or even "Bringing nanotechnology in life sciences". But it can be interpreted also as a demiurgic plan to make life through technol-
ogy, which constitutes the Faustian risk of creating adverse unexpected properties.

4. Perspectives

Let consider now some sensors still prototypes, but examples of the technological developments expected in the coming years.

4.1. Thermal sensors

Early detection of thermal discomfort (premise, in the worst case, of a malignant hyperthermia) can be made through the capture of multiple information on both the temperature and the resistivity of the skin, the humidity and the intensity of the ambient air flow ambient. The establishment of an acquisition and processing network of such thermal sensors [ADD03, DADG04] allows the early prevention of abnormal heat-regulation caused for example by a summer heat wave. The acceptability is ensured by using smart jackets and bracelets for capturing the surface temperature in the chest, wrist and ankle, through familiar objects belonging to usual clothes and devices (broadly defined). The thermal sensors, like pyrometer networks (e.g., made from thermocouples [NF01]) can also be fixed on home walls to watch the body temperature of a person on bed or chair in the monitored room.

4.2. Fall sensors

Clothes can comprise drop sensors [Nou02] for detecting abnormal acceleration of the trunk. This information, intersected with actimetric data (pressure sensors on the ground [HDC+07], radar or infrared remote monitoring, magnetic sensors detecting doors opening) can sign a loss of activity and then trigger a selective alarm information to the victim of the fall and/or an automatic intervention if this victim does not or can not respond (at least verbally). The acceptability of drop sensors is strongly related to its specificity and its redundancy with environmental sensors, in order to avoid false positives, therefore untimely interventions.
4.3. Pressure pad and Tongue Display Unit (TDU)

The principle of monitoring a pressure pad is same as for the anti-decubitus actimetric mattress [CFP+96]. In collaboration with the Texisense® company, a prototype was developed [VCP+07, CVMG+09] improving an original device [APD03], which allows the measurement in real time of the pressures applied on the buttocks of a dependent subject using a wheelchair. This pad is composed of two right and left hemi-cushions. Each cushion contains 6x12 pressure sensors. Each pressure sensor has an area of about 1cm². The distribution of the sensors in the pad is non-linear, to allow better resolution in the ischiatic zones where the risks of bedsores are higher. These sensors are powered by a semiconductor powder distributed in a polymer shell. This powder has elastic properties and acts according to the principle of percolation: when its volume changes in response to a pressing force its conductivity increases and the variation of current passing through the powder is thus a function of the pressure. Each sensor is connected to an electronic system which allows the measurement of its electrical potential coded on 4 bits (corresponding to 16 levels of pressure). The pad is coupled with another prototype, allowing the feedback to the subject, named "Skin or Tongue Display Unit" (SDU or TDU) [APD03], originally developed and validated by J.M. Samsó-Dies [Die62][Die65] and P. Bach-y-Rita [BYR67][BYRKTGL98] for a population of deaf or blind for which the auditory or visual information captured by a microphone or a video camera were transcoded in skin or tongue electrotactile stimulations.

It was for example well adapted (including the wireless version of the device) to subjects at risk for pressure ulcers. The subject can keep the electrodes in contact with his skin or tongue (mouth closed). Sweat and saliva having rather good conductivity, SDU or TDU require only a voltage output of 5 to 25V and a current of 4 to 10 mA to stimulate skin or lingual receptors. Thus, when an electrode is activated, the subject feels at the corresponding level, a "tingling" on the surface of his skin or tongue. A subject without spinal cord injury can thus perceive and interpret information provided by the SDU or TDU electrodes placed on the skin or tongue, then adopt a postural attitude suited to the decoded information (cf. Figure 2 Left) in order to obey an postural
order or limit the overpressure zones. The same message can be delivered by using a vibrator located on skin or teeth or by visualising the information on the screen of a smartphone, PC, clock, tablet, ... (cf. Figure 2 Right). The acceptability of a device transmitting pressure information to skin or tongue through stimulation electrodes or vibrators implanted in a skin pad, artificial palate or dental prosthesis constituting a non-invasive tool to restitute this information has been demonstrated in [VCP+07][CVMG+09].

![Figure 2](image)

Figure 2: Left: Alert reaction of a deaf old dog after an electrical cutaneous stimulation of the skin on his back through an electrotactile device encoding an acoustic call by his master. Right: Visualisation of a pressure information on screen of several devices (smartphone, PC or tablet and clock)

### 4.4. Avenues for future

Regardless of the micro-nano-technology used (microtechnologies having still a great future for the reasons mentioned above), the future research in home monitoring could develop inside 3 axes, namely, the temporality, the complexity and, the heritability of the health system centred around the elderly:

#### 4.4.1. The temporality

The human lifespan can be understood in the Hippocratic chrono-
logical framework (recording medical and social data at given ages or *chronos* imposed by equidistant observation times), or in the Herophilic kairotic schedule, succession of *kairos*, i.e., opportune moments a human body is subjected to acute pathologies or to episode of sudden ageing as part of longevity step-downs), or even in the immanent Aristotelian time, the *aion*, which corresponds to the clock relative to a physical or biological process of degradation or genesis of matter. The kairos is reflected in the individual genetic profiling, which detects significant life times (embryogenesis, development, maturity, and then entrance in the longevity at the age of “discretion”, based on neo- and dysgenetic processes). In particular, the future study of gerontogenes [Par01], which may be symmetrical to initial morphogens, allowing a smooth "landing" (controlled by the Hayflick limit of cell division in a given tissue through apoptotic regulatory processes), involves the construction of microarrays dedicated to the monitoring of gene expression throughout the life, in order to anticipate malfunctions due to degenerative pathologies. The study of the expression of these gerontogenes provokes cell differentiation (i.e., changes in the number and nature of metabolic behaviours in gerontogenic control networks) allowing:

- early diagnosis of degenerative diseases (which subtle changes in lifestyle constitute specific markers?)
- quantification of the degree of autonomy of elderly (which are the main dependence symptoms?)
- identification of interactions between actors detected by a monitoring system at home (which relationships between the person and his and caregivers provide an optimal surveillance?).

The construction of prototypes of smart homes [RDN+03][NVY+03] allows to test the integrity of the captured activity data. A local processing station can send away the crucial elements signing the different types of normal and pathological behaviours. Understanding individual chronobiology will give meaning to current empirical classifications of various behaviours, related to emergent properties of some genetic systems, like PER/TIM clock [ST05] involved in the circadian regulation [VND02].
4.4.2. The complexity

The complexity arises from the interactions between many elements related to a dependent person, spread in time and space and whose consideration in the observation plan is necessary to detect the emergence of invariant temporal structures, signing a global behaviour triggering alarms when it becomes eccentric with respect to the canonical profile of the watched person in his environment [DVD+02][DBWM+03], which would be the real signature of his socio-sanitary condition. In a holistic approach without hierarchy, the study of interactions between actors of the dependence becomes essential. The main questions are: Who should monitor the surveillance? Is there the emergence of new businesses (gerontechnology, domologistics, ...)? What will be the relationships between the surveyed person and his caregivers, referring physician and social professionals? The study of the matrix of interactions between actors has to be drown (with nodes in side family, friends circle, educative or professional world,...), the emergent properties being studied as for the complex city networks [PSB+09].

4.4.3. The heritability

The French law of March 4, 2002 (“Loi Kouchner”) and a recent decision of the CNIL (National Commission Independence & Liberty) linked to familial data encryption, especially for designing pedigrees necessary for example for inbreeding studies [QGAC05] and early prevention of familial diseases, allow to consider the development of familial data files, in which the elderly should find their genetic heritage, managed by a health "notary" chosen among their medical or paramedical referents. Such a storage of information about the dependent person and their familial environment would interest individuals, families, patient associations, and more generally the whole society with the objective of optimizing and personalizing individual surveillance, education and therapy as well as public health policies (e.g., in the prevention of allergic reactions to vaccination in a given population). Corresponding research programs could be done in the context of specific French or European actions like AILE (Intelligent Apartments for an Effective Longevity), AAL (Ambient Assisted Living) or SHEILA (Smart Home for Effective Improvement in Longevity and Ageing), in the framework
of international collaboration with projects in countries having the same Latin cultural approach of the medical knowledge and practice, like the Chilean project HILO (Habitaciones Inteligentes para una Longevidad Óptima). In 2025, three million of Chileans will have 60 years and over (16% of the population). The demography of Chile is identical, with a lag of generation, to that of European countries and the experience of these last ones should be capitalized today to benefit tomorrow to whole Latin America, whom Chile represents one of the most advanced countries in terms of scientific and medical research and development. Pontificia Universidad Catolica of Chile created for example already since 1989, a "program for seniors", whose fundamental principles were:

- to improve their quality of life
- to develop gerontechnologies in Chile
- to promote research and development in the field of sustained longevity and ageing.

International convergence of these projects could benefit the medical sector of the economy by creating jobs in terms of service and manufacturing monitoring devices and software.

5. Conclusion

Elderly people must now progressively enter through personalized medical records in "Temporal/Complex/Heritable" data repositories, in order to facilitate an efficient personalized, non-invasive and non-intrusive monitoring, permitted by the recent advances in ICT applied to medicine, favour a return or remain at home, increase the autonomy and quality of life, and allow an effective sustained longevity, in accordance with the ethics of the person and the family. If above conditions are met, the collaboration between gerontologists, social researchers and ICT specialists will become fruitful and accelerate the evaluation and implementation of monitoring systems, useful for any homogeneous risk class of dependent elderly, having their specific monitoring procedures, optimizing economic and human cost of the surveillance, care and therapeutic education at home or in seniors residence.
References


