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1. Baseline Analysis
(Where are we)

This section provides an overview on state of the art in the field of Ambient Assisted Living and Aging, both in the commercial and research context.
State of the art activities are presented in three different subsections: acquisition, management (accessing and archiving huge amounts of data), and processing.

1.1 Data Acquisition

There are two main research activities in Assisted Living:
- Remote medical control and telemedicine;
- Smart house.

1.1.1 Remote medical control and telemedicine

Remote medical control aims controlling patients, in continuous way or on specific alarms, without moving them to the hospital. The remote monitoring is based on physiological data.
To this aim, a major objective in existing project is to develop standard protocols and infrastructures to support remote medical control.
Remote medical control requires an integrated *station*. In general, it consists of a PC equipped with a videoconference setup (e.g., a microphone and a webcam) integrated with physiological sensor systems, e.g. ECG, Blood Pressure Measurement and glucose tester.
At scheduled times, or on demand (e.g. an emerging sickness in the patient), the patient goes to the station, and starts the communication with his contact (e.g. a clinician), he/she adjusts the sensors on his body following the indication of the clinician, and possibly receives a new prescription.

In telemedicine there is also the possibility to transfer image information, such as TAC images. In this case, generally the communication is from a centre endowed with the technologies but without personnel for diagnosis.
The main research tasks on technologies in this area are related to:

- the standardization of the file format;
- the transfer protocol;
- the security in transfer data.

For all of these tasks there are local standards (see for example the Spicca model for telemedicine architecture http://www.telemedicina.campania.it/telemedicina/progetto/spicca.jsp) and international standards as HL7 (*http://www.HL7.org/*) for describing the exchanged data. Normally data are in XML format. An overview on standards used in this area is available on the website of the ***E****uropean* ***H****ealth* ***T****elematics* ***O****bservatory* (http://www.ehto.org/)

▪ Related projects, commercial solutions and publications

[1.1] *http://www.telemedicina.campania.it/telemedicina/progetto/obiettiviRisultati.jsp*
Italian project at regional level, for a standardization of telemedicine in Campania.

[1.2] http://www.asur.marche.it/media/files/3950_progetto_sistema_pacs_ris.doc#_Toc107718905
Italian project at regional level for supporting PACS and RIS standard for medical images.

[1.3] *http://www.health.gov.bc.ca/rural/initiative.html*
An archive of remote medicine including Telehealth projects in British Columbia.

[1.4] http://www.telesal.it/homecare.html
Italian project at national level for building a central homecare and telemedicine structure.

1.1.2 Smart house

Smart house projects aim at building an autonomous technological infrastructure capable to continuously monitoring elder and impaired subjects at their homes.
The telemedicine case described in the previous section consists of a single station integrating all the sensors, installed in a PC workstation in a fixed place. On the other hand, in the smart house scenario the whole house is sensorized and the whole living space is potentially capable to extract and process data from the patients living in the house. Sensor networks are typically used; the extracted signals are analyzed in order to produce alarms, feedback, or reminds to the patient.
The data from sensors are heterogeneous and with different sample rate and/or activation time; therefore, they have to be synchronized and pre-processed in order to be analysed as a multimodal stream. In state of the art smart house application, a centralized *station* is still present, but with a higher computational power, since the station has to receive all the signals, to process them and to generate the correct feedback, before communicating with the (remote) centralised archives (some projects envision “villages” of smart houses).
No shared standards are available to develop the architecture of the station. Some approaches use standards to define and translate rules describing the behavior of the smart house; conceptual structures in formal languages are also used, e.g. XML-based languages to represent the rules scheme, UML2/SYSML, VHDL-AMS.

In a smart house the sensors are distributed all over the house and they must be as less invasive as possible. For this reason the sensors are generally connected to the station via a wireless connection, so an important technological aspect is the battery power duration of these sensors and how to recharge them.

A doctor, or a stakeholder, should always be able to access to the current data (i.e. access to the home station), or to access to the history of the patient data (i.e. access to archives).
The platform used for viewing the data is not currently standardized: there are many different ad hoc solutions.
Another relevant aspect is enabling the possibility of viewing data from different devices such as Pc, mobile phones or PDA. The same devices are used in case of emergency to contact the clinicians depending to the alarm generated by the system.
For physiological data there are some solutions that aim to embed sensors on a wearable and comfortable jacket or T-shirt [2.5][2.10]. Other studies aim to develop wearable sensors with a reasonable power duration, but the dimensions for physiological sensors are not enough small to be ignored by the monitored subject [2.1].

- **Related projects, commercial solutions and publications**

[2.1] Robert Matthews, Neil J. McDonald, Paul Hervieux, Peter J. Turner, and Martin A. Steindorf, **A Wearable Physiological Sensor Suite for Unobtrusive Monitoring of Physiological and Cognitive State,** in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.

[2.2] http://www-sop.inria.fr/orion/personnel/Francois.Bremond/topicsText/gerhomeProject.html **GER'HOME** project A French project on smart home.

[2.3] http://www.infomobilityforum.com/it/images/stories/donzelli.pdf
Italian project for smart home.

[2.4] http://www.instantatlas.com/health.xhtml
Commercial platform for monitoring and reporting of general health data. It is a general platform that works on statistical data and maps, not only indoor.

[2.5] http://www.microsystems.it/index.php/ita/Azienda/Divisioni/Webcare
Italian commercial solution for home care. It uses a core station receiving the physiological data, a jacket with ECG sensors a blood pressure measurement wireless connected to the core station. There are also possibilities for a mobile core station.

[2.6] Bonhomme S, Campo E, Estève D, Guennec J. , **An extended PROSAFE platform for elderly monitoring at home**, in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.

[2.7] **Xuan Hoa Binh Le, Maria Di Mascolo, Alexia Gouin, and Norbert Noury** Health Smart Home - Towards an assistant tool for automatic assessment of the dependence of elders **in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.**
The focus of this work is the evaluation of the independency of the patients. They suggest three scales used in medicine. Their aim is to evaluate the Activities of Daily Living (ADL) i.e. the basic activities that an individual needs to perform to live independently. In this paper there are some interesting references on health smart works with non-invasive sensors, but such works do not evaluate the ADL. The approach is to identify two states of the patient, Immobile and Mobile, according to the sensors data in order to adapt the monitoring system to the user.

[2.8] **Datong Chen, Ashok J. Bharucha, MD and Howard D. Wactlar** Intelligent Video Monitoring to Improve Safety of Older Persons **in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.**
This work is more related to the management of multi-camera information for evaluation of "elopement" in dementia patient. They used HMM and find some problems with false alarm generation.

[2.9] **Wan-Young Chung, Sachin Bhardwaj, Amit Punvar, Dae-Seok Lee and Risto Myllylae** A Fusion Health Monitoring Using ECG and Accelerometer sensors for Elderly Persons at Home **in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.**
Authors claim the importance of recorded heart rate with the posture and behavior information, in order to correctly monitoring the cardiovascular regulatory system of the patients during their daily life activity.
In this study ECG and accelerometers data are continuously recorded and clinicians can monitor the data from the hospital with a special remote client software.
The paper explains the accelerometers characteristics, e.g. the acquisition frequency (40Hz). For the ECG analysis the authors used an improvement of the Pan-Tompkins algorithm developed in C# .NET . The sensors data are compared and manipulated in order to generate the alarm. No details on clinicians interface are provided. The data can be visualized on PC or PDA; the ECG parameter box shows values (R-R, QRS, PR etc) at different intervals.

[2.10] PERSONA, PERceptive Spaces prOmoting iNdependent Aging, Eu project, http://www.aal-persona.org/index.html

1.1.3 Sensor Systems adopted in Remote medical control and telemedicine, and in Smart house

The most common sensor systems include the following:
- Webcams and industry video cameras. In most cases IR videocamera are used, at low resolution (e.g. 352x288) and standard frame rate (25/30fps);
- Body sensors for physiological data (e.g., ECG, EMG) and accelerometers; in several cases they are integrated in "life jackets";
- Sensors on medical devices (e.g., on pill dispensers);
- Sensors on furniture for detecting events (e.g., opening or closing doors; pressure sensors on chairs);
- Microphones, to measure vocal controls and to communicate with clinicians in remote medicine applications.

Sensor networks are usually adopted in Smart house applications.

The heterogeneity of these signals needs for preprocessing and synchronization. Usually, a selection process is defined to individuate the data to be stored.

2 Data Management

Management of data has different key aspects starting from the privacy policy and the security of the transfer protocol. Since Internet is the common platform used for transferring data, the protocols used are generally TLS and SSL. Some approaches also used cryptography for the signature, and authentication processes with smart cards (e.g. Crypto-smartcard e Java-card) or Digital Identity.
Normally data are stored in a data base and the access to the data follows the same rules used for the storage (authentication, cryptography and so on).
Moreover, following the countries laws, the personal data can be stored in a different site with respect to the related health data.
In current state of the art, there are no examples of management of huge database of patients data.

3 Data Processing

Starting from the acquisition, the data have to be processed in different steps. In the most complex scenario, i.e. smart house, the signals acquired from sensors have to be:

- noise filtered, (well know process that depends on the signal and communication channel);
- synchronized one other as a multimodal stream;
- analyzed in order to extract higher-level information, and to generate feedback/alarms;
- manipulated before the transmission and the storage process.

3.1 Data synchronization for multimodal processing

Some of the data can be synchronized directly using hardware devices, e.g. in multi-camera monitoring systems, professional video cameras can be synchronized using a Genlock signal. Genlock can be an external sensor signal.

In case no such hardware solutions are possible, the methods at the state of the art are the following: manual synchronization using time stamps [1.1] or synchronization using software tools.

For example, the EyesWeb XMI server can analyze simultaneously, in a synchronized way, and transparently for the user, signals from a wide range of devices (e.g., video cameras, microphones, physiological sensors, shock sensors, accelerometers) [1.2].

3.2 Data analysis

The analysis of the data in AAL is focused on the generation of alarms caused by potential dangerous situations.

The ambient sensors are related to individuate potential danger situations such as, for example, falls. Other controls can be related to the therapy e.g. to automatically control whether a patient has taken the correct tablet at the due time.

In order to perform these activities the data from sensors have to be automatically checked, applying some rules that can be complex. For example, in fall detection it is necessary to track the subject in his house (or outside e.g., by means of devices as GPS) and to control whether he is moving or not. If the subject is not moving, the system needs controlling in which room he is, at what time (to avoid to generate false alarms), and how long is in his immobility. It is important also to check if there was motion in the floor direction before the immobility, e.g. using accelerometers or gyroscopes weared by the subject. See the papers on fall detection from the CAALYX European project http://caalyx.eu/index.php?option=com_content&task=view&id=18&Itemid=31

Since the rules for behavior analysis in the smart house are complex, no standard solutions are available in current state of the art. Some automatisms are used in the conversion phase between verbal rules and the programming languages seen in the previous section on data acquisition.

Another main aspect concerns the analysis of physiological data. In the case of automatic generation of alarms, the rules to follow depend also on the kind of sensors and on the monitored subject.

For examples, in case of ECG signals, it is important to set the critical threshold, for generating doctors call, with respect to the normal values of the subject [1.5].

3.3 Data transfer

The privacy aspect is the main point for protecting the data over the communication channel (see section Data management).

The transmission of data needs some preliminary manipulation in order to reduce the size and to maintain data coherence, or simply to extract the required information.

Generally the video data used in the analysis are not stored in the archive. Some solutions at the state of the art store B/W images of a particular situation, e.g. pictures of the subject during an alarm event or video sequences of the subject during a communication with the clinician.

Since video cameras produce big amounts of data, the image quality is reduced, before the transfer process, in time and spatial resolution and/or compressed.
The sensors on house furniture are normally stored when activated, e.g. infrared-sensor data monitoring a door are stored only when they recover an event. This data are normally associated to a timestamp.
Physiological data, instead, are converted in standard format (e.g., HL7, PACS) and are all stored for subsequent studies and statistics.

The transmission of the data is not only related to the storage process but also to the communication, e.g., with doctors (from the storage unit or from the real time acquisition).
The instruments used for receiving data vary from PCs to mobile phones [1.2][1.3][1.4][1.6], with different resolution and possibilities for receiving data. The data have to be manipulated in order to be transmitted on the correct channel, and in order to be correctly viewed on the chosen device (e.g., modifications of the resolution).

3.3.1 Related projects, commercial solutions and publications

[1.1] Xuan Hoa Binh Le, Maria Di Mascolo, Alexia Gouin, and Norbert Noury Health Smart Home - Towards an assistant tool for automatic assessment of the dependence of elders in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.

[1.2] **EyesWeb XMI Server and EywRAD client (www.eyesweb.org)**
The EyesWeb XMI server exploits the EyesWeb XMI open platform and the EyesWeb Expressive Gesture Processing Library to provide services related to multimodal and/or physiological signals. EyesWeb XMI manages the synchronization of multimodal streams of data having different clocks. The EyesWeb XMI server can thus analyze simultaneously and in a transparent way for the user signals from a wide range of devices (e.g., video cameras, microphones, physiological sensors, shock sensors, accelerometers). As a result from such analysis, the EyesWeb XMI server generates metadata related to embodiment, expressivity, and gesture.
The EywRAD client is an application for both desktop computers and mobile devices running Windows Mobile operating system. In its current form, it is an user interface for the remote control of EyesWeb applications running on EyesWeb XMI servers. The EywRAD client might support transmission of the sensorial inputs available on the mobile device (e.g., webcam, audio input, accelerometers, gps, etc.) and could also exploit EyesWeb to perform some processing of such data on the mobile device itself (this may reduce the data to be transmitted, with benefit for power consumption). The EywRAD client comes with a designer (authoring tool) that let users draw the user interface for a specific EyesWeb XMI patch.

[1.3] A. B. José, T. M. G. de A. Barbosa Jr., I. G. Sene Jr., A. F. da Rocha, L. S. da S. Castro, F. A. de O.Nascimento, J. L. A. Carvalho and H. S. Carvalho, **A Framework for Automated Evidence Gathering with Mobile Systems Using Bayesian Networks** in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.

[1.4] Pu Zhang, Yuichi Kogure, Hiroki Matsuoka, Masatake Akutagawa, Yohsuke Kinouchi, Qinyu Zhang **Remote Patient Monitoring System Using a Java-enabled 3G Mobile Phone** in proc of EMBS 2007, the 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007.

[1.5] **CAALYX** Complete Ambient Assisted Living Experiment 6FP EU project eHealth. One of the objective is to "identify which vital signs and patterns are more relevant in determining probable critical states of an older persons's health"

[1.6] http://www.mobihealth.org/
European project for design GPRS/UMTS mobile services for application in health care.

2. Visioning

(Where do we want to go)

Following the Tom's story scenario, the technologies in a future ambient assisted living situation should include:

- Adaptable interfaces, able to evolve with the subjects and with the situations under analysis;
- Paradigms of interaction that exploit other channels of communication such as expressive gesture [REF];
- Natural interfaces enabling everyday objects to be transformed into interfaces for monitoring elderly activities without impact on their life, e.g. novel multimodal interfaces such as tangible acoustic interfaces [REF];
- Novel "social interfaces", capable to measure social cues, such as empathy, emotion entrainment/synchronization among subjects, to analyze the involvement of the elder in social interaction, leadership and integration measures in group of elder subjects, attention cues.
- Interactive therapeutic exercises based on multimodal interaction and interactive multimedia (audiovisual) stimulation in real-time. Moreover, novel measures of the effect of therapies should be extracted during the exercises performance.
- A flexible support for clinicians with tools and interfaces enabling intelligent browsing and querying techniques on huge amounts of data from a potential high number of patients.
- System for monitoring impaired vital functions, to generate the correct alarm and the first aid action/call. The system should also communicate with the device of the caregiver, or clinician, to transmit all the needed data for a very fast triage and intervention.

3. Gap Analysis

(What are we missing)

4. Implementation

(Suggested methods to realize research actions)

As for fall prevention and cognitive decline, we propose to reinforce activities on the following topics:

- Research on novel multimodal interfaces and novel behavior descriptors to monitor more carefully elder patients;
- Research for novel paradigms for rehabilitation exercises based on « aesthetical resonance » paradigms;
- Research for novel movement and gesture descriptors. This action has to be based also on research in expressiveness and emotions, and on research in experimental psychology and related disciplines;
- Research for a better support for clinicians by automated quantitative and qualitative measures of the evolution over time of the performance of motor tasks.