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Ambient Multi-Perceptive System with Electronic Mails for a Residential Health Monitoring System

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***Abstract*— Based on several years of experiments, we propose a model of information systems for residential healthcare, and technical guide to select available hard and software technologies. An implementation is described, based on Emails. The system is under experimentation within the framework of the French national project AILISA.**

I. INTRODUCTION

With the progress of medical techniques, the hospital is concentrating on acute situations within highly specialized technical platforms and the period of post-observation shortens. This is often preached for economic motivations (high cost of hospitalization stay), and justified for logistic reasons (clogging of the hospital). Eventually, societal reasons correspond to the wish of the patient to leave the hospital environment as fast as possible. Thus, more and more healthcare is delivered at home (chronic diseases, fragile people) with remote monitoring of health status and wellness of the patient. This is the starting point of the concept of "medical remote monitoring".

The characteristics of such systems were identified in the Nineties [1]: communicant, opened and integrating various, existing or to come technologies, flexible enough to adapt to each patient and to the dynamics of health.

As the remote monitoring mainly takes place in the residence of the person, it is linked to the concept of "smart house" (home automation) in which sensors "sense" the habits of inhabitants, intercommunicate with actuators, to intelligently assist inhabitants in daily repetitive tasks.

Many research teams proposed architectures and prototypes for the remote medical monitoring in residence, so it is difficult to draw an exhaustive list [2,3]. Most of the systems are based on specialised information system. Their authors remain very discrete on implementation details, so it is difficult to draw generic design rules. The system presented in this communication, based on Emails, is compatible with the majority of existing networks. It was developed with open source softwares. It is fully operational, tested on 4 sites since year 2004 within the framework of the French national project AILISA [4].

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II. MATERIAL AND METHODS

A. The experimental platform HIS

The HIS experimental platform gathers data on the patient, through a sensor network connected to a computer (PC) to the Internet. The local software builds indicators on the patient status. Data is exchanged via emails (SMTP). This has numerous advantages: it is widespread over Networks, can work off-line (PSTN or GSM). As Email addresses are independent of the machine (IP address), dynamic IP nodes (DHCP) are reachable, as well as nodes placed behind routers (VPN). Also SMTP may initiate the connection between nodes to further negotiate a more effective protocol (FTP). Eventually Emails can exchange parameter settings. The main drawback is lack of time of delivery guarantee (QoS). Although, an American private study (Reverses Network Technology inc., July 1997) revealed that 91 % of the electronic mails are delivered in less than 5 minutes, 5 % in the following half an hour, 1 % in one hour and 3 % between 1 and 12 hours, less than 0.3 % in more than 12 hours. The record of slowness was established at 27 hours.

B. Sensors

Three types of information can relevant in remote health monitoring [5]: physiological parameters (health), environmental parameters (comfort), and patient activity (Activity of Daily Living). The HIS platform includes presence infra-red sensors (PIR), a weight scale, a tensiometer and a pulse oxymeter.

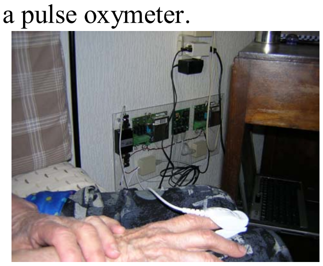

Fig 1.The pulse oxymeter

The PIR sensors (DP8111X, ATRAL) detects the infra-red radiations emitted by body surfaces (face, hands). The wireless scale (BodyMaster, CALOR) integrates a wireless modem. The semi-automatic wrist tensiometer (DIAGNOSTEC EW285, NAIS-MATSUSHITA) holds a digital RS232 link. We designed a pulse oxymeter from OEM (XPOD, NONIN Médical) to deliver information on the local LAN at a 1 Hz sampling rate.

C. The SmartCAN electronics

It is unnecessary to design a specific home network (LAN) as many industrial standards exist (I2C, CAN, FIP, EHS, EIB, Batibus, X10, Lonworks, Profibus…) as well as office networks (Ethernet, USB, RS232) readily available on any PC. To guide our selection we defined a set of criteria: - "producer-consumer" model - "multi-Master" - multiple access - bus topology (or free) - medium flow (10 KBPS) - simple and inexpensive installation

Our choice ended on the industrial standard CAN, for its robustness and simplicity of implementation. Initially proposed to network sensors and actuators in a car, it is based on the "producer-consumer" model, broadcasting information to each node, thus enabling "intelligent local loops". Several Integrated Controllers provide an economic way for all the functionalities (medium access, priority management, error detection and correction, messages repetitions). The CAN runs on any physical medium (pair of wire, coaxial, optical fibre, transmission current, wireless transmission). We chose a basic telephone cable, economic and easy to place in an existing housing, with wireless accesses for the movable and embarked sensors.

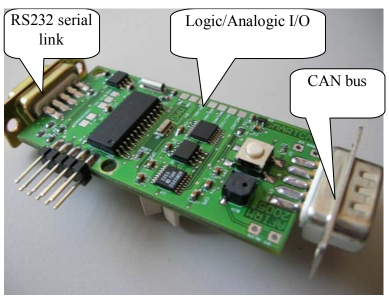

Fig 2 . The SmartCAN2 is the communication node for sensors

In order to connect any sensor to the CAN bus, and to benefit of a distributed intelligence, we designed a specific electronic board, the "SmartCAN2" (Figure 2), to communicate with the sensors (Logic and analog I/O, RS232), with a CAN controller and an interface to the telephone line, a radio transceiver, a microcontroller (18F258, Microchip). The SmartCAN2 is powered from a 3Volts button cell battery or a DC voltage delivered on the bus.

D. The wireless network

Many wireless technologies are available for smart objects (IrDA, Wifi, Bluetooth, UWB, Zigbee, ISM433...), so we established a set of 8 criteria to guide our choice: - the operational environment is obviously that of a building, even if "free field" operation can be considered (terrace, garden), - the range (maximum distance between transmitter and receiver) must fit a large apartment (40 meters), - the bandwidth must be 9600 Bauds minimum, - the availability must be maximum as the data production is asynchronous (collision detection/avoidance), - the quality of service (QoS) must be excellent as the data producers have a limited intelligence and cannot manage transport protocols, - the power consumption must be as reduced as possible because the communication nodes are supposed to run during months without intervention (6 months), - the software overhead is an important criterion for the rapidity and cost of our developments, - the material cost must be reduced because each communication node is likely to be accessible wirelessly.

We eliminated optical data links (IrDA) which require in sight connection and have a poor autonomy. Several wireless technologies (ISM433, ISM868, Bluetooth, Wifi, ZigBee, UWB) were evaluated with our criteria. The ISM868 fitted best our application: The "Industry Sciences & Medicine" (ISM) offers 3 free bands for smart objects communications (433 MHz, 868 MHz and 1.2 GHz), but only ISM868 exhibits distinct bands for each type of application (European recommendation CEPT/ERC/70-03). One band is reserved for "social alarms" (band 7d: BW=25 KHz, @10mw) which we used in our project.

E. Architecture of software

The local software was developed with "open sources" to be "editor independent": JAVA language (NetBeans) to run either under Windows or Linux operating systems, and MySQL data base. We built the software on a classical "centralized model" (Seeheim): the dialog controller (central class) collects data from the LAN and communicates with specialized classes (Graphic User Interface, Database…). Other models such as MSC ("Model-Sight-Control") and PAC ("Presentation-Abstraction-Control"), offer more "plastic" interface to adapt to the physical resources and to the environment, but with longer development delays.

1) Extensions to Java langage

As the generic JAVA JDK is limited, we added several language extensions (JAR libraries). As we communicate on the CAN bus with a dedicated electronic board (SmartCAN) plugged onto the serial adapter (RS232 or USB) we use the serial communication drivers of the Java library (Java Comm Serial API). Two other APIs are required to send Emails and to attach files to the message. A last API (JDBC-Java Data Connectivity Base) performs communication with the data base (MySQL).

2) Events supervision agents

The daily report is available only once day. Thus critical or risk situations can't be detected. So, we developed software agents for specific scenarios. The basic scenarios detect idle activities within a single volume. The delays depend on the room: 30 minutes in the WC is regarded as suspect, 1 hour (day) or 10 hours (night), for the bedroom.

3) Software agents for activity, mobility, presence

The activity of the person can be interpreted by the physician in term of autonomy. But the "level of activity" is a fuzzy concept: aptitude of the person to move inside and outside, and capacity to sustain a significant activity (in the same room or not). We thus distinguished two components in activity: agitation and mobility. Agitation represents the number of total detections per unit of time in any room. Mobility reflects the number of room changes per unit of time. Mobility and agitation are not correlated: a “mobile” person can be poorly agitated, whereas an “agitated” person can show little mobility. The mobility agent analyzes the flow of detections throughout the day, cumulates the number of changes, and transmits this information to the dialog controller which adds it to the daily report. The agitation agent cumulates all the detections, delivers regularly its information (every 10 minutes) to the dialog controller which transmits it to the GUI. The maximum sampling frequency of the presence detectors being one second, the maximum number of detections is 600 every 10 minutes, so the number of detections is easily normalised as a percentage displayed on a scale.

A third agent detects if the person is outside or not, and should not be disturbed. The absence is established when the last detection at the entrance is followed by a given period of no detection (10 minutes). We assumed that the resident does not wish to be disturbed when in the bathroom or the WC. The dialog controller displays this information with an interpretable colour code: a green framework surrounds the agitation scale when “present”, orange when “unavailable” and red when “absent”.

4) The oxymeter software agent

The pulse oxymeter delivers oxygen saturation and heart beat at 1 Hz. The flow of information being important it was necessary to compress it for the daily report. A software agent first seeks for records longer than 10 seconds computes the statistics (mean, median, standard deviation), respectively on saturation and beat. It then reports, for each record, the start and end time, duration, number of recorded values and statistics. This compressed information is still relevant to the physician to analyse the variability within the same day or the trend over a given period.

5) Automatic restart of the system

This type of system must run uninterrupted over long periods. This depends on the quality of the hardware and software, the stability of the operating system and the strategy to detect and correct predicted malfunctions. We selected portable laptops (little volume and noise level) as their internal batteries can filter network power fails (3 hours). To automatically restart the application, without end-user intervention, we use a service commonly offered by the operating systems: under MS-Windows we place a shortcut in the “start directory”, under Linux, we add a command line at the end of the batch starting file (/etc/rc.local). Eventually, in case the application does not run for 24 hour, the server will detect the absence of daily report.

III. RESULTS

A. The AILISA software

The main screen was carefully designed to respect the intimacy of the person, deliver sufficient information to the caregivers and to remain attractive. We chose a picturesque representation of the room seen from outside: the wall and the door. The door is “closed” when the person is absent, half opened when the person is busy, wide opened in other cases. When "pushing" the door (mouse pointing and left click) one accesses the following screen. Hour and time are also displayed to draw attention and as the sign of activity of the software.

The next screen displays a synoptic diagram (Figure 3) with the most recent detection (and elapsed time).

A user menu is accessible by a simple click on an icon, in the administrator mode (login and password) for software configuration (i.e. to fill in the Email addresses) and to display the contents of the data base, in particular for data retrieval. The administration screen allows the selection and localisation of the sensors installed within the apartment: with the diversity of situations, the application must adapt to any kind of habitat (plasticity).

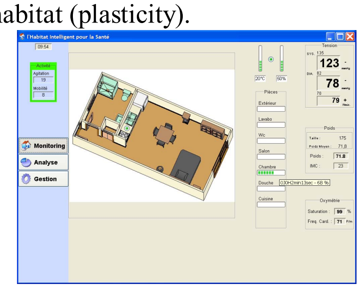

Figure 3-The synoptic screen

The data flow is simply carried out with files (free format) attached to Emails. Actually the difficulty was moved to the main server which needs a "communication front-end" to collect Emails, extract the contents of the attached files, transfer it to the data base. Once a day (23:50 pm), the software elaborates a daily report, creates 2 attached files, one in the text format, one in the MySQL export format. The 2 files, after encryption, are attached to the Email sent to the beforehand configured addresses.

We reported 100% of the Emails delivered within 1 minute (checked on the distant sites, in Paris and Toulouse, over a 12 months period); same report for “emergency messages” which do not necessarily happen during the off-peak hours as the daily messages.

B. The experimental platforms AILISA

We installed 4 experimental platforms, 2 in hospital environments - the Geriatric Hospital La Grave in Toulouse and the Hospital Charles Foix in Ivry Sur Seine -, and 2 in institutions for elderly in Grenoble. In the hospital platforms, we follow up the occupations in the bed and the armchair as well as the events at the entrance and in the toilets. The portable PC computer is placed in the nurse office, visibly fixed on the wall to free place on the already encumbered desks (Figure 5).

Figure 4- The local station is fitted on the wall in the nurse office

In the apartments downtown we supervise all the functional zones of the residence (Figure 5). The workstation was systematically placed on a shelf close to the telephone (access to telephone and power lines).

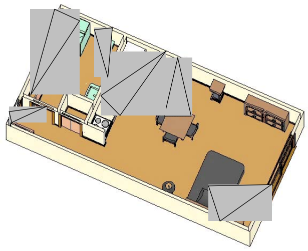

Figure 5- A private flat set up (the detections zones are greyed)

The PIR sensors were located to detect the presence/absence of the person in each functional zone. The data is analysed following either a direct (each zone associated with functionality) or a global approach (rate of detection per unit of time). This information is further used as a training basis: from the standard deviation, we build 2 thresholds for "hyper" and "hypo" frequentation for each volume and each time period [6] so that to set alarms on the behaviour. In following work we are interested in the total analysis of detections of presence from a pseudo temporal signal with "N" distinct levels corresponding to the number of installed sensors.

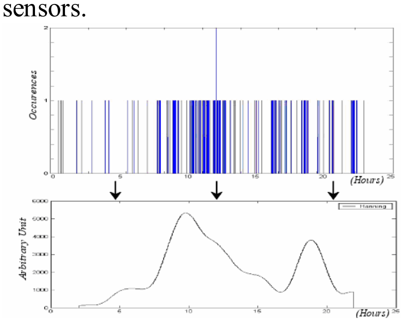

Figure 6-Agitation along the day. Maximums are clearly visible.

When cumulating the stay times for each room on a 24 hours basis, the simple graphic visualization of the parameters of mobility and agitation already reveals "patterns" which characterize the activity of the person at home [7].

IV. Conclusion

Work on information systems for residential health monitoring, is now entering “multi-perceptive information systems” to follow up health and activities parameters in the private environment of the person. Most of the technologies are available on the market. The task of the technologist thus consists in selecting the best compromise in term of flexibility and costs of deployment. The “off-line” model of communication fulfils the need for monitoring, with the proviso of giving them a sufficient autonomy (local intelligence). The “on-line” systems allow faster reaction times to serious events but they impose full time availability and a band-width which limits their rapid deployment, therefore their adoption. We developed such a system in the past [8] which proved to be inadequate.

Research efforts are now carried on the analysis and presentation tools in order to make them exploitable by caregivers. These systems produce large data flows, not easily interpreted by the caregivers, not familiar to them (activity index). Thus there is a need to compress this mass of information into reliable and meaningful indicators. Our own work attempts to combine two approaches of the presence data: a fine analysis of particular events correlated with function, and a macroscopic approach on the whole of the collected data. These two approaches probably will converge towards a new "time-frequency-space" representation tool.

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