Ambient Intelligence Might Support Increased Longevity

Norbert Noury, *IEEE Senior Member*

***Abstract*— Several technologies entered our homes to change our lives. First electricity brought light and comfort, now communication technologies are transforming our living place into a connected place allowing new services to be invented, comfort, security, wellness and health services. The ICTs in homes can now help prolonge our longevity.**

I. INTRODUCTION

Longevity of human beings recently increased more rapidly. This result was obtained thanks to improvements in the 4 following areas: the medical knowledge, the quality of nutrition, the working conditions and the living conditions. Most improvements came with electricity distribution, the first 'enabling' technology. More recently, Information & Communication Technologies (ICT) boosted the development of modern societies. We hypothesis ICT will support human longevity with democratization of tools for medical diagnosis and therapies delivery at home, also through the control of ambient environment.

As the prevalence of chronic diseases remains unchanged with increased longevity, people 'live longer with their pathologies' (Figure 1). ICT can help patients to become 'health conscious', more involved in their own "personal health".

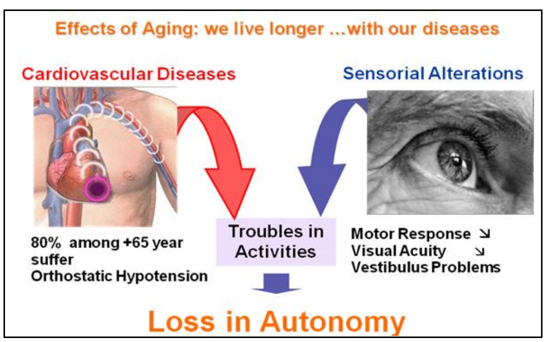

Figure 1. As an effect of aging, we live longer with our chronic diseases.

Introducing ICT in Health has the potential to both increase the financial burden and to reduce expenditures. But the threat is ICT may increase the 'digital divide' with social isolation for those who cannot afford technological aids.

II. ICT FOR REMOTE COLLECTION OF HEALTH DATA

The concept of home health monitoring appeared, in the early 90's, with the new technical possibilities offered by telematics to support Telemedecine. The Electrocardiogram was transmitted on the public switched network [1], the foetal cardiac rhythm was transmitted in pregnancy [2], hand held devices connected to the telephone [3] were used by insulino-dependent diabetics patients, a versatile smart hand held Biomaster [4] could collect medical data in home and automatically transmit through a Minitel to a distant data server [5]. Health telematics opened the way to monitoring various parameters in chronic diseases but the need for remote monitoring of the health of fragile and elderly people rose more recently with increased longevity.

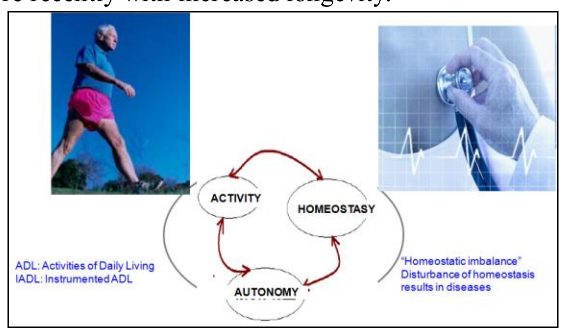

Figure 2. There is a strong relationship between homeostasis and Health, between autonomy and good Health and activity. Eventually, the activity is an expression of homesostasis.

Although Aging is not pathology, elderly are more likely to suffer multiple chronic diseases in their old age. There came the idea of monitoring their health and well-being with sensor-embedded houses. A specific attention is generally given to the monitoring of activities because there is a strong relationship between regular (healthy) physical activity and "Homeostasis", which is the capacity to maintain internal body stability when facing unbalanced external conditions. One expression of homeostasis is the movements in daily activities of humans. The autonomy of elderly subject relies on his ability to perform the basic actions involved in his daily living: transfer to/from the bed and in/out of a chair, move around and out of the flat, grooming, use of restroom, etc. Thus, there is a strong relationship between homeostasis, activity and autonomy (Figure 2). Many diseases result from "homeostatic imbalance". The aged organism loses control efficiency increasing risk for illness. Thus, some specific parameters are worth monitoring in elderly such are the loss of weight

Prof. Norbert Noury was with University of Grenoble, France, lab. TIMC-IMAG, UMR CNRS 5121. He is now with the University of Lyon, France, lab. INL UMR CNRS 5270 (e-mail: norbert.noury@insa-lyon.fr).

(tumors), the Body Mass index (degeneration), the dehydration. Some interesting parameters are not yet accessible (perception of pain, wellbeing, level of socialization), yet simple information can bring clues on the vital wish to interact with others (time on phoning, time outside their home).

For the measurement of activities, the most widely spread technology is Passive Infra-Red (PIR) detectors. The PIR only detect movements, not presence, are prone to misdetections, have reduced detecting area and are not selective. Nevertheless they allow detecting activities of a single subject at accessible costs.

III. Smart Homes Initiatives

The research and developments are numerous in the field of health smart homes because it has a high societal impact, it is an attractive field of applications for already existing researches in sensors, in image and signal processing, in communication engineering and in human machine interactions. The researches on Health Smart Homes were first motivated by the aging of populations. This is probably the reason why it first started in Japan and Asia in the mid-eighties [6-13]. The Universities in Western European countries followed at the beginning of the nineties [14-22]. The North American Research labs entered this new promising market with the new century [23-33].

IV. From Data to Information

The following examples show the possibility offered by the in home activity monitoring from PIR sensors data, but same methods might be applied on other sensors.

A. Graphics of Activities

The most 'natural' way to graphically represent data of activity, is to allocate a different level to each presence sensor as a function of time: the "ambulatogram" (Figure 3), was first used in the AILISA project [34] to visualize the detections of presence sensors distributed around the flat. It points out the main periods of activity/inactivity, the spatial frequencies and thus the periods of higher activities.

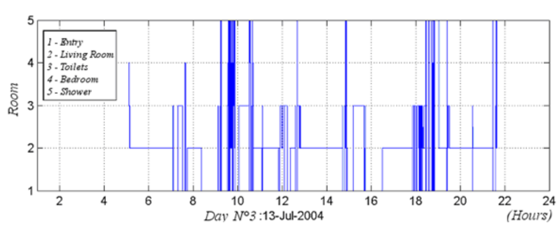

Figure 3. Ambulatogram of activity on a daily basis (horizontal scale is time in hours; vertical scale is the number of rooms visited.

The ambulatogram can be viewed on a daily basis or on cumulated periods, to show the trends of the distributions of activities. The profile of "Agitation" can show regular patterns of activity (rhythms) of the inhabitants (Figure 4).

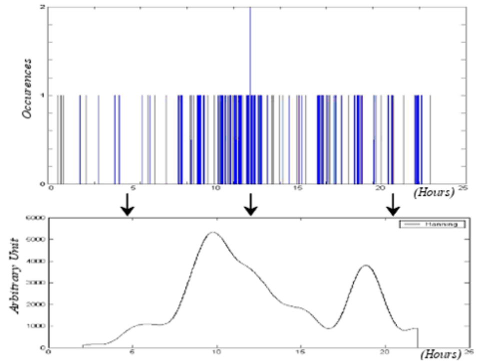

Figure 4. An example of the signal "Agitation profile" (top). After applying a convolution with a Hanning time window (bottom) the circadian rhythms are visible.

Another graphics, the "spatio-temporal" diagram, allocates a different color to each activity (Figure 5). It was first used in the MAPA project (Orange Labs, [35]) on activities collected from the events on the electrical power line.

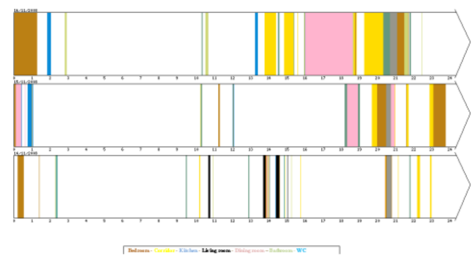

Figure 5. The spatio-temporal diagrams show the successions of activities along the day (here 3 days from bottom to top). Each activity is allocated a unique color. Horizontal scale is time of the day.

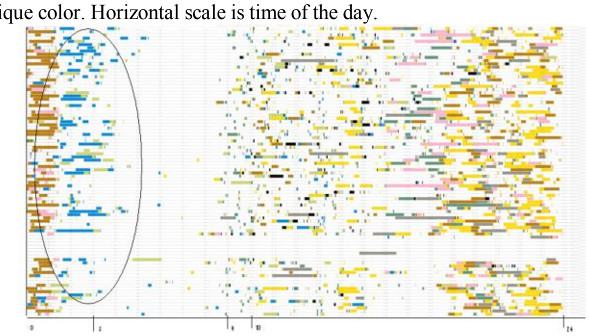

Figure 6. This subject (ID32) has late activities at night, with frequent visits to WC and bathroom (after 3-4 o'clock), and wakes up late after 9 o'clock.

A field experiment, involved 12 senior citizens (age = 80.5±3.2) living alone on their own (51840 hours recorded during 6 months). Researchers discovered that spatio-temporal diagram show specific and regular patterns for each subject (e.g. a 'biometric activity signature', Figure 6).

C. Monitoring distribution of Activity

The first level of analysis on the raw data, is to figure the mean time spent in each room ('time of stay', Figure 7) at different time scales (day, week or month) so as to visualize the habits of the inhabitants.

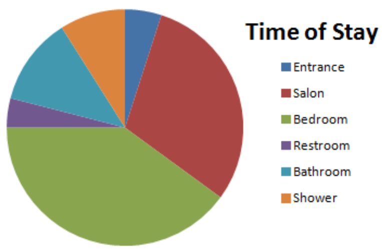

Figure 7. Graphical representation of mean time of stay in each room.

A second level of analysis is to figure the frequency of transitions between each room ('distribution of transitions') which gives additional information. A 'low active' subject will show a diagram with mainly 1 or 2 rooms occupied (e.g. the bedroom and Living room) and little transitions. A 'highly active' subject shows more transitions and also a more regular diagram of stay.

D. Monitoring distribution of Inactivity

The inactive periods also provide useful information about the human activity (i.e. duration of sleeping periods). An example of inactivity distribution for the Living room is given in Figure 8 [37]. We can define a "threshold of inactivity" and raise an alarm in case of unusual inactivity in a specific area (i.e. longer stay in restroom).

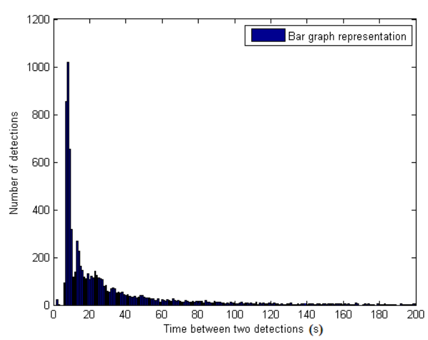

Figure 8. Histogram of time of inactivity in the Living room recorded during 2 months (AILISA project- Residence for Elderly 'Notre Dame', Grenoble, France.

E. Night and day alternation

The natural alternation cycle between night and day activities is well known. The diurnal level of activity is lower after a restless nighttime). Thus a "high (low) level of activity during both the day and the night is abnormal". In Figure 9 we visualize the night and day level of activities (data collected on one subject during 2 months in a hospital suite [38]). Within the AILISA project, we recorded long term data in 2 hospital suites, together with written observations from the nurses. Physicians confirmed that the periods of resynchronization corresponded to periods when the patient felt poorly, complaining a lot to the medical team.

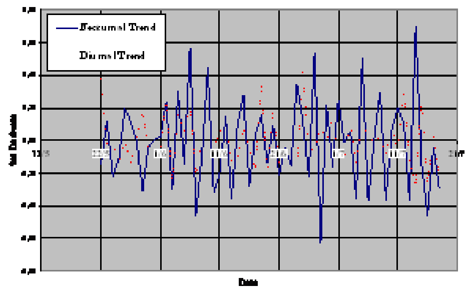

Figure 9. The diurnal and nocturnal activities are correlated (Monitoring of an elderly person during a 2 months period - May to July 2007).

F. Circadian activity rhythms

Circadian biological rhythms were discovered for years [39] and are still extensively studied in chronobiology [40]. The circadian rhythms are driven by a 24 hours circadian clock, and adjusted to the local environment by external "synchronizers" (zeitgebers), the most important of which is daylight. It is thus natural to consider the 'circadian rhythms of living activities' (CAR) of the inhabitants. We proposed several methods to compute the CAR, among them the convolution of the ambulatogram with a time window [38], or the distribution of time spent each hour in each room (Figure 10). An alarm can be triggered in case of activities deviating outside a "regular" pattern [41].

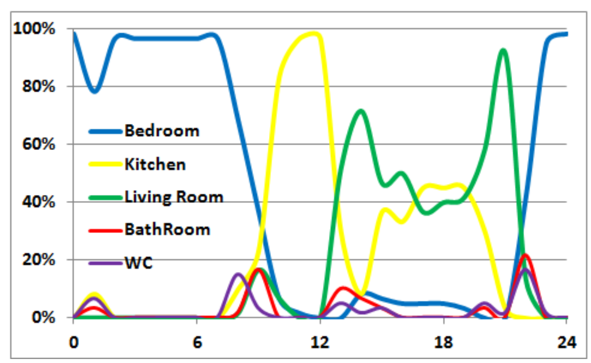

Figure 10. The Activity rhythms : distribution of time stayed each hour in each room.

V. Discussion

Researches on activities in smart homes raised various questions. The level of details (granularity) of collected signals induces the quality and nature of information. We can launch alarms on detailed information ("microscopic" granularity). A coarse information ("macroscopic" granularity) allow detecting the slow trends of the activity (i.e. loss in autonomy).

Reliability of data is generally little addressed although we cannot take good decisions on corrupted, inconsistent or incomplete date.

A huge quantity of data is produced. Data mining techniques must be developed to timely analyze a mass of information collected in data ware houses, so as to produce ”aggregated index” and to detect efficiently when the subject needs help.

A major task is to produce objective measures on imprecise concepts such as ’age’, ’good health’, ’autonomy’ (Figure 11).

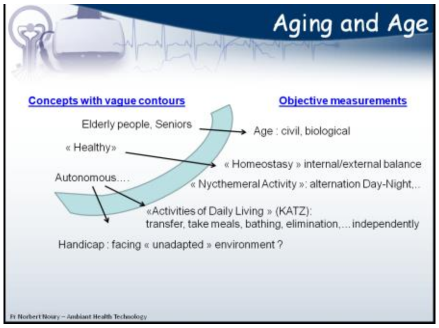

Figure 11. Many concepts hve vague contours. But Objective Measurements are needed.

There is a difference between civil age (over 65) and biological age (elderly). Good health is also controversial as our body develops pathologies in reactions to external unbalanced situations. The “efficiency” of the homeostasis of the subject, is probably a good measure of his vitality to face illnesses. Natural ’nycthemeral rhythms’ are also good indicators of the global wellness. Autonomy is evaluated using limited manual scales (ADL). The level of handicap depends on the environment which can be adapted to reduce handicap or prolonge autonomy.

The questions of intrusiveness of technologies and the ethical issues are often raised but are little treated. Many find it unacceptable to collect and moreover to build information in the intimacy of the home. Although technologies ’invited’ by users in their homes are sometimes also very intrusive. An interesting approach is probably to use the home environment itself as a sensor (i.e. to detect the main activities through the electrical activities on the residential power line [42]). Nevertheless, the main concern is to help people to remain independently in their own affective environment. If technology can help, then no doubt it is acceptable. Humans will only accept technologies which will serve them. The ”non-ethical” behavior would be to let no chance to the elderly because technology might disrupt them. Ethics is not ”Morals”.

Very often, the placement of a senior in a specialized institution is the decision taken by the medical team because there is no reliable information on the health, wellness and security of the person living alone at home. The loss of autonomy of the subject, is feared by the medical and social actors as well as by the subject himself. The ”curve of autonomy” (Figure 12) is natural, ascending in youth and decreasing with age. If we can detect advanced signs of degeneration we can adapt the environment to maintain the subject above the threshold of dependence, or prepare an accepted institutionalization.

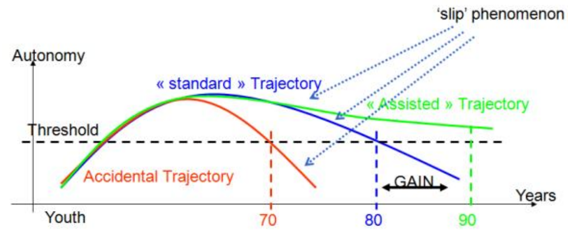

Figure 12. The curve of autonomy overpass the threshold when children become autonomous and underpass the threshold in case of accident or when age comes.

The results we obtained show that there are measurable information built upon simple sensors. Still, the work must be further carried on methods to better understand the signals of activities and the correlations between daily activities and wellness and homeostasis. This work must be done in close collaboration with physicians and physiologists on large scale field.

VI. Conclusion

The first technology introduced in our homes, electricity, brought artificial lighting, allowing humans to maintain their activities after setting sun. It also opened our home to numerous technologies which changed our lives, such as the fridge which contributed to safety of our diet with major consequences on our longevity. The last revolution in homeland is the telephone which made it possible to stay connected to others. The Internet amplified this phenomenon with the possibility to instantly share communications and information. Individuals now wish their living place to be more responding to both their vital needs and higher aspirations.

Smart Homes technologies are offering a new chance to meet the deeper needs of humans to develop their own personality in a secure environment of wellness and good health. Humans invite in their homes the technologies which make sense to them, servicing their basic needs and helping them concentrate on their main achievement in life.

ICT have entered our Homes and might now participate in increasing the longevity of humans.

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