Elder Care Architecture – a physical and social approach

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***Abstract*— As we observe society in our days, we can see that people live longer; this means that we have an older population, more likely to have health issues. The special needs presented by the elderly are becoming a major concern for all of us, along with the lack of time demonstrated by society as a whole and, as a consequence, the lack of time is seen when families are not able to take care of their own elders. Many solutions are being presented in order to solve this problem. Some of them are taking advantage of the new technological developments in the body sensor networks area. In this paper we propose the architecture of a system called Elder Care. The Elder Care solution has two primary goals: monitoring vital signs, sending alerts to family and to specialized help and providing a social network in order to help end the elderly's social isolation.**

Keywords - health monitoring; wireless sensors networks; body area network.

I. INTRODUCTION

It is a fact that global life expectancy is rising; therefore, the number of older people is increasing, as shown in TABLE I. and TABLE II. . Because women are working outside the home more and are less time at home, they are no longer able to give support to old family members. Another fact is the scalability of new technologies [2] [3] [4]

TABLE I. COMPARISON OF POPULATION IN 2005 AND 2050 (%) [5]

Region	Population in 2005				Population in 2050			
	0-14	*15-59*	*60-79*	*80+*	*0-14*	*15-59*	*60-79*	*80+*
Global	28.3	61.4	10.3	1.3	19.8	58.3	21.8	4.4
Africa	41.4	53.4	5.2	0.4	28.0	61.7	10.4	1.1
North America	20.5	62.7	16.7	3.5	17.1	55.6	27.3	7.8
South America	29.8	61.2	9.0	1.2	18.0	57.8	24.3	5.2
Asia	28.0	62.7	9.2	1.0	18.0	58.3	23.7	4.5
Europe	15.9	63.5	20.6	3.5	14.6	50.9	34.5	9.6
Oceania	24.9	61.0	14.1	2.6	18.4	56.9	24.8	6.8

TABLE II. POPULATION/DEMOGRAPHIC INDICATORS IN PORTUGAL [6]

	1970	**1980**	**1990**	**2000**	**2004**
Population ages 0-14 (% of total)	28.8	25.9	20.4	16.2	15.9
Population ages 15-64 (% of total)	62.0	63.6	66.2	67.6	67.2
Population ages 65 and above (% of total)	9.20	10.5	13.4	16.1	16.9

Facing this new scenario, there are many solutions that aim to monitor the elderly in order to provide a higher quality of life in their homes and to decrease health costs.

Wireless communications made remote monitoring of people possible, allowing us to have 24 hours of surveillance with low costs and to obtain a great amount of accurate data about a patient, such as heart-rate, blood pressure, blood oxygenation, carbon dioxide partial pressure or fall detection [3] [4] [7]. This patient's historical record can be a very useful factor in medical decisions, leading to a decrease of errors made by lack of information. It also has a major importance in detecting sicknesses early so that measures can be taken to prevent illnesses from getting worse.

Older people are a target population for the use of these solutions due to their fragile health. They also show a strong determination to live at home as long as possible and have their own independence. Despite of the need for living an independent life, they also demonstrate great fear of feeling unsafe and alone [8] [9].

A solution that involves uniting caring for elderly, with information and communication technologies, was considered because there is an increase in the use of technology by the elderly. Figure 1. illustrates this trend.

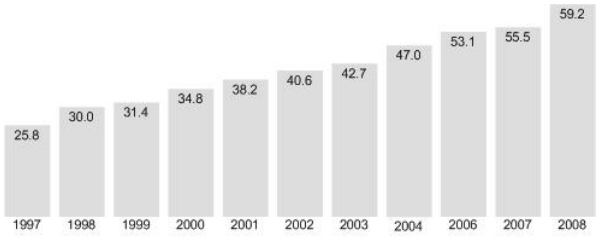

Figure 1. Computer use by elder in home care facilities (in %) [10]

To overcome these questions, we propose an architecture to monitor vital signs and give the proper response in abnormality cases, and also create a social infrastructure to bind older people and make them more valuable to society [1].

This article intends to give an overview of the Elder Care solution, by supplying a global synopsis of related existing solutions and projects (approached in Section 2) and giving a contextualization of the main architecture of Elder Care (shown in Section 3) as well as explaining the different modules in which Elder Care is divided. Section 4 shows a briefing of the interviews made in order to accomplish the requirement analyses. Section 5 presents some conclusions and future work.

II. RELATED WORK

Many solutions, both academic and commercial, are presented to provide a better life for older people and to be able to reduce health costs. For instance, the solution Alarm-net developed by the University of Virginia is capable of real time and long-term monitoring using wearable sensors, continuously records the information to assist diagnosis and has medication reminders [11].

There are some solutions that use Bluetooth technology like Nonin [12], which developed a bracelet that reads SpO2 and blood pressure. Others use motes, such as the Code Blue project from Harvard University [13] [14] [15]. There are also companies that are developing t-shirts with wireless sensors, for example Sensatex [16] and Vivometrics **Error! Reference source not found.**. In [18] a solution is presented where the routine life of older people can be monitored and alerts occur whenever there are abnormal behaviors.

The importance of solutions to deal with older people is so extreme that there are numerous projects in development referred in [19] and [20]: OLDES (Older People's e-services at home), CAALYX (Complete Ambient Assisting Living EXperiment), K4CARE (Knowledge-based HomeCare eServices for an ageing Europe), ALADIN (Ambient Lighting Assistance for an Ageing Population), ENABLE (A wearable system supporting services to enable elderly people to live well, independently and at ease), SHARE-IT (Supported human autonomy for recovery and enhancement of cognitive and motor abilities using information technologies), EASY LINE+ (Low cost advanced white goods for a longer independent life of elderly people), PERSONA (Perceptive spaces promoting independent aging), SOPRANO (Service oriented programmable smart environments for older Europeans), WAI-AGE (Web accessibility initiative: ageing education and harmonization), ESBIRRO (Bio mimetic actuation, sensing and control technology for limit cycle bipedal walkers), COGKNOW (Helping people with mild dementia navigate their day), ESANGATHAN (Collaborative working environment for ageing workforce).

Most of the found solutions aren't in production and are still in an embryonic state. Some of them are also not focused for a specific population. As some deficiencies are found we can conclude that:

- they don't interact with national health systems, which implies that all the information obtained through monitoring is still not accessed directly by the patient's doctors and, therefore, the potential of providing detailed information to allow doctors to make more accurate diagnosis and prevent illnesses is underestimated;
- many solutions are generalist, and do not include a target population and their special needs. For example, in the elderly's case, interfaces must be simplified and all the tasks have to be intuitive without the necessity of huge memorizing process.
- numerous solutions are concerned with the physical side but neglect the psychological side;
- most solutions do not provide a global response, allowing the senior population to have only one centralized and simplified solution. The fact of having to interact with different products and solutions, in order to have physical monitoring and social support, increases task complexity, causing the elderly to abandon the use of those solutions;
- although the elderly are aware of the fact that their privacy is somehow invaded by a continuous survey and give consent to the use of the obtained information for medical purposes and family alerts, none of the solutions have a pausing ordered by users, for a specified period of time.

The Elder Care solution, besides monitoring physical issues, is also mainly concerned in giving a proper solution to the psychological and social aspects. Elder Care stands out from all other architectures by expanding its purpose to a social level, focusing not on the physical well-being of elderly people, but also by giving an emphasis to the social issues while offering solutions the deficiencies presented above.

III. PROPOSED ARCHITECTURE

In order to achieve the presented architecture, a qualitative interpretative research method based on semi-structured interviews was used.

In interpretative research, learning comes from interaction with the phenomenon. i.e., through the knowledge that the researcher already has, in interaction with the new aspects of the phenomenon, new knowledge is obtained on the reality that is being explored [21] [22] [23].

In semi-structured interviews, the interviewer follows some guidelines and questions to conduct the interview but gives some flexibility to the interviewee [21].

The process, reflected on Figure 2. , began by making a requirement analysis to allow an architecture sketch. After this step, interviews were conducted in order to validate the identified requirements and add new ones, according to the interviewee's points of view.

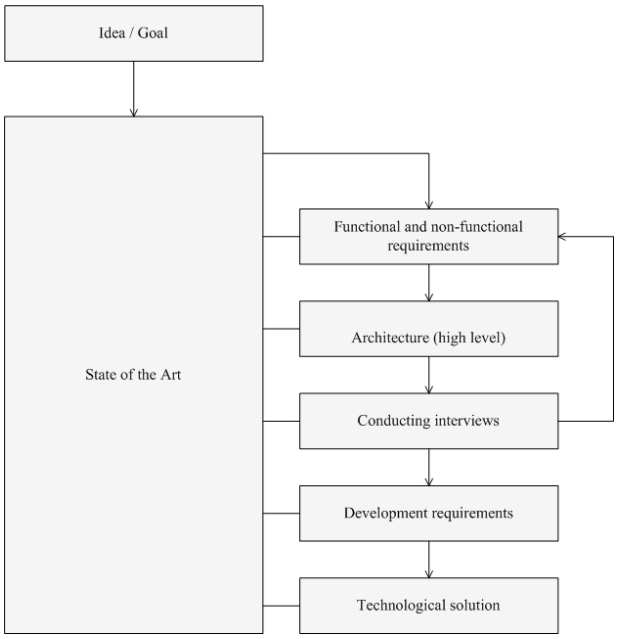

Figure 2. Research guideline

All of the requirements initial and added by the interviews led to the proposed architecture.

Some of the most important requirements are the following:

- each user will have a set of wireless body sensor that will allow continuous vital parameter monitoring;
- the parameter monitoring should not interfere with user's daily routines;
- the system will be responsible in sending alerts to family members and emergency services whenever an abnormality is detected (abnormal parameter values or sudden routine changes);
- the elderly will be able to order pause surveillance during a specific period of time;
- multimedia devices will be installed at the elder's residence in order to provide interaction with a virtual leisure room;
- the multimedia device will also be responsible to inform the elderly to take his medication;
- the virtual leisure room will be divided in areas that will allow communication, knowledge record, hobbies, education and culture and service requests.

To respond to all the requirements, including the ones specified above, the proposed architecture is divided in 3 primary modules: local monitoring, control center and virtual leisure room (visible in Figure 3.).

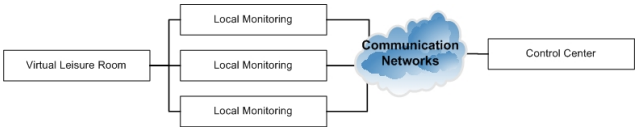

Figure 3. Elder Care block diagram (level 0)

The local monitoring will be installed at the patient's home, obtaining vital signs and sending them to the control center that will be responsible for setting in motion the proper alerts and specialized help in motion as a response to abnormal situations.

The local monitoring will also have a media center in order to allow users to communicate with other users that acquire the Elder Care solution, through the virtual leisure room. This virtual leisure room, as the name indicates, will represent a virtual room where users can meet and interact, creating a social network.

Figure 4. represents how information will be exchange between the different modules.

Local Monitoring will send medical data acquired through wireless sensors, to the control center. This data will be encrypted and sent over Ethernet in XML format.

The local monitoring center will also interact with the virtual leisure room. Inputs will be provided from a web cam, microphone and touch screen device, at the elder's residence, and sent over Ethernet to the virtual leisure room.

The control center will receive all local monitoring center information and manage the alerts, sending SMS alerts to the elderly's family, as well as activating local help support.

As regarding user's information, the control center will also let certified health units access information, with previous authorization from the elderly.

Certified health units and the elderly's family can also upload relevant information to the control center such as clinical analysis, medical exams, allergies and blood type.

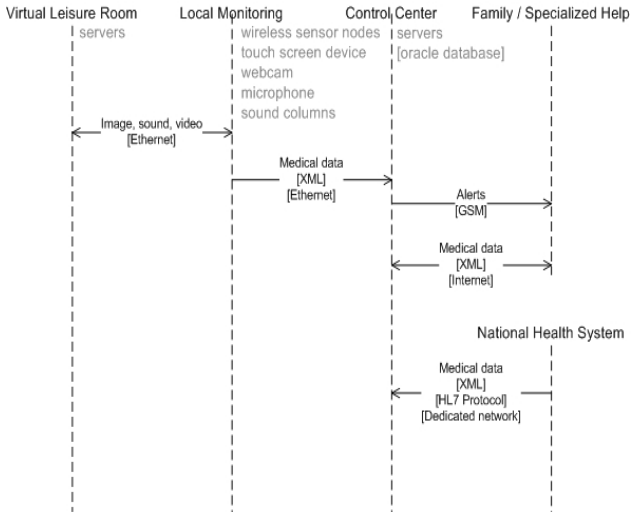

Figure 4. Elder Care information exchange

The subsections bellow explain, in a more detailed perspective, how each one of these three modules works.

A. *Local Monitoring*

The basic concept of Body Area Network (BAN) is the idea of having a set of compact mobile units, allowing the transfer of patient's vital parameters to the control center or responsible medical staff [24].

This system is based on several sensor nodes, each with its own power supply, processing unit, memory unit, radio, one or more sensors and analog to digital conversion module [25] [26] [27]. Each node is able to communicate with other nodes or a control center through wireless technology. In turn, the control center establishes communication sending all information by Ethernet or cellular network [28]. The basic concept of BAN is used in Local monitoring module.

Local monitoring will be installed in older people's home. It will acquire vital signs from body wireless sensor, in a non-invasive method, and send the abnormal information and samples of normal information to the control center through a communication network. The vital signs to monitor are, for example: blood pressure, heart rate, respiratory rate, temperature and fall detection. This choice was made after some interviews with doctors and nurses that indicated these parameters as the most important to survey in elder people.

As it can be seen in Figure 5. , the elderly will have body wireless sensors communicating with the gateway node. If the elderly are in their own residence, the information will be sent through cable network. When the elderly are outside their residences, the information will be sent through their cell phone. The information will be treated in the control center module.

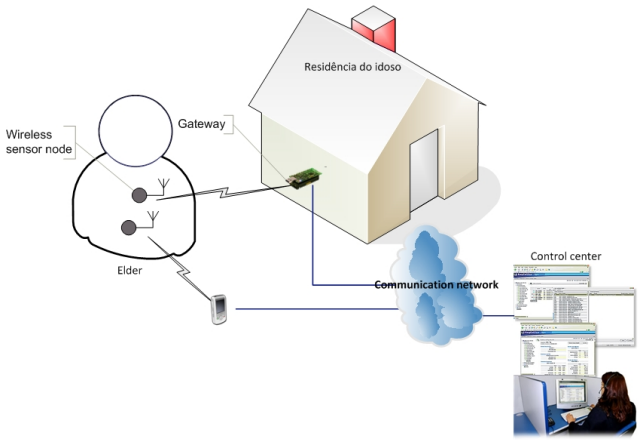

Figure 5. Communication in monitoring vital parameters

Some routines, like the time spent at home and outside by the elderly, will also be monitored. This appraisal is going to be helpful in order to detect unusual behavior. For example, if a person has the habit of being in the garden for 30 minutes every day between 2 and 3 p.m., and the local monitoring module detects that it is 4 p.m. and s/he has not entered home, it will send a message alert to the control center module, that is responsible to manage all the incoming alerts from the different local monitoring modules. As regarding privacy invasion, the possibility for users to pause the routine monitoring will be given.

Local monitoring will also be detecting movement, gas, flood and fire and deploy a trigger to the control center whenever a problem occurs.

Besides, it will have reminders for taking medication, people's birthdays, and other configurable events.

Moreover, the local monitoring module will have a media center composed by a touch screen device, webcam, sound columns and microphone that will allow the user to interact with the virtual leisure room module, which will be approached bellow in this article. The program installed in the device with the touch screen will have a simple interface and few options, in order to guarantee accessibility and easy memorization by older people.

Due to the sensitive nature of the information, this will be encrypted when sent to the Control Center. All the information in the Control Center will be accessible only by the elderly and by people whose access was given consent by the elder, for instance their family and doctors that are treating them.

A representation of local monitoring module can be seen in Figure 6.

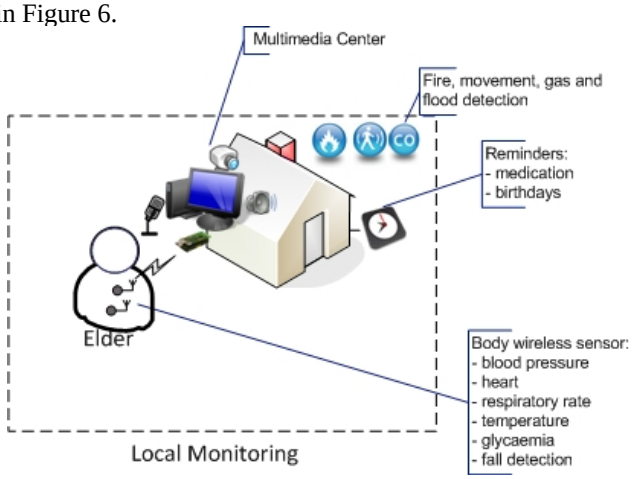

Figure 6. Elder Care local monitoring module

B. *Control Center*

The control center, represented in Figure 7. , will receive the information from all local monitoring.

In addition to the fact of being an information repository, the control center manages all the alerts. This means that, it is possible to compare current data with the patient records and check what parameters are abnormal. It can, then, inform the family as well as activate proper emergency responses. This allows having a personalized response for each case because, besides the incoming alert, the control center has all the medical records and previous alerts of each patient.

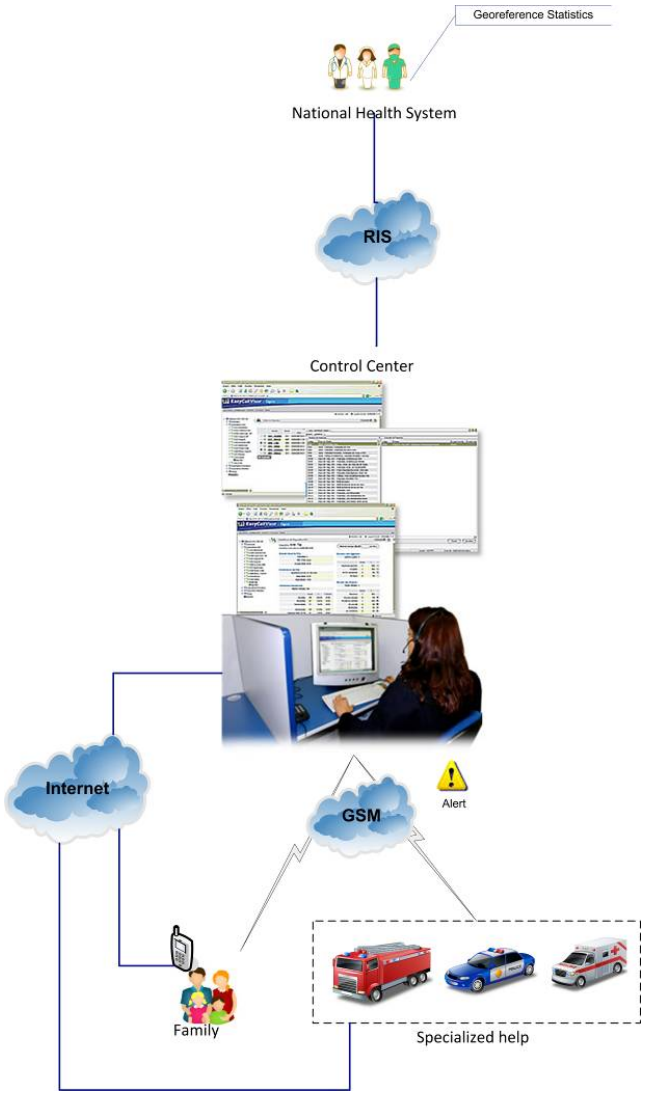

Figure 7. Elder Care control center module

In a more and more frantic life style, sometimes people have no time to take care of their family's elders. With this in mind, alerts will be sent to the elder's family, from control center to their mobile phones. This implies that all families that have adopted the Elder Care solution may rest easy with the assurance that their elders are being monitored and, whenever some irregularity happens they are alerted.

In addition, authenticated family members can access a web site, through personal computer or mobile phone, to consult all the history of the user.

By having an extremely rich information database, the control center may provide data to the National Health System in order to create georeference statistics while providing a complete historical record of the patients with local monitoring module. This may help during medical diagnosis by supplying more complete and accurate data.

The communications with the National Health System is going to be developed by using a standard protocol such as HL7, DICOM, HIPAA, CEN/TC 251 (WGIII) - Security, Safety and Quality, ISO TC 215 (WG 4) - Security, IEEE P1157 Medical Data Interchange (MEDIX), IEEE P1073 Medical Information Bus (MIB) [29] [30], according to the country where the solution will be implemented. The future tendencies are to have common protocols exchanging medical information in order to guarantee the integrity of all systems.

By having a great amount of vital information, the control center will have huge measures to back up information and to provide a no fault tolerant service.

C. *Virtual Leisure Room*

As people are getting older, they have a propensity to isolate themselves at home, mostly due to physical movement difficulties. As a consequence, they start to feel sad and to be a burden to society by not being able to contribute in some way.

The virtual leisure room promotes a social relationship between the elderly with the Elder Care solution, in order to prevent social seclusion (Figure 8.). The virtual leisure room is going to be conceived to cover most of the elderly, including illiterate people and with some motor disabilities, but cannot be applied to those who suffer from degenerative mental illnesses, such as Alzheimer.

The virtual leisure room will be divided in areas such as: communication, knowledge recording, hobbies, education, culture and service requests.

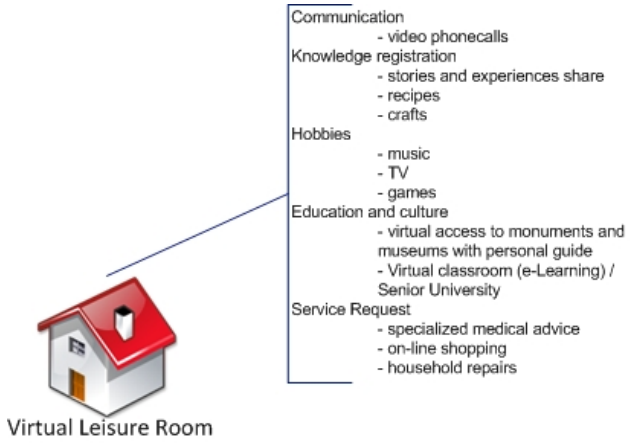

Figure 8. Elder Care virtual leisure room module

Communication will appear in order to allow Elder Care users to interact with each other and with their family and friends by wrapping applications that are already in use, such as Google talk, messenger, blogs and other social web applications.

Another particularity of the virtual leisure room is going to be the possibility for users to post their life experiences, exchange recipes and describe some traditional professions and handcrafts. This will allow for the saving of much knowledge that will be lost if not passed to the generations. The elderly have endless knowledge that is many times lost.

The area for hobbies will provide a way for older people to play some games, listen to some music or watch interactive television.

The virtual leisure room will provide some cultural activities like virtual visits to monuments and, in some occasions, it will also have a tour guide that will inform the visitors by giving historical explanations and responding to questions. This means that the user can visit the monument any time of the day, and interact with other users that are already in that monument, but also has the possibility, in certain stipulated hours to visit the monument with a professional tour guide.

Furthermore, the virtual leisure room will be a platform for e-learning classes, as many older people are returning to schools to obtain knowledge in new subjects.

The virtual leisure room will also offer the opportunity to the users to expose their doubts to doctors, nurses and medical staff. This is a benefit because older people feel, many times, embarrassed to ask some questions to their own doctors in a face to face situation. This feature will allow users to pose some questions without having to meet the doctor in person.

Other services like on-line shopping or household repairs (like plumbing) will also be available in the virtual leisure room.

In summary, the virtual leisure room will provide an open door for those who feel forlorn, by returning some hope, pride and dignity to people who are sometimes forgotten.

The intention of building the virtual leisure room is to centralize most of the social aspects that are important to the elderly. It is also a way to provide these features to users with health problems.

IV. INTERVIEWS

Six interviews were made to agents that are familiarized with the problem: a hospital director, a social security and elder home care director, a doctor, an older person and two nurses.

As mentioned in the research method, the purpose of these interviews was to validate the identified requirements and add new ones in order to obtain a more robust and complete architecture.

The Leximancer software webpage indicates that "through a rigorous scientific process, Leximancer drills into textual data: documents, e-mails, call center transcripts, blogs, Web sites, etc., and extracts the main concepts, themes and causal relationships to provide the information needed to make critical decisions" [31].

Leximancer was therefore, applied to the interviews made, in order to provide a schematic relationship between concepts and terms spoken during the interview. This allows for a notion of what terms are more important to these interviewed.

A. *Hospital Director*

The interviewed hospital director belongs to an Integrated Care Coordination Unit.

He mentioned that the elderly don't like to leave their homes nor have a stranger in their own home watching after them; especially in the beginning where no bound has been made.

Even though they are receiving home assistance, there are still periods, mainly at night, where the elderly are alone. The apprehension shown by the hospital director in this matter is not just about lack of monitoring, but also, the loneliness experienced by the elderly. Besides the night period, there is also a main preoccupation with geographic isolation that affects many elderly in our country, making continuous support more difficult.

The hospital director pointed to the urgent need to have something to prevent the elderly social isolation.

Through Leximancer software, it was seen that the most often spoken word during the interview was "Elder", as shown in Figure 9.

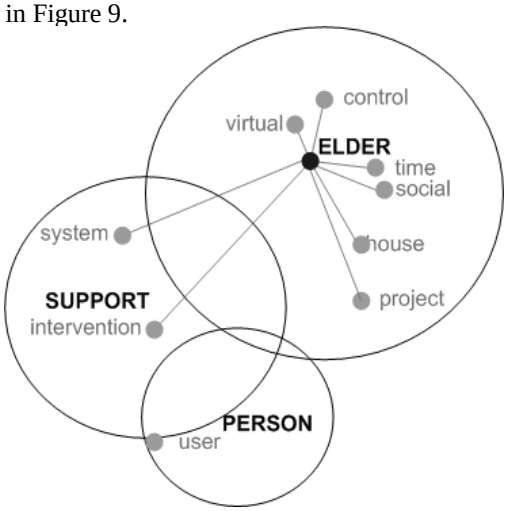

Figure 9. Hospital director interview concept map

As a response to these concerns, the presented architecture has continuous monitoring of vital signs and a virtual leisure room.

B. *Social security and elder home care director*

The interviewed social security and elderly home care director interviewed works in private home care where 70 older people live.

She usually takes the elderly to a city council program that consists in weekly visits to an internet space. With this continuous contact with the elderly and their interaction with technology, the social security and elderly home care director was able to observe and indicate their biggest difficulties: to work with the keyboard and mouse. But the barrier is overcome by the huge curiosity and interest of being able to search any subject on the web.

The Leximancer concept map, visible in Figure 10. , shows that the most used terms where “Person”, “Home” and “Internet”.

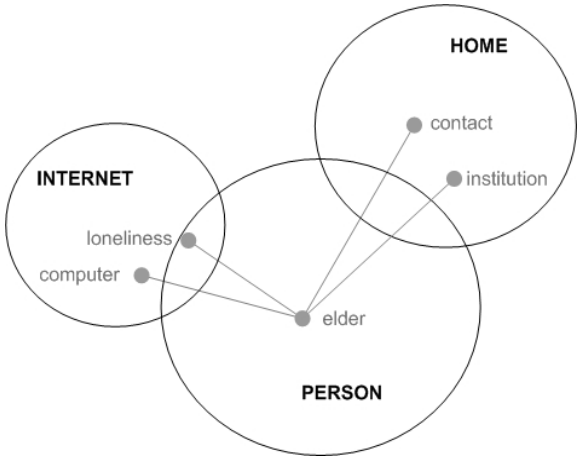

Figure 10. Social security and elderly home care director interview concept map

In order to overcome this hindrance, the proceedings involved in the proposed architecture must be simple and repetitive, attending to the elderly feeble skills and trouble to memorize.

C. Doctor

The interviewed doctor has been a doctor in a public health unit for more than 20 years.

He mentioned, as one of his major concerns, the fact that several of his elder patients that live alone, had already a stroke or had fallen and lay on the floor for innumerous hours before neighbors or family missed them. After these episodes, family members, usually daughters and sons become very worried and start making frequent phone calls to their parents in order to check on them. This procedure affects family in their daily tasks.

The Leximancer concept map, represented in Figure 11. , shows that the most used terms where “Elder”, “Talk”, “Home” and “Fall”.

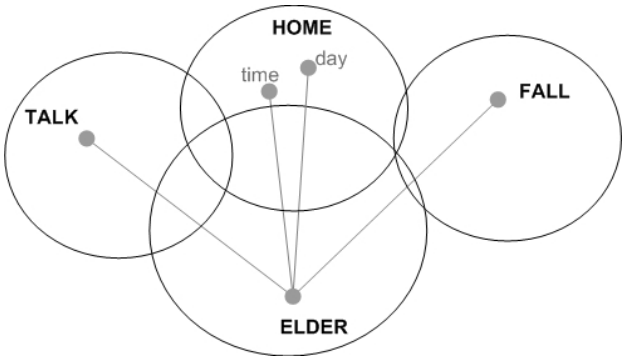

Figure 11. Doctor interview concept map

To solve the problems mentioned above, the proposed solution monitors the elderly leading to increased safety feelings of their own and their family members.

D. Elder

The interviewed elder is a 74 year old female widow who lives by herself at home. She retired 3 years ago and used to be a university language teacher.

At the beginning of her professional activity, all processes where made in paper. With the emerging of technologies, many processes started to be developed using computers. She indicated that her biggest fear is to damage the software or hardware and be without the equipment during its repair. She gets anxious whenever the computer responds differently than she is expecting. She referred the use of automatisms, routines and mnemonics in order to do her work properly.

When asked if she sees any problem in doctors accessing her medical record resulting from a continuous monitoring, she doesn’t consider it an issue. As a matter of fact, she thinks that it is very beneficial that doctors can access all her information in order to me more accurate in their decisions. In her opinion, it is important that the medical staff can access the information so as to be able to have a truthful medical diagnosis. It is also important to be continuously monitored in order to have a real time response if an abnormality occurs.

The Leximancer concept map, presented in Figure 12. , shows that the most used terms where “People”, “Time”, “Security”, “Computer”, “Messages”, “Cell phone” and “Phone”.

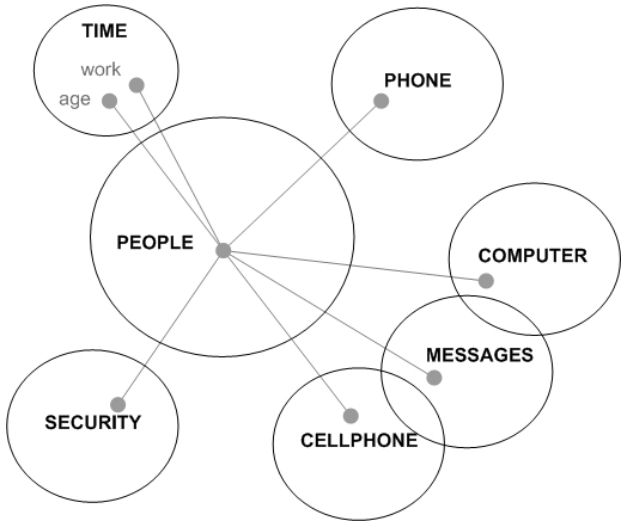

Figure 12. Elder interview concept map

As a result of this interview, the significance of a simple interface in Elder Care can be observed. We can also conclude that it is very important to have training courses to involve Elder Care in their daily routines.

E. Nurse 1

The interviewed nurse has been practicing for the last 14 years.

In her opinion, resulting from her experience, the elderly are not likely to use technology. After some years watching older people struggling over cell phones, there are still some of her patients who complain about their inability to use them. Many of her patients can't even read, so they have to memorize proceedings to be able to call 2 or 3 people and to ask for help if they need other functionalities from the cell phone.

Nevertheless, she thinks that having one accessory monitoring vital signs is an advantage, as well as having some device that allows the elderly to communicate is an advantage because, she thinks that isolation is one of the critical problems that should be solved.

The Leximancer concept map shows that the most used term where "Elder", "Nurse", "Phone", "Family" and "Hard" (Figure 13.).

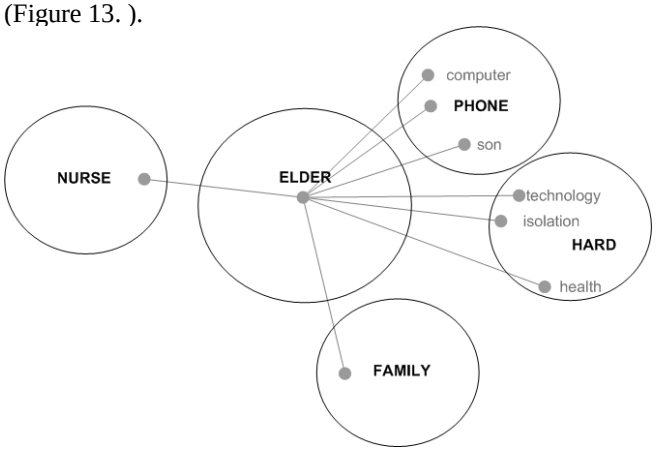

Figure 13. Nurse 1 concept map

To struggle with the problem of interaction between the elderly and technology, Elder Care is designed to have a simple touch screen device with configurable options to show only images or text and images associated with sound. The application on multimedia device will also have few options for easy memorization.

F. Nurse 2

The interviewed psychiatric nurse worked with the elderly in a hospital emergency room and, during 3 years, in an elder care home. At the present date he is a university teacher.

His greatest concern is the isolation experienced by many older people. He observed that their social isolation is not a small town phenomenon where people are often geographically isolated, but also in big cities where they do not feel safe on the streets and start to spend more time at home.

He thinks that monitoring the elderly while providing them with security is a very important subject because it increases their welfare. As a nurse, he enumerated the following items as the most important to watch over in an older population: blood pressure, heart rate, temperature, respiratory rate and blood glucose. He also referred that it was crucial to have GPS coordinates of the elderly to precise their location whenever there was a problem outside their residence. These problems occur frequently when they work alone in agricultural grounds frequently using tractors or other agricultural tools.

Adding an idea to the virtual leisure room, he mentioned that, a measure to increase welfare could be to provide an option for the elderly to require services such as small house repairs, on-line shopping and other types of services that could improve the lifestyle quality because the elderly are a population with many needs and without a global and easy access solution.

The Leximancer concept map shows that the most used terms where "Elder", "Health", "Monitoring", "Person", "Hospital", "Technologies" and "Social" (Figure 14.).

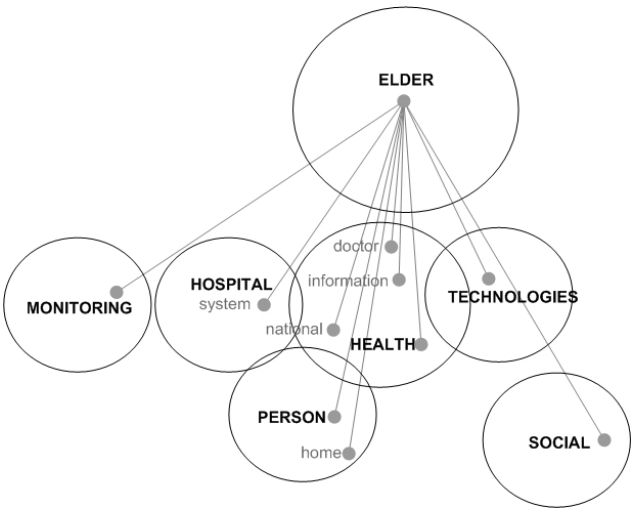

Figure 14. Nurse 2 concept map

As a response for solitude, Elder Care has a virtual leisure room. The idea of having service request was embedded in the virtual leisure room.

G. Review

As the interviews were being conducted, a sketch of the architecture was being done. At the end of each interview, this sketch was shown so that more targeted reviews were made.

All interviewed expressed, as the first and main concern, the loneliness experienced by the elderly population, overruled by the existence of the virtual leisure room.

Another feature behind the whole system, and identified as a very important added value, was the sense of security that Elder Care provides due to alert management.

Some interviews also revealed requirements that were not previously planned and the reformulation of existing requirements, such as:

- the inclusion of a blog with social events occurring around the user's residence;
- a device worn by the elderly that obtains GPS coordinates;
- the most relevant parameters to be measured are blood pressure, heart rate, temperature, respiratory rate and glycemia;
- the monitoring users' position must consider that, when at sleep, the elderly are in an horizontal position, but not due to a fall. The sleeping periods must not be a fall alert.

V. CONCLUSIONS AND FUTURE WORK

To be able to give older people quality of life as long as possible is an emerging problem, which many people are noticing and are trying to develop a proper solution with technological features.

Elder Care is an attempt to give a response to the fact that we have more and more older people and have a lifestyle that prevents us to take care of the elders in our families. This is due to the fact that in most families, active members are workers or students and cannot be at home. Many elders are reluctant to go to care home or accept caregivers' help since they feel that they are losing their independence. Even when the caregivers are their own sons and daughters, they feel reluctant to accept help [6].

With Elder Care solution we will be able to maintain the elderly in their homes, survey their health and make them useful through interaction in the virtual leisure room.

We followed a qualitative research with semi structured interviews in order to obtain the necessary requirements to the proposed architecture.

At this point we have a high level architecture. In the future we will advance with prototype implementation of the proposed architecture, testing it in a real scenario, with elderly who are mostly underprivileged and live in remote areas. This choice of a critical target is going to allow us to get a reliable and robust solution.

It is also our intention to integrate our solution with the elder care in specialized nursing homes, by giving a global coverage to all entities that deal with elderly people.

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