An Ambient Assisted Living System for Telemedicine with Detection of Symptoms

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Abstract. Elderly people have a high risk of health problems. Hence, we propose an architecture for Ambient Assisted Living (AAL) that supports pre-hospital health emergencies, remote monitoring of patients with chronic conditions and medical collaboration through sharing of health-related information resources (using the European electronic health records CEN/ISO EN13606). Furthermore, it is going to use medical data from vital signs for, on the one hand, the detection of symptoms using a simple rule system (e.g. fever), and on the other hand, the prediction of illness using chronobiology algorithms (e.g. prediction of myocardial infarction eight days before). So this architecture provides a great variety of communication interfaces to get vital signs of patients from a heterogeneous set of sources, as well as it supports the more important technologies for Home Automation. Therefore, we can combine security, comfort and ambient intelligence with a telemedicine solution, thereby, improving the quality of life in elderly people.

Keywords: Telemedicine, CEN/ISO EN13606, architecture, chronobiology.

1 Introduction

We have a problem with aging of the population, as a result of increased life expectancy and declining birth rate. Today there are around 600 million persons aged 60 in the world. The number will be double by 2025 and will reach almost 2000 million by 2050 when there will be more people over 60 years than children under 15 years old [1,2]. So that the demand of healthcare services is increasing in Europe and we find the problem that we have not the possibilities to react to the demand of healthcare services because of lack of personnel, old people's home and nursing homes.

For this reason, it is well known that the information and communication technology (ICT) must provide an answer to problems arisen in the field of healthcare. So Ambient Assisted Living (AAL) is a new technology based approach from ICT to support elderly citizens. The goal of AAL is aims to prolong the time that elderly people can live independent in decent way in their own home [3]. We can achieve it increasing their autonomy and confidence in to know that if happen some problem they are not really alone, furthermore to

J. Mira et al. (Eds.): IWINAC 2009, Part II, LNCS 5602, pp. 75–84, 2009.

easier activities of daily living with home automation and finally to monitor and care for the elderly or ill person with telemedicine solutions, Hence to enhance the security and to save medical resources.

Other problems associated with aging of the population, are the issues related to health status. We must be aware that elderly people have an increased risk of heart disease, diabetes, hypertension etc. They have a tendency to get sick easily. That is why it is very important to carry out early detection of diseases, because there is ample evidence that an appropriate treatment in the onset of the disease, increase likely of that these patients will have a positive outcome. So, early identification of these patients is critical to successful treatment of the disease [4].

For this purpose, nowadays preventive measures are primarily based on periodically scheduled evaluations at clinic visits that are intended to detect the onset of an illness. Such visits often present an incomplete assessment of the patient's health by providing only instantaneous patient's state. So that is possible that patient is in the onset of an illness but symptoms or important events are not manifested in the clinic visit time. For this reason, we considered necessary monitoring of the elderly people at home, equivalent to the monitoring that takes place in hospitals. So we are able to detect symptoms and anomalies in any time.

These kind of monitoring solutions are possible with the recent technology advances in consumer electronics devices and the development of embedded artificial intelligence platforms for wearable and personal systems. That has achieved high capabilities by a low cost. So that it can be reachable for everyone. Some of these advances are in communications for PDA (Personal Digital Assistant) and cell phones, as well as, in WBAN (Wireless body area networks) with Bluetooth and ZigBee networks technologies. Trough this WBAN, the wearable system is wirelessly connected to numerous physiological and contextual sensors located on various parts of the body or elsewhere in the environment. Furthermore with the ZigBee network we can define a WLAN (Wireless local area networks), so we can connect wirelessly the wearable system with the control unit that exists at home [5].

Our contribution is an architecture, which supports from the system to be installed at home to monitor the wearable systems, until the remote systems that will be in the health care supervision centrals. In the next section, we will see that this architecture has been endowed with a variety of communication interfaces, to provide a great flexibility in connectivity. In addition to improve the quality of life in elderly people, this system is equipped with the latest technology in home automation.

In Section 3, we have established that the export of medical data is made on the recent standard CEN/ISO 13606, so that the captured data can be incorporated into the patient's electronic health record (EHR). Hence, it is able to be consulted and used by medical or by the system as we will see in the next section.

In Section 4, we will analyze as symptoms are detected in the current system and will do a brief overview of our goals and future work to extend the detection of symptoms to disease. We will show the importance of providing all the historical patients in a standard format such as CEN/ISO 13606, in order to use in future work to build temporal model-based for diagnosis. On these models to diagnose, we will show our first steps, where we analyze the field of possibilities that chronobiology opens for the detection of diseases, detection of abnormal patterns and building models that relate one vital sign with others. In particular we will see from chronobiology the detection of myocardial infarction eight days before that it happens and our first results about relation between different vital signs, in this case the relation between peripheral body temperature and blood pressure.

2 System Architecture

Our architecture serves as a framework to deliver telecare services to the elderly and people in dependant situations. This framework is used as a basis to deploy specialised services, coverings aspects such as:

- Home automation: It service is going to do easier the home facilities. Our system was originally conceived as a system that integrates multiple technologies for home automation, adding a high-capacity and heterogeneous communications to interact with other local or remote systems.
- Security: It is very usual to find security solutions together with home automation ones. For this reason, it is able to be used like a security system too, and for that purpose, it implements the standard protocol used nowadays in security systems to send alarms to a central security, i.e. contactID over PSTN technology.
- Ambient Intelligence: We are going to use ambient intelligence to increase the easiness of use of home facilities provided by the home automation and to adapt home to the Activities of Daily Living (ADL). ADL refers to the basic task of everyday life, such as eating, bathing, dressing, toileting and transferring [6]. If a person can cope for that ADL, then we can talk of independence. These kinds of tasks are very difficult in elderly people. So learning behaviours and habit using Ambient Intelligence, environment is going to do easier ADL to the person. Getting to increase independence and QoL.
- Telemedicine: The last service is monitoring and care of elderly or ill person with telemedicine solutions. For vital signs and health condition monitoring, a set of biometric sensors can be located in the preferred environment of the elderly, and transmit, via the central module, information about his/her health status to the EHR central, so that it could be used by qualified professionals so that they can evaluate their general health conditions with a big amount of information, so Medical could do a better diagnosis. Furthermore, these sensors are able to raising alarms in case an emergency occurs. We will see this in the section 5.

Our system used for telemedicine is shown in the figure 1 and description of the elements shown in table 1:

We have developed a modular architecture to be scalable, secure, effective and affordable. It last feature is very important, because we are defining a very complex system, very flexible and with a lot of possibilities. Usually a user is not going to use all the technologies that system provides, so that each client can define an ad-hoc architecture from his needs [7,8].

One of the more important parts of a system that work with users is the user interface. We can find a lot of literature about Human Machine Interface (HMI) and the need of simple and intuitive interfaces, especially in our case, we need

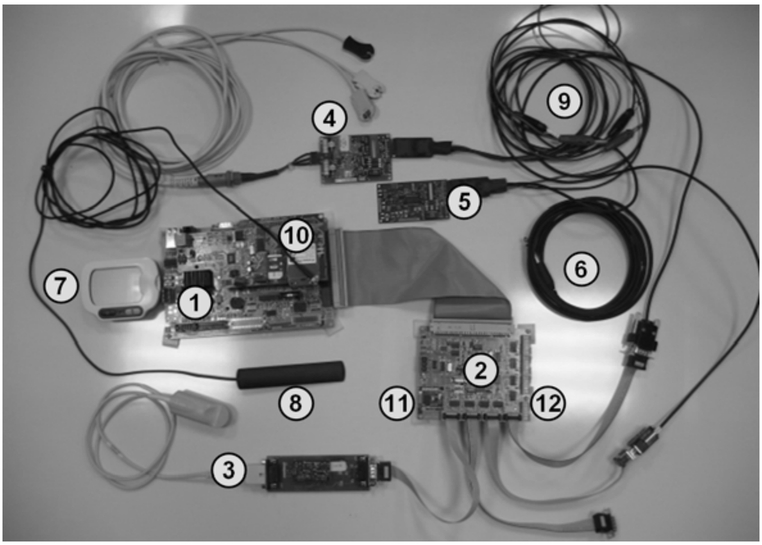

Fig. 1. Telemedicine architecture elements

Table 1. Control unit, medical expansion and Medical sensors used

Element	Extended description
1	Control unit with GPRS and Ethernet communication interfaces
2	Medical extension with Serial and Bluetooth communication interfaces
3	Test Kit Mini pulsoximeter OEM Board. EG0352 of Medlab
4	Test Kit EKG OEM Board, EG01000 of Medlab
5	Test Kit Temperature OEM EG00700 (2 channel YSI 401 input) of Medlab
6	YSI Temperature Sensor 401 of Medlab for core and peripheral temperature
7	Bluetooth glucometer of OMRON
8	GPRS Antenna
9	Power supply
10	GPRS Modem
11	Bluetooth Modem
12	Serial ports

a very simple interface because we work with older people who are not fully adapted to the world of new technologies (ICT) and have vision problems or cannot learn to use the system (Alzheimer patients), is why the proposal is that the user does not need to communicate with the system.

However, we offer an intuitive LCD touch and Web interface with a 3D (360 degree cylindrical panoramas) home/hospital representation to access and control the system for hospital personal, old people's home personal, management personal or patients if they are able to use it.

The communication layer provides privacy, integrity and authentication during process of exchanging information between agents. Therefore, we must define a robust communication interface [9]. We cipher all the communications with AES cryptography to get privacy and security. We use hashing with MD5 to get integrity and authentication using user and password, we offer ACL based on IP address and we have defined different roles and privileges for the different kind of users in an organization.

As we mentioned, we want to work with sensors for medical purpose from different vendors. So we have a very flexible connectivity support. The system has the next communication interfaces:

– External communications. Ethernet connection for TCP/IP communications (Internet), modem GPRS (Internet) and Contact ID using PSTN [10].
– Local communications. X10 home automation protocol, EIB/KNX (European Installation Bus), ZigBee, Bluetooth, Serial, CAN (Control Area Network) and Wire communications using digital or analogy input/output.

3 Standard to Exchange EHR Information: CEN/ISO 13606

We can find a lot of different reasons why standards are needed in the healthcare domain [8,9]. One such reason is that standards allow computer documentation (EHR) to be consistent with paper-based medical records. Another reason is that information sharing (communication) among different actors, for the purpose of addressing an end-user's problem, is facilitated by the existence of standards-based integrated environments. This includes all agreements on data and context that needs to be shared. So that finally your full health record could be access from any hospital and decision support applications are provided together your information. There is where we can improve and easier of professional personal work and improve the quality of your diagnosis. We can find some approximation to the solution in [11,12,13]. But finally we have the CEN/ISO 13606 standard for this purpose [13,14,15].

Furthermore, we can use that information in our future work to build temporal model-based for diagnosis and detection of illness. So we can get information from a set of real cases in a standard digital format.

In the figure 2 we can see the integration of our system in the Health Information Systems Architecture (HISA).

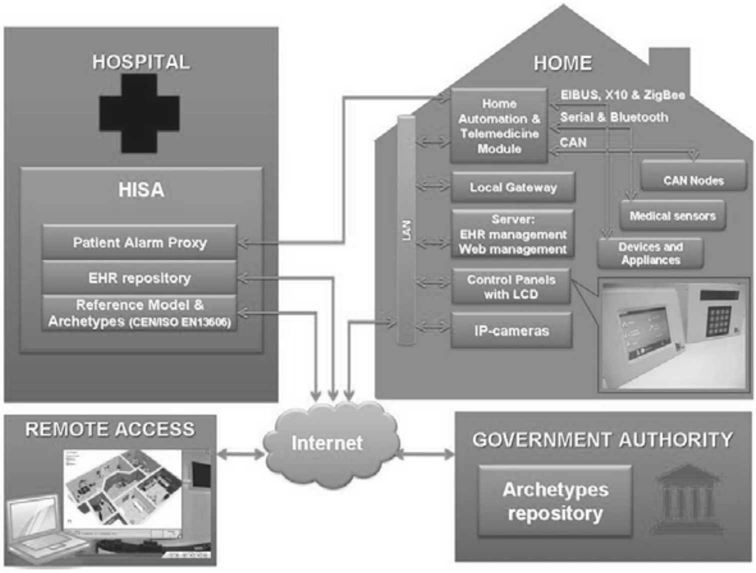

Fig. 2. Logical diagram of our architecture to support CEN/ISO EN13606

4 Detection of Symptoms and Chronobiology

In determining the patient's medical condition, several wearable systems focus on monitoring a single dominant physiologic feature as a symptom of a medical condition by performing a simple rule-based classification on individual sensor data to generate alerts [5]. With this kind of solution we get a first approximation of the medical condition, but we know that it may not lead to an accurate medical. That is the reason that we are defining all the base of elements to get a capture of several vital signs, to get in the future work to build temporal based-models for diagnosis using different physiologic features.

Detection of symptoms is carrying out with simple rules from medical literature, e.g. we are going to examine as detect hypothermia from temperature sensors [16].

Hypothermia is defined as a body temperature less or equal to $35°$ C were classified as mild ($32-35°$ C), moderate ($28-32°$ C) and severe ($< 28°$ C). We are defined this kind of classifier with a set of simple if-then rules.

We consider it very interesting to detect level and mild hypothermia, which are often not notified. And it can have deadly consequences, for example in 1979 reported a total of 770 cases of fatal hypothermia environment. Furthermore elderly people are at higher risk for them.

The most important causes of hypothermia are malnutrition, sepsis, severe hypothyroidism, liver failure, hypoglycemia and/or hypothalamic lesions, volume depletion, hypotension, increased blood viscosity (which can cause thrombosis) etc.

We conclude that this kind of symptoms are very important to be monitored and notified to the doctor, because some of the diseases listed could be happening and as in the case of the level or moderate hypothermia, the patient may not realize about his abnormal health state.

In the same way, the other symptoms that are detected are: fever, abnormal SpO2 levels, hypertension, hypotension, tachycardia and arrhythmia.

Chronobiology is a field science that studies the temporal structure (periodic and cyclic phenomena) of living beings, the mechanism which control them and their alterations. These cycles are known as biological rhythms. The variations of the timing and duration of biological activity in living organisms occur for many essential biological processes. These occur in animals (eating, sleeping, mating, etc), and also in plants. The most important rhythm in chronobiology is the circadian rhythm, a period of time between 20 and 28 hours [17].

On the next two points we show two solutions from chronobiology. The first inference has been obtained from [17] and the second one is the result of our own investigations [18].

The detection of myocardial infarction is based on the beat rate of a patient that is very variable from a moment to other, is chaotic in a normal patient. This is very usual because a person can make an effort, move, go up stairs and even without conscious activity as digestion or heat the body the heart is working.

In the figure 3 we can see the variability of the heart beat rate in a normal situation and days before to a myocardial infarction.

On the left column we can see some graphs which show the cardiac frequency (i.e. the variation of the cardiac rhythm over time). On the second column we see the spectral analysis (i.e. the variation of pulses amplitude over time) and on the

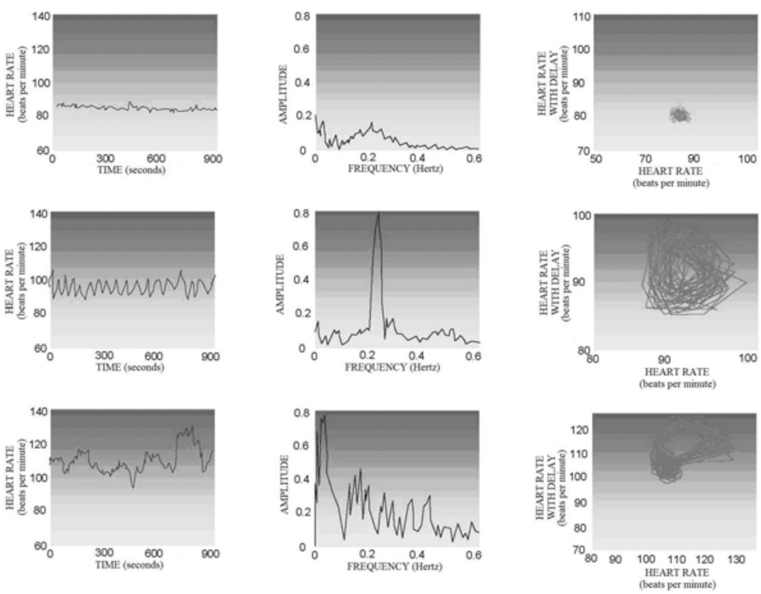

Fig. 3. Heart rate days before a myocardial infarction

third one we see the trajectories in a space of phases (the cardiac rhythm at a given moment over the cardiac rhythm at a time immediately preceding). These phase diagrams show the presence of an attractor (An attractor is the pattern we see if we observe the behavior of a system for a while and found something like a magnet that "attracts" the system towards such behavior).

The individual represented in the top row shows an almost constant heartbeat, suffered a heart attack three hours later. We can observe that the variability is less of 10 beats. The central register of the row, showing a rhythm with periodic variations, was obtained eight days before sudden death. We can observe that 8 days before the variability it is between 10 and 20 beats. The Bottom row corresponds with a heartbeat of a healthy individual. We can observe that in a normal situation the variability is between 30 and 40 beats.

So we can analyze this variability in heart beat rates in circadian periods to detect the risk of myocardial infarction.

Other solution that we can define from chronobiology is the relation between different vital signs, so that we can estimate blood pressure from peripheral temperature. It is interesting for this type of systems to be able to infer blood pressure without using a sphygmomanometer which would be invasive for the patient as it has to press the arm or wrist.

This hypothesis was tested in lab on a group of 30 persons from the University of Murcia, you can find this study in [18], where we obtained a relationship between peripheral temperature and average blood pressure. Now we want to study this kind of relations with groups of elderly and illness people. So that we can obtain results more important so that finally can be defined a model to infer blood pressure values from temperature. Finally, remark that for the detection of symptoms and the construction of temporal model-based for diagnosis [10,19,20] from chronobiology is very important to have a temporary record of the patient, that allows us to perform these tasks, so we use the EHR standard CEN / ISO 13606 for this purpose.

5 Conclusions and Future Work

We are built an architecture [21] to give support to care-delivering environments, such as at patients home, i.e., self-care, this architecture provides a set of services that can be used autonomously by the elderly people. The set of care-delivering environments is very wide, that is the main reason that we provide an architecture very flexible and with a lot of different options of configuration, so that the final user can define an ad-hoc solution to his needs.

In a monitoring system is very important keep a register with the information from patient over time. For this purpose we save information in CEN/ISO 13606 format, so it can be deliver to other medical information systems as HISA at hospitals. Furthermore we are going to use this information register to build temporal models for diagnosis of illness and for testing chronobiology hypotheses, as the relation between peripheral temperature and blood pressure that we have shown.

In the actual solution we can detect anomalies in vital signs that show symptoms, as well as, we can detect myocardial infarction using a chronobiology algorithm [17]. But it does not offer an accurate base of diagnosis, for this reason, as future work, we want to improve the artificial intelligence layer, so we can detect diseases too using temporal based-models.

Furthermore until the moment, this system just has been tested by the members of our team. So, we want to test it with elderly people and real patients, and together them and their experiences implements ambient intelligence algorithms to detect patterns in the user behaviour. Finally, in the technology side, we are going to implement 6lowPAN [22] and ISO/IEEE 11073 [15] over ZigBee network.

Acknowledgments

This work has been carried out in frames of the Spanish Program: Programa de Ayuda a los Grupos de Excelencia de la Fundación Séneca 04552/GERM/06 and the FOM/2454/2007 project from the Spanish Government.

References

1. Walter, A.: Actitudes hacia el envejecimiento de la población en Europa, University of Sheffiel, United Kingdom (1999)
2. United Nations.: World Population Ageing 2007 (2007), `http://www.un.org/esa/population/publications/WPA2007/wpp2007.htm`
3. Steg, H., et al.: Europe Is Facing a Demographic Challenge - Ambient Assisted Living Offers Solutions. In: VDI/VDE/IT, Berlin, Germany (2006)
4. Wang, S.J., et al.: Using patient-reportable clinical history factors to predict myocardial infarction. Computers in Biology and Medicine 31(1), 1–13 (2001)
5. Wu, W.H., et al.: MEDIC: Medical embedded device for individualized care. Artificial Intelligence in Medicine 42(2), 137–152 (2008)
6. Cortes, U., et al.: Intelligent Healthcare Managing: An assistive Technology Approach. In: Sandoval, F., Prieto, A.G., Cabestany, J., Graña, M. (eds.) IWANN 2007. LNCS, vol. 4507, pp. 1045–1051. Springer, Heidelberg (2007)
7. Alsinet, T., et al.: Automated monitoring of medical protocols: a secure and distributed architecture. Artificial Intelligence in Medicine 27, 367–392 (2003)
8. Magrabi, F., et al.: Home telecare: system architecture to support chronic disease management. Engineering in Medicine and Biology Society. In: Proceedings of the 23rd Annual International Conference of the IEEE, vol. 4(25-28), pp. 3559–3562 (2001)
9. Katehakis, D.G., et al.: An architecture for integrated regional health telematics networks. In: Proceedings of the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 3642–3645 (2001)
10. Jih, W.-r., et al.: Context-Aware Service Integration for Elder Care in A Smart Environment. In: AAAI 2006 Workshop, Boston, USA (2006)
11. Li, Y.-C., et al.: Building a generic architecture for medical information exchange among healthcare providers. International Journal of Medical Informatics 61, 2–3 (2001)

12. Catley, C., et al.: Design of a health care architecture for medical data interoperability and application integration. In: 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, vol. 3(23-26), pp. 1952–1953 (2002)
13. Maldonado, J.A., et al.: Integration of distributed healthcare information systems: Application of CEN/TC251 ENV13606
14. OpenEHR : CEN Standards, EN13606, a standard for EHR System Communication (2008), http://www.openehr.org/standards/cen.html
15. ISO/IEEE 11073. Point-of-care medical device communication, http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=36347
16. Harrison, et al.: Principios de medicina interna. McGraw-Hill, New York (1999)
17. Madrid, J.A., Rol de Lama, M.A.: Cronobiología básica y clínica. Editorial EDITEC RED (2007)
18. Jara, A., Zamora, M.A., Skarmeta, A.: A wearable system for tele-monitoring and tele-assistance of patients with integration of solutions from chronobiology for prediction of illness, AmiForum (2008)
19. Wang, C.-C., et al.: A Rule-Based Disease Diagnostic System Using a Temporal Relationship Model, Fuzzy Systems and Knowledge Discovery. In: Fourth International Conference on FSKD 2007, vol. 4, pp. 109–115 (2007)
20. Palma, J., Juarez, J.M., Campos, M., Marin, R.: Fuzzy theory approach for temporal model-based diagnosis: An application to medical domains. In: Artificial Intelligence in Medicine, October 2006, vol. 38(2), pp. 197–218 (2006)
21. Zamora, M.A., Skarmeta, A.: Sistema Integral de Control, Seguridad y Domotica en edificios Inteligentes. Patent number: P200802506, 08-08-2008. University of Murcia (2008)
22. IETF: 6LowPAN (2008), http://www.ietf.org/html.charters/6lowpan-charter.html