

# Psychosocial and Technical Perspectives of User Centred Design in e-Health Services: the Case of Telecardiology

E. P. Gil-Rodríguez, I. Martínez, Y. Bona, J. García, A. Farré-Cobos

Technology and Social Action Group (ATIC),  
Internet Interdisciplinary Institute (IN3),  
Universitat Oberta de Catalunya (UOC),  
Av. Canal Olímpic s/n B3, 08860 – Castelldefels (Spain)  
{[egilrod](mailto:egilrod@uoc.edu), [ybona](mailto:ybona@uoc.edu), [afarreco](mailto:afarreco@uoc.edu)}@uoc.edu

Communications Technologies Group (GTC),  
Aragon Institute for Engineering Research (I3A),  
University of Zaragoza,  
c/María de Luna 1, 50018 – Zaragoza (Spain)  
{[imr.jogarmo](mailto:imr.jogarmo@unizar.es)}@unizar.es

## Abstract

Nowadays, one of the main issues of Human Computer Interaction (HCI) studies is the study of interactions established between people and new technologies. Nevertheless, the research in HCI has been mainly focused from a cognitive point of view, and most studies don't consider other variables related to the social impact of technology. In this paper we present an interdisciplinary perspective through its application in designing new e-Health services in the area of cardiology. From this standpoint and in order to extract the maximum benefit from these new services, it is essential to accurately define not only technical requirements and network resources management, but also user requirements and all those contextual particularities of the scenarios where these services could be implemented. In this way, we propose an interdisciplinary methodology that provides us a field of working in which technical and psychosocial qualitative knowledge influence each other. Thus, the results obtained in specific scenarios of implementation for a telecardiology service allow new user-based designs that can be directly integrated in the medical practice in an efficient way.

## 1. Introduction

The relationship between people and new technological devices is an important issue in Human Computer Interaction (HCI) studies [1] because its study can be applied in the design of reliable and friendly user interfaces and, therefore, it helps to promote digital inclusion. The proposal of HCI is to obtain theoretical knowledge on the

interactions that are established between people and new technologies. And this knowledge reverts to the design of technological devices functionalities and their interfaces, guaranteeing success in further implementations. In fields like e-Health, we can find a wide sphere to develop this kind of studies, because it is common to find a context in which users are not able to take advantage of the entire potentiality provided by these technological devices because of the design criteria.

Nevertheless, within this discipline, the study of users has been carried out from a cognitive point of view, without considering other variables related to the social impact of technology. From our interdisciplinary perspective, it is necessary that the Information and Communication Technologies (ICT) establish permeable relations with the psychosocial processes, producing qualitative changes. Besides, we should analyse how technology is appropriated by people, endowing it with unpredicted meanings that do not follow developers' guidelines [2].

Hereafter we will show how this perspective could be applied in the specific context of telecardiology services design and which are its most relevant contributions and added values within this field in particular, but also in optimizing transversal research work that reverts in a best Quality of Life (QoL) of patients and health professionals.

A technical start point focused in the case of the telecardiology services is given in [Section II](#). The methodology of our research is presented in [Section III](#). [Section IV](#) shows the results obtained in this specific case, where we present the specific scenarios of implementation obtained from the methodology proposed. Discussion and conclusions are presented in [Section V](#).

## 2. Providing a start point

Advanced ICTs have increasingly been used for clinical activities and research to improve health care delivery, providing new e-Health services and reaching the patient self-management and self-evaluation of the disease [3], [4]. These technologies have undergone many investigations to evaluate their effectiveness, efficiency, and feasibility [5]. These new e-Health services are usually based on multimedia technologies [6], [7] and they are expected to support diverse clinical applications over different network topologies [8]. Such heterogeneous environments require that different type of services (Real-Time (RT) vs. Store & Forward (SF) services) should be provided with different Quality of Service (QoS) technical requirements [9].

The implementation of e-Health applications is possible in a great variety of scenarios: hospital, home, rural, mobile environments (see Fig.1), where the specialist virtually “displaces” to the patient point-of-care through a mobile or fixed communications network. Thus, the technical description and analysis of these scenarios constitutes the previous step to select the most appropriate one for assistance environments. This selection will permit to define the specific user requirements and to optimize the design.

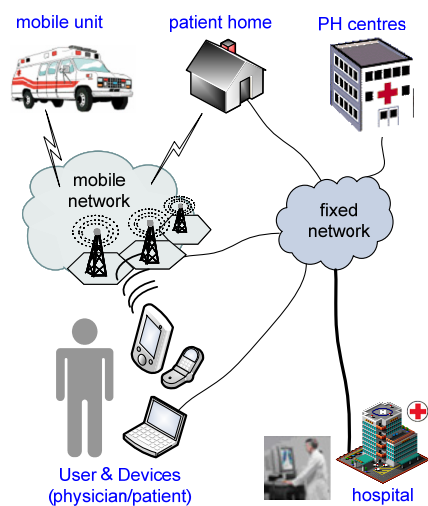


Fig. 1. E-Health generic scenarios considered in this study

These main generic scenarios are:

- *Hospital scenario.* Its basic characteristics are associated to the communication between doctors of different specialties (intra-hospital connections) or between doctors of the same specialty of different hospitals that share applications (inter-hospital connections). Since the intra-hospital connections do not usually suppose QoS or resources limitations, this scenario is focused in inter-hospital communications, based on switched broadband networks that share the available resources between different application types. Thus, the technological interest point is the evaluation of the resources sharing that permits to select the best parameters (compression rate, digital images resolution, etc.) in order to optimize the service and guarantee the technical QoS level.
- *Mobile scenario.* Its basic characteristics are associated to a high variability in the mobile link with network resources limitation and heterogeneous performance. In e-Health environments, it is focused in the interconnection between a non-specialist (from a mobile unit) and a specialist, during the run of the ambulance from the accident site to the closest hospital. Thus, the technological interest point is the QoS evolution regarding the network conditions.
- *Rural/home scenario.* Its basic characteristics are associated to the communication between a non-specialist (in the Primary Health (PH) centre) and the hospital in order to interchange medical tests and patient data. The PH can be located in a rural or metropolitan area but the difference is focused in the user profiles and the type of e-Health service. Thus, the technological interest point is the evaluation of the users and services performance, studying the optimum number of simultaneous e-Health services that permit to guarantee QoS from a technical point of view.

Over these scenarios, a high number of published experiences [10] relate the technological evolution of the traditional applications towards e-Health services: *telemonitoring* (reducing patient displacements to the health centre), *teledermatology* (remote evaluations of digital images), *telesurgery*

(including a high quality videoconference and remotely-controlled robots), *teleelectrocardiology* and *teleechocardiology* that are two of the most relevant telemedicine services [11]. The main technical characteristics of these services are described below:

- *Teleelectrocardiology*. The use of the communication networks to transmit remotely the ECG (from a rural health centre or the patient home to the hospital) supposes an advantage in terms of time, money and QoL for doctors, patients and health service. The teleelectrocardiology [11] is based on the ECG signal, associated to electrical impulses that are generated by the heartbeat and acquired in a non-invasive way by several electrodes (between 3 and 12 channels). It uses sample frequency  $f_s=250\text{Hz/channel}$ , with resolution  $h=12\text{-}16\text{bits}$ ; it implies mean ECG sizes  $S=10\text{ MB}$ . Usually these sizes are considerably reduced with compression methods in a factor 2:1 or 3:1 (lossless techniques), and 10:1, 15:1 or 20:1 (lossy techniques). The operation mode is usually SF: the ECG is pre-acquired and further digitally transmitted to the hospital. Moreover, other tests, such as emergencies, are based on RT mode.
- *Teleechocardiology*. The vital organs echography is usually used as the first diagnosis for a cardiac patient. It is a non-invasive technique, based on the ultrasounds image [12], that does not produce ionized radiation and it is relatively cheap. The ECHO signal captures the ultrasounds obtained from video-images of the structures of the organism. There are several types of ECHO, but the most commonly used are based on images of 512x512, 640x480 or 1024x1024 pixels, with resolution  $h=8, 16$  or 24bits/pixel, transmitting 24 images/s during several minutes. It is usually implemented in SF mode, but there are RT projects based on a portable echograph that allows the remote diagnosis.

However, the analysis of the implementation of an efficient e-Health solution requires the integration not only of these technological requirements but also the user variables: a complete study of the health organizations, leading to a detailed description of their environments, as it is presented in next section.

### 3. Methodology

In order to integrate technical requirements with organizational and user needs for a specific telecardiology service, we designed a methodology to redefine potential scenarios (what technology can do) of these services from the user and health organizations point of view (what technology must do). This methodology can guarantee a major efficiency and acceptability in the implementation of the service. In this study, we have distinguished two phases:

#### *A. Exploration of welfare levels in health assistance.*

First, we study real needs of health organizations, identifying specific welfare levels where ECG and ECHO transmissions will help health-related professionals' work. Thus, this first phase uses qualitative methodologies, based on interviews and *focus groups*, in order to define the telecardiology scenarios of interest.

The design of interviews takes into account:

- a. *Organizational variables*, needed to study specific scenarios in real medical healthcare.
- b. *Cultural variables*, specific to the meanings that patients and doctors give to their daily routines and devices. The knowledge of these meanings serves to improve the design of Graphical User Interfaces (GUI) by minimizing, for example, the usual negative associations that the patients establish between the medical device and their illness.
- c. *ICT use variables*. The observation of the use of ICTs from health-related professionals and patients, taking into account cognitive (the process of information with or without ICT devices), symbolic (cultural meanings of ICT) and practical aspects of this use (the ways of improve health-related professionals' tasks and patients QoL) that will be very useful in the design of the device.

In order to gather information about these variables, we made 25 interviews with experts in telemedicine and 9 interviews with relevant cardiologists in Catalonia (Spain).

On the other hand, *focus groups* [13] are collective sessions of discussion about a specific topic –in this case ideal scenarios, from a medical perspective, for the implementation of a telecardiology service. In these sessions, different points of view about the same topic can be confronted and discussed to collect the specific characteristics of the scenarios and ideal services to implement a telecardiology service. We made a *focus group* with the coordinator and other relevant participants of the Catalan Cardiology Association, in order to identify specific characteristics of these ideal services.

The next step is the content analysis of the previous interviews and *focus group*. Content analysis allows us extracting and ordering different categories of information related with variables considered in the study. The content analysis is supported by the qualitative analysis software ATLAS-ti [14] that aids identifying the most relevant subjects and establishing inter-relations (see Fig. 2). As result of this analysis, the different implementation scenarios of the service and its potential users are identified.

It's well known in the HCI discipline the potential of scenario analysis methodology to study the implementation of new technologies in specific contexts and applications currently not developed [15]. The scenarios are descriptive narrations about the contexts in which selected people do specific actions, and these descriptions have shown themselves effective for managing interdisciplinary work between technology developers and user study experts; they allow explaining in an illustrated way: the contexts in which an application will be implemented, its functionalities, the characteristics of its users and their interactions. This knowledge allows selecting different but realistic proposals of environments where implementation of the services and devices give responses to real problems: improvement of the accessibility quality of medical services, the job of healthcare professionals, and the patient QoL.

Finally, the scenarios which can be selected as relevant from the previous analysis lead to varied technical situations. The different characteristics of each application or network technology may present very diverse QoS

levels, which can have an important impact on the final application performance, mainly on multimedia RT services. The most relevant parameters that influence QoS are Packet Loss Rate (PLR), End-to-End Delay (EED) and link capacity (C). Thus, an accurate estimation of the network performance is critical for the success of the design of the telecardiology service.

### B. Implementation and evaluation.

This second phase studies the implementation and evaluation of these technological requirements *in situ* (over the scenarios previously defined) by means of ethnographic methodology [16]-[18]. To reach our project goals it is specially pertinent an ethnographic approach since it allows us to obtain an in-depth knowledge that takes into account diverse factors such as socio-cultural, organizational, and of course, factors relating to the uses of the ICT that keep in mind not only users cognitive aspects, but also aspects like symbolic and practical dimensions of these uses.

In our ethnographical research, we adopt the sociological perspective of Actor Network Theory (ANT) [19]. ANT studies the relations established between human actors (people and organizations: physicians, doctors, patients) and artefacts (Electronic Patient Record (EPR), medical devices). From ANT, artefacts are understood as actors (like humans), because they have the ability to change relations in social organizations in a very meaningful way [20]. For example, in the case of ECG transmission from mobile units, ANT allows us to identify the sociotechnical network related to this scenario conformed not only by health-related professionals, technical staff and patients, but also by technological devices, transmission networks, and clinical information in the specific context of emergencies. Therefore, ANT perspective allows knowing the real user needs when the users interact with technology, and designing e-Health systems with customized functionalities and Graphical User Interface (GUI). This is a key-point for efficient GUI designs collecting these cognitive, symbolic and practical characteristics of the ICT use on daily tasks in the specific scenarios.

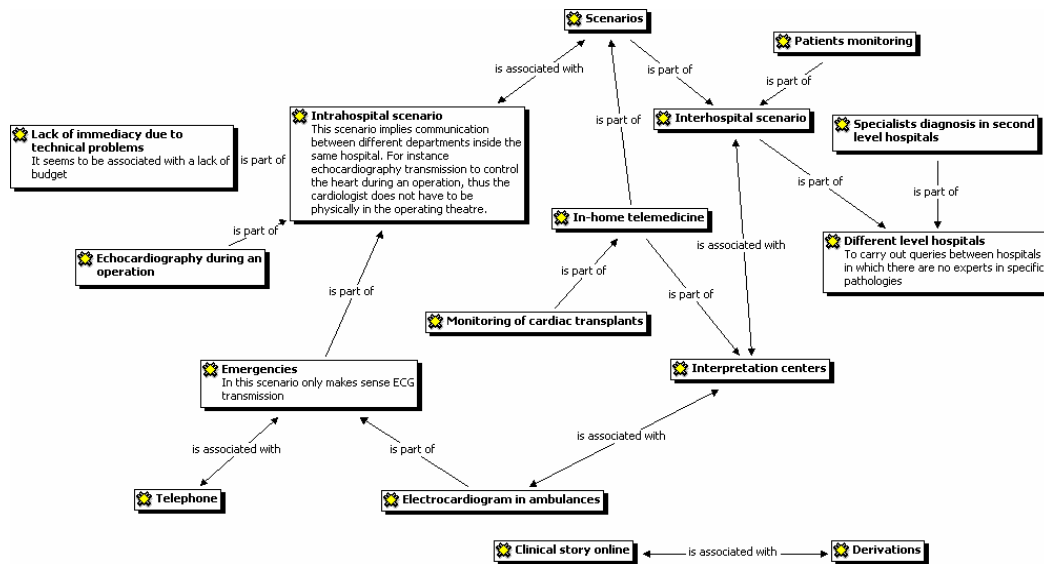


Fig.2. Relations network obtained with ATLAS-ti.

#### 4. Results

This paper proposes an integrated definition of an optimal scenario to implement a telecardiology device taking into account not only technical requirements but also organizational and user needs. This integrated vision implies two different type of results to optimize the QoS of the service and to guarantee the success of its further user implantation, because we take into account real needs of organizations and users of e-Health system.

##### A. Service dimensioning according to QoS thresholds.

From the technical standpoint and regarding technological demands of biomedical signals RT transmission, a QoS may be good at rating what available resources are needed according to how many users are connected at the same time. An example of the QoS study on a rural e-Health scenario is presented now.

It evaluates the QoS in rural environments associated with the remote communications among physicians that belong to a PH centre, and the specialists in the reference hospital to

send patient medical tests, to share interactive applications (e.g. for tele-assistance), etc. These PH centres, without broadband access, usually use Public Switched Telephone Network (PSTN) or, at the most, Asymmetric Digital Subscriber Line (ADSL) technologies.

Thus, the maximum upstream transmission rate from the user connection to the hospital is usually 64kb/s, depending on the available network resources. All these user connection are multiplexed in the hospital server that provides a higher capacity  $C=k \cdot 64\text{kb/s}$  ( $k>1$ ), but this multiplexation level is a key parameter for guaranteeing QoS to a high number of simultaneous users ( $N$ ). Moreover, each user connection includes different multimedia applications (associated with specific QoS requirements) as videoconference and remote accesses to EPR to support the telecardiology service based on biomedical signals (ECG and ECHO) RT transmission.

In previous technical QoS studies [21] the optimal number of simultaneous users regarding link capacity (values of  $N$  according to  $k$ ) has been evaluated. Thus, Fig. 3 shows the evolution of the link occupancy factor ( $\rho$ ),

defined as the efficiency of the resources sharing between the number of users (from  $\rho=1$ , 100%, to  $\rho = 0$ , 0%). These trends, obtained from a technical perspective, allow dimensioning the telecardiology service. For example, with  $N=14$  users only is possible to guarantee an efficiency  $\rho > 0.85$  if the available link capacity is  $C > 320\text{kb/s}$  ( $k > 5$ ).

In summary, the results shown in this example indicate that these studies permit to establish several good-performance areas and to determine the maximum number of users, according to the available resources, to guarantee QoS. Thus, it could be interesting to monitor the available resources and the value of  $N$ , and send a *feed-back* message (from the network to the user device) in order to manage the service parameters.

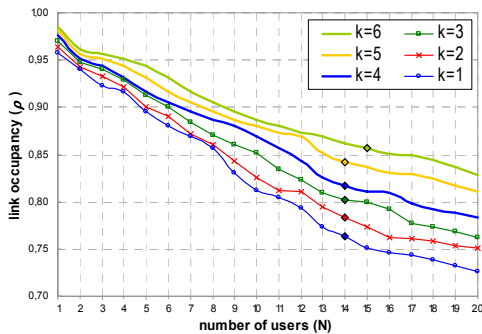


Fig. 3. Recommended performance areas, depending on the useful  $\rho$  thresholds, for the variation range of capacity ( $k$ ) and number of users ( $N$ ).

#### B. Optimal election of telecardiology scenarios and services.

The technical results allow quantifying the QoS levels but it is necessary to complete this numeric values with the psychosocial perspective. From the first methodological phase, we can redefine this previous telecardiology scenarios: for example, home telecare only is really useful for patients with hearth transplant; but is also a privileged scenario for monitoring of chronic heart diseases –although it is only necessary to control basic parameters such as blood pressure and patient weight increases, which do not suppose challenges in network transmission.

Thus, the results identify three relevant contexts in which the implementation of a TM system would be well valued by the cardiology experts:

- I. Remote specialist consultation of ECGs and ECHOs, due to avoid patient and cardiologist displacements. It could be developed by means of an established protocol: for instance, a cardiologist from a rural hospital that consults periodically an expert from a third level hospital about its doubts with ECHO interpretations. Even it can have an occasional character, like in case of specific pathologies consultation in which the doctor that attends the patient is not as expert as another doctor located at a hospital in another city. And teleechocardiography can be very useful in rural or inter-hospital environment, because in this scenario the displacement of expert cardiologists for image diagnostic is often required. In this case, it is important to note that ECHO transmission requires the presence of a cardiologist or expert acquiring the test, in order to guarantee the quality of diagnostic images. On the other hand, the ECG transmission seems very useful in an inter-hospital scenario, especially when there are no experts in interpretation of ECG assisting patients.
- II. Diagnosis interpretation outsourcing or cardiology test devices outsourcing. Telediagnosis services contraction, involves image transmission between professionals from different countries. And cardiology test devices outsourcing also involves image transmission, in this case between health organizations. In both cases it is necessary to transmit signs because there is no spatial and temporal coincidence between the people who administer the test and the people who interpret it.
- III. ECG transmission is also interesting in a mobile scenario, where a fast diagnosis allows a fast treatment of some sharp heart diseases.

These results allow establishing the optimum scenarios to implement a specific design for the telecardiology systems that differs enormously: rural or urban contexts, home telecare or telediagnosis (sick sharp or chronic, punctual diagnoses, monitoring), extreme or well routine

situations, etc. In every specific scenario, the telecardiology services can be optimized with a study of user requirements in situ, by means of ethnographic methodology [22]. The main objective of ethnographic methodology is to study real user needs in this specific scenario [23]. Ethnographic research allows integrating user needs and requirements with the previously described variables. For example, in mobile scenario we will study real transmission of ECG: we observe the work of health-related professionals (physicians, nurses and technical staff) from mobile unites and hospitals in emergency situations. We study also the processes needed to coordinate this transmission. Finally, we will observe also specific tasks needed to gather and transmit ECG in its real context too.

From all these considerations and after studying the user requirements in the chosen context, the second phase of the work would remain to be done. From the user-centred design perspective, in a further study these needs and requirements will be translated into recommendations for functionalities and design of a GUI device intuitive and easy to learn and used by patients or health-related professionals [24]. Thus, an evaluation of the demonstrator of the service will be performed not only from the technological point of view, but also from the user point of view in their specific context. Finally and from these results obtained, we propose a listing of characteristics about health organizations, users and technical aspects in which the e-Health systems should be assigned to turn out to be more manageable. Evidently, these points are not axiomatic but they should be understood as lack of pragmatic norms to keep in mind:

- *Organizational aspects*: organizational culture (its important to explore the different meanings that health-related professionals give to their tasks and to the use of ICT), economic factors (the TM system must have a business plan economically sustainable), the adjustment to the scenario (a system can be very useful on a specific context and no sense in a different one), and the amount of information (in order to facilitate diagnosis, the system must take into account and be able to share important information about patients).
- *User aspects*: usability (the system must be easy to use and to learn), user profiles and

requirements (take into account different levels of users in design), and the increase of volume of work (resistances from users can come from the increase of work in their tasks because of the implementation of ICTs).

- *Technical aspects*: low technology equipments in hospitals, technical problems, and security.

## 5. Discussion and conclusions

In order to answer the question about “not what technology can do but rather what must do”, it is remarkable the importance of an interdisciplinary work among health-related professionals, engineers, and social researchers, integrating organizational and user needs with technological requirements. In this way, it is necessary to adopt a perspective wide enough to allow us consider all those variables related to the psychosocial processes involved in user’s daily practices.

Moreover, it is necessary to learn the user *know-how* in order to understand how people make sense of technology in their everyday life: frequently e-Health designs are without knowing about user specifications (e.g. patients do not want to wear something that stigmatizes them as “ill”). The results obtained demonstrate that each scenario (first diagnosis, emergencies, chronic illnesses monitoring) has its own set of rules that may be subsumed under the default encoding of a system already fixed on a laboratory-context if we do not pay attention to the user needs, attitudes, intentions, etc. Moreover, to get something to work (for years) is not only necessary that “it works out” but the device has to be accepted and appropriated [25] by real users.

In the case of the QoS there are questions that would be solved in further studies: decisions about resources availability as function of simultaneous users, plug-and-play and interoperability functionalities, decision making about priority among type of services, etc. Technologies do not only facilitate things, they also introduce more complexity in a context, health, in which different positions about the management of these technologies coexist. The user and scenario centred design should emerge as an intermediate bridge between data processing and engineers on one side and health organizations on the other.

## Acknowledgements

This work was supported by projects from Comisión Interministerial de Ciencia y Tecnología (CICYT) and Fondos Europeos de Desarrollo Regional (FEDER) TSI2004-04940-C02-01 and -02, and VI Framework Programme IST-27142 Pulsers II IP.

## References

- [1] J.A. Jacko & A. Sears Eds. “*The Human-Computer Interaction Handbook*”. New Jersey: Lea, 2003.
- [2] R. Silverstone & E. Hirsch Eds. “*Consuming technologies: media and information in domestic spaces*”. Barcelona: Bosch, 1996.
- [3] D. Kruger *et al.*, “Effect of modem transmission of blood glucose data on telephone consultation time, clinic work flow, and patient satisfaction for patients with gestational diabetes mellitus,” *J Am Acad Nurse Pract*, 15(8):371–375, 2003.
- [4] S. de Lusignan *et al.*, “Compliance and effectiveness of 1 year’s home telemonitoring. Report of a pilot study of patients with chronic heart failure,” *Eur J Heart Fail*, 3(6):723–30, 2001.
- [5] C. Sicotte *et al.*, “Feasibility and outcome evaluation of a telemedicine application in speech-language pathology,” *J Telemed Telecare*, 9(5):253–258, 2003.
- [6] B. Harnett, “Telemedicine systems and telecommunications,” *J Telemed Telecare*, 12(1):4–15, 2006.
- [7] M. Maheu, P. Whitten and A. Allen, “E-health, telehealth, and telemedicine: a guide to start-up and success,” *Jossey-Bass Eds.* 362.102821-E103, San Francisco, USA, 2001.
- [8] J. Gemmill, “Network basics for telemedicine,” *J Telemed Telecare*, 11(2):71–76, 2005.
- [9] W.C. Hardy, “QoS measurement and evaluation of telecommunications Quality of Service,” *John Wiley Eds.* [Review R.Chodoreck, *IEEE Communications Magazine*, 40(2):30–32, 2002].
- [10] G. Demiris and D. Tao, “An analysis of the specialized literature in the field of telemedicine,” *J Telemed Telecare*, 11(6):316–319, 2005.
- [11] N. M. Hjelm and H.W. Julius, “Centenary of teleelectrocardiography & telephonocardiology,” *J Telemed Telecare*, 11(7):336–339, 2005.
- [12] Red europea de investigación de robótica y telemedicina, “OTELO. mObile Tele-Ecography using an ultra Light rObot,” <http://www.bourges.univ-orleans.fr/otelo/home.htm>.
- [13] MR. Ede, “Focus group to study work practice”. *Usability Interface*, 5(2), <http://www.stcsig.org/usability/newsletter/9810focusgroups.html>. 1998
- [14] J. Muñoz, “Qualitative data analysis with ATLAS-ti”. 2003. <http://antalya.uab.es/jmunoz/indice/filetrax.asp?File=jmunoz/cuali/manual-atlas.pdf>
- [15] J.M. Carroll, “Making use: Scenario-Based Design of Human-Computer Interactions”. Massachusetts: MIT Press, 2000.
- [16] J. Latimer, “Distributing knowledge and accountability in medical work. An ethnography of multi-disciplinary interaction”. *Cardiff School of Social Sciences Working Papers Series*, <http://www.cardiff.ac.uk/schoolsanddivisions/academicschools/socsci/publications/abstracts/wrkpaper6-ab.html>. papers 1 – 10 (6), 2000
- [17] C. May, M. Mort, T. Williams, F. Mair, and L. Gask, “Health technology assessment in its local contexts: Studies of telehealthcare”, *Social Science & Medicine*, 57(4), 697-710, 2003.
- [18] J. Savage, “Ethnography and health care”. *BMJ*, 321, 1400-1402, 2000.
- [19] B. Latour, “Reassembling the Social: an Introduction to Actor-Network-Theory,” *Oxford: Clarendon*, 2005.
- [20] B. Latour, “Technology is society made durable,” *Law, J. (Ed.) A Sociology of Monsters: Essays on Power, Technology and Domination*. London: Routledge, 1991.
- [21] I. Martínez, J. García, E.A. Viruete, J. Fernández, “Performance Evaluation of Rural e-Health Scenarios: Users and QoS Management” *IEEE Engineering in Medicine and Biology Society (EMBS)*, 2006.
- [22] M. Myers, “Investigating information systems with ethnographic research”. *Communications of the association of information systems*, vol 2, art 23, 1999. (ISSN: 1529-3181).
- [23] H. Beyer and K. Holtzblatt, “Contextual Design,” *San Francisco: Morgan Kaufman Publishers*, 1998.
- [24] B. Schneiderman, “Designing the User Interface,” *Boston: Pearson*, 2004.
- [25] M. Lie, K.H. Sorensen, “Making technology our own? Domesticating technology into Everyday Life,” *Oslo: Scandinavian University Press K.H.*, 1996.