MMAR 2004 10th IEEE International Conference on **Methods and Models in Automation and Robotics**
30 August - 2 September 2004, Międzyzdroje, Poland

TELE-MEDICINE SYSTEM BASED ON A PERSONAL ROBOTIC ASSISTANT

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Abstract. This work describes the main ideas of a tele-assistance system based on a personal robotic assistant for elderly. We will focus our attention in to equip an intelligent robot assistant with a robust user-machine interface, which enable this robot to communicate, interact, and collaborate with human users in a natural and intuitive way. Then, we will comment a integrated telemedicine system that permits to do home-care tasks. The current prototype robot is built on top of a commercial robot equipped with onboard PC. Using this robot, several subsystems have been designed, each one with a specific goal in mind for assisting the elderly (user´s interfaces, navigation algorithms, tele-presence and tele-medicine applications). Finally, an application of the telemedicine module will be explain.

Key Words. Tele-medicine, tele-assistance, robotic home assistant, human-machine interface.

1. INTRODUCTION

In the last years, the number of elderly in need of care is increasing dramatically. In the European Union it is estimated that 10-15% of the total population is over 60 years old. This means that in EU there are about 60 million elderly [1]. Besides, several reports also show that there is a strong relation between the age of the person and the handicaps suffered, the latter being commoner in persons of advanced age. Given the growth in life expectancy in the world (in the countries of the Organisation for Economic Cooperation and Development (OECD) it is expected that the proportion of older persons aged 60 years and above will have reached a ratio of 1 person in 3 by the year 2030), a large part of its population will experience functional problems [2]. Aware of the dearth of applications for this sector of the population, governments and public institutions have been promoting research in this area in last years. Various research groups at a world level have begun to set up projects to aid communication and mobility of elderly with the aim of increasing their quality of life. These will allow a more autonomous and independent lifestyle and greater chances of social integration for them [3],[4],[5],[6].

At the same time, the development countries are facing an explosion of costs in the health-care sector for elderly. Current nursing home costs range between $30,000 and $60,000 annually. Over the last decade along, costs have more than doubled. The dramatic increase of the elderly population along with the explosion of costs pose extreme challenges to society. The current practices of providing care for the elderly population is already insufficient. Undoubtedly, this problem will multiply over the next decade.

The society needs to find new technologies and alternative ways of providing care to the elderly, where the need for personal assistance is larger than in any other age group. Several factors suggest that now is the time to establish new applications in the home-care sector: Firstly, we actually have the technology (internet) to develop new applications in home health-care sector. Secondly, at the currently, the robots exhibit the necessary robustness, reliability, and level of capability. Thirly, the need for cost-effective solutions in the elderly care sector is larger than ever before. Aware of this necessity, nowadays exists several research groups working in this area, and some important projects such us

"Citizen Health Systems" [7], "TelemediCare" [8], "Nursebot" [9] and "Morpha" [10].

In order to offer a solution for described problem, a research group of Electronics Department at the University or Alcalá is working in two projects called TELEASISNET [11] (spanish acronym for Teleassistance System) and "SIRAPEM" (spanish acronym for Robotic System for Elderly Assistant) [12]. The main goals of this projects are the development of personal robotic aids that serves several primary functions such us tele-presence, tele-medicine, intelligent reminding, safeguarding, mobility assistance and social interaction [13].

This paper describes the general architecture of tele-assistance system. Then, we present an initial application of our system in telemedicine area. It has been divided into the following sections: section II describes the general architecture of the system (hardware and software design). An example of telemedicine is shown in section III. Section IV draws the main conclusions and points to future research work.

2. GENERAL ARCHITECTURE

This section describes the development of a pilot internet & communication technology-based tele-medicine system for primary community health-care at home. Figure 1 shows a block diagram of the system implemented. The architecture proposed utilize the existing internet technology to develop PC-based medical applications.

The telemedicine system consists of a medical stations (central unit) for community health centres and a station for each home (assistance unit).

This system allows the development of home assistance units oriented to improve the quality of sanitary services through remote monitorisation. These units would consist on a generic hardware able to include many different applications and specific hardware to get adapted to the specific needs of every sector of the society which is intended to be used. Such data include statistics on medication (when did the person takewhat), daily living activities, and factors related to the prediction of specific medical risks (blood sugar, blood pressure, biosignal as ECG, ...). Thus, developing a complete set of software modules adapted to different pathologies would allow having a versatile system through reprogrammability of the hardware system. With these remote assistance units, a doctor can tele-diagnostic a patient from a remote hospital or health-centre.

In this work we use a robotic personal assistance to increase the power of the telemedicine system which allows the user to be completely monitored 24 hours from the assistance centers because it incorporates high-level services module that includes several tasks of tele-assistance, tele-monitoring, providing reminding and social interaction.

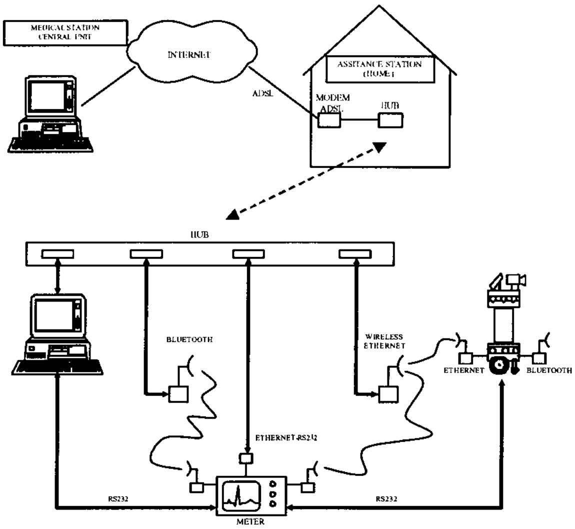


Fig. 1. Telemedicine system block diagram.

2.1. Personal robotic assistant

SIRA (robot's name) is based on a commercial platform (the PeopleBot robot of ActivMedia Robotics [14]) with a differential drive mobile base. Its architecture is composed of four main modules: environment perception, navigation, human-machine interface and high-level services, as it can be seen in figure 2. The first module is endowed with encoders, bumpers, two sonar rings (high and low) and a vision system based on a PTZ (pan-tilt-zoom) color camera connected to a frame grabber. The navigation system combines information from the different sensors for global navigation using Partially Observable Markov Decision Processes (POMDPs). This module is controlled by the high-level services. The human-machine interface is composed of speakers, microphone, a tactile screen, the same PTZ camera used in the perception module, and wireless Ethernet link. The system architecture includes two human-machine interaction systems, voice (synthesis and recognition speech) and touch screen for simple command selection (for example, a destination room to which the robot must go to carry out a service task). The high-level services module controls the rest of the systems and includes several tasks of tele-assistance, tele-monitoring, providing reminding and social interaction.

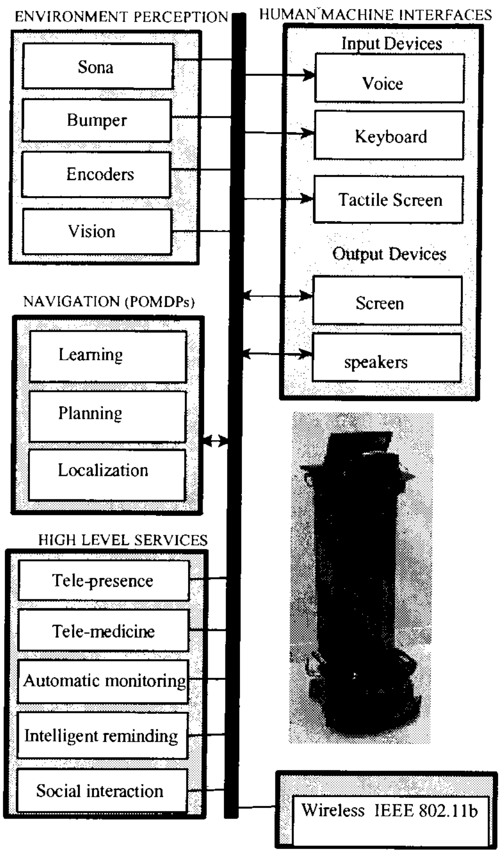


Fig. 2. SIRA general architecture.

- High level services: Our goal is to facilitate communication between users and other health-care professional such as nurses and doctors. With this subsystem doctors can visit their patients using the tele-presence module by means of a video-conference. Besides, it is possible to connect to sanitary services through remote monitorisation using devices coupled to the robot such as blood pressure or ECG meter. The tele-presence interface consists of a camera, a touch screen, a mini-keyboard, a microphone and a speaker on-board the robot. The video and audio signal are transmitted from patient's living room to a remote station placed in the doctor's office, enabling the doctor to establish a diagnostic from his office.

- Human-machine Interfaces: One of the major goals in robots assistants is to develop a robot that allows the most natural interaction between the users and the robot. Many elderly can have difficulties interacting through unfamiliar means, such as keyboards, it is therefore of great importance that the robot communicates in ways familiar means. To that end, tactile and spoken interaction with the robot is essential. Keeping this in mind, we have developed two interfaces:

  - Tactile interface: consists of a 8,4" tactile screen where user selects desired actions pressing on the touch panel. Several graphical applications for the high level services provided by the system have been designed. Besides, this screen shows a virtual 3D face (robot face) moving as he was speaking, when robot works in social interaction tasks. In this way, relationship between the robot and the user is friendlier because he can appreciate how a face is speaking and it makes different facial expression as function of the conversation context. This face and facial animation have been made using OpenGL library.A voice interface, in this case actions are activated by voice commands using a speech recognition and synthesis system based on botspeak software.

  - Voice interface: consists of two speakers and a microphone onboard the robot. Actions are activated by voice commands using a speech recognition system. This is controlled by a dialog manager that generates the appropriate questions and responses using a speech synthesis system. The speech synthesis/recognition system is based on the botspeak software provided for ActivMedia Robotics. Currently, we are developing a new synthesis/recognition system based on IBM viavoice and cloudgarden libraries using JAVA language.

Figure 3 shows the components onboard the robot for the designed HMI.

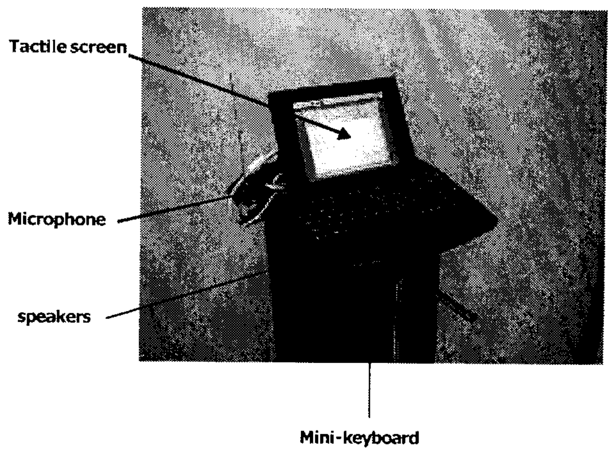


Fig. 3. HMI components.

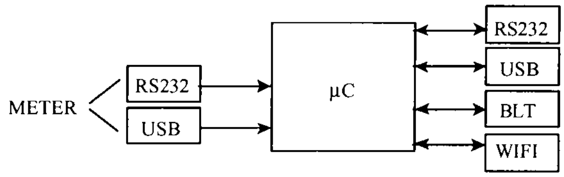
- Navigation: The navigation subsystem enables the robot to navigate safely to arbitrary target locations in indoor environments. It does this by first learning a map of the environment, which is represented using Saphira map protocol. Once a map has been acquired, it enables the robot to maintain an accurate sense of its location in y space (x, y, θ). This enables the robot to move to arbitrary target location. By differencing sensor readings and the learned map, the robot can detect changes in the environment and adapt itself. Nowadays, to global localize a robot in office environments we are using Partially Observable Markov Decision Process (POMDP) [15]. From a topological representation of the environment and the characterization of the uncertainties related to motor behaviors and sensor perceptions, a Markov-based localization system has been developed, which maintains and updates a probability distribution over all states contained in the topological map. The planning system uses this belief distribution to select the best actions that direct the robot to a goal location. The main novel feature of our approach is that it combines sonar and visual information in a natural way to produce state transitions and observations in the framework of Markov Decision Processes. This multisensorial fusion improves the robustness of the navigation subsystem [16].

- Environment perception: This subsystem is essential, both from the point of view of safety navigation (to avoid collisions and falls) and of tracking (to allow positioning). The lowest level is made up with simple bumpers and contact detectors activated by situations of imminent collisions. A higher level, we use ultrasonic and vision sensors. As we have explained in the below paragraph subsystem navigation is based on the fusion between ultrasonic and vision sensors. In the future we will use vision sensor for monitoring users actions too.

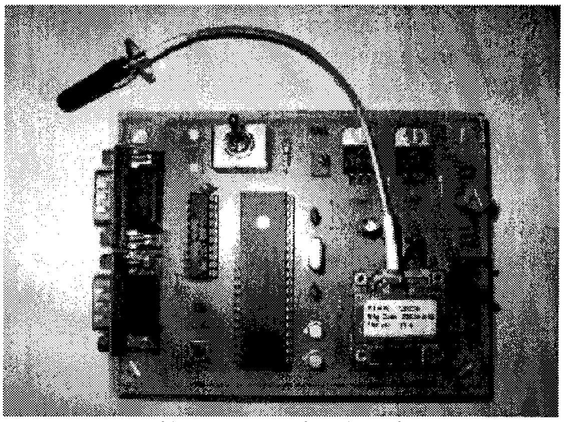
3. REMOTE TELEMEDICINE

As it can be see in figure 1 (telemedicine system block diagram), this module must permits to acquire data from medical devices (blood pressure meter, glucometer, ECG meter, etc) through remote monitorisation.

This unit must allows to connect using different technologies communications (serial, Bluetooth, wireless) capable to be adapted to the home communication possibilities. This way, the objective is develop a electronic system making up each one of the portable modules consists of a microcontroller-based electronic circuit, thus providing an open system that can be reconfigured at software level; the system can be adapted to the characteristics of the environment to be monitored and/or controlled. Another of its advantages is the possibility of modifying the application software that is run in the microcontroller (teleprogramming) by sending the appropriate command and software via the communications system. Figure 4 shows the module diagram developed.



a) Block diagram



b) Prototype developed

Fig. 4. Electronic module.

This module allows different connection types: a) directly to internet using bluetooth or wireless if in home exists a bluetooth or wireless network. b) to a PC using serial, USB, Bluetooth or wireless. c) to a personal robotic assistant using serial, USB, bluetooth or wireless.

Using SIRA robot, the tele-presence module allows the doctors to give a first diagnosis of the patient using visual diagnosis and answers to the doctor's questions (establishing a bidirectional video-conference as it can be seen in figure 5), but sometime this information is not enough for correct diagnosis. One important key in the health care sector is the possibility of collecting data for patients from their private homes in order to do a correct diagnosis of them. We have the intention of developing a complete system able to measure some vital parameters of the patient as: temperature of the body, blood pressure, blood sugar and electrocardiogram.

At the moment we have developed a glucometer based on a commercial sensor [17] as it can be seen in figures 6 and 7. The user inputs a blood sample in the meter. This measures the glucose level in blood and automatically sends the data to the robot over wireless and then to an ADSL router which allows connection with a remote station via Internet (wifi). In this manner, measurement results can be seen on the robot's screen and in the medical station center. Our application is able to associate data with a patient from a database, then, complete clinical information can be obtained for each patient in an automatic way.

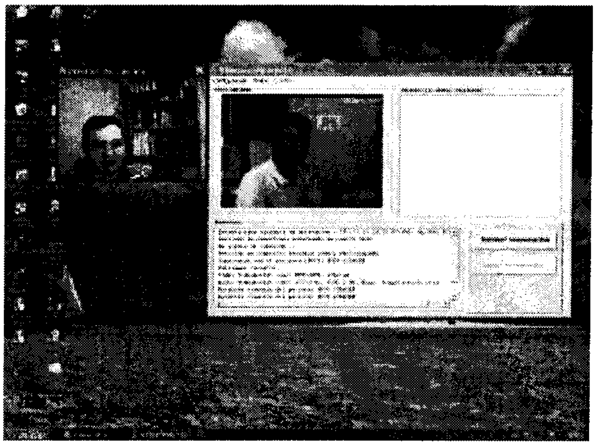


Fig. 5. Bidirectional video-conference.

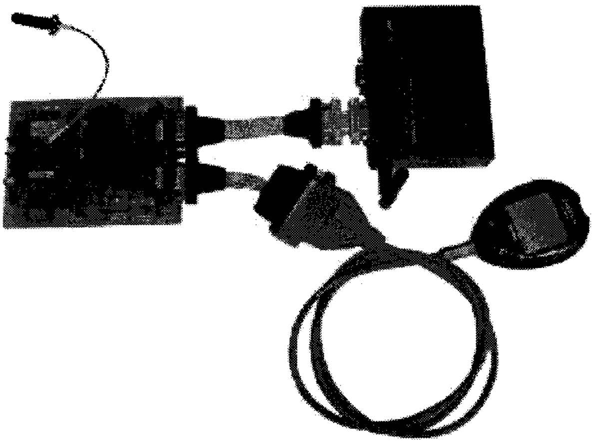


Fig. 6. Interconnection glucometer–electronic module-wifi.

4. CONCLUSIONS

This work reports the initial design and results of a tele-assistance system for elderly and/or sick people. This system could be implanted in medical centers and at homes of elderly and/or sick people y/o and it will provide them with three primary functions: a) Tele-presence: capacity to carry out a video-conference between a doctor located in a medical center and the sick person or elderly in their house. This interface allows them not only to carry out diagnosis and monitor tasks, but also it allows to carry out tasks of social interaction providing a communication way for people living alone. b) through the videoconference connection, the doctor will be able to examine the patient allowing him to carry out a diagnosis. c) Remote tele-medicine: By means of certain interfaces, it will be able to collect and send the user's data (blood pressure, temperature, ECG...) to the doctor for their analysis, and this way it is possible to carry out an on-line tele-diagnosis of the patient. This will increase the use of new communication technologies (ethernet, bluetooth) in data acquisition.

This project is motivated by the great demand that it estimates it will exist of this type of applications in a near future, due mainly to the progressive aging of the population and to the reduction of costs of sanitary attendance. The outlined proposal is novel and with great possibilities of to be able to be implanted with success in medical centers and at homes. Also, these applications can also be added in the design of assistance robots that it is an emergent line in the investigation of this field. Keeping in mind the importance of providing care for elderly, our goals is to develop a mobile robot that will provide a range of services for these users. In this paper, a general description of the robotic system has been presented and a initial robot application have been commented, explaining the main features of the design, user interface, hardware and software architecture.

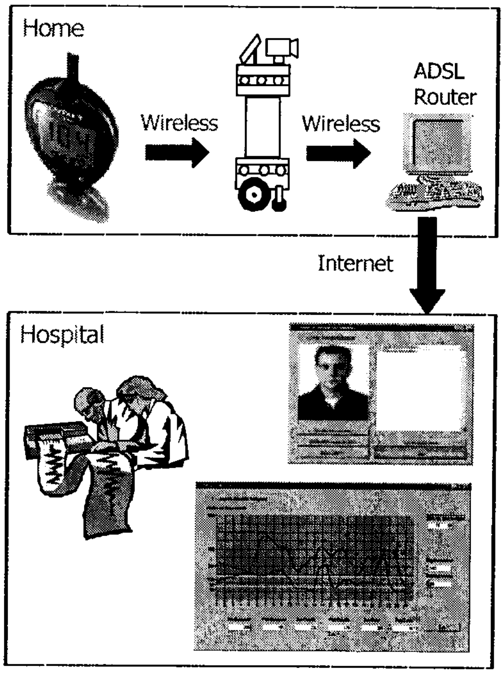


Fig. 7. Block diagram of tele-medicine system using SIRA.

5. ACKNOWLEDGMENTS

The autors would like to express their gratitude to the Ministerio de Ciencia y Tecnología (MCYT) for their support through the project SIRAPEM (DPI2002-02193), to the Comunidad de Madrid for TELEASISNET project (07T/33/2003) financing.

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