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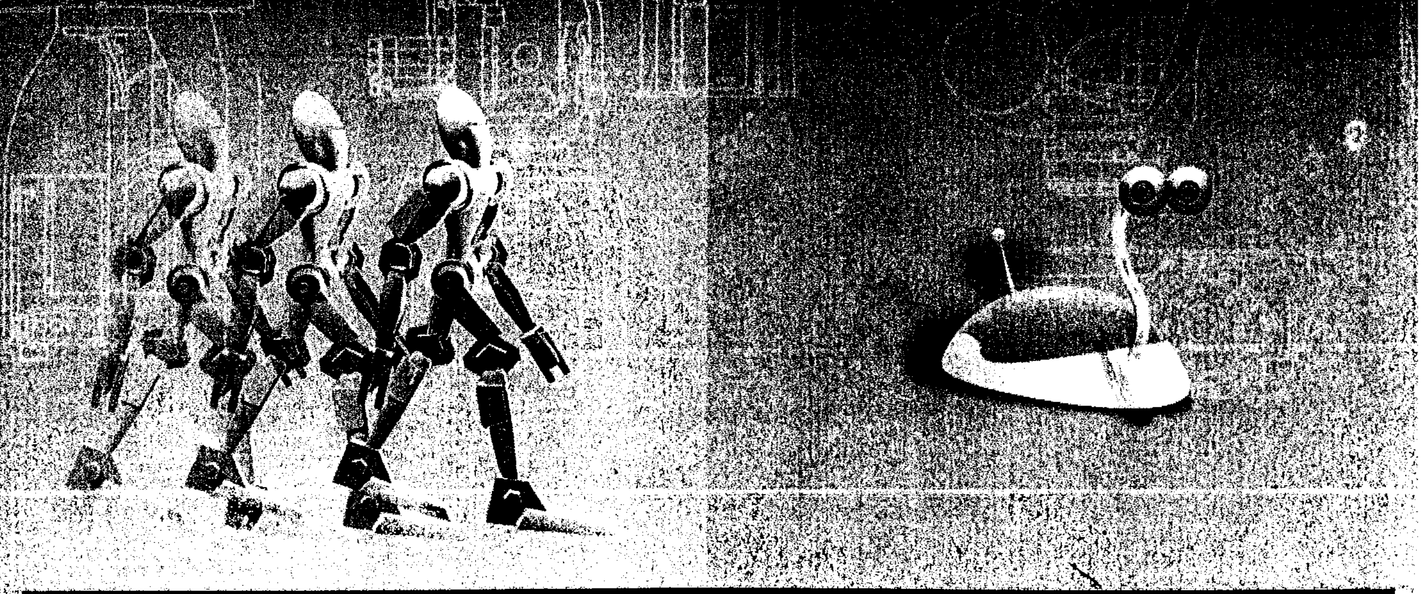

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35 th International Symposium on Robotics

CONFERENCE PROGRAMME

TUESDAY March, 23 2004

KeyNote Speaker:
10:00 – 11:00

Parallel Sessions
3:45-5:15 p.m

Session WE 41: ROBOT COMPONENTS (2)

Session WE 42: INDUSTRIAL ROBOT IMPROVEMENTS (2)

Session WE 43: APPLICATION INTO HOSTILE ENVIRONEMENTS (1)

THURSDAY March, 25 2004

KeyNote Speaker:
9:00 – 10:00

TH 01

Parallel Sessions
10:00-11:30 a.m

SIRA, a Robotic System to Assist the Elderly

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Abstract

The SIRAPEM project is a multi-disciplinary effort aimed at developing mobile robotic assistants for the elderly. In this paper, we present the initial design and results of one such robot called SIRA. First, we provide a brief overview of its general architecture. Then, we explain the human machine interfaces and the designed navigation system. After that, we describe some high level services specially designed for assisting the elderly. Finally we present the current project status and the conclusions and future works.

1. Introduction

In the last years, the number of elderly in need of care is increasing dramatically. In the European Union, about 15% of the total population is over 65 years old. As the baby-boomer generation approaches the retirement age, this number will increase significantly. By 2030, more than 25% of the population will be 65 and over. This increase could collapse the Hospitals and assistance centers. One alternative to this problem could be using assistance at home, but current nursing home costs range between 30,000 € and 60,000 € annually. The dramatic increase of costs poses extreme challenges to society. We need to find new technologies and alternative ways of providing care to this sector of the population, where the need of personal assistance is larger than in any other age group. Aware of this necessity, nowadays there are several projects and research groups working on the development of assistant robots. Among them we can find the "Nursebot project", with robots *Flo* [1] and *Pearl* [2], "I.L.S.A" [3] and "Morpha" [4] projects.

In order to contribute to this research field, the Electronics Department of the University of Alcalá is working on the SIRAPEM project (Spanish acronym of *Robotic System for Elderly Assistance*). The goal of this project is the development of a robotic assistant (called SIRA) which allows the user to be completely monitored 24 hours a day and tele-diagnosed from the assistance centers. Therefore we guarantee the security of the user and decrease the health-care cost because the care givers only would go to the patient's house if it were strictly necessary.

This paper describes the general architecture of SIRA, its main functions and the initial results obtained by SIRAPEM project, focusing the attention on the human machine interfaces, the navigation methodology and the high level services.

2. General Architecture

SIRA is based on a commercial platform (the *PeopleBot* robot of *ActivMedia Robotics* [5]) 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 1. 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. SIRA is equipped with two on-board PCs for supporting all its architecture and batteries with a lifetime of 4 hours approximately. We are working on a mechanism for connecting the robot to a battery charger automatically, without human assistance.

2.1. Human-Machine Interface (HMI)

One of the major goals in assistant robotics is to develop a robot that allows the most natural interaction between

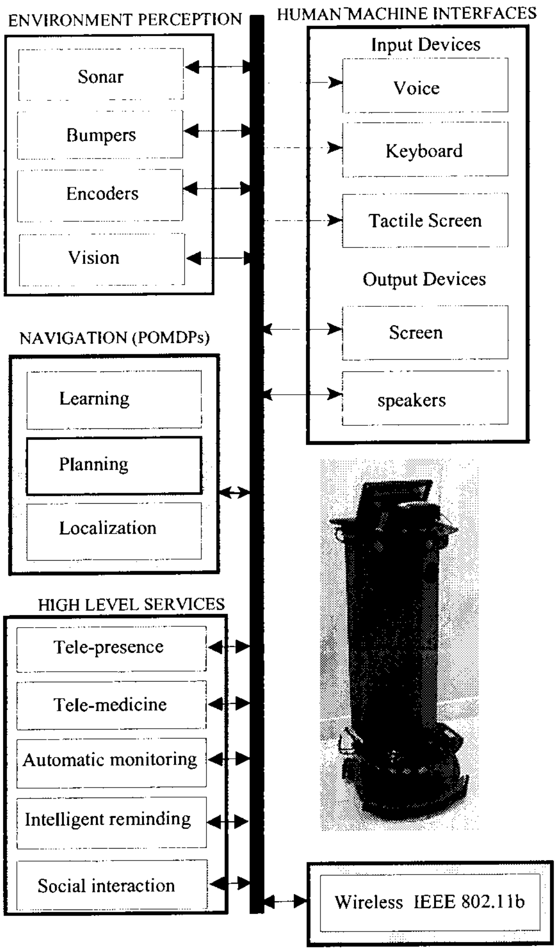

Figure 1. General architecture

users and the robot. Many elderly can have difficulties interacting through unfamiliar means, such as keyboards. Therefore, it is very important that robots interact with humans in a natural and familiar way. For achieving this goal, tactile and spoken communication with robots 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.

- 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 2 shows the components onboard the robot for the designed HMI.

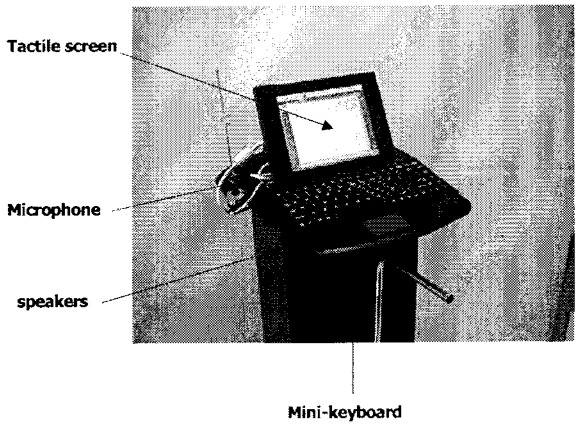

Figure 2. HMI components

2.2. Navigation System

The navigation system guides the robot to the destination rooms in which it must perform its service tasks. Robustness and autonomy are basic requirements in order to allow the robot to safely navigate during long periods of time. Another desired characteristic is the exportability to different working domains, using a simple environment representation, natural landmarks for positioning and learning mechanisms to make easier the robot installation in new indoor environments.

To cope with all these objectives, a Partially Observable Markov Decision Process (POMDP) has been used as reasoning model [6]. The *states* of the model are related to the nodes of a topological graph, defined as "regions" of variable size in accordance with the topology of the environment. Figure 3 shows the discretization of the map of a floor of the "Príncipe de Asturias" Hospital in

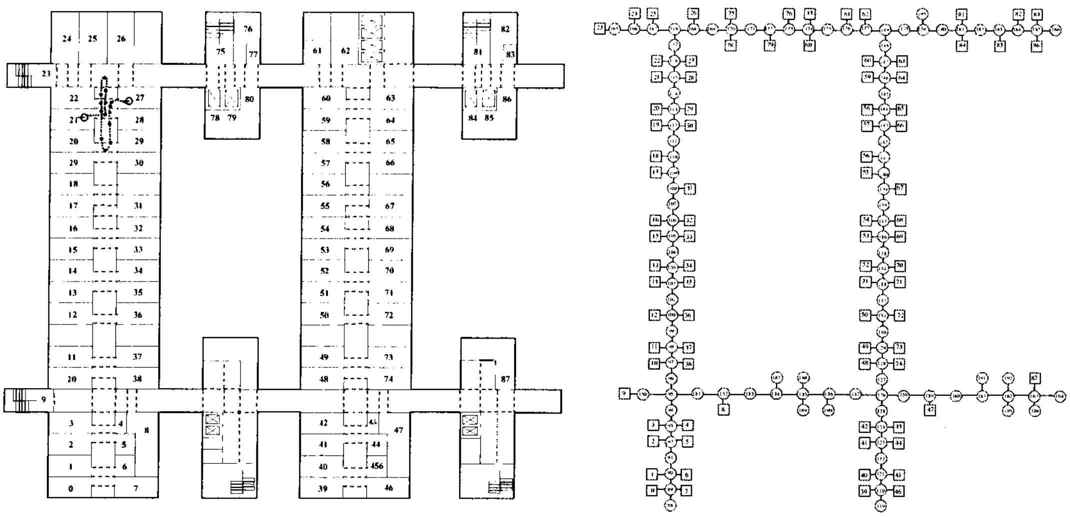

Figure 3. Map of the sixth floor of the "Principe de Asturias" Hopital, topological discretization and corresponding graph.

which some experimental tests have been carried out, and the corresponding topological graph. To perform the state transitions, five local navigation behaviours have been developed as *actions* of the Markov model: (1) turn 90° to the left, (2) turn 90° to the right, (3) follow corridor, (4) enter room and (5) go out room. The *observations* are obtained from the sonar sensors (combination of the "free"/"occupied" percepts around the robot) and the CCD camera (number of doors in the image and length of some typical corridor vanishing lines).

Figure 4 shows the global architecture of the navigation system, that is made up of three main modules:

Localization. This system uses a state estimator based on *Markov localization* [7] to maintain a probability distribution over the nodes of the graph in which the robot can be located. Global localization with unknown initial position is very fast, thanks to the combination of sonar and visual observations.

Planning. A two decision level planning architecture has been developed [7]. The lower level is a *local policy* that assigns actions to states using several planning objectives, as the guidance to destination rooms and the reduction of locational uncertainty. The higher level is a *global policy* that incorporates to the final decision the uncertainty about the location of the robot using several heuristic methods for solving POMDPs.

Learning. This module automatically adjusts the Markov model parameters of a new environment, making easier the robot installation in new working domains. The topological graph introduced by the designer and some predefined uncertainty rules are used to compile an initial POMDP. This initial model is adjusted by means of an active exploration stage, in which a modification of the *Baum-Welch algorithm* [8] is used to update the parameters of the transition and observation functions.

The resulting navigation system performs its guidance missions in a very robust way with low computational resources, as it will be shown in the results section.

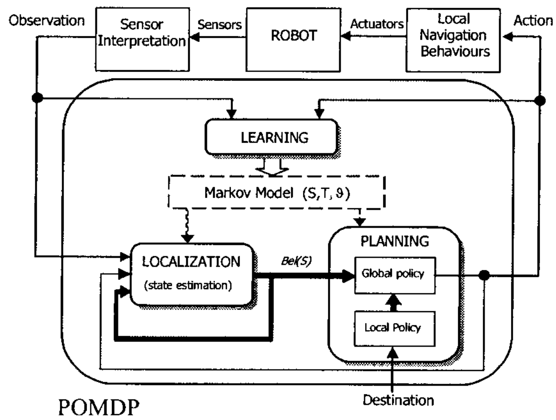

Figure 4. Global architecture of the navigation system.

2.3. High level services

The goal of this project is the development of personal robotic aids that provide five high level services specially though for assisting the elderly.

Tele-presence. The idea is to use Internet technology in order to establish a bidirectional video-conference from the caregiver's office to the robot which is in the patient's house. This system facilitates the communication between the users and caregivers without having to go off to the user's house if it is not strictly necessary. The system is able to localize and identify the user in the house automatically when the caregiver wants to communicate using the vision system.

The tele-presence interface consists of a video-conference system on-board SIRA and on assistance center station. The robot transmits the video and audio signals to the remote station and vice versa. The video feed is compressed into a JPEG feed on board the robot, and then both signals are transmitted to a local base-station over wireless Ethernet, and then to the remote station over ADSL. At the remote station the JPEG is decompressed and synchronized with the audio before they are played back on the remote PC's screen and speakers. The process is the same in the other direction, from the assistance center to the robot. Figure 5 shows an example of the bidirectional video-conference working.

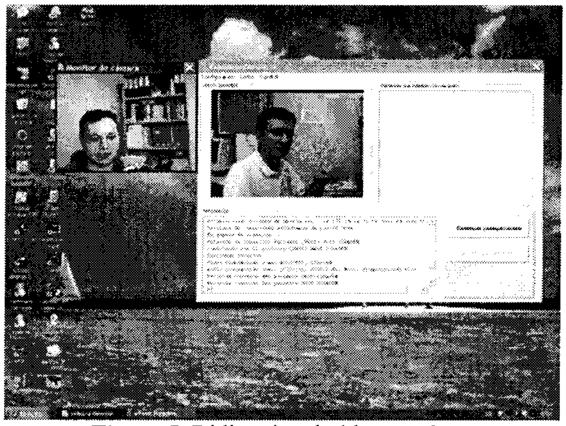

Figure 5. Bidirectional video-conference

Tele-medicine. The tele-presence system allows the doctors to give a first diagnosis of the patient using visual diagnosis and answers to the doctor's questions, 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 [9] as it can be seen in figure 6. 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. In this manner, measurement results can be seen on the robot's screen and in the remote assistance 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.

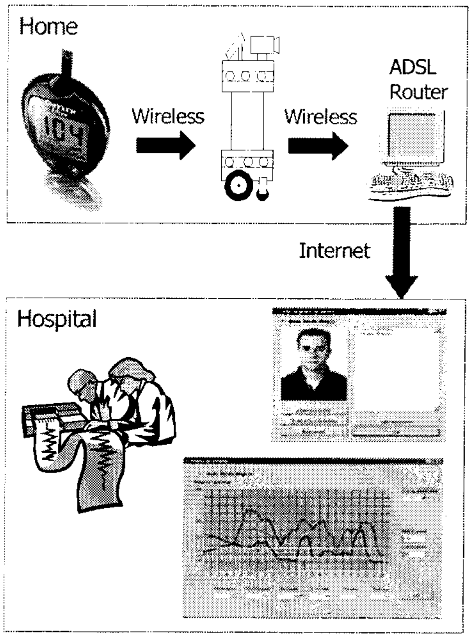

Figure 6. Tele-medicine system

Intelligent reminding. A large fraction of the elderly population suffers from varying degrees of dementia. This problem can produce that they forget to take medicine, to see the bathroom, to measure some health parameters, etc. We have developed an application for reminding the user about some daily activities using visual and audible information.

To program the system, the caregiver for an elderly user remotely inputs a description of the user's daily activities as well as their periodicity and some constraints on the time of their performance. This plan may be changed in one of three ways: (1) the user, from the robot, or the caregiver from the assistance center, may add new activities; (2) the caregiver may modify or delete activities of the plan, however, the user is allowed to change some activities as lunch time, but is blocked from modifying others as for example medicine-taking; (3) the user may execute one of the planned activities. Figure 7 shows an example of visual warning that the user can see in the robot screen.

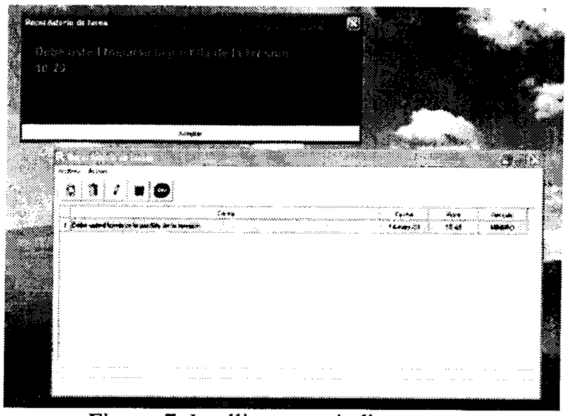

Figure 7. Intelligent reminding system

Automatic monitoring. Though the vast majority of older adults live in the community, many reside with similarly frail relatives, or live alone with little or no outside support. Family members are often widely dispersed and minimally involved in meeting the day to day needs of their elders. In home services from community agencies are generally time-limited and prohibitively expensive for many older adults. These circumstances can pose substantial risks, for example, loss of stability or fading can cause the user falls on the floor. This can have, if undetected by others, severe consequences up to the patient's death. By reducing these risks, we are implementing a system which is able to answer to the call of the user by monitoring his state and sending an alarm if it detects a danger situation for him. Then, the robot achieves an automatic monitoring periodically, localizing the user and detecting his situation.

At the moment, we have designed a system for localize, identify and track the patient's face based on computer vision. These abilities are essential for finding a user and for being able to interact with a person while he is moving. Our system follows the scheme shown in figure 8. Firstly, the camera and the robot are moved looking for human faces in a room. The robot navigates towards free zones, using reactive behaviour in order to avoid obstacles, until a face is found. Our face localization system is based on a detector of simple features called *Haar-like* and a classifier based on the learning algorithm *AdaBoost* [10]. This method generates an image representation called *integral image* that allows for very fast *Haar-like* feature evaluation (e.g. dark zones around bright areas in horizontal or vertical). Once the integral image has been computed, any one of these *Haar-like* features can be computed at any scale or location in constant time. *AdaBoost* algorithm selects a small number of critical visual features from a larger set and yields extremely efficient classifiers. Once a face has been found, a tracking algorithm based on the explained method applied in a window placed in the last detected frame, tracks the face. While tracking a person's face, the camera and the robot are continually adjusted to keep the person centered in the camera image, with a predefined size, and the robot aligned with the user. Once the tracking system has centered the user, an identification algorithm is run in order to known if the detected person is the wanted person or not. If the answer is true the face tracking is enabled and the robot tracks the user, stopping when he is enough closer to the user for establishing a tele-conference. If the answer is negative the system continues looking for another face in the room.

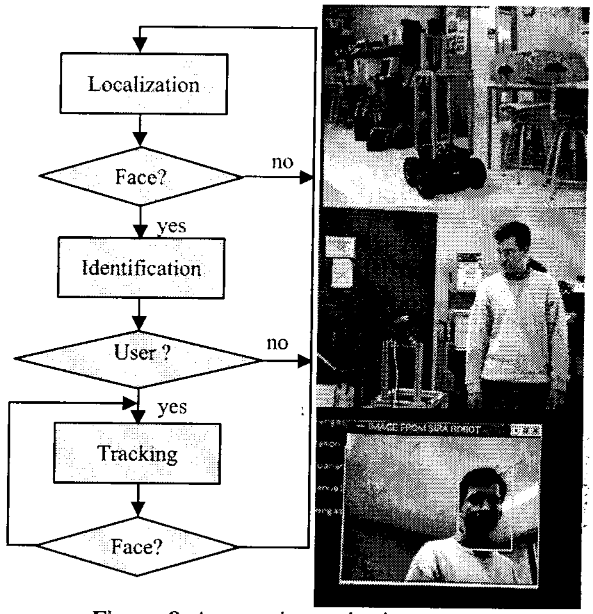

Figure 8. Automatic monitoring system

As face recognition algorithm we have used an embedded Hidden Markov Model (HMM) [11] which reduces computational complexity and thereby process time. The most significant facial features of a frontal face image include the hair, forehead, eyes, nose and mouth. Furthermore, these features occur in a natural order, from top to bottom, even if the images undergo small rotations. Therefore, the image of a face may be modeled using a HMM by assigning each of these face regions to a state. Our embedded HMM uses observation vectors that are composed of 2D Discrete Cosine Transform (DCT) coefficients obtained for each of the face regions.

Social interaction. When the user lives alone is deprived of social interaction. Social engagement can significantly delay the deterioration and health-related problems. Robots cannot replace humans but can help to endure solitude by providing a communication interface with relatives and friends increasing the user contact with the outside world.

3. Current Project Status

We have developed a first robotic prototype shown in figure 1 with the environment perception sensors and human machine interfaces as we have explained. Regarding the navigation system, this is capable of successfully performing its guidance missions in highly symmetrical and complex environments, as has been demonstrated with several experiments in the map of figure 3 (with 520 states, 88 of them corresponding to rooms), that has two identical vertical corridors. Figure 3 shows a guidance example from room 27 to room 21, in which the initial room is unknown. The success rate reaching destination rooms with unknown initial position is about 96%. The ability of global localizing the robot with unknown initial position ensures that the navigation system is also capable of recovering global localization faults. This property ensures the required level of robustness and autonomy needed for the final application. At the moment the navigation system has been tested in complex simulated environment and in a real corridor with the robotic prototype.

The tele-presence, tele-medicine, intelligent reminding and social interaction services have been tested with technical users in a PC outboard the robot, obtaining good results. The automatic monitoring service has been tested on board a preliminary second prototype over an embedded Pentium III processor at 800 Mhz. The face detector reliably finds faces under a wide range of viewing and lighting conditions and runs at 5 images per second. The face tracker works at 20 fps. This rate is sufficient to track people's faces even when they are moving rapidly. The face recognition system is invariant for a large range of orientations, gestures and face appearances. Furthermore, it can be used for modeling faces of different sizes without pre-scaling of the images. It requires approximately 300 ms per image using a small database of 100 images (10 users and 10 images per user) with a resolution of 120x100 pixels. The recognition performance of this method is around 90%.

4. Conclusions and future works

This paper reported the initial design and results of a mobile robot called SIRA aimed at the elderly population. In the future we want to adapt and test our navigation system to a complex and real environment. Then, we want to incorporate all the high level services into the two processors onboard the robot, to complete the measure systems of vital parameters and the automatic monitoring system, developing a computer vision algorithm for detecting dangerous behaviour of the users.

While the robot and services has not yet been tested with elderly people, in the future we have the intention to do that in order to adapt our system to the real problems of the elderly.

Acknowledgments

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