A Description of the SENA Robotic Wheelchair

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***Abstract*— This paper describes a robotic wheelchair called *SENA*. It is based on a commercial powered wheelchair which has been endowed with several sensors and devices managed by an onboard laptop. The sensorial system of SENA entails a proximity laser scanner, a ring of infrared sensors, a camera mounted on a pan&tilt unit, and two rotating sonars. SENA is a long-term project aimed to cover the requirements needed to perform in daily indoor environments. Some experiences of the use of our robotic wheelchair are also described at the end of the paper.**

I. INTRODUCTION

Assistant robots are those robots that relieve people of dealing with certain daily works. Thus, they must perform within human environments interacting closely and intelligently with them. Some examples of assistant robots are house clean and keeper robots, tour guiders, assistant robots for elderly people such as robotic wheelchairs, etc. All of them must possess two remarkable qualities to serve people. First, the work of assistant robots must be dependable, that is, they have to carry out their tasks properly without damaging surrounding people, and second, they must be easily commanded by humans.

Recently, the Human Centered Robotics (HCR) concept has emerged to cope with some of the specific requirements of assistant robots [11], [15]. Within the HCR context, the two qualities commented before, dependability and human-friendly interaction are identified as the most important topics to be considered. Dependability refers to physical safety for both people and the robot, as well as to other desirable characteristics such as operating robustness and fault tolerance. On the other hand, human-friendly interaction implies the capability of commanding the robot easily as well as reporting execution information in a proper human way. It is important to remark this latter topic since assistant robots are designed to serve non-expert people who prefer to communicate and to interact with machines in the same manner that they do with other people.

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A special case of assistant robots are robotic wheelchairs for impaired or elderly people. In this kind of applications which exhibit a close tie between the robot and the user, dependability and user-friendly interaction are critical issues.

Figure 1. The SENA robotic wheelchair. While designing SENA, we have paid special attention to the positioning of the onboard sensors and devices in order to keep as free as possible the user space while preserving their functionality.

In this paper we describe the robotic wheelchair SENA developed within a long-term research project to provide elderly or impaired people with high levels of dependable mobility, and human-like communication capabilities.

In the robotics literature, several works have been done in the design of robotic wheelchairs [1], [13], [14], [17], and in the improvement of human interfaces for vehicle guidance, such as voice recognition, eye- or face-movement commanding, breath-expulsion mechanisms, etc. [13], [14], [9], [1]. Here we describe a different approach, in which a special attention has been paid to endow SENA with a comprehensive sensorial system managed by a robotic architecture [5] that provides human-friendly interaction and high dependable performance.

The rest of the paper is organized as follows. Section 2 gives a general description of SENA, delving into its hardware design. Section 3 describes some real experiences with SENA in a real scenario. Finally, section 4 outlines some conclusions and future works.

II. HARDWARE OF SENA

The SENA robotic wheelchair (see figure 1) is based on a commercial powered wheelchair (Sunrise Powertec F40 [20]) that has been equipped with several sensors to reliably perform high-level tasks in indoor environments. Sensors of SENA are managed by a laptop computer which can also connect to remote stations via Wi-Fi.

The hardware components of SENA are depicted in figure 2. Notice that the original wheelchair which SENA is based on has undergone minimal modifications. We use the original controller and motors, although two encoders have been connected to the motors' axis to estimate the wheelchair odometry. The original battery volt meter, as well as the joystick line, have been bypassed to the microcontroller. A switch multiplexes the input of the motor system between the joystick signal and the output of the computer control (although this change of control can also be performed through a verbal command). This allows the user to disable the autonomous navigation of SENA in order to take control at any time.

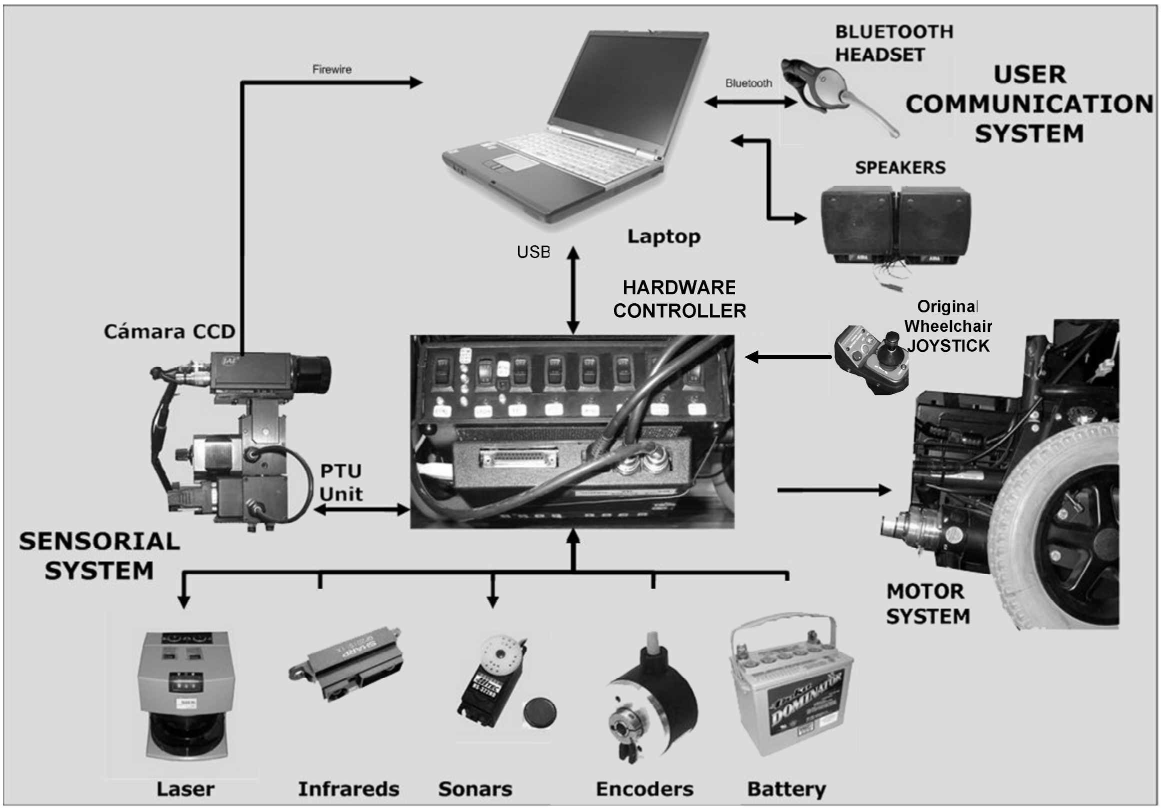
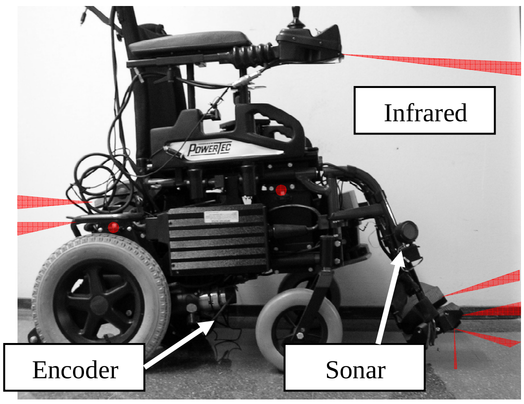


Figure 2. Scheme of the hardware of SENA. Low-level control of sensors and motors is carried out by a microcontroller that provides a high-level interface to the software running in the laptop. Our design provides high flexibility, since the user can work on her/his personal computer (i.e., checking for her/his email) at the same time she/he is using the vehicle.

All devices and sensors of SENA are managed by a laptop which is connected to the vehicle microcontroller via USB (see figure 2). This microcontroller serves as an interface to the different components of SENA and implements the motion control of the vehicle. In the following, we detail sensors and devices.

- A *180º radial laser scanner (PLS)* is placed in front of the wheelchair, mounted on a retractile mechanism between the user legs for avoiding any nuisance to her/him. The use of this kind of sensory devices is widely extended in mobile robots since they exhibit a high precision and short period of scanning. In our application the laser scanner is employed to check for mobile obstacles, for environment map construction [7], and for robot localization [18].

a)



b)

Figure 3. Two views of SENA. It shows the area scanned by the ring of infrared sensors.

- A *ring of thirteen infrared sensors* are placed around SENA to detect close obstacles when the wheelchair is maneuvering. Infrareds are small and cheap sensors which provide an operational range between 10 and 70 centimetres. Two of them are located underside of the wheelchair to check for portholes, kerbs, stairwells, etc. Other two infrared sensors are located in the backside to avoid possible obstacles when SENA moves backwards (see figure 3).

- *Two ultrasonic rotating sensors* are also located in the front of SENA. Each one is mounted on a servo which enables it to scan a range of 180º. Ultrasonic sensors present lower precision than the PLS and its scanning period is higher, however they complement the PLS readings since they survey at a different height and can detect transparent and narrow objects which may not be properly captured by laser sensors.

- A *CCD camera* mounted on a pan-tilt unit serves to localize SENA [16]. In contrast to sensors commented before, the CCD camera is placed at a high position, imitating the position of the human eyes at stand-up, where perceived elements of the environment are nearly static (walls, furniture, etc.). Currently, we are working on detecting obstacles with this camera too.

The selection and location of SENA's sensors are aimed to provide fault tolerance and robust operation. Some critical tasks like obstacle detection or localization make use of the redundant and complementary information provided by them ([7], [16], [18]).

The vehicle accounts for two small speakers and a bluetooth headset that allow communication with the user through a speech generation [21] and a voice recognition software [10]. This verbal communication supported by a proper symbolic world model ([2], [8], [12]) provides a high-level human-like communication (please refer to [3], [5] for further explanation).

III. EXPERIENCES WITH SENA

SENA has been largely tested within office-like environments. In our experiences, after a training phase in which the user teaches the environment structure to the vehicle, SENA is ready to safely navigate to the distinctive places indicated in a human-friendly manner (please refer to [3]).

Figure 4 shows some images taken from our experiences with SENA. The successfully performance of SENA hinges on a software architecture called ACHRIN [5] which provides, among other features, the human participation into al levels of the robotic system. For example, in our experiences, the user of the wheelchair can warn the robot about any risk, i.e. collision, giving extra information to the sensorial system of the vehicle. ACHRIN, based on its internal world model, can also foresee the participation of the human to overcome some situations in which the vehicle can not continue by itself, for example, to open a close door. In these cases, SENA stops in front of the door asking the user for help. In other cases after a navigational failure, ACHRIN realizes that the human help is needed, and thus it verbally inquires the user to manually guide the vehicle to the destination.

The human can also interact with SENA to decide the path, that is, the sequence of rooms and corridors to arrive a destination [6].

Figure 4. Experiences with SENA. Some of them are taken from live-TV shows.

IV. CONCLUSIONS AND FUTURE WORK

This paper has described SENA, a prototype of robotic wheelchair for impaired and elderly people. We have also identified the main features required by assistant robots in general.

The current development of SENA provides a relevant solution to improve disabled people with dependable mobility and human-like communication. Thus far, SENA has navigated within a real, but controlled scenario since it still exhibits some limitations that prevent it to operate in a fully autonomous manner within daily and crowded scenarios. Mainly, in this type of environment, failures occasionally occur in estimating the robot location.

Our final goal is to achieve a completely robust and dependable robotic wheelchair able to interact intelligently with people in a daily environment.

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