SANCHO, a Fair Host Robot. A Description

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***Abstract*—This paper describes SANCHO, a mobile robot intended to perform within crowded areas as a servant, for instance as a fair or congress host. This robot has been constructed upon a commercial platform on which a number of sensors and devices have been integrated. A software control architecture has been implemented and adapted to this particular robot, enabling it to perform in human scenarios. Among the different subsystems of the control architecture developed for SANCHO, we highlight in this paper two of the most relevant ones: the *navigation component* which permits the robot to navigate in a safe and robust manner within crowded and dynamic environments, and the *communication component* which provides different possibilities for human-robot interaction. We illustrate the performance of SANCHO through a number of experiences carried out in public shows.**

Keywords-Mobile robotics, entertainment robots.

I. INTRODUCTION

In the last years, robots are becoming a significant part in our society, providing a valuable assistance in a variety of fields. Some examples are their use for taking care of elder people ([1], [26]), assisting in surgery ([12], [24]), education ([17], [20]), entertainment applications ([21], [9]), etc. However, all these are only sporadically found in practical applications due to the difficulties and constraints that entail the inclusion of robots in the daily life.

A clear example that reveals such difficulties is the use of a mobile robot as a museum or fair assistant. For this application, the performance of a robot within a highly dynamic and crowded scenario, where it has to interact with a number of people acting in an unpredictable way, become an exceptional challenge. Some works striving this challenge can be found in [23][13].

The minimum requirements needed by robotics applications within human environments are treated by the Human Centered Robotics (HCR) paradigm ([16], [5]). Among the different questions considered by this paradigm, two important issues highlight: *dependability* and *human-friendly* interaction. Dependability refers to physical safety for both people and robots, as well as to operating robustness and fault tolerance. Human-friendly communication, in turn, implies the capability of easily commanding the robot as well as reporting execution and useful information in a proper human way.

In this paper we present SANCHO (see figure 1), a mobile robot intended to work within human environments as a conference or fair host. It is constructed upon a Pioneer 3DX platform [19], on which different elements are integrated. A structure has been mounted on the platform in order to support the sensory system, which comprises, among other devices, a radial laser scanner, a set of infrared sensors and a motorized color camera. The human-robot communication system entails a pair of speakers, a microphone and a tactile color screen for displaying information as well as for human-robot interaction. All the elements of SANCHO are managed by an onboard laptop, which can communicate with remote stations via wireless Ethernet. Please refer to the detailed description of the hardware of SANCHO in Section 2.

Figure 1. The SANCHO service robot structure. Sancho is constructed upon a commercial mobile platform. Among other capabilities it can project video and interact with users through tactile and voice interfaces.

The general performance of SANCHO is controlled through a software architecture called ACHRIN [11], an set of software components that fits on the HCR paradigm. This architecture features SANCHO to manage high-level information about its workspace, e.g. "*my recharging station is at the end of the corridor #3*", and to reasoning about it to plan and execute general tasks such as "*I need to go to the stand-19 to ask Peter for more brochures to deliver*".

SANCHO has demonstrated its abilities in a number of public demonstrations and live TV shows having been used for state-of-the-art robotics research in the last years ([1],[3],[10]). In the rest of this paper we describe the hardware of SANCHO (in Section 2), then in Section 3 we discuss the software architecture focusing on the navigational subsystem of the robot and on its capabilities to communicate and interact with people. In Section 4, some of the performances of SANCHO are illustrated. Finally, Section 5 concludes outlining some future work.

II. HARDWARE OF SANCHO

SANCHO has been constructed utilizing commercial and standard devices. It uses a PIONEER 3DX mobile platform on which a three tiered structured is mounted to contain sensors, devices and auxiliary circuits (see figure 2).

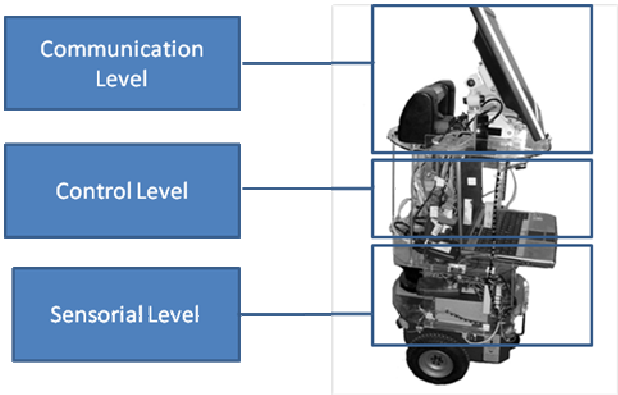

Figure 2. General structure of SANCHO. The sensory level contains most sensors and devices of the robot. In the control level a laptop is placed to control the performance of SANCHO. Finally, the communication level holds devices for human-robot interaction.

A. Lowest Level. Sensorimotor system of SANCHO

On the lowest level, the closest to the floor, two auxiliary batteries are placed as well as the following sensors:

- A SICK PLS [22]; this radial scanner is used for mapping, localization and obstacle detection. It is managed by a specific circuit designed to enhance the communications between the laser and the laptop of SANCHO, providing USB connectivity, timestamps and filtering of wrong frames (see figure 3).

Figure 3. Left) SICK laser scanner. Right) Auxiliary circuit that manages the laser readings and sends them via USB to a PC.

- A Hokuyo laser scanner [15] (see figure 4) placed in the rear part of the platform for improving vehicle maneuvering. This small sensor also helps in the map construction process as well as in robot localization. Its location permits the detection of moving obstacles, e.g. people, approaching the robot from its back.

Figure 4. Hokuyo laser. This small sensor provides high-resolution measurements in a short range (4 metres).

- A set of five infrared sensors around the platform to detect close obstacles. An auxiliary circuit has been also developed to efficiently receive and communicate sensors' reading to the laptop through USB (see figure 5).

Figure 5. Left) Infrared SHARP sensor. Right) Auxiliary circuit to manage the meassurements from all the sensors and communicate them to the laptop via USB.

- Finally, depending on the application the lowest part of SANCHO may allocate two artificial noses constructed from scratch using TGS Figaro gas sensors [8]. Each nose consists of four of these sensors placed in a circular formation on a plastic backing (see figure 6). The sensors are fitted inside a retractable plastic tube sealed with a fan that provides a constant airflow into the tube. Readings from the gas sensors are collected by an onboard data acquisition system.

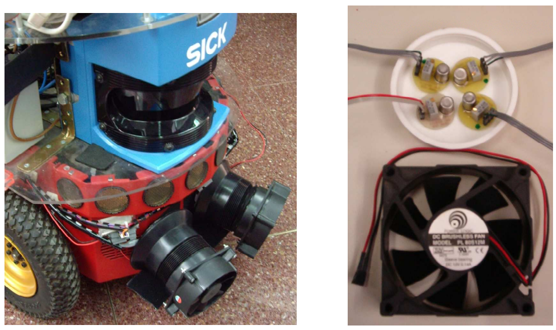

Figure 6. Left) Lowest part of SANCHO showing the two noses. Right) The formation of the four gas sensors for one of the noses and the cpu fan.

B. Control Level

The middle layer of the SANCHO hardware structure contains a conventional laptop for executing the control software as well as for processing information from devices and sensors through standard connections, i.e. USB and Firewire. The laptop is connected to remote stations and Internet through wireless.

C. *The Highest Level. Communication system of SANCHO*

The top tier of SANCHO contains the elements involved in the human-robot interaction:

- A tactile screen that permits people to visually command the robot at the same time it shows interesting information related to the considered application. For instance, if the robot works as a fair host, information about the different stands and advertisements about the products exhibited in the fair can be shown in the display.
- The voice interface is composed of two speakers and a set of three microphones to permit SANCHO to orientate itself towards the main source of audio, i.e. the person who is talking to it.
- A motorized colour camera is placed on front of the robot for remote teleoperation and control of the robot when needed.
- Finally, another set of five infrared sensors are also located in this layer for increasing robustness and safety.

III. SOFTWARE OF SANCHO

Next we describe the control architecture in charge of managing all the subsystems of the robot. After that, in section B, we focus on the navigation subsystem which accomplishes one of the most critical tasks of the robot: navigating within crowded areas in a safety and robust manner.

A. *ACHRIN*

ACHRIN, Architecture for Cognitive Human-Robot Integration, is a layered robotic architecture [11] aimed to ensure robustness operation and human-robot friendly interaction, i.e. the topics highlighted by the HCR paradigm. The main features provided by ACHRIN are:

- Human and robot can communicate in a human-like manner. The robot can share part of the human symbolic world model, and thus, people and robot can univocally refer to the same world concepts: objects, places, etc. using their names in a common language [7]. This is achieved through the use of a hierarchical and symbolic representation of space.
- Humans can extend the robot capabilities with new skills. These skills may range from complicate low-level motions to high-level decision-making, for instance to open a door, to warn the system about risky situations undetectable by the robot sensors, to plan the most convenient path to arrive a destination, etc.
- Humans can perform the actions initially assigned to the robot in different and sometimes, more dependable ways. For example, a human can recover the robot from a navigation failure by manually guiding it to a well known location where the machine could continue navigating autonomously.

More deeply, ACHRIN is a hybrid robotic architecture made up of a number of software components, called modules, which are grouped into the classical three layers, i.e. *deliberative*, *control*, and *functional* (see figure 7).

The *deliberative layer* maintains a symbolic representation of the robot workspace and produces plans to achieve robot goals. It also provides a cognitive human-robot integration thanks to a shared hierarchical world model [6].

The *executive and control layer* supervises the execution of plans managing the information collected from the functional layer and the robot's sensors. It tunes the behaviour of the robot with respect to the dangerousness of the situations detected by the sensors, i.e., collision.

Finally the *functional layer* is composed of a number of modules which physically perform robot actions. For the particular case of SANCHO, the functional layer only contains the navigational component which is described in section III-B and a text-to-speech module for voice synthesis [25].

More detail about the ACHRIN architecture can be found in [11]. The next section focuses on the navigational module developed for SANCHO. Section III-C describes the three different ways of commanding our robot: via-voice, via-Messenger, and via-StateCharts.

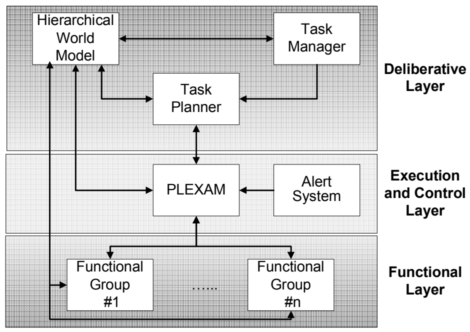

Figure 7. A general view of ACHRIN.

B. *The Navigation Subsystem*

This software component is in charge of taking the robot to a given target position, while avoiding potential collisions along the path. The target is typically provided as a pair of Cartesian coordinates (x,y), which is not an appropriate format for human-robot interactions. Hence this subsystem receives the commands from the ACHRIN architecture, which is in turn responsible for the proper translation of human-friendly commands, such as “Go to office 14”, into the corresponding numerical coordinates.

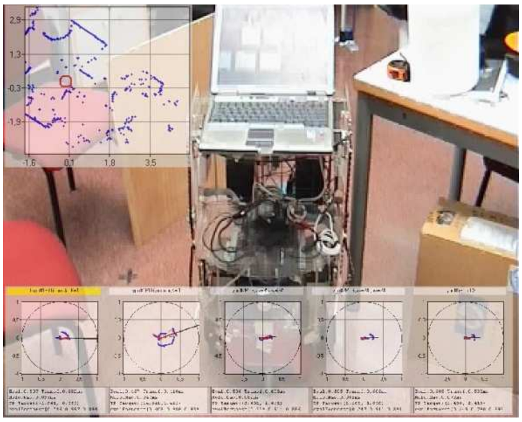

Figure 8. A demonstration of Sancho's navigation capabilities. The upper-left graph displays a snapshot of the 2D obstacle points detected by both laser scanners, and the five plots at the bottom show these obstacles into different transformed spaces which help the obstacle avoidance.

We approach the problem of path planning under the perspective of *reactive* navigation [1]. In this paradigm, the robot actions are governed by relatively simple rules in response to the *immediately* sensed obstacles. Figure 8 shows a screenshot of SANCHO navigating in a crowded scenario where the generated maps and the selected path are overprinted.

Several obstacle avoidance methods have been proposed in the literature in the last two decades, many of them focusing on the hard problem of robots like SANCHO, where motor actions are non-holonomic and the robot shape is not exactly circular. The technique that addresses these issues on SANCHO is based on Parametrical Trajectory Generators (PTG), an approach reported by the authors elsewhere [1]. In short, the underlying idea is to abstract both the geometry of feasible paths (e.g. curve arcs) and the robot shape into a space transformation, in such a way that simpler obstacle avoidance methods (designed to deal with circular, holonomic robots) can now be used to determine the next robot movement into the transformed space. For further details or navigation experiments carried out with SANCHO, please refer to [1].

We must remark that this navigation module is general enough to be successfully applied to other robots, for instance to robotic wheelchairs [1].

C. *Human Interaction with SANCHO*

The Task Manager module from the deliberative layer of ACHRIN is in charge of managing all the requests to be planned and carried out by the robot. In our current implementation we consider three channels to command SANCHO: 1) via voice, 2) via a graphic tool to design robot missions, and 3) via textual communication through standard messenger tools. SANCHO communicates to the user utilizing the same channel, except, obviously, for the second option in which the robot provides information about its execution verbally.

Next, the implemented software for coping with these three channels of interaction with SANCHO is described.

Communication with SANCHO via voice

For verbal communication we have relied on commercial tools. Verbio technology [25] has been considered for voice synthesis and recognition. For the latter, a grammar is automatically generated based on the information stored in the symbolic representation of the robot workspace. That is, we automatically customize the grammar used for improving voice recognition according to the specific application entrusted to SANCHO.

Designing missions for SANCHO

SANCHO accounts for a visual tool that permits non-expert people to design robot missions by combining simple robot tasks by means of StateCharts [14] (see figure 9).

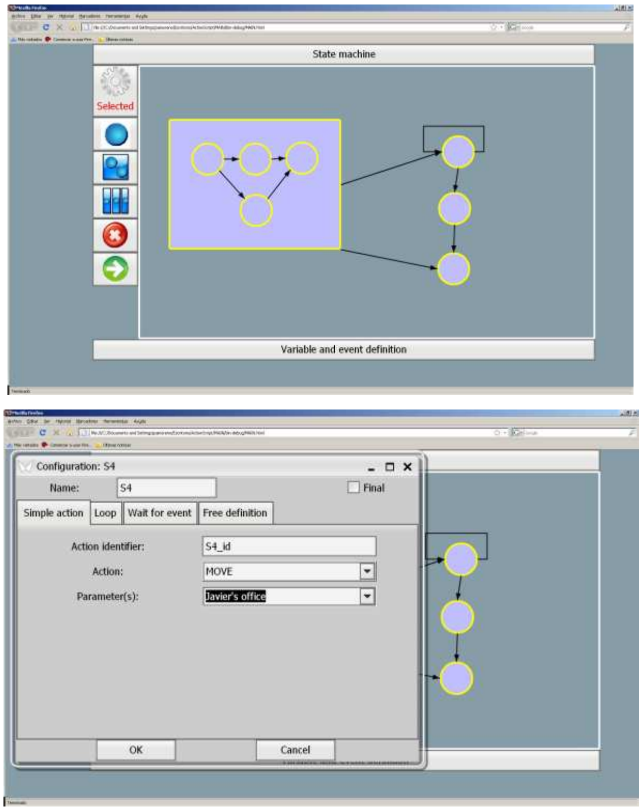

Figure 9. Statecharts Graphical Interface. Through this interface the user can graphically define missions for SANCHO. Up) a robot mission that includes loops and a macro state. Down) the definition of a move command .

Through this visual tool, operated through the tactile display of the robot, the user can insert a number of states, each one containing a list of robot tasks. Such tasks are picked from a list of all available robot operations and their allowed parameters. Transitions between states are also inserted by specifying the conditions that trigger the starting of a new state. Among others, the main features of this programming tool are:

- *Possibility of parallel states*. The robot can perform different operations at the same time, for instance, moving and speaking.
- *Macro-states*. The user can create a super state including a number of child states.

- *Transitions can hold conditions and loops over variables created by the user*. For instance a state can be set to be executed 4 times or while a variable, updated by other state, reaches a certain value.

SANCHO as a Messenger Contact

An interesting feature of SANCHO is that it can connect to messenger clients and interact with its contacts (see figure 10). The Agenda component of ACHRIN has been enhanced to access Microsoft Messenger Live [18] and to interpret messages received by any contact of the robot. When connected, the robot SANCHO appears as a normal contact that responds to the commands listed in table 1.

TABLE I. SANCHO INTERACTION THROUGH MESSENGER

Command	Description
Help	Reports a full version of this table
Retrieve file	Ask SANCHO to send a particular file
Change directory	Access and navigate through the SANCHO file system
Get World Info	Access to the internal world representation
Execute Task	Add a task to be perform in the SANCHO chores' list

Figure 10. Sancho as a Messenger contact. Left) Sancho connects to Internet as a contact of standard messenger applications. Right) An example of interaction using Windows Messenger Live.

By means of the set of commands accepted by SANCHO, a remote user can interact with the robot in the same manner as in the situations commented in previous sections (via voice and via statecharts). Moreover, SANCHO automatically accepts any incoming request for receiving files (useful for updating any internal file) and for video calls, which permits the remote user to monitor the performance of the robot at the same time that communicating with any person in the workspace.

IV. EXPERIMENTS AND DEMONSTRATIONS

SANCHO has been the main character in many public demonstrations, some of them in live TV shows. One of the main features of SANCHO is its versatility for playing different roles according to the desired application. This is achieved through the different channels of interaction with the robot (as commented previously) and the use of a generic representation for the workspace. For instance, figure 11 shows a performance of SANCHO in an auditory, interacting with an anchorman.

Figure 11. SANCHO performance in the auditory of the Computer Science building of the University of Málaga.

In other demonstration, (see figure 12), SANCHO was configured to work as a surveillance agent within an office environment. In this case, the robot carried out delivering tasks at the same time that pursued the fulfillment of basic norms, like for instance no smoking.

Figure 12. SANCHO performance in an office environment interacting with people.

V. CONCLUSSIONS AND FUTURE WORK

In this paper we have described the mobile robot SANCHO, a long-term project that has occupied our research efforts during the last years. The final result is a robot able to perform within human scenarios in a robust and safety manner, carrying out a variety of different tasks.

A special emphasis has been made in the hardware design of SANCHO, properly selecting sensors and devices that provide robust navigation and human-friendly interaction. Regarding the latter, three different channels for communication have been developed achieving a high level of user satisfaction when interacting with SANCHO.

In the future, we plan to extend the robot abilities for communicating with other devices, for instance, in a domotic environment, as well as enhancing its performance with manipulation.

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REFERENCES

[1] Arkin R.C., Behaviour-Based Robotics. Massachusetts Institute of Technology, 1998.

[2] Blanco J.L., González J., and Fernández-Madrigal J.A.. Extending Obstacle Avoidance Methods through Multiple Parameter-Space Transformations. Autonomous Robots, vol. 24, iss. 1, pp. 29–48, 2008.

[3] Blanco J.L., Fernandez-Madrigal J.A., and Gonzalez J., Towards a Unified Bayesian Approach to Hybrid Metric-Topological SLAM, IEEE Transactions on Robotics, vol. 24, nº2, pp.259-270. 2008.

[4] Dong H., Hyun S. Han J., and Myung J. Human-friendly care robot system for the elderly. Proc. of the Eight Int. Conf. on Rehabilitation Robotics. ICORR 2003.

[5] Dorais G., Bonasso R.P., Kortenkamp D., Pell B., and Schreckenghost D. Adjustable autonomy for human-centered autonomous systems on mars. Mars Society Conference, 1998.

[6] Fernandez J.A., and Gonzalez J., Multi-Hierarchical Representation of Large-Scale Space. Kluwer Academic Publishers, 2001.

[7] Fernandez J.A., C. Galindo and J. Gonzalez. Assistive Navigation using a Hierarchical Model of the Environment. Integrated Computer-Aided Engineering Vol. 11, No.4, 2004, pp. 309-322.

[8] Figaro gas sensor. http://www.figaro.co.jp

[9] Fujita, M., Juroki, Y., Ishida, T., and Doi T. A samll humanoid robot SDR-4X for entertainment applications. Proc. Of Advanced Intelligent Mechatronics, pp. 938-943, 2003.

[10] Galindo C., Fernández-Madrigal J.A., and González J. Multihierarchical Interactive Task Planning. Application to Mobile Robotics" IEEE Transactions on Systems, Man, and Cybernetics, part B, vol. 38, iss. 3, pp. 785–798, 2008.

[11] Galindo C., Gonzalez J., and Fernandez-Madrigal, J.A. A Control Architecture for Human-Robot Integration: Application to a Robotic Wheelchair. IEEE Trans. On Systems, Man, and Cybernetics Part B., vol. 36, n.5 pp. 1053-1067.

[12] Glauser D., Fankhauser H., Epitaux M, Hefti J., and Jacottet A. Neurosurgical Robot Minerva: First Results and Current Developments. Journal of Image andd Surgery, vol 1 pp. 266-272, 1995.

[13] Goldberg S. and Bekey A. Online Robots and the Remote Museum Experience. In Beyond Webcams: An Introduction to Online Robots. MIT Press, 2002, pp. 295 - 305.

[14] Harel D. StateCharts, (1987). A Visual Formalism for complex Systems. In Science of Computer Programming, vol. 8.

[15] Hokuyo homepage. http://www.hokuyo-aut.jp

[16] Khatib O. Human-centered robotics and haptic interaction: From assistance to surgery, the emerging applications. Third International Workshop on Robot Motion and Control, November 2002.

[17] Lixiang Y., Pui T., Quan Z., and Huosheng H. A Web-based Telerobotic System for Research and Education at Essex, 2001 IEEWASME International Conference on Advanced Intelligent Mechatronics, 8-12 July 2001 Como, Italy, pp.284-289.

[18] Microsoft Live Messenger. http://microsoft.com

[19] Mobile Robots Inc. http://www.activrobots.com

[20] Safaric R., Sinjur S., Zalik B., and Parkin R.M. Control of Robot Arm with Virtual Environment Via the Internet. Proc. of the IEEE, 91(3), March 2003 pp. 422 – 429.

[21] Schraft R., Graf B., Traub A., and Dirk J. A mobile robot platform for assistance and entertainment. Industrial Robot: An International journal, vol. 28, nº1, pp. 29-35, 2001.

[22] SICK homepage. http://sick.com

[23] Thrun S., Beetz M., Bennewitz M., Burgard W., Cremers A., Dellaert F., Fox D., Hahnel D., Rosenberg C., Roy N., Schulte J., and Schulz D. Probabilistic algorithms and the interactive museum tour-guide robot Minerva. Journal of Robotics Research, 19(11), pp. 972-999, 2000.

[24] V. F. Muñoz, J. Gómez-de-Gabriel, J. Fernández-Lozano, I. García-Morales, C. Vara, C. Pérez-del-Pulgar, M. Azouaghez. Development of a telerobotic camera manipulator for laparoscopic surgery. 15th Triennial World Congress, Barcelona, Spain, 2002.

[25] Verbio Speech Technologies. http://www.verbio.com

[26] Wada, K., Shibata, T., Saito, T., and Tanie K. Robot assited activity for elderly people and nurses at a day service center. IEEE Int. Conf. in Robotics and Automation 2002, vol.2 pp 1416-1421.