Development of the RobChair Assistive Navigation System

We are moving to the goal of intelligent service robots that can assist people in their daily living activities. Disabled, elderly and chronically ill population can greatly benefit from the advances in Rehabilitation Robotics. The development of new multi-modal Human-Machine Interfaces (HMI) and new guidance systems are current research robotic trends towards Human-Oriented Robotics. One of the main goals is to reduce humans efforts to control, communicate, and interact with robotic systems. Particularly, HMI plays an important role in assistive technology, i.e. technology that contributes for disabled and elderly social integration and independence, with the level of dignity that they deserve. This paper presents Robchair project under development at the Institute for Systems and Robotics (ISR-Coimbra). A voice unit interface (VUI) is used to command a powered wheelchair which is equipped with a reactive control system to assist user in steering the wheelchair.

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1 Introduction

The use of powered wheelchairs with high manoeuvrability and navigational intelligence is one of the great steps towards the social integration of severely physically disabled and mentally handicapped people [1,2,3,4,5]. Driving a wheelchair in domestic environments is a difficult task even for a dextrous person. It becomes even more difficult for people with arms or hands impairments. Tetraplegic people are completely unable to operate a joystick unless they use the tongue or the head and eyes movements, which is obviously a very tedious task. Simultaneously blind and paraplegic people deal with a very uneasy situation which couples two problems: locomotion and localisation. In the ISR-Coimbra, research is being carried out towards the development of an intelligent control system for Human-Oriented Mobile Robots (HOMR). Figure 4 presents the major components of the control architecture under development. Parts of it have been tested in a motorised semi-autonomous wheelchair prototype being developed under the Robchair project running in ISR-Coimbra [1]. The main goal is to develop control techniques and methods which can be applied to improve for instance the wheelchair navigation autonomy, with safe and smoother steering, and thereby to reduce users effort. These set of augmented functionality's make it possible the accomplishment of some important tasks in daily life.

2 Hardware Architecture

Our experimental platform is a Vector Mobility™ powered wheelchair with two motorised rear wheels, casters in front, and a fifth rear wheel connected to the back of the wheelchair with a damper. The wheelchair was equipped by the Kiss Institute for Practical Robotics (KIPR) with 12 ON/OFF infrared sensors, a front bumper, and a MC68332 based microcontroller for sensor data acquisition, joystick signal readings and

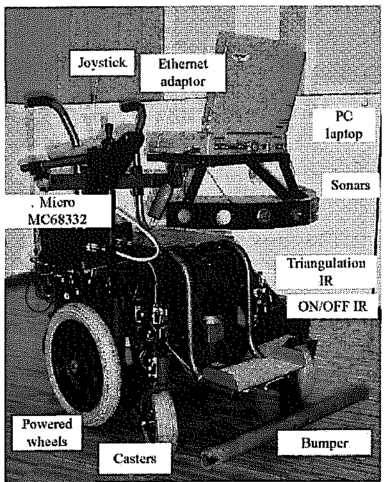

Figura 1 Picture of RobChair

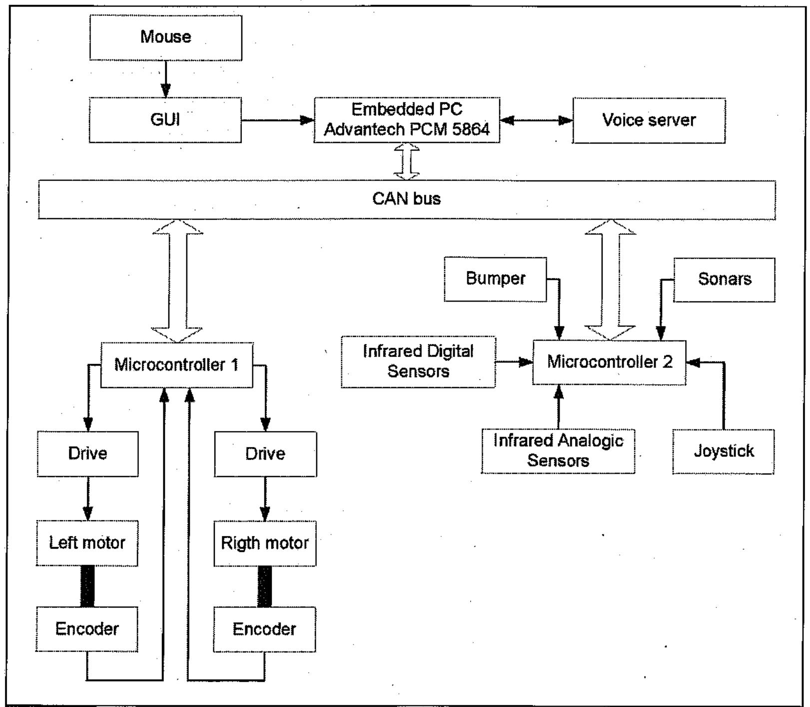

Figura 2 CAN based hardware architecture

motor control. Additionally at the ISR laboratories, the sensorial system was improved. Specifically, 12 analogic triangulation based infrared sensors, optical encoders on wheels, and 7 sonars were introduced. The MC68332 microcontroller, used for low level tasks, was connected via RS232 to a PC laptop with Linux for high level processing and to run navigation algorithms (see figure 1). However, currently, a new hardware and software architecture is being developed allowing a more distributed and modular implementation. Two HC12 microcontrollers based cards are connected through a CAN (Controller Area Network) bus with an embedded PC (Advantech PCM 5864). One microcontroller reads sensorial data and joystick signals. The other reads optical encoders information and executes path tracking and wheels velocity control (see figure 2).

3 Software infra-structure

Figure 3 depicts the RobChair new overall hardware and software infra-structure. The HC12 based microcontrollers communicate with the embedded PC using two CAN communications mechanisms: message queues and shared memory. The embedded PC sends steering commands to microcontroller 1 (see figure 2) via messages queues and receives odometry information using shared memory. Shared memory is also the technique used by the embedded PC to acquire sensorial information sent via CAN bus by microcontroller 2. The embedded PC with RTLinux (Real time Linux) runs three processes that intercommunicate through shared memory: a process that handles the communication with the microcontrollers; • a process that runs navigation algorithms (see section 5); • a Graphical User Interface (GUI) used for sensorial data and wheelchair movements visualisation (see figures 6 and 7).

There is also a speech recognition application running at a station with Windows95. This application recognises a set of voice commands used for RobChair steering, as described in table 1. Currently, we are seeking for a speech recognition solution for Linux. This would significantly simplify our infra-structure (see figure 3).

4 Conceptual architecture

Conceptual RobChair architecture, as shown in figure 4, is organised as a hybrid architecture combining deliberative reasoning with low-level reactive behaviours [5]. Deliberative reasoning provides the system with the ability to reach proposed goals. Reactive behaviours are indispensable to ensure a safe navigation, enabling the vehicle to react in real time to emergent situations in the environment. In most robotics applications, a purposeful navigation depends on the integration and interaction of these two control levels.

RobChair is a specific system integrating closely the human and the machine. The human is a cognitive entity that substitutes parts of the deliberative layer. Presently, without having global environment information, RobChair system is unable of a purposeful navigation without user intervention, so the reason we call it a semi-autonomous system.

The proposed architecture is a four layer distributed architecture: a reactive layer embodying reactive behaviours; a localised action layer for execution of specific tasks dependent of local environment; a deliberative reasoning layer responsible for high-level planning; and finally a mission layer where global goals are defined. The wheelchair user is part of this layer and intervenes in the cognitive state. In this way, the user can define goals for the deliberative reasoning layer, as well as, depending on system state, goals for reactive control layer guidance. The main modules of the conceptual control architecture and their interconnections are illustrated in figures 4 and 5.

Mission Layer - In this layer a set of static or dynamic goals are defined by the user or by other human operator. Examples of deliberative goals might be "go to room B".

Deliberative Reasoning Layer - This layer relies on long-

Command	Description
Forward/Back	Straight forward/backward instruction
Stop	Stop instruction
Left	The wheelchair rotates 30º left
Right	The wheelchair rotates 30º right
TurnLeft	The wheelchair rotates continuously left
TurnRight	The wheelchair rotates continuously right
Fast	Speed increase instruction
Slow	Speed decrease instruction

Table 1

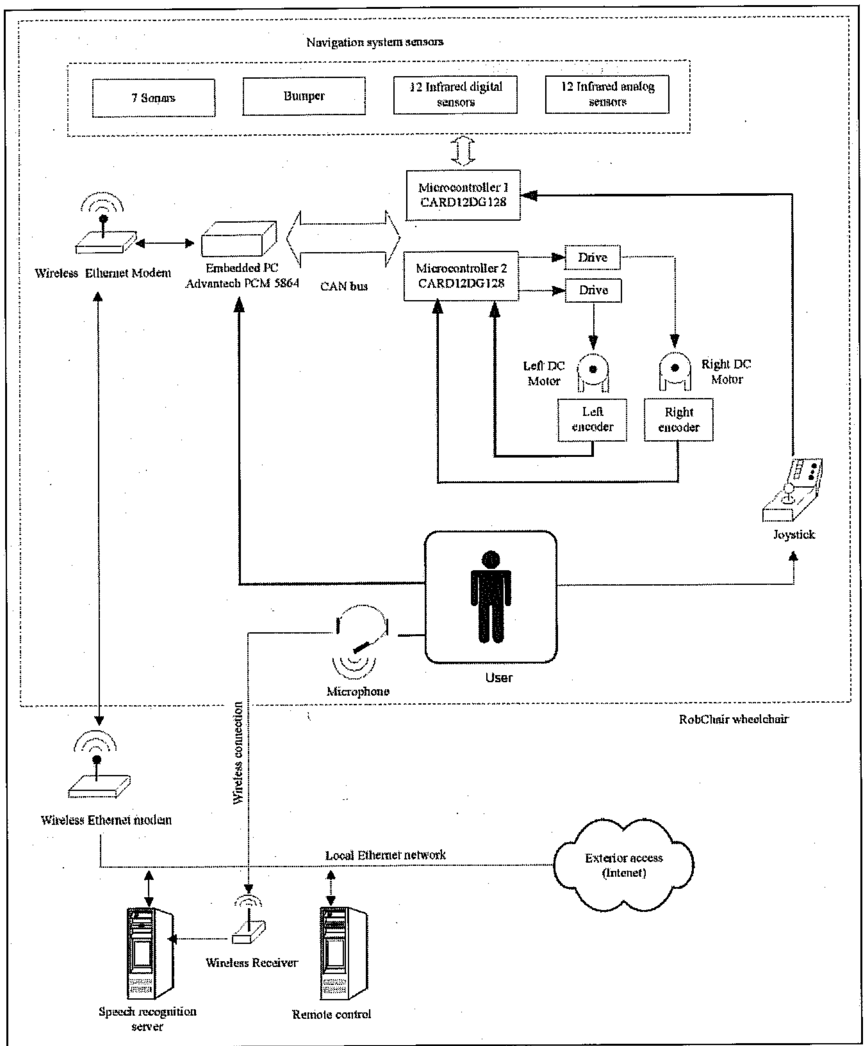

Figura 3 Overall hardware and software infra-structure

short-term memory, which integrates sensory information, in a local map [6], and guidance information from the upper control layers. Two localised action tasks are being implemented: a door-passage and a table/writing desk approaching.

Reactive Layer - This layer, fully implemented, will be described in the next section.

5 Reactive Layer

The reactive layer embodies three behaviours: collision detection, intelligent obstacle avoidance and contour-following (see figure 5). These behaviours rely upon actual sensory information without resorting to environment models. The behaviours are simple, directly coupling perception to action. This layer receives guidance from upper layers. This guidance basically consists on system state information and steering commands. An integration/fusion of the guidance variables and data from each behaviour is carried out in this layer.

The obstacle avoidance is the principal behaviour of the reactive system. It is implemented by means of a fuzzy logic controller that combines user input commands and sensorial information [1]. The controller accepts infrared sensor readings and voice/joystick commands (direction and speed) as inputs. The outputs of the controller are steering commands. The collision detection behaviour consists of simple rules to check front bumper collisions; if the collision detection behaviour comes to action only reverse manoeuvres will be accepted. The contour-following behaviour, also

term memory information, and basically, performs global path-planning providing bottom layers with a set of points defining the path to accomplish the tasks. To perform path-planning it may be required other cognitive capabilities relying on global map updating, integrating over time local maps into the global map, self localisation, etc.

Localised Action Layer - This is an intermediate, short-term memory layer. The action plan relies essentially on

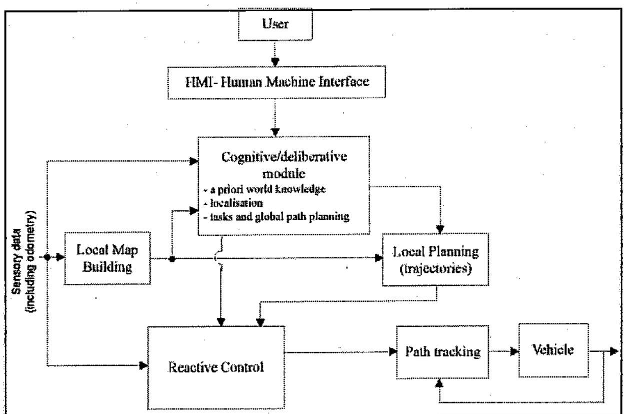

Figura 4 Hybrid architecture

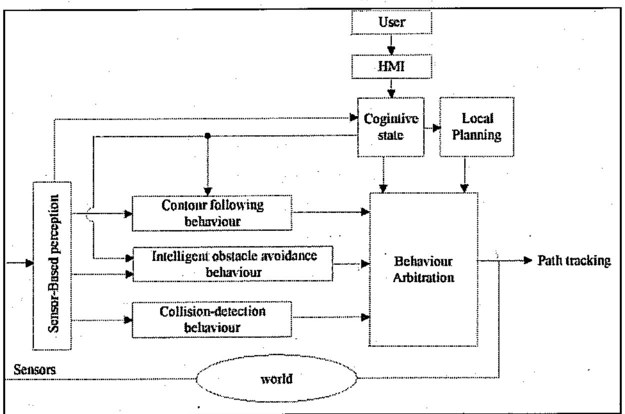

Figura 5 Reactive layer structure

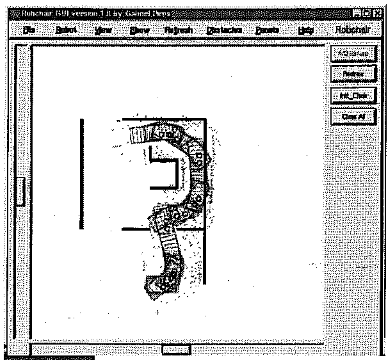

Figura 6 Path that resulted on experiment 1, performed without the reactive module

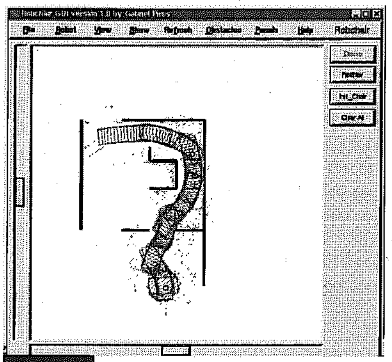

Figura 7 Path that resulted on experiment 2, performed without the reactive module

implemented by a fuzzy logic controller, can be used, for instance, to follow long corridors. By default, the intelligent obstacle avoidance behaviour is the running behaviour. Currently, the contour-following behaviour is activated explicitly by the user.

6 Assistive Navigation

It is practically impossible to steer with simple voice commands a wheelchair without the reactive module. The main reason is that voice commands are provided discretely. A retarded voice command leads to a wrong direction to be taken. Having the reactive based module, assistive navigation is possible. Safe and smooth travel can be achieved even with imprecise joystick commands and inadequate voice commands.

Figures 6 and 7 present results of navigation Experiments 1 and 2 performed with the user on-board the wheelchair. The dimensions of the environment on these experiments was 5 x 7 m. In this figures the representations of the results were constructed from the real sensory and actuation raw data collected during the navigation experiments, and were grabbed from the own GUI of the wheelchair, exactly as they are presented to assist the user. The navigation results of Experiments 1 and 2 (see figures. 6 and 7) were obtained without and with reactive module assistance respectively. In the figures small circles represent the positions where the user provided voice commands. The path travelled in the first experiment was achieved by an experienced user after several unsuccessful trials. The user provided 15 voice commands and suffered one front collision. The second experiment was done with the reactive module assistance. The user just provided 5 voice commands and therefore steered the wheelchair with much less effort. Additionally, the wheelchair described smoother trajectories. The importance of the reactive module to assist the user in navigation was clearly demonstrated in these and many other experiments performed.

7 Conclusions and future work

This article presented an hybrid architecture suited for Human-Oriented Mobile Robots. Currently the Robchair can navigate in dynamic environments in the presence of humans, commanded by simple voice or joystick instructions. The navigation is currently supported by a pure reactive layer, enabling obstacle avoidance and contour-following. An efficient map-building method was developed [6] and is being integrated in Robchair to improve local navigation, i.e improving safety and further reduce the effort of the user. Furthermore, investigation on a new trajectory control and planning system, with application in nonholonomic robotic systems, is being carried out to enhance the navigation capabilities of Robchair, and mobile robots in general.

8 Acknowledgement

This research was partially supported by Fundação para a Ciência e Tecnologia /Ministério da Ciência e Tecnologia, under research project MENTOR, contract: PRAXIS/P/EEI/13141/1998.

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ISSN: 0874-9019

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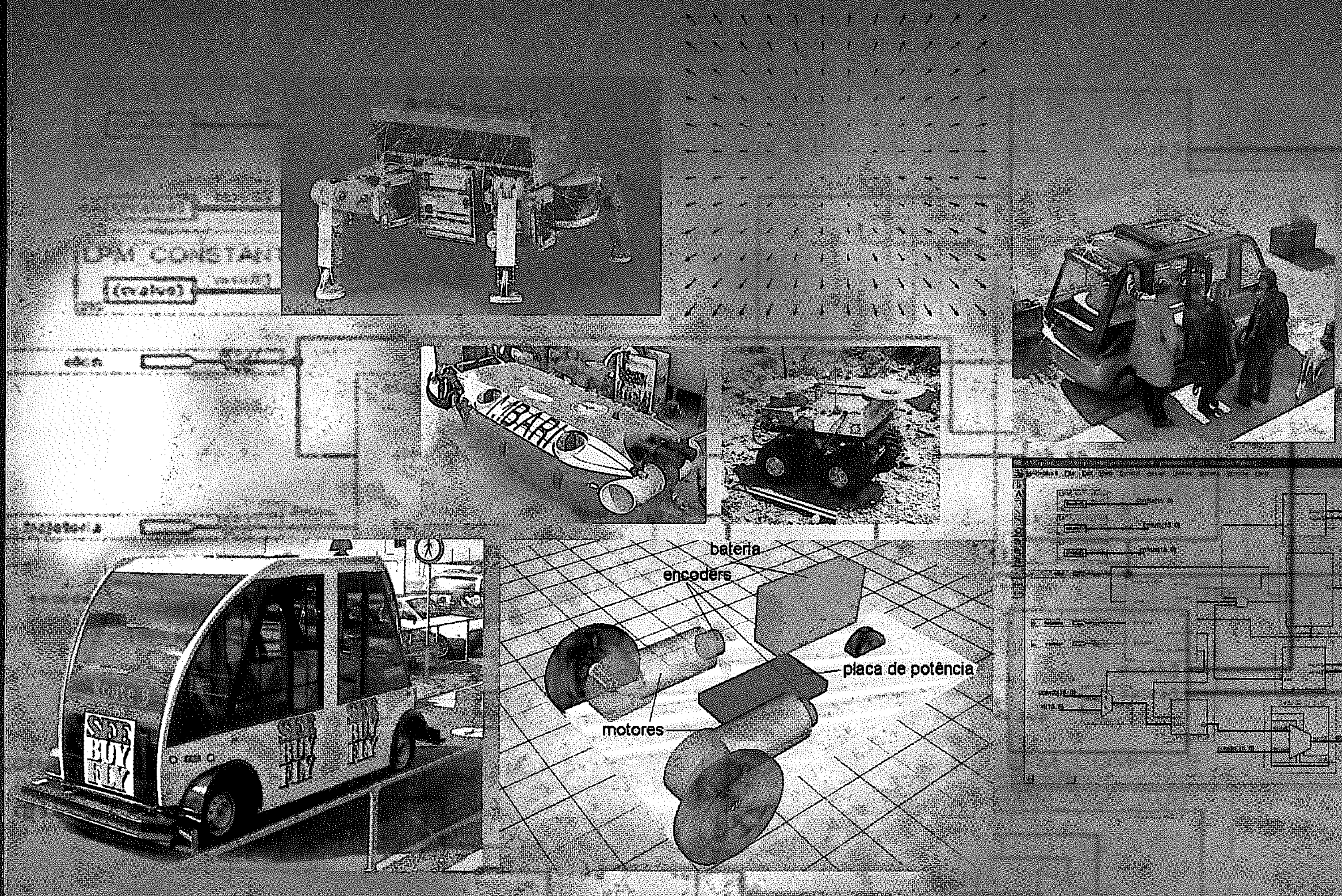
Revista Técnico-Científica

N.º 43 • 2.º Trimestre 2001 • 1250$00



Robótica Móvel e aplicações

Estado da arte da robótica móvel em Portugal Development of the RobChair assistive navigation system Detecção e localização de minas antipessoais utilizando robôs móveis Utilização de circuitos lógicos programáveis para controle de atuadores em robôs móveis Estudo e implementação de um sistema para monitorização e controle na soldagem robotizada com electrodo revestido Labconrob remote / virtual laboratory of real-time robot control EmailWare: uma ferramenta para e-Manufacturating. Do it by e-mail