ROBCHAIR - A SEMI-AUTONOMOUS WHEELCHAIR FOR DISABLED PEOPLE

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Abstract: This paper describes the *RobChair* assistive navigation system. *RobChair* is a project under development which aims to assist disabled people to operate powered wheelchairs. *RobChair* is being developed in order to provide several levels of functionality to assist different users. This paper describes some reactive navigational strategies, namely the potential field method, used for local obstacle avoidance; presents a teleoperation environment to allow remote operation by Internet observers; and introduces a voice human-machine interface (HMI).

Keywords: behavioural architecture, obstacle avoidance, human-machine interface.

1. INTRODUCTION

Unfortunately, “there is a significant growth in the absolute and relative number of older people in all Member States such that by the year 2020 it is estimated that one in four of the European population will be over 60 years of age” (Tide, 1994). This is a very alarming situation, since older people usually suffer from motor problems such as partial paralysis and tremors. There is also a great number of chronic physically handicapped people. Rehabilitation technology represents a major tool to overcome problems in daily life related with disability. The use of a wheelchair can, in many cases, integrate the disabled to have a normal social life. There are several kinds of disabilities which compels the wheelchair system to have different levels of functionality. For instance, a paraplegic person can, just as a normal person, use a joystick to control the wheelchair. However, a tetraplegic person has to use the tongue or the chin to operate a special joystick or has to use voice commands. In the first case, a wheelchair equipped with a normal joystick and a collision avoidance module (to provide a safe travel) would be enough. However, in the second case it would be desirable to have: a voice HMI (because controlling a joystick with the tongue or the chin is a very tedious and difficult task); a collision avoidance module; and, if possible, an autonomous navigation module. *RobChair* system is being developed with the following main purposes: guarantee the safety of wheelchair users; help users to perform some complex manoeuvres in cluttered environments; allow permanent communication between users and remote observers; provide an efficient HMI to guarantee that the wheelchair can be operated by users with different impairments; and finally, design a modular system with autonomous navigation capability. It is a concern of this project to design a wheelchair for the disabled and not a wheelchair for engineers.

The organisation of the paper is as follows: section 2 describes the configuration system; section 3 presents the teleoperation environment; section 4 presents the navigational control architecture; section 5 introduces the voice HMI; section 6 presents some experimental results; and section 7 draws some remarks and conclusions.

2. SYSTEM CONFIGURATION

The powered wheelchair[1] is depicted in Figure 1. It is a conventional powered wheelchair with two motorised rear wheels and casters in front. There is also a 5th rear wheel connected to the back of the wheelchair with a damper used for stability. The mechanical structure is conventional, there were not performed any mechanical adaptations in order to serve different users. This was not the case in other projects, for instance, in the OMNI project (Hoelper, et al., 1995) it was designed a prototype with omnidirectionality capability (able to move with 3 DOF in a plane) and with an adaptable and ergonomic structure. The *RobChair* can be commanded by a normal analogic joystick and by a voice HMI. Nevertherless this last module is not yet fully integrated in the wheelchair system. The sensorial system is composed by 12 infrared sensors, 4 ultrasonic sensors, a front tactile bumper and optical encoders on wheels. Sensor arrangement is shown in Figure 5.

3. TELEOPERATION ENVIRONMENT

The idea of developing a teleoperation environment emerged from the necessity of a permanent communication between the user and a remote observer. Indeed, if a disabled stays alone in a hospital room or at home, he will have to be permanently observed. Some problems may occur, for example, the disabled gets stuck or is unable to perform a complex manoeuvre. In these situations a remote operator would have to teleoperate the wheelchair. With this purpose, it was made a Graphical User Interface (GUI) (see Figure 3) to allow the execution of the teleoperation task. The teleoperation just relies on sensor and dead-reckoning information. Video cameras are not included in the *RobChair* system, but they would be of main interest since video cameras are much more informative than other sensors (sonars or infrareds) and because the wheelchair dead-reckoning accuracy is very poor.

Figure 2 shows a block diagram representing the interaction between the user, the wheelchair and remote operators. The wheelchair can, at any moment, be commanded by the user or, instead, by a remote operator. Sensorial information is also accessible to both. User and operator can bere in permanent communication.

Fig. 1. Wheelchair picture.

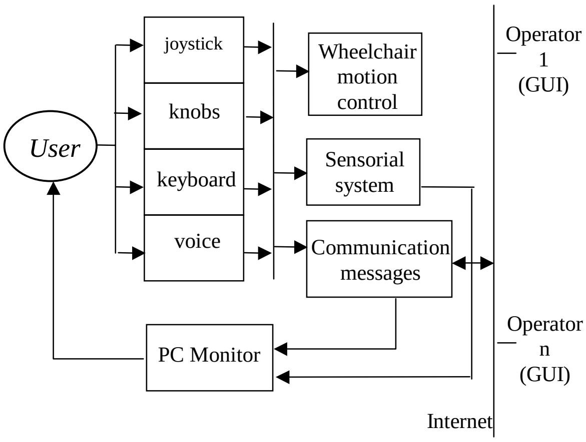

Fig. 2. Block diagram representing the interaction between the several modules of the system.

3.1 *Graphical User Interface (GUI)*

The GUI is completely user transparent and allows to perform high level tasks. The GUI was created using the FORMS[2] library, a GUI Toolkit for X, which uses the services provided by the Xlib and runs on any workstation having X Window System installed. This toolkit is very useful to create 2D graphical environments (menus, buttons, scrolling, panels, and drawhandlers). The Interface is shown in Figure 3. The main panel (Figure *3a)*) displays the wheelchair, the world environment and sensor data.

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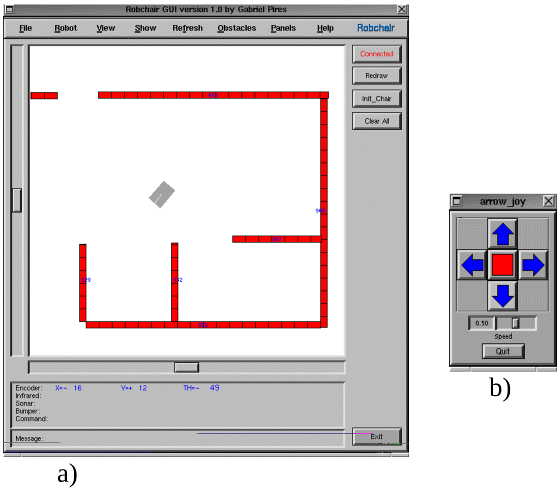
[1] The wheelchair is a KIPR (KISS Institute for Practical Robotics) product.

[2] 1996 by T.C. Zhao and Mark Overmars



a)

b)

Fig. 3 GUI interface. a) Main panel. b) graphical joystick panel.

It has a menu-system to accede to other application panels such as a "*joystick*" panel, a "*record & playback*" panel and a "*command line*" panel. The GUI has the ability to create complex world environments, composed by walls, round and square obstacles, allows a zoom in/out capacity and shows sensor data and backtrace positioning.

4. NAVIGATIONAL CONTROL ARCHITECTURE

The architecture of the *RobChair* system follows the Brooks' *subsumption architecture* (Brooks, 1986). The *subsumption architecture* is an horizontal layered model. To each layer, it is assigned a level of competence generating a behaviour. The behaviours work in parallel and compete to control the system or a certain set of actuators. A diagram representing the *RobChair* architecture is shown in Figure 4. The *RobChair* system is different from a mobile robot, it is a *human-machine* system, which means the user has to share control with the machine. The user represents a cognitive module with full perception capability and knowledge about the environment. In the first phase of this project it is being developed a semi-autonomous wheelchair. This way, there is no need to resort to representational world modelling or to plan global trajectories. The user must feel that the wheelchair reacts in real-time to input commands (joystick or voice). The several levels of functionality of the *RobChair* system are represented by: safe travel, denoted as a *collision avoidance behaviour* and *speed control*; and an *obstacle avoidance behaviour*. The collision avoidance behaviour represents the ability to not hit obstacles, while the obstacle avoidance behaviour represents the capacity to contour the obstacles efficiently. The methods used to implement these two behaviours are reactive methods that directly couple real-time sensory information with motor actions. The collision avoidance uses a simple and very primitive reflexive stimulus-action behaviour (*if measure > threshold then stop*). The obstacle avoidance behaviour is composed by two components: a *goal-driven behaviour* which represents the direction the user wants to follow and repulsive forces associated with the obstacles. The conjugation between these two components creates a potential field (kathib, 1985) described as follow.

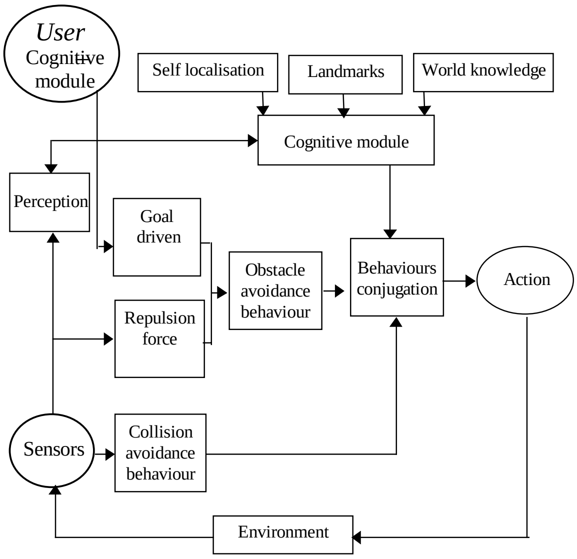


Fig. 4. *RobChair* Control architecture.

4.1 Potential Field Method

The potential field is a reactive method used for local mobile robot control. The classical approach involves an artificial force acting upon the robot, derived from the vector summation of an attractive force representing the goal and a number of repulsive forces associated with individual known obstacles:

$$\vec{F}_t(x) = \vec{F}_o(x) + \vec{F}_g(x) \tag{1}$$

where:

$\vec{F}_t(x)$ = resultant artificial force vector

$\vec{F}_o(x)$ = resultant of repulsive obstacle forces

$\vec{F}_g(x)$ = attractive goal force

The repulsive force can be represented by:

$$\vec{F}_o = \sum_{i=0}^{n} w_i \vec{s}_i \qquad (2)$$

where w_i is the weight associated with sensor i and s_i is the inverse of the sensor reading. By inverting the reading, closer objects apply a larger force. Each sensor gives a weighted vector directed to the robot with an inversely proportional force with sensor measures.

4.2 Autonomous navigation

On a second phase of the *RobChair project*, even without achieving a completely autonomous (without user intervention) navigation, such as *"go from room A to room B"* autonomously, it will be necessary to provide the system with a self cognitive module. Obviously, this cognitive module should have a perception capability (e.g. to perceive a door appearance or have a localisation capability) to map sensor information to cognitive attributes. Even a non-fully autonomous wheelchair must have some capabilities to help the user, for example in the passage through a door. A solution to a "*door passage*" could be based on a reactive behaviour, specific to this task as long as supported with perception, and cognitive capabilities necessary to this end. Certainly, there is a nearly optimum way to pass through a door in what concerns the trajectory to follow by the wheelchair relatively to the door. The behaviour must be provided with a set of information which allows it to accomplish this task with efficiency. This control system integrates a cognitive component to plan actions with a behaviour based actuation (see Figure 4).

5. VOICE HMI

Only a few works have been done concerning voice commands access for robotics HMI. Torrance (1994) developed a natural language interface for navigating indoor office-based mobile robot. In addition to giving commands and inquire information about the robot' s status, the user can associate names with specific locations in the environment. Lueth et all (1994) present a natural language interface developed for the KAMRO autonomous mobile robot. KAMRO's natural language interface is founded on a dialogue-based approach, i.e., the human-machine interaction is not restricted to unidirectional communication.

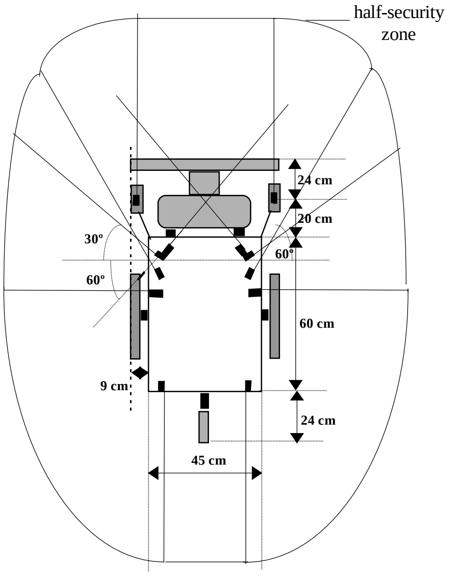


Fig. 5. This figure shows the 12 IR sensor arrangement (top view). Continuous lines represent the IR range measures (maximum distance 100 cm) which define a half-security zone.

Mechanical input devices, such as joysticks, are very problematic to people who suffer from poor manipulative capability because these devices are as accurate in controlling the wheelchair as the dexterity of the user who operates the device. Using natural language commands, like *move forward* or *move right*, relieves the user from precise motion control of the wheelchair. To tetraplegic and blind people this is the only way to control the wheelchair. With a simple voice command, it is possible to perform a set of actions corresponding to a task. Such feature is difficult to implement with mechanical devices.

The user interface will have to interpret fuzzy commands such as *move closer* or *move very slowly*, providing the user with a natural way to command the system.

In the *RobChair* System, the user's voice is captured by a head microphone and is processed by a voice recognition system[3]. The system has the capability of being trained which leads to a more recognition accuracy after being used many times. The voice HMI is under development. However, simple commands such as *forward*, *stop*, *rotate*, *slow*, *fast* were already implemented showing promising results.

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[3] Dragon VoiceTools.

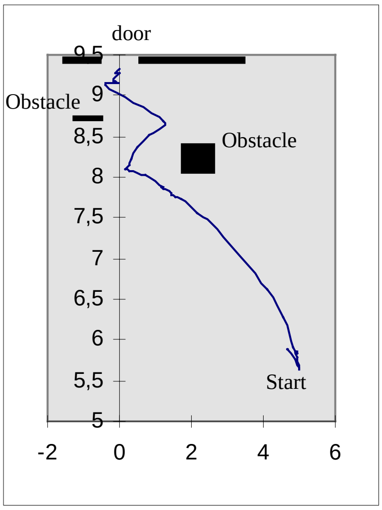

Fig. 6. Path described by the wheelchair to pass through a door-passage in an environment with some obstacles.

6. EXPERIMENTAL RESULTS

The first experiment was done to prove the effectiveness of a safe travel. Whenever an obstacle is detected in the half-security zone (see Figure 5), the wheelchair speed is reduced. In order to prevent collisions, if a sensor measures a distance below a specified threshold, the wheelchair will stop the movement. If this fails, the front tactile bumper, when activated, will halt the motors. The experiments proved that the wheelchair allows a safe travel. However, if the obstacle is a table, the sensors will not “see” it and the probability of collision is high. In order to be more easily detected, the furniture in domestic environments should have a special design. For example, instead of being supported by one or more legs, the table should have a solid surface around it.

The second experiment consisted of a door-passage. Figure 6 presents this experiment, using the obstacle avoidance module, performed by a non-experienced user (who never used neither a wheelchair nor a joystick device). The environment has just two obstacles near a door 90 cm wide. The direction to follow is always an input from the user. However, the wheelchair system, if detecting obstacles, do not strictly “obeys” to these inputs and tries to avoid the obstacles. The door--passage was well succeed and performed without collisions. This task was showed on a TV video system during the conference.

7. CONCLUSION

A powered wheelchair provided with some intelligence and aiming to assist disabled people has been presented. The *Robchair* project, under development, aimed to provide the end-user with an easy and safe way to steer the wheelchair and with a voice interface to control it. As concerns the first objective some practical results were already achieved based on purely reactive control. Nevertheless, work must be done to implement a more realistic and practical system that incorporates learning and planning capabilities, i.e., that integrates cognitive capabilities. The second objective is being pursued.

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