INTUITIVE COMMAND MODES FOR ROBOTICS ASSISTANCE TO DISPLACEMENTS.

O. Horn, M.A. Hadj-Abdelkader, F. Leishman et G. Bourhis
Laboratoire d'Automatique humaine et de Sciences Comportementales (L.A.S.C.),
Université Paul Verlaine, bât.ISEA, 7 rue Marconi
57070 METZ Cedex 01, France
{horn, hadjabde, leishman, bourhis}@univ-metz.fr

Abstract

In the field of mobile robotics applied to assistance of displacements for people with motor disability, we propose two studies that aim at fill the gap between technological advances and needs of users. By being inspired by methods of the teleoparation, we designed two approaches for the assistance to driving : the deictic interface which allows easily activating autonomous navigation functionalities and the force feedback joystick which makes easier the command of the classic joystick. For each approach we carried out the device as a whole from the human machine interface since the human-machine interface until the interpretation of the laser measures for the perception. We describe these realizations and the tests carried out in our laboratory with the perspective of an evaluation by person with disability.

Key words : intelligent wheelchair, cooperative control, deictic, force feedback.

I. INTRODUCTION

The technological advances of time can improve the way of life of people with disability ; thus in the 70s the existence of electrical motors allowed the development of electrical wheelchairs giving an autonomy of displacement to the persons who could not propel a manual wheelchair. But these electrical wheelchairs are still inaccessible to those who, for diverse reasons, are in the incapacity to drive them by means of the usual joystick. [1], [2], that is why studies are led since the 80s to employ the advances of mobile robotics to make these electrical wheelchairs accessible to the largest number. The original idea is to give possibilities of autonomous displacement to the wheelchair in order to lighten the driving task. On this idea many devices were designed, they differ by their mechanical or software structure, by the type of functionalities proposed and by the perception modes (kind of sensor) and the action modes (kind of order) of the vehicle. Historically the first prototypes consisted of mobile robots equipped with a seat[3], then one saw some integrated prototypes robot-seat [4] as well as a great number of usual powered wheelchairs equipped with computer and sensors [5], [6] and finally additional devices [7] developed independently of the wheelchair and intended to be able to adapt on any wheelchairs. However to date very few got out of the laboratories. Beyond the technical reasons for which the projects failed, one can see there a sign of the lack of exchange between laboratories and institutions such as hospitals or rehabilitation centers. This weakness limits the feedback between the design of the prototype and its potential use, it is thus difficult to forecast if these devices interest the possible users. Consequently, this field of research is now less attractive and the number of studies on this topic decreases. For as much it would be a mistake to consider that all work undertaken was it to no purpose. There is a hope that these robotized assistances lead one day to technologies that really improve the life of people with motor disabilities. But it is necessary for that to look for the adequacy between the state of the available technology and the potential demand. We describe, in this article, two approaches which we lead simultaneously : the deictic interface to easily activate autonomous navigation functionalities and the force feedback joystick for an easier command of the classic joystick. It is two different ways but which are situated in the same perspective of simplification of the driving of wheelchair by means of a cooperative command. After a presentation of the choices which governed our step, we will present the two approaches and will evoke the results obtained for each one of them.

II APPROACHES OF THE ASSISTANCE TO MOBILITY

a) The dead end of the intelligent wheelchairs

The postulate that the advances of mobile robotics can allow to lighten the driving task for the electrical wheelchair users, is the originally of the projects carried out on the design of intelligent wheelchairs. This led to several studies on different aspects of the robotic aids for the displacement. Thus we have seen different approaches on the user interface, on the trajectory planification, on the software architecture, on the localization, on the training…, all the functionalities of the mobile robotics adapted for their use on electrical wheelchairs. The devices conceived from these studies offer potentially interesting functionalities but they did not touch the universe of the users. The systems from these studies offer potentially interesting features, they were not however able to penetrate into the universe of the users. This is the consequence of an insufficient consideration of the strong constraints notably about the ease of use, the warrant of the security, the psychological acceptance, the adaptability at every wheelchair and the nonprohibitory price. These requirements being often incompatible with the modules such as they were established. Here is the contradiction between the complexity of the technical contribution and the chances to employ it in the universe of the users. In that, it is remarkable to note that two really employed devices (SCAD [8] and Smart Wheelchair[9]) used only simple functionalities of line following and obstacle avoidance. However they were conceived to answer a clearly identified need, because they were worked out within rehabilitation centers. One then notes another weakness of the bases of work in this field: they were started without undertaking any detailed dialogue with the people with disabilities or their therapists. A new approach must be envisaged which, at the same time as the development of the prototypes, will establish a dialogue with the potential users to estimate the demand but also to stimulate it, because the demands are also connected to the range of the possible. It requires establishing a bridge between the rehabilitation centers and the laboratories, which pass through the development of light functionalities, both for their installation on the wheelchairs and for their use, so that they can quickly be presented and valuated. It is on this scope that we attempted to approach the assistant to the mobility in the form of additional devices being inspired by modes of command such as analyzed in teleoperation.

b) Modes of control of powered wheelchairs

The first works on the smart wheelchairs dealt with the design of devices able to automatically assume a part of the driving tasks. The general sketch is that of an automatic system on which the person sends certain instructions that the machine carries out all alone. The evolution from manual control toward automatic control can be represented by the following figure (Fig.1).

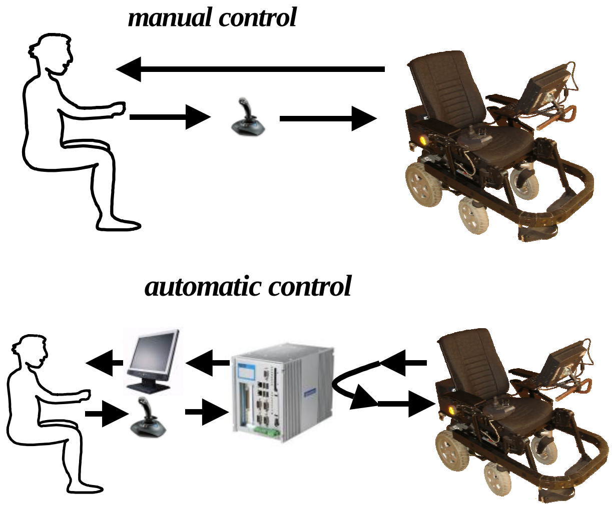

Fig.1 : Control of classical powered wheelchair and of autonomous wheelchair

This model appeared unsatisfactory as far as once the task is started the person hasn't no more means to intervene on its vehicle. It raises a problem both in terms of psychological acceptability of the device and in terms of the safety of the person. Thereafter a closer relationship between the man and the vehicle was established and the functionalities of assistance were conceived in relation to their mode of activation. For this reason one can refer to the models of telerobotic especially because the robotized assistance is similar to it by certain aspects. Indeed in the teleoperation, the robot acts under the orders of the person which is unable to achieve himself the required tasks, there is thus a narrow synergy between the machine and the person so that the reactions of the one can benefit the actions of the other one. Although the context is radically different (because the person is on the wheelchair contrarily to the operator which is far from the effector) in our approach, it is a question of making carry out functions that the person is unable to do himself, the distance for the teleoperator is replaced by the motor disability for the user of smart wheelchair. The driver-wheelchair relationship is thus similar to the operator-effector relationship and the mode of control for smart wheelchairs can be considered according to the models defined by Sheridan in telerobotic [10]. They distinguish the traded control where the machine sometimes replaces the man and the shared control where it relieves him permanently. They take then the following configuration (Fig. 2) :

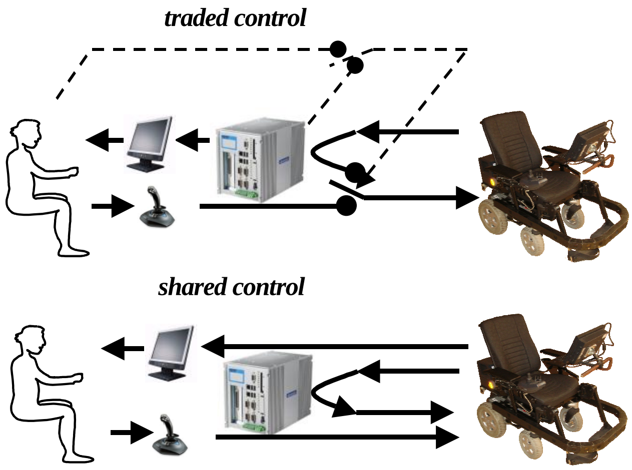

Fig.2 : control modes of smart wheelchair

In these control modes the computer and the man participate both to the driving of the vehicle. For the traded control it is either the man or the computer which command the vehicle and the passage, from one mode to the other, is made on indication of the man or of the machine, while for the shared control, there is a permanent link between the man and the wheelchair, and the required actions are modulated according to the analysis done by the machine.

c) Towards devices of assistance to driving

Starting from these considerations relative to the téléopération as well as from our experience on the robotics assistance to the mobility, at the moment, we turn to the realization of light devices of assistance to the driving. They aim at establishing a simple and intuitive cooperation between the driver and the machine, and they will allow to lead a fast validation with the users. During the last twenty years the works, achieved in our laboratory, on the robotics assistance to the movements, led to the development of several prototypes that follow the evolutions described previously [11] [12]. At present we work on a standard wheelchair Storm equipped with an industrial PC, with a camera and with a laser range finder. We do not use the odometry in order to design a system that could be easily transferable on any type of wheelchair. We propose here two approaches that conceive functionalities of assistance using the laser perception for the navigation and giving a particular attention on the man-wheelchair communication.

III DEICTIC CONTROL : VISION LASER FOR A TRADED CONTROL

a) Principle

It is about a particular type of traded control where the passage from one mode to the other is decided by the driver. The camera où le passage d'un mode à l'autre est décidé par le conducteur. The camera offers via the screen an outline of the environment on which the person will choose its movement that can then be realized in an autonomous way from the perception of the laser. If the person wants to drive himself, he just has to activate the joystick that becomes immediately the organ of control. Thus the person has the support of assistance to the mobility but the user never feels the prisoner of an autonomous movement.

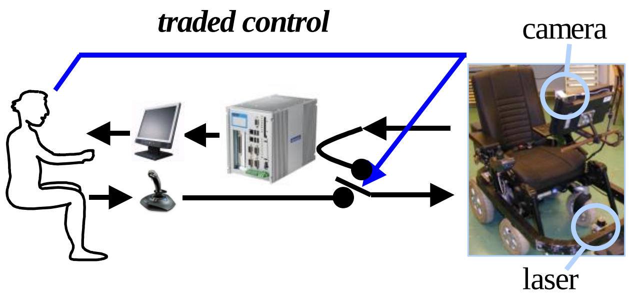

Fig.3 : The deictic control

b) Deictic interface

The deictic term comes from linguistics where it indicates words whose sense depends on the situation in which they are expressed. For example in the sequence "give me this book" it is the presence of the book which give the sense of the word "this" and the formulation becomes simpler because of the fact to show. In the same way the principle of the deictic control [13] is to give the instructions while indicating what must be done, its interest lies in the intuitive nature of the instructions

In order to measure its potentialities for the assistance to the mobility, we implemented it on our wheelchair for two functionalities of autonomous displacement: passing through narrow passages and wall following. The interface with the user is split in two zones on the screen; a large part of the image gives an outline of the environment and, onto the left, a menu proposes the various possible tasks. At the start the person select the displacement mode between “manual control”, “wall following” or “passing through narrow passage”. If one of the two autonomous functionalities is chosen, the selectable areas are highlighted on the video image of the environment and the target will be determined by clicking on one of these highlighted areas.

Fig.4 : Example of display screen

The figure above (Fig. 4) give an example of the display screen when the passing through narrow passage was selected. The green area represents the passages that can be chosen (only one in that case) and the wheelchair is still at stop, what is displayed in bottom on the left of the screen. Then the movement is carried out by an adjustment of the trajectory according to the laser perception and the user can see, in overprint on the screen, the name of the task which runs. At every moment he can send a counterorder if the movement does not suit him. When the sequence is ended the choice arises again of taking a manual control or of launching another functionality. This cooperation mode allow to easily altern between machine control periods and manual control period. This cooperation mode allows easily alternating between machine control periods and manual control periods.

c) Realization on the wheelchair

In order to develop this interface on the wheelchair, a first modulus aims at converting the image points to points of the environment expressed in the coordinate system related to laser sensor. It allows to display area which can be selected in the image (narrow passages or walls) and then, once a point of the image is clicked, to convert it in a target adapted to the navigation with the measures laser. This correspondence was established from the characteristics of the camera and from its position on the system. Modalities of the conversion are given in [12]. Then the trajectory is generated by the definition of a set of successive target points calculated according to laser perception and to nature of the task.

For the narrow passage, the first step is to look for the possible passages by merging the obstacles in laser measures. Then, relatively to the passage, a set of areas is defined and, for each of them, an objective is established which is located in the adjacent area.

For the wall following, the targets points are computed relatively to the distance to the wall followed, to the distance to the opposite wall (measure of the free space in the case of a corridor) and to the presence of obstacle forward.

The navigation is achieved by a closed loop control of the wheelchair on the succession of the targets by the means of two modulus. A numerical PID which corrector allows giving the position of the joystick which a person who wants to drive the wheelchair towards the target points would give. And a simulation of the joystick which uses the fuzzy logic to calculate the voltage corresponding to each of the possible positions of the joystick [12].

d) Results

We realized in our laboratory several runs alternating manual control and autonomous functionalities. These tests allowed showing the ability of the wheelchair to manage the autonomous displacements as well as to estimate the easiness to pass from one control mode to the other. Besides the statement of trajectories during the autonomous primitives shows that the movements are fluid and get close to those that would have made a person driving directly the wheelchair. We are currently in touch to persons working with people with motor disabilities in order to present this device at the potential users.

IV HAPTIC INTERFACE : LASER PERCEPTION FOR AN ASSISTED CONTROL

a) Principle

In this second study, it is a question of adopting the principle of the haptic feedback to conceive a new mode of control of the electric wheelchair exploiting measurements of the laser rangefinder. The idea is to send a force feedback on the joystick according to the proximity of the perceived obstacles. We are not exactly in a shared control mode insofar as the instructions of the machine are not directly addressed to the wheelchair but intervene at the joystick level through the haptic feedback. It is a particular mode that we entitle " assisted control "because the laser perception allows to propose directions, indicated by bending the position of the joystick, which the pilot will choose to follow or to ignore. Physically the man machine communication lies only on the joystick.

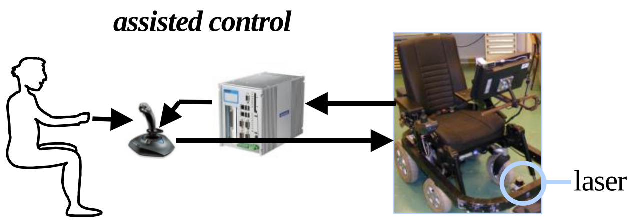

Fig.5 : The force feedback joystick

b) The force feedback

We base our method on the recording of distance measures from laser sensor, in the form of grids according to modalities close to the VFH algorithm[14], which was designed for the obstacle avoidance with US measures. During the construction of the grid every measure is transcribed by incrementing the cell corresponding to the distance delivered by the sensor. As we don't use the odometry the recording of a grid is made only from a single position of the wheelchair (contrary to the VFH where grid are incremented from several successive positions of the sensor). Then we apply the potential field principle to the grid in order that each cell will apply a repulsive force, the force magnitude is proportional to the value of the cell and inversely proportional to the distance between the cell and the center of the grid. Then the grid is split in sector of 5° on which a polar density of obstacle is given, this density is the sum of cells lying on the sector. Then the grid is split in sectors of 5° to which a polar density of obstacle is given, this density is the sum of the values of all cells within the sector. Thus we obtain a density polar histogram, where the peaks show the obstacles directions and valleys represent the free directions in the environment. We apply a smoothing function in order to consider only the valley that are wide enough. Once the valleys determined, we adopt two methods of calculation of the force feedback :

. Active force feedback : the direction of the force feedback corresponds to valley closest to the direction requested by the user.

. Passive force feedback : the joystick is maintained at its central position with a resistive force, the magnitude of which increases if the direction of movement approaches a peak

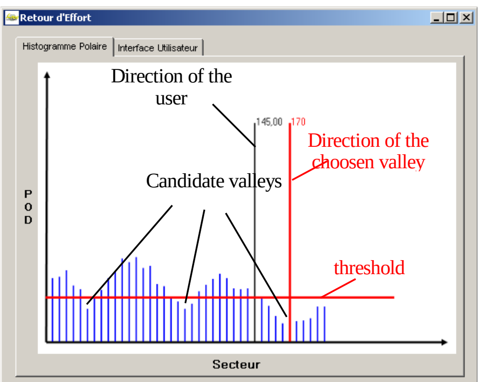

Fig.6 : obstacle density histogram

c) Evaluation of the joystick in real situation

We asked to 5 persons of the laboratory to drive the wheelchair in an experimental environment that requires different behaviours of driving [15]. After some tours of training, the user will make at first a course without force feedback then with force feedback in passive mode then in active mode. The driving performances are evaluated by the course completion time, by the number of collisions and by the responses of the users to the TLX (Task load index) questionnaire that allows evaluating the drivers' workload. Globally the tests show that in the difficult zones, thanks to the force feedback, a decrease of the collisions and of the time of course is obtained. On the other hand the workload is felt as more important with force feedback, and it, especially in active mode. This additional difficulty seems to come from the autonomous movements of the joystick which try to guide the user but implies from him a bigger concentration. However some users having done more trial runs with the force feedback in active mode redid some tests afterward, which showed then fewer collisions and less workload. Thus, for the next tests, we shall introduce a more consequent preliminary phase of training for the use of the haptic control. Besides we develop at present a 3D simulator so that persons with disabilities can test this device without any risk-taking [16].

V CONCLUSION

To be able to succeed, the researches on the robotics assistance to the mobility require an evaluation by the persons with motor disabilities. A first stage in order to establish this intervention is to conceive devices in the form of light structure offering a simple and effective exchange between the man and the machine. Our works in this way attempted to realize two processes of assistance to the driving, the one proposing an intuitive interface, to activate autonomous functionalities of navigation, and the other one establishing a force feedback on the joystick to guide the movements. The tests achieved in our laboratory establish a first stage in the evaluation of these processes before presenting them to interested people.

VI RÉFÉRENCES

[1] L. Fehr, W.E. Langbein, S.B. Skaar, "Adequacy of power wheelchair control interfaces for persons with severe disabilities: A clinical survey", *J. of Rehabilitation Research and Development,* 37(3):353_360, june 2000.

[2] R.C. Simpson, E. F. LoPresti, R.A. Cooper, "How many people would benefit from a smart wheelchair?", *Journal of Rehabilitation Research and Development,* 45(1):53_71, 2008.

[3] G. Bourhis, A. Pruski, K. Moumen, C. Bop, " The V.A.H.M. project (Autonomous vehicle for disabled) ", *ECART, Maastricht:*95_96, 1990.

[4] H.A. Yanco “Wheelesley, a robotic wheelchair system: indoor navigation and user interface”, *Lecture notes in computer science,* 1458: 256_68, 1998.
[5] P. Mallet, J.M. Pergandi., “Towards smart wheelchairs”, *AAATE, Lille:* 328_335, 2005.
[6] G. Del Castillo, S. Skaar, A. Cardenas, L. Fehr, “A sonar approach to obstacle detection for a vision-based autonomous wheelchair”, *Robotics and Autonomous Systems* 54: 967_981, 2006.
[7] R.C. Simpson, D. Poirot, F. Baxter, “The Hephaestus Smart Wheelchair”, *IEEE Transaction on Neural Systems and Rehabilitation Engineering,* 10(2): 118_122, 2002.
[8] M. Langner, “Single track system for powered wheelchairs to provide an opportunity for children to safely venture away from helpers with greater autonomy”, *Journal of Intelligent Mobility* 5(1): 65_77, 2002.
[9] P.D. Nisbet, J. Craig, J.P. Odor, S. Aitken, “‘Smart’ Wheelchairs for Mobility Training”, *Technology and Disability* 5: 49_62, 1996.
[10] T.B. Sheridan “Telerobotics, automation, and human supervisory control”, *Cambridge, Mass.: MIT Press,* 1992.
[11] G. Bourhis, O. Horn, O. Habert, A. Pruski, “*The* VAHM Project: Autonomous Vehicle for People with Motor Disabilities”, *IEEE Robotics and Automation Magazine, Special Issue on Wheelchairs in Europe* 7(1): 21_28, March 2001.
[12] F. Leishman, O. Horn, G. Bourhis, “Multimodal Laser Vision Approach for the Deictic Control of Smart Wheelchair”, *ICOST, Tours France:* 98_107, July 2009.
[13] J.D. Crisman, M.E. Cleary, “Progress on the Deictically Controlled Wheelchair” *Assistive Technology and AI, LNAI* (1458):137_149, 1998.
[14] J. Borenstein, Y. Koren, “The Vector Field Histogram- Fast Obstacle Avoidance For Mobile Robots”, *IEEE Trans. on Rob. and Aut.* 7(3): 278_288, 1991.
[15] M.A. Hadj Abdelkader, G. Bourhis, B. Cherki “Commande par retour d’effort d’un fauteuil roulant électrique”, *CIFA 2010,* Nancy, 2-4 juin 2010.
[16]Y. Morere, S.M. Meliani, G. Bourhis, “Evaluation en simulation de la conduite en fauteuil roulant électrique”, *CIFA 2010,* Nancy, 2-4 juin 2010.