Obstacle Avoidance for the VAHM Smart Wheelchair

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Abstract:

The VAHM project aims at helping disabled peoples in the displacement of their wheelchair in a cluttered indoor environment. In such a project, the obstacle avoidance module is certainly one of the more important. It is used by a set of specific tasks as doorway crossing, direction following, free space finding to safety move the wheelchair in a daily environment. This paper discusses about the obstacle avoidance methodology used on the VAHM-2 wheelchair. Its behavior during a doorway crossing is detailed.

1. INTRODUCTION

Wheelchair driving assistance is a field that has been widely and internationally covered by numerous research teams. The utility of such a system is no more to be proved. A person needs are different according to its disabilities. Assistance becomes necessary when the person has pain in the manipulation of the control system (usually a joystick) or if he doesn't be able to scan the surroundings to perceive any danger induced by the obstacle presence or to evaluate the proximity of an obstacle.
The VAHM project, which is a French acronym for autonomous vehicle for disabled person, concerns a smart wheelchair having some driving assistance functions. The project has started at the end of the 80th and turns now to a usable smart wheelchair.

2. RELATED WORKS

Numerous projects that automatize motion functions are in progress today or were developed in a recent past. According the projects, the automatization is obtained by different ways. Either it concerns a global work over the motion function or it concerns a specific motion aspect. The first project type leads toward a global system with an adapted mechanical structure, a trajectory predetermination, an adapted man-machine interface, a communication standardization, safety improving by obstacle avoidance [BUL97] [CRA93]. The second type of projects is more numerous. Each focused on one or a set of functions in order to assist the person in a particular context. The ATW [WEL94] has focused on overcome obstacle like stairs by adapting two manipulator arms at the front of the wheelchair. Most of projects focused on the reactivity problem according to the environment. This module is essential because it allows to safety use the system. In the framework of these projects, ultrasonic sensors are largely used to obtain perceptual data of the environment. Despite a lot of drawbacks (specularities, crosstalks, multi-reflections) such a sensor still represents the cheapest way to perceive an environment. That's the reason why most of projects work in improving the performance of the environment detection [BEL94a] [BEL98b] [ALA] [GEL97] [BAL98] [SCH98].

3. THE VAHM PROJECT

3.1. Introduction

The VAHM project has started late in the 80th and turns on two prototypes. The first one, named VAHM-1, was constituted by a platform equipped with all technical characteristics of a mobile robot: odometer, ultrasonic sensors, control system. An armchair has been fixed on this robot, allowing a disabled person to take place. Three possible controls were proposed to the disabled operator, leading to three motion mode: manual motion, assisted motion, autonomous motion. The first motion mode allows the platform to be driven as a usual powered wheelchair. The second motion mode allows to move the wheelchair by taking into account the environment perceptual data. The third motion mode consisted in automatically reaching a target defined by the operator, letting the robot dealing with the motion between the source and the target position. All details, functioning and architecture, are referenced in [BOU98].

The aspect of the first prototype is quite far from a usual wheelchair one. Moreover, performance and robustness of VAHM-1 must be improved. Experience that has been drawn by VAHM-1 allows us to design the VAHM-2 prototype. For this new prototype, numerous algorithms have been simplified and robustness has been improved. The next section describes VAHM-2 technical specifications.

4. THE VAHM-2 SPECIFICATIONS

Disabled oriented applications require the use of low cost and easy to modify materiel. We have chosen a PP201 powered wheelchair sold by the Swiss firm PowerPush. This wheelchair owns a DX bus architecture. Such architecture makes easier the computerization of the system. So, it is constituted with two DX components, a master remote controller and a power module. All the DX components are manufactured by the firm Controls Dynamics.

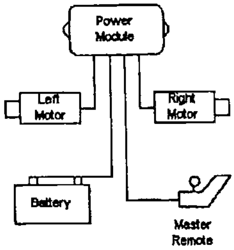


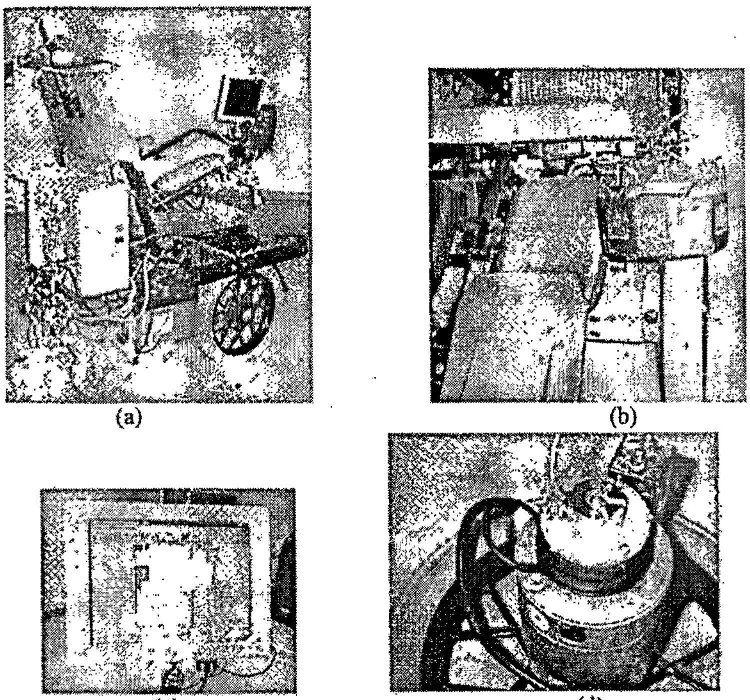
Figure 1: DX bus Architecture

The master remote controller includes a joystick used for controlling wheelchair speed and direction. The DX Power Module converts the signals from the user control device, usually a master remote, into high current outputs suitable for driving the motors that determine wheelchair speed and direction. All DX modules are connected by a single cable containing a 4 wire "DXBUS" which forms a parallel backbone to the system providing each module with power and data.

To add perceptional means to our basic wheelchair, 16 ultrasonic sensors have been mounted around (see figure 2a). To improve the front visibility, most of ultrasonic sensors are mounted at the forepart of the wheelchair (see figure 2b). The sensors are controlled by a specialized card where perceptual data are updated every 60 ms. These data can be accessed at any time by the computational means through a printer port.

Localization means are obtained by the use of two incremental encoders both mounted on each motor shaft (see figure 2d). Such sensors easily allow obtaining a dead-reckoning localization of the wheelchair.

Computational means are obtained by sitting a computer on the wheelchair. This computer deals with high computational tasks as paths planning, perceptual and localization data fusion, motors control, … This computer allows to add others specialized cards (counter card for the encoders, digital to analog card for controlling the motor). A LCD screen has been added in order to view all man/machine interfaces (see figure 2c).



(a) (b)

(c) (d)

Figure 2: The VAHM-2 spécifications

5. THE VAHM CONTROLS

5.1. Introduction

The wheelchair driving is performed by the disabled operator through a set of macro controls. The choice of the more efficient control according to the person and the environment context is defined only after a complete evaluation. That's the reason why a set of macro-controls is proposed. These controls can be classified into three categories:

1) Manual controls allowing to emulate a usual powered wheelchair;
2) Assisted controls as wall following, free space following, direction following, initial position return;
3) Goal oriented control.

The degree of man or machine implication varies according to the control type. In the first type the man has all responsibilities: action, perception and decision. The second control type is the result of a task allocation between the man and the person. Man takes decision to execute a control whose effects are known after a context evaluation. The machine takes over the action referred to its perception faculties. In the third type of control, the reason of the motion is defined by the person and both the application methodology and the task execution are taken over by the machine.

The proposed controls number seems to be important. The controls must be the most natural and simple to use. At any time, the onboard person must feel that she 's mastering herself the motion in order to preserve the machine psychological acceptability. In this paper we develop a functionality common to the control types (2) and (3). It concerns the sensor-referenced motion. Such an action concerns the machine safety and uses the ultrasonic environment sensing. The major goal of the proposed method essential is to guaranty an easy and robustness implementation according to the US. This sensor are used despite their drawbacks, nevertheless they have a low-cost advantage. As a consequence, a lot of US can be mounted around the wheelchair and such a technical solution offers a versatile way to obtain a most complete as possible set of perceptual data of the environment.

6. PRINCIPLE

The basic idea consists in controlling the wheelchair as if it was following a vector passing through or outside the rotation center. The motor controls are performed by a fuzzy logic method that is out of the paper object. Nevertheless it has the advantage: to be simple to implement, to obtain motions compatible with human movement feeling and to be usable by a lot of macro-controls as obstacle avoidance or wall following. A reactive control entirely based on ultrasonic sensor is sensitive to reading errors that can be large in magnitude and in occurrence. In [BEL94a] the authors limit the impact of reading errors by using a certainty grid. This allows obtaining a local image of the environment where each cell is the average of numerous measures that have been read at some different position of the wheelchair. The motion control is then defined according that grid. Different control types are used in the literature for the obstacle avoidance. The most frequently used is based on artificial potential. But it becomes unusable when the environment is hardly constrained by such configuration as narrow corridor or doorway. In [BEL94A&B] the authors propose an original method based on a polar diagram representing the obstacle proximity according to the mobile position. The method we propose lays on a simpler concept and is easier to implement .We define in table the wheelchair 's behavior for each sensor. At the present time, the wheelchair's behavior consists in defining for each sensor a vector to be following when an obstacle is detected. (see figure 3).

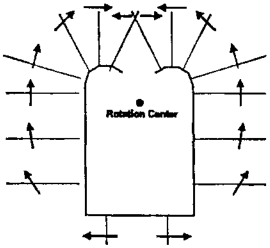


Figure 3: The θ_i orientation values in the behavior table

A great precision for these values is not required. The global direction θ that must be followed by the wheelchair depends on a combination of all the table elements θ_d and the measured distance values. It equals to the average of the angles given by the table weighted by the inverse of the measured distance dist(i). The obtained vector has to be placed at the rotation center.

$$\theta = \frac{\sum_{i=1}^{m} \frac{\theta_d(i)}{\text{dist}(i)}}{\sum_{i=1}^{m} \frac{1}{\text{dist}(i)}}$$

Such a control information allows obtaining a swift motion when the wheelchair is going away from the obstacles. Concerning the reactivity level, this type of control gives good results. A big obstacle is usually well detected and the avoidance process works perfectly.

In a disabled person environment context, which is either an apartment or a specialized center, the obstacles are usually difficult to detect or non -cooperative. In such an environment, the wheelchair can meet small and difficult to detect obstacles as chair legs. Due to their particular shape, some obstacles create specularities or crosstalk phenomena, which induces measurement errors.

As an example, let's take a door crossing. In such a configuration we have a particular specular case. The door stiles favors the US waves dispersion for some sensor placements (see figure 4)

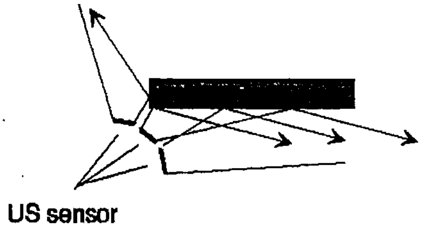


Figure 4 : specularities induced by the obstacles

The more the sensor is close to the obstacle corner more the specularities phenomena occur. A direct robot control according to the US instantaneous values leads toward a collision. On the other hand, we can see that the specularities occur only for a specific sensor positional configuration. So, we propose to take into account the history of the controls emitted to the robot. Each control θ is given according to all sensor measurements. We define a control that takes into account a set of controls related to the previous measurements. Let d_i the Euclidean distance between the wheelchair position at the emission of a control θ_i and the actual position. The different controls are put into a FIFO list with the first element given for i=0. We deduce from the set of controls a new one as

$$\theta = \frac{\theta_0 + \sum_{i=1}^{n-1} \theta_i \frac{k}{d_i} \frac{1}{i}}{1 + \sum_{i=1}^{n-1} \frac{k}{d_i} \frac{1}{i}}$$

Comments: n represent the control number to take into account for the θ computing. θ_0 is the deduced control according to the instantaneous sensor information and θ_I one of the n control used. We take into account only the controls which varies of a Δθ value according to the previous value. We have $|\theta_i - \theta_{i+1}| > \Delta\theta$. Thus if the sensor information is not modified then the related controls are not stored. The value $\frac{k}{d_i}$ is limited to 1 for $d_i < k$. In our application k=5cm. We don't consider directly the wheelchair rotations. If the robot moves on the spot it may gives a large weight to the previous controls despite the robot placement modification. In order to limit these effects we propose to weight each control by a second weight related to its position in the list. This weight is given by $\frac{1}{i}$.

7. RESULTS

In our experiments n was chosen equal to 3. The experiments we conduct concerns the door crossing in order to compare our results with those defined in [BEL94A&B]. A variable width door has been realized. The door stiles are made with smooth wood. The obtained results are given in term of percentage of success of door crossing (see figure 5).

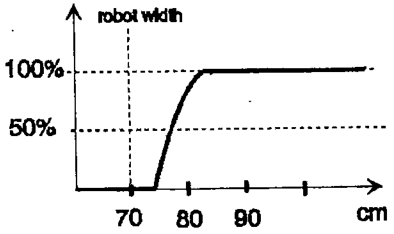


Figure 5 Percentage of success of doorway crossing.

As we can see the system can cross an 85 cm doorway with a 100% success which corresponds to a 15 cm difference with the wheelchair width. This experience was conduct with different orientations of the robot according to the door opening. Below 85 cm we obtain some successes but they depend on the robot starting orientation. These results are to be compared with those obtained in [BEL94a&b] but the methodology we propose is simpler. The used US sensors have a 12 cm dead zone where they can't measure anything. In our experiments we verify that the robot can't cross a doorway with a clearance less than the left and right cumulated dead zones. Actually the theoretical limit of a controlled door crossing is equal to the wheelchair width where one dead zone is added (70cm + 12 cm = 82cm).

8. CONCLUSION

Our experimentation shows that simple methodology can allow an efficient obstacle avoidance, and this despite the presence of cross-talks and specularities phenomena. It allows navigating in a corridor-like-environment that is not possible with a method derived from the artificial potential. Our future investigations are now to evaluate the system in a daily disabled person environment.

9. REFERENCES

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