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Intelligent Powered Wheelchair Evolving in a Virtual Environment

Abstract: *This paper presents the first results in the development of a platform of simulation. The aim is to develop a system of simulation based on virtual reality techniques for different uses: driving simulator, facilitate the study of powered wheelchairs, help to the prescription of wheelchairs. An intelligent wheelchair has been simulated. The present progresses have been outlined and the models used in the virtual world have been described.*

Key words: *Simulation, powered wheelchair, virtual reality.*

1. Introduction

Most of the time physically disabled people use powered wheelchairs controlled by a joystick sensor. However, even if some of them have driving capabilities too weak to use safely such an analog device, they can to use other types of sensors such as a simple button to validate controls. The use of such a device to control the wheelchair needs an "intelligent" system to assist the user in his mobility. It is the aim of the V.A.H.M. project [BOU98] (French acronym for "Autonomous Vehicle for Disabled People"), which assists the driver in the control of the wheelchair in the way that several tasks can be performed autonomously (wall following in a corridor, door crossing, ...).

The figure 1 shows the VAHM robot which is basically a usual powered wheelchair to which several devices have been added:

- In order to manage to react with its environment, the robot is equipped with a belt of 16 Ultrasonic Sensors (US) which evaluate the distances to the nearest obstacles.
- An odometer makes it possible to estimate the instantaneous state (position and orientation) of the robot, assuming the knowledge of its initial state and measurements of wheel rotations.
- An on board PC is dedicated to generate the engine controls and manages the high level tasks, such as path planning or obstacle avoidance.
- A screen display to visualise the graphical interface which permits the interaction between the user and the machine to achieve a task.

The main idea is to carry out a system which adapts as well as possible the allocation of tasks between the man and the machine, according to the degree of handicap of the user and the complexity of the environment.

In this context, the possible operating modes are :

- the manual mode in which the robot is driven as a classical powered wheelchair,
- the assisted mode complete the precedent mode with predefined functionality's such as the wall following or the obstacles avoidance, to facilitate the driving of the wheelchair,
- the automatic mode where the wheelchair performs autonomous displacements to achieve the task given by the user.

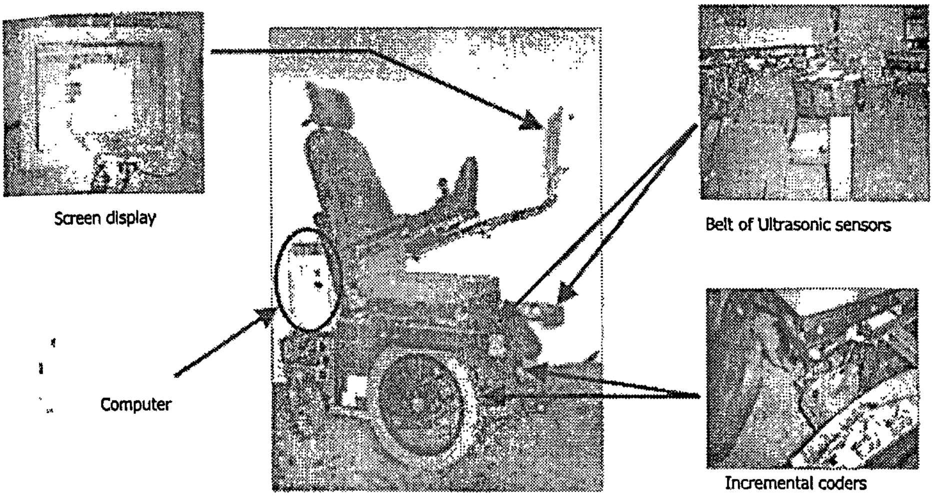


Figure 1: Prototype of the VAHM robot

However, during the stage of real evaluation, some problems may appear:
- the physical efforts and the concentration required can be difficult to support for some disabled people.
- the creation of real environments used for the tests requires much time in most of the cases,
- the elaboration of scenes to study the behaviour of the user's facing particular situations (modification of the environment, situations of danger...) induce a waste of time, and can be impossible to realise in the real world.

The application of Virtual Reality techniques in the context of the project allows to carry out the experiments without these constraints.

In addition to the development of new functionality's for "intelligent" wheelchairs, the design of the system of simulation pursues mainly two goals:
- training to the control of powered wheelchairs for young disabled children: VR allows a first experiment of autonomous mobility without the inherent risks of the real world (collisions with the environment) [HAR00].
- to contribute to the prescription of powered wheelchairs [GAR96]: the creation of a library of currently available wheelchairs can make it possible to test virtually several vehicles in varied simulated environments.

The evolution of the VAHM robot in a virtual environment requires:

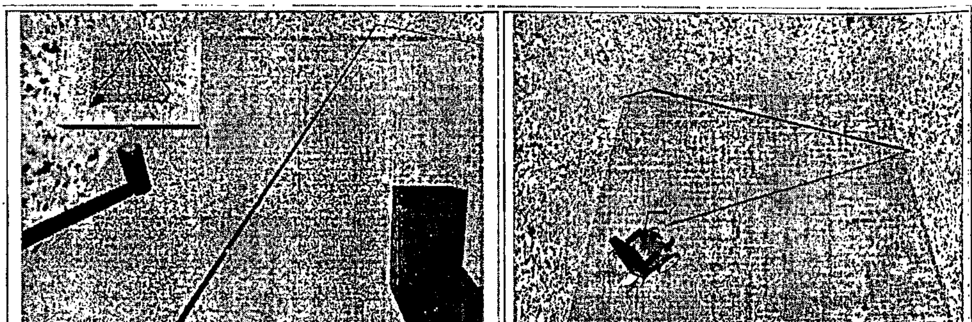
- **the development of the software of simulation,** and also modules of communication between the simulator and the external devices (such as incremental coders), which permits to test a powered wheelchair in complex situations.
- **the modelling of the ultrasonic sensors** to measure the distances between the virtual wheelchair and the different obstacles.
- **the design and the realisation of the platform of simulation** which must make it possible to give the user sensations similar to those he would experience in the real world (accelerations).

2. Visualisation of scenes

Concerning the software of simulation, at the moment a first version is available and deals with most of the tasks enumerated in introduction. It allows the modelling of the various actors of the scene such as the walls, the fixed objects in the environment but also the powered wheelchair which kinematics has been modelled.

The user can navigate in a virtual world he chooses, by using the wheelchair according to three operating modes which are associated for him:

- on board mode (figure 2a): the user can take place in the virtual wheelchair by the means of virtual reality helmet and see all what he would have seen in reality.
- following mode: it allows the visualisation of the displacement of the wheelchair while placing the viewer at each instant at the vertical of the wheelchair, which gives him a global vision of the wheelchair and its environment. He can see for example what occurs at the back of the wheelchair (in particular collisions), which is not possible in the precedent mode.
- the spectator mode (figure 2b): the viewer is fixed regarding to the reference frame of the scene in which the user navigates.



(a) (b)

Figure (2a): On board mode, the user sees the simulation through the virtual helmet. On the virtual monitor the spectator mode is displayed

Figure (2b):Spectator mode, the viewer is fixed regarding to the reference frame.

3. Modelling of the ultrasonic sensors

Usually, models of ultrasonic sensors are based on geometric considerations, and most of the cases (except when sensors are used in arrays [HOL95]), they concern only 2D (or 2D-like) environments [DEM99][HAR98][HOG94]. We have considered initially the ray casting in an ideal way: the beam has its origin at the center of the sensor and directed perpendicularly to the plan of the transducer. The data delivered by the sensor is the exact distance between the origin of the ray and the first polygon encountered. Then we have integrated the characteristics of the cone of emission (aperture angle, wave propagation inside the cone), inside which the wave is represented by a cylinder with a small height. The wave is propagated and reflects on the surfaces till it encounter the sensor which has generated it or when the transducer emits a new wave. If the waves return to the transducer, the measurement given by the virtual sensor is the distance covered by the wave before attaining an obstacle (figure 3).

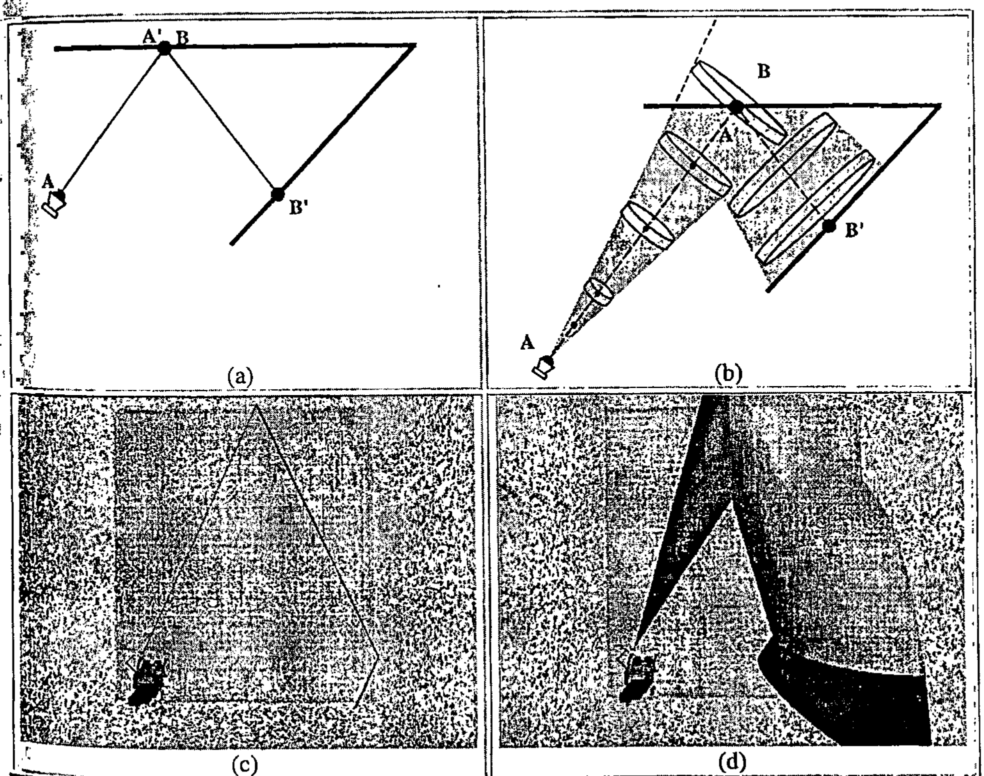


Figure 3: Differents steps of the simulation of the ultrasonic wave propagation. The wave reflects on surfaces till it encounter the sensor which generated it or if the covered distance is greater than a maximal value (corresponding to the elapsed time during the transducer operates as a receiver).

The next step in the model of the sensor is to take into account of phenomena depending on the nature of the environment in which wheelchair moves, particularly the nature of surfaces separating free space from occupied space (walls, obstacles...). This parameter (roughness, type of material) influences directly the way the ultrasonic wave is reflected, and thus the data given by the sensor.

4. The platform of simulation

At the moment the platform of simulation is in the design stage. In order to simulate displacements of a wheelchair in a virtual environment, the wheels are disconnected from the engines, so that the engines can be controlled, but the real wheelchair don't move [NIN00]. The wheelchair sends data given by the incremental coders located on the axes of the engines, trough the serial port of the PC. These data are necessary for the simulator to establish the instantaneous position and orientation of the robot in the virtual scene.

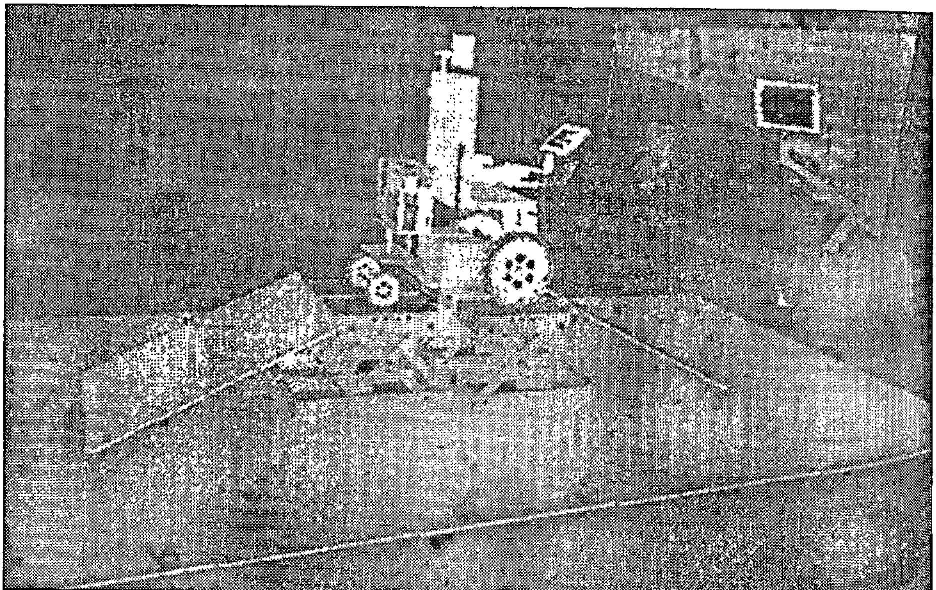


Figure 4: Example of a design of the platform of simulation. The simulation can be viewed through a virtual helmet or projected on a giant screen.

The simulation platform has to deal with various types of wheelchairs: driving wheels at front or at back. In order to study the way the user navigates with a given type wheelchair, it is necessary that he receives feedback informations that are close to those experienced in the real world (accelerations, shocks, sound...). This tool will permit us to put the person in particular situations in order to study its behaviour, with the aim of model the way a disabled person drives and evaluate the control of the wheelchair, particularly in constrained environments.

5. Conclusion

The first results in the development of a system of simulation for powered wheelchairs have been outlined in this paper. The user can navigate inside a virtual environment using the wheelchair in the manual mode. At present, a study is on progress to model the dynamics aspects of the wheelchair (inertia, accelerations,...). The ultrasonic sensors has been modelled more realistically, in the way that a wave is propagated and it stops as it encounters an obstacle. Concerning the environment, some parameters such as the type of the surface has to be taken into account, because it influences directly the way the waves are reflected. Finally, in the virtual world, the user should control the robot as in the reality, so it is necessary to simulate the graphical interface of the wheelchair in the virtual scene to access the various modes of navigation of the VAHM (manual, assisted and automatic).

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