Simulation of the behaviour of a powered wheelchair using virtual reality

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ABSTRACT

This paper describes the firsts results of a project of simulator for powered wheelchair, using Virtual Reality. We have simulated the kinematics of an existing intelligent wheelchair, which was designed in order to facilitate the driving of a powered wheelchair. We also present the integration of modeled ultrasonic sensors in the simulation.

1. INTRODUCTION

Recently Virtual Reality has been essential in the field of simulation. This technique indeed allows to build a world which can resemble closely to the real world by leaving the user the possibility of handling the elements. For this reason, the application's fields of RV was spread quickly in the following areas: car and aerospace's industries, architecture, medicine (Çakmak and Kühnapfel 1999), and more recently in the arts like sculpture. Concerning the domain of the handicap, several projects were developed, aiming to build simulators for powered wheelchairs.

These projects pursue various goals:

- design of powered wheelchairs (Inoue and Hirose, 1998),
- drive training for handicapped children (Desbonnet, 1997),
- study the accessibility of public infrastructures to the wheelchairs (Browning, 1993),
- simulate the wheelchair's navigation in domestic environments (Simon, 1997).

The search in progress presented in this article aims to assist disabled people. It is the extension of the VAHM project (Vehicule Autonome pour Handicapés Moteurs) (Bourhis, 1998): it is related to an intelligent system which assists the driver to control the powered wheelchair (Figure 1).

The characteristic feature of this robot is to help controlling the wheelchair by adapting the allocation of the tasks between the handicapped person and the machine as well as possible, accordingly to the degree of the user's disability and the complexity of the environment. During the test phases, it is necessary to involve disabled people. However, this can generate some problems. For each test the user is surrounded by a medical staff, which causes a problem of availability. Moreover, the driving of the wheelchair is not free of collisions with the environment, which could be relatively violent. Therefore, the real tests are affected by material problems; those often induce a waste of time (breakdowns, detection and replacement of a defective component...). Finally, the creation of real environments used for the tests requires generally much time. The use of VR makes possible to carry out the tests in a fictitious world, and thus proposes a solution to these problems.

2. DESCRIPTION OF THE PROJECT OF SIMULATION

The simulation system in progress follows several aims: First of all the platform structure has to simulate as much as possible the powered wheelchair moving in not plane environments (access ramps, roughness of the ground...) Moreover the user will be able to feel accelerations in the same way as in the real world, which will contribute to improve realism of the simulation. This project also aims to develop a support for driving a powered wheelchair. This permits the evaluation of the user's ability to drive, and thus to choose the wheelchair more appropriately. Finally a software tool for a design assistance will come to supplement this system of simulation.

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2.1 Presentation of the VAHM2

One of the major projects of the LASC is the design of an intelligent system of assistance to control a powered wheelchair for disabled people. The second prototype in the VAHM project is presented in Figure 1.

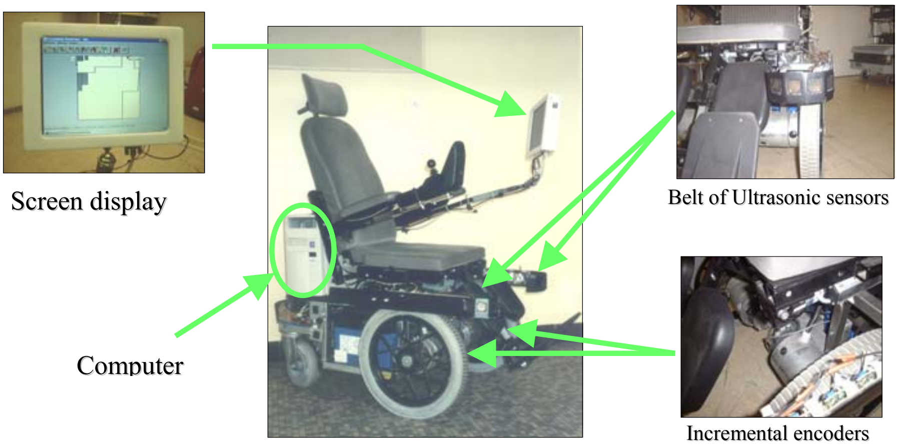

Figure 1. *The VAHM2 prototype.*

The robot is composed of a traditional powered wheelchair equipped with:

- an odometer which estimates the instantaneous position and orientation of the robot knowing the initial position and measuring the rotation of the wheels
- a belt of 16 Ultrasonic Sensors to measure the distances between the wheelchair and the closest obstacles
- a computer that controls the engines and generates high-level tasks as avoiding obstacles or global path planning.
- a display to visualise the graphic interface which manages the interactivity between the man and the machine.

The robot can work under three navigation modes:

- Mode I (manual mode): the robot is used as a traditional wheelchair because its equipment are not activated.
- Mode II (half automatic mode): the navigation is similar to the manual mode, but there is an assistance for operations that could be difficult according to the seriousness of the user's deficiencies. A good example is passing through a door or follow-up a wall...
- Mode III (full automatic mode): it allows the wheelchair to follow a trajectory by itself, connecting two points of the environment which are chosen by the user, avoiding unexpected obstacles. It is the case for example of a chair which has been moved, or a person who crosses the robot trajectory. In these three modes, the user always has the possibility to stop the robot using an emergency button.

2.2 Principle of the present simulator

The current simulator contains a workstation which is equipped with virtual reality helmet. It has to manage the simulation in the virtual world and the interactions between the real worlds and virtual environment.

The user can navigate in a virtual world he had chosen, using the wheelchair accordingly to its three operating modes (Figure 2). The closest aim is to get free of the helmet by projecting the simulation on a giant screen. At the moment the simulation is realised by data exchanged between the real robot and the simulator (Figure 3).

For the simulation of the robot's motion, we have disconnected its wheels from the engines (putting them on neutral position). While the robot is motionless in the real world, it is controlled in the virtual scene by a real joystick (in the case of the manual and assisted modes), or by the path planning unit (in the automatic mode). The odometer of the real robot can estimate the wheelchair's position and orientation using the data of the incremental coders which are placed on the engines' shaft. These data allows the simulator to manage displacements of the robot in the virtual environment. In order to make the robot capable to avoid obstacles which were not initially modeled (for example a moving obstacle), the simulator sends back to the robot the measurements of distance taken by the sensors modeled in the virtual environment. The following step is to place the robot on a plane surface, located at a few centimetres of the ground. Using cylinders on which are placed incremental coders, we can avoid the use of the robot's odometer, and then we can simulate the motion of any ordinary wheelchair. The final step is to equip the platform with jacks, in order to be able to simulate a navigation on inclined surfaces and also simulate the accelerations the pilot is submitted to. The figure 4 shows a design of the final platform.

Figure 2. *Principle of the current simulator.*

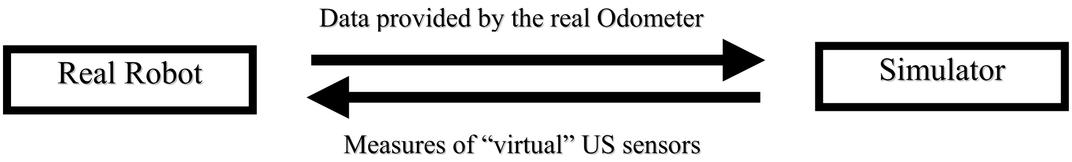

Figure 3. *Data exchange between the real robot end the simulator.*

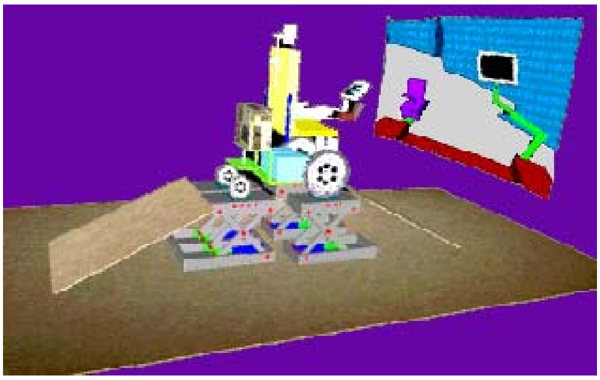

Figure 4. *Design of the simulation platform.*

2.2 Models

2.2.1 US Sensors. In order to be able to navigate safely, the wheelchair needs to measure its distances to the closest obstacles. Since the real wheelchair remains motionless, it is necessary to integrate the simulation with a model of ultrasonic sensors. These " virtual " transducers have to send to the real robot the distances measured during the simulation, like the real sensors do. In a first approach to the problem, we modeled the transducers in an ideal way.

Figure 5 shows an example for the measurement of distance in the simulated environment. Each transducer emits a beam which is totally reflected in the same direction given by the acoustic axis (we have shown only the impact of 2 up to 16 sensors). Currently we use a 2D model (Figure 6) which is an extension of the previous model. We consider the beam angle of the transducer crossed by a discrete number of rays in a horizontal plane. Each ray gives us a measure, and we consider only the smallest returned value. The advantage of this method is its low computation time. Its disadvantage is that the modeled transducer perceives only obstacles located in a plan parallel to the ground. For example, in the case of a table, the transducer will perceive only the table's feet; then a collision may occur between the table's surface and the wheelchair. Using the same concept of a 2D sensor, a study is in progress and it involves an experimental model proposed by Harris (1998). This model is related to the Polaroid 6500 series ultrasonic ranging system (Polaroid, 1991) which we use for the VAHM2. This study should enable us to determine if a 2D model is appropriate for our application, or if it is necessary to extend the model to the 3D case (Figure 6).

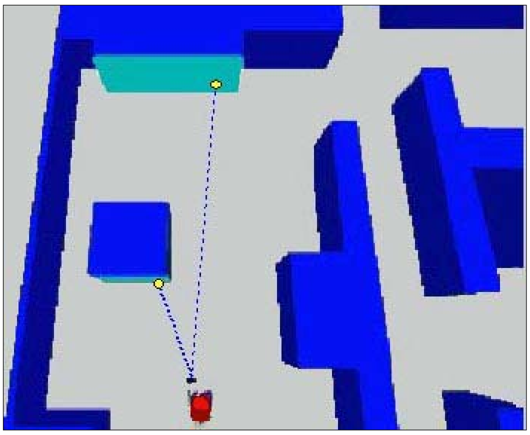

Figure 5. *Example of the measure of the modeled sensor. The measure is done on the acoustic axis of the sensor. We show only 2 up to 16 sensors.*

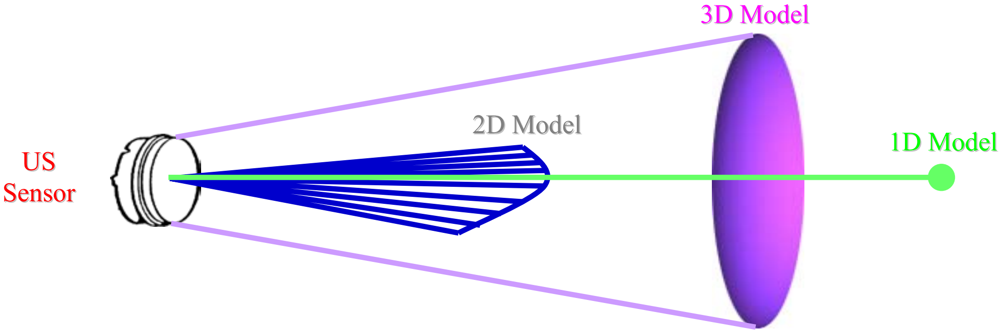

Figure 6. *Models used to simulate the ultrasonic transducer. In the first simulations we used the 1D model, and now we use a 2D mod l based on the previous one: the measure is taken inside a cone, but at a fixed height.*

2.2.2 Kinematic of the VAHM2. Till nowadays we considered in our simulation the wheelchair as a "*free flying point"* (without mass): the control of the wheelchair was done by imposing a trajectory to this point which was taken between the wheels (Niniss, Nadif and Bourhis, 2000).

Using this simple model (Figure 7), we have simulated the wheelchair working under its three navigation modes, but we didn't take into account the kinematics of the wheelchair. The kinematics of the wheelchair was integrated to the simulation in order to study the effects of the different configurations of the wheelchair on the navigation in environments with obstacles (Figure 7).

Placing the driving wheels on the front, on the center or on the back of the wheelchair will influence the way of executing the same task (avoiding an obstacle, half-turn...). For these reasons, it was necessary to consider the instantaneous rotation angle and the speed of each driving wheel to determine the instantaneous position and speed of the wheelchair. In this way the simulated wheelchair can behave more realistically. Like the real wheelchair, the control of the simulated one is based on the tension (controlled by the joystick or the computer) which has to be applied to each engine. The position and the orientation of the wheelchair are estimated by the odometry principle, which considers the measure of rotations of the driving wheels.

Figure 7. *Simulation of the VAHM2 prototype.*

Figure 8 shows how the wheelchair is controlled in the manual mode, for both the real case and the simulated one. When the joystick is pushed forwards or backwards, the two driving wheels turn at the same angular speed and in the same direction ($\omega_l = \omega_r$), which causes a translatory movement. If it is pushed on the right or on the left, the wheels of the wheelchair turn at the same speed, but in opposite direction ($\omega_l = -\omega_r$), which causes a rotation around an axis located in the middle of the wheels. If the joystick is in diagonal position, one of the wheels turns while the other remains motionless, then the wheelchair describes a circle centred on the motionless wheel.

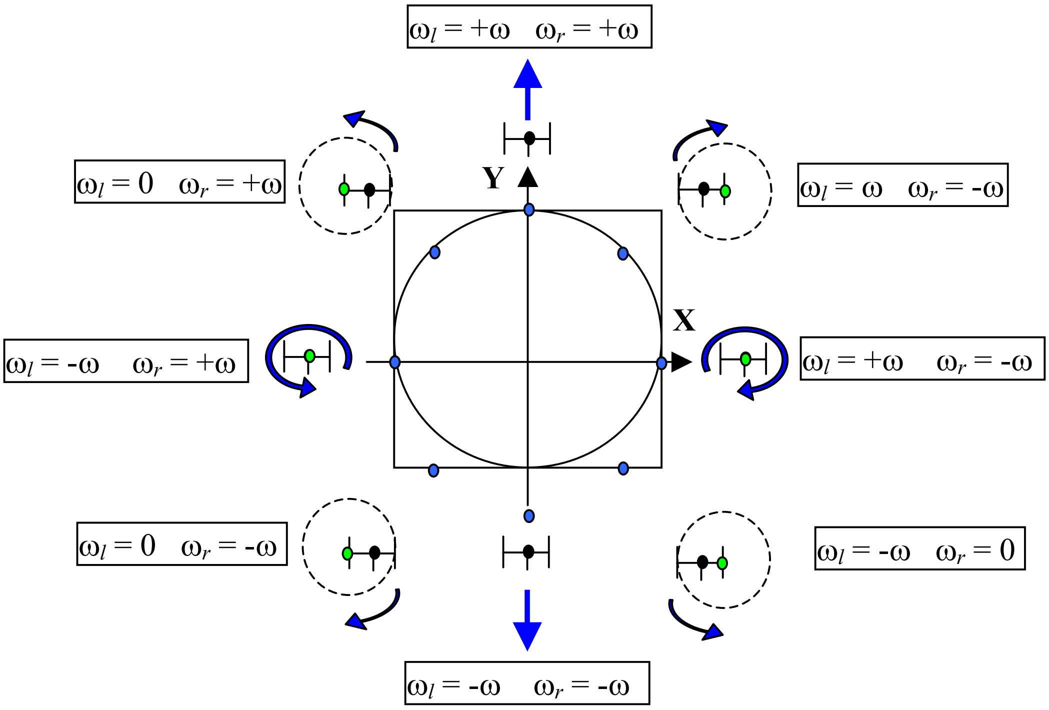

Figure 8. *Control of the wheelchair in the manual mode.* ω_l *represents the angular speed of the left driving wheel and* ω_r *is the angular speed of the right driving wheel. We constantly have* $0<\omega<\omega_{Max}$*, where* ω_{max} *is the maximal angular speed that can be obtained.*

The kinematics of the simulated wheelchair is a satisfactory approximation of the real wheelchair when the engines reach their stationary state. However for the transient states (for example when we turn the wheelchair on), a dynamic model must be elaborated, to take into account the mass of the physical system composed by wheelchair and the user in order to simulate its inertial aspects.

During the simulation we can use a virtual joystick as well to control the wheelchair. For the moment we can only simulate the VAHM2 prototype, but our final goal is to be able to simulate any kind of powered wheelchair (which will have to be chosen in a data base) using a traditional one. In this prospect, it could be interesting to control the “virtual” wheelchair with a simulated joystick. The user has the possibility to control the “virtual” wheelchair inside the simulation using the “virtual” joystick.

The last step is to integrate the computer screen in the simulation. This will allow the user, immersed in the virtual scene, to have access to the graphical interface, (used by the VAHM2) which role is to make a link between the user and the machine.

3. CONCLUSION

We have presented our first simulations of a powered wheelchair using Virtual Reality. To carry out these simulations it was necessary to model a certain number of real elements. The main element is an intelligent system designed in the aim to help driving powered wheelchair. This system can works in three modes (manual mode, semi-automatic mode and full automatic mode). In a previous work we have simulated the three modes of the robot (Niniss et al., 2000), using a simple geometric model for the wheelchair, and also a trivial model for ultrasonic sensors. In this present work, we have taken into account the kinematics of the wheelchair in the simulation. We have studied the wheelchair’s navigation in its manual mode (the other modes are the extensions of this mode), in order to make the behaviour of the simulated wheelchair more realistic. We also used an ideal 2D model for the ultrasonic sensors. A study in progress based on experimental data should permit to evaluate this model and to determine if it is necessary to extend the model of ultrasonic sensors to the 3D case. Finally, for the modeling of environments, we would like to consider the characteristics of the surfaces (roughness, type of material) which determine the way the beam is reflected and then also the measure of distances.

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