Initial Report on
Wheelesley: A Robotic Wheelchair System

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Abstract

An assistive robotic wheelchair system should allow its user to travel more efficiently and with greater ease. While standard electric wheelchairs can be used by people with limited upper body mobility, some tasks such as door opening and moving around corners require fine joystick control that these users often find difficult. This paper reports initial work in the development of a semi-autonomous robotic wheelchair system. The robotic wheelchair system described in this paper, *Wheelesley*, automates many common navigational tasks for the user. The system consists of a standard electric wheelchair with an on-board computer, sensors and a graphical user interface running on a mounted notebook computer.

Introduction

Assistive robotics can improve the quality of life for disabled people. This project aims to develop a robotic wheelchair system that will assist its user with navigational tasks while supplying information about the world to the user. Electric wheelchairs can be used by people with limited upper body mobility through joystick control. However, the joystick requires fine control that the person may have difficulty accomplishing. Our system allows the user to tell the robot where to move in gross terms and will then carry out that navigational task using common sensical constraints such as avoiding collisions.

For example, it may be easy for a disabled person to gesture in the direction of a doorway, but it may be difficult for that person to do the fine navigation required to direct the wheelchair through a doorway that is barely wider than the wheelchair. To move through a doorway using our system, the user will tell the robot that there is a doorway ahead using our graphical user interface. The robot will then move through the doorway for the user.

Our robotic wheelchair system is intended to be a general purpose navigational assistant in environments with accessible features such as ramps and doorways of sufficient width to allow a wheelchair to pass. We will not rely on maps for our navigation, which will allow the wheelchair system to be used in any accessible building. We believe that a robotic wheelchair system should not be limited to one particular location, either by requiring maps or by environment modification. The current focus of the research is indoor navigation, but we are also developing navigational assistance for outdoor use. The tasks of the wheelchair include navigating down busy corridors, moving through doorways, pulling up to desks and tables, and moving up and down ramps.

This work is based on previous research in robot path planning and mobile robotics. The primary focus of mobile robotics research is autonomy. However, a robotic wheelchair must interact with its user, making the robotic system semi-autonomous rather than completely autonomous. A mobile robot is often only given its goal destination and a map. The wheelchair can not subscribe to this method. The user may decide to change course during traversal of the path -- as he starts to go by the library on the way to the mail room, he decides to stop at the library to look for a book he needs. The wheelchair robot must be able to accept input from its user not only at the start of the trip, but throughout the journey. When the user may have restricted mobility in his arms or may be blind, the robot should have the

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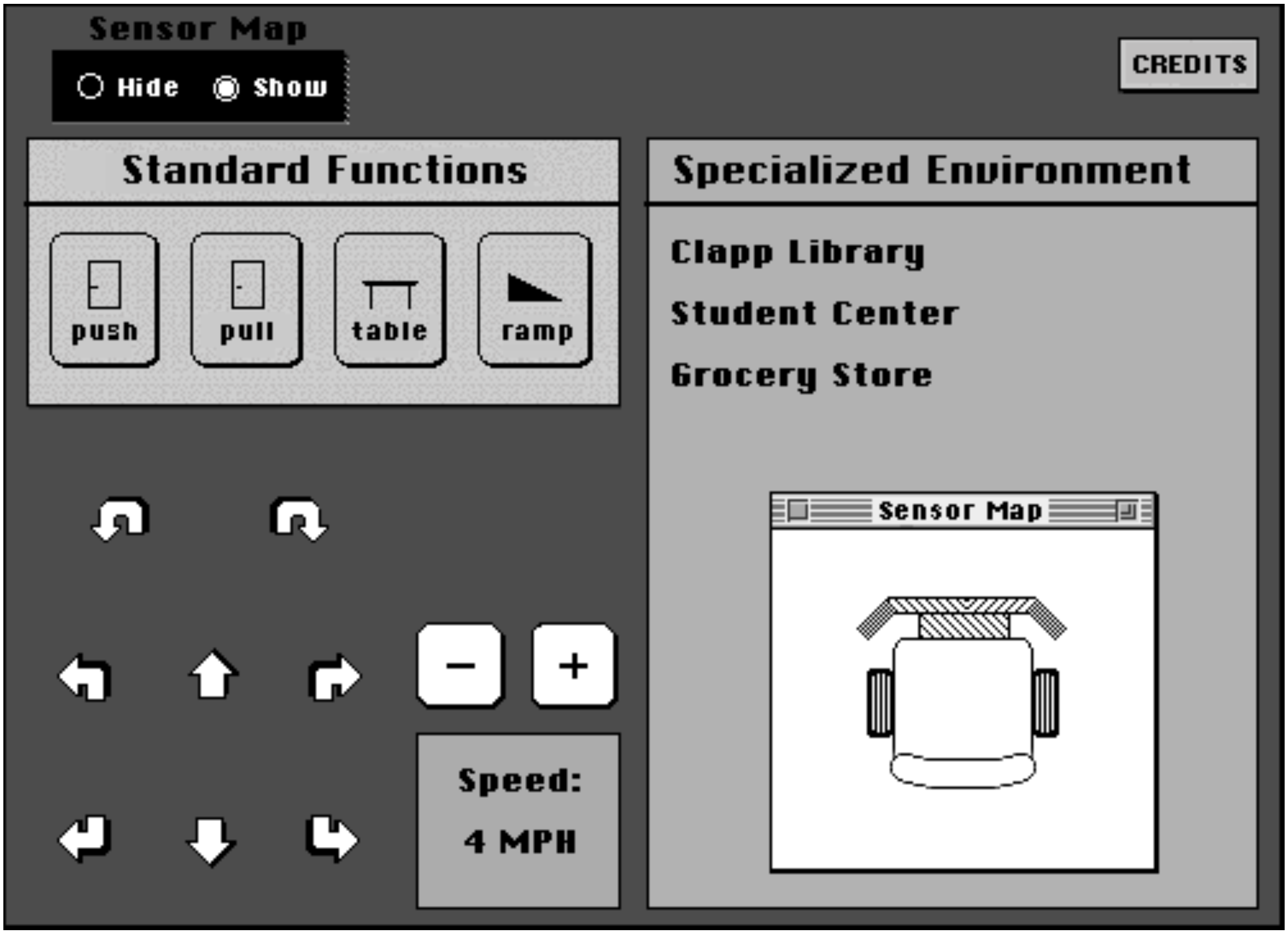

Figure 1 Screen shot of the primary screen of the graphical user interface.

ability to take on a greater autonomous role, but the robot will still need to work in conjunction with the user. The user interface developed for this purpose is described below.

We are seeking advice from wheelchair users throughout our design process. Since none of the team members use a wheelchair, we can not fully determine the areas in which an assistive wheelchair would be the most useful. In this initial research phase, we have begun to interview wheelchair users to determine which functions are most needed in an assistive robotic wheelchair system. We hope to incorporate these users in our testing phases as the research develops.

Graphical User Interface

We have developed a graphical user interface that allows the user and robotic wheelchair system to communicate with one another. The user controls the robot using our point-and-click user interface. The primary user interface screen is shown in Figure 1.

To control movement, the user clicks on the arrow buttons on the lower left of the interface screen. There are six movement buttons: forward, forward to the right, backward to the right, backward, backward to the left, and forward to the left. There are also two buttons that allow the user to turn in place to the left or to the right; these buttons are directly above the movement buttons. When the user commands the robot to move in a particular way, the robot attempts to carry out the command given that it is able to do so in the current environment. For example, if the robot is told to go forward, it will go forward while avoiding obstacles. If the robot is completely blocked, it will stop moving and wait for further instructions from the user.

The user controls the standard speed of the robot by clicking on the plus and minus buttons to the right of the direction buttons. The robot may move at a slower pace than the user requests when the current task requires a

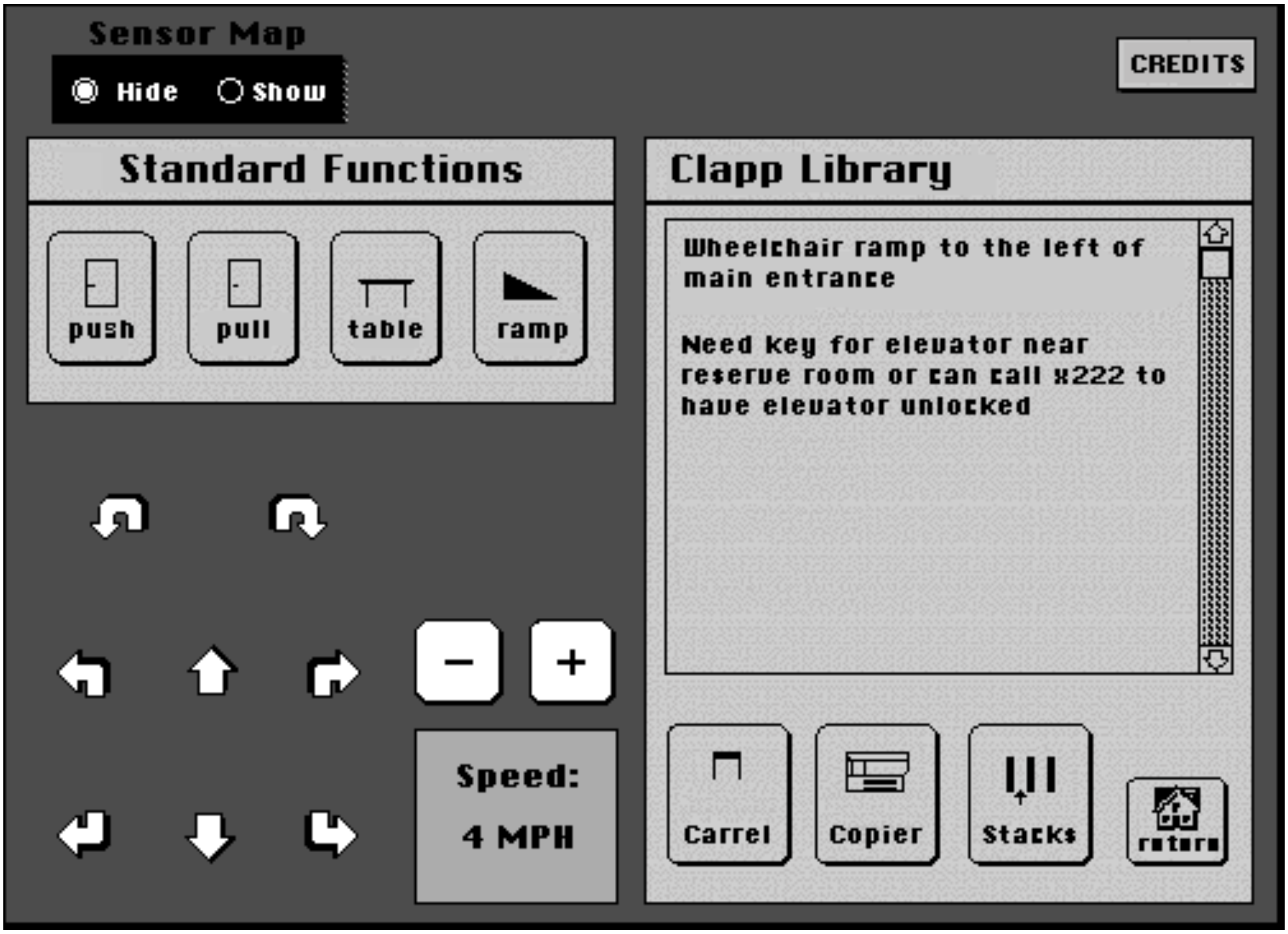

Figure 2 Screen shot of the specialized environment screen for Clapp Library.

slower speed in order for the task to be carried out safely. The actual speed of the robot is displayed by the robot under the speed control buttons.

Above the movement buttons are the "standard function" buttons. These tasks include moving through doors (the task is broken down to doors that open away from the wheelchair and doors that open toward the wheelchair), pulling up to a table, and moving on ramps. These standard functions are currently under development.

The user can choose to hide or to show the sensor map. The sensor map shows a representation of the wheelchair. Obstacles detected by the sensors would be displayed on this sensor map. This is intended to provide a user who is unable to move his head with a picture of the obstacles in the world around him. In Figure 1, the sensor map is shown but no obstacles have been detected by the robot.

To the right of the standard functions and movement buttons is the specialized environment area. In this region, the user can tailor the system to their needs. In the system in this example, there are three specialized environments. When the user clicks on "Clapp Library", the right side of the screen changes to the specific information for Clapp Library (see Figure 2). There is a region for the user to make notes about the location of ramps, elevator locations and details about moving around the particular environment. The specialized environment area may not only be used to customize the robot to move more quickly around places the user travels frequently, but also can be used to record information such as the location of ramps in very infrequently traveled locations.

The specialized environment area also includes some buttons for tasks that are specific to the environment. In the library, there are customized routines for pulling up to a study carrel and the copy machine. Notice that these two routines are similar to the standard "table" routine, but in these two cases the user enters in the specific heights of the objects to allow the robot to pull up more effectively. The "stacks" button performs the same task as moving down a corridor, but with a

Figure 3 *Wheelesley*, the robotic wheelchair system.

higher tolerance for tight spaces. To return to the primary interface screen, the user clicks on the "return" button in the lower right hand corner of the specialized environment region.

We recognize that a point-and-click interface may not be optimal for users with limited upper body mobility. This interface is not intended to be a final product, but a step towards an effective user interface for a robotic wheelchair system. The point-and-click interface could be changed to one that recognized voice commands.

Equipment

The robotic wheelchair system was built by the KISS Institute for Practical Robotics (KIPR) and is shown in Figure 3. The base of the robot is an electric wheelchair. This wheelchair has two drive wheels under the center of the robot, two drive wheels and a back caster. The placement of the drive wheels allows our robotic to turn in place. For sensing the environment, the robot has 12 SUNX proximity sensors, 6 ultrasonic range sensors, 2 shaft encoders and an instrumented front bumper. The on-board computer is built with a 68332 processor. The user interface runs on a Macintosh Powerbook.

Related work

Some of the previous wheelchair robotics research has resulted in wheelchair robots that are restricted to a particular location. In many areas of robotics, environmental assumptions can be made that simplify the navigation problem. However, a person using a wheelchair should not be limited by the device intended to assist them.

One example of restrictive assistive wheelchairs are systems that rely on map-based navigation. Maps may be provided to or created by the robot, but the system will perform efficiently only when a complete and accurate map is available. The system will either fail to work or work inefficiently when the robot is operating in an environment for which it has no map. If the robot can only operate efficiently in one building (as, e.g., [Perkowski and Stanton, 1991]), the user will not be able to use the technology once she leaves the doorway of the known building. Since most people need to be in several buildings during one day, this system is not general enough, although it is a step towards assistive robotics.

Even more restrictive than a map-based system is that of [Wakumi et al., 1992]. This system requires the use of a magnetic ferrite marker lane for navigation. Once the wheelchair's user leaves the magnetic path, the technology of the assisted system is useless.

Not all work in wheelchair robotics depends on modified environments or maps. In [Crisman, 1994], a wheelchair robot navigates relative to landmarks using a vision-based system. The user of the wheelchair tells the robot where to go by clicking on a landmark in the screen image from the robot's camera. The robot then extracts the region around the mouse click to determine to which landmark the user wishes to travel. It then plans and executes the route to the landmark. While this system does not rely on any environmental modifications or maps, the vision computation can add a tremendous amount of overhead to the processing on the robot. Our system uses sonar sensors to navigate reactively in the environment, eliminating the overhead of the vision calculations.

In [Bell et al., 1994], the NavChair is able to navigate a corridor in an office environment. They report that their wheelchair has difficulty moving through doorways since the width of the doorways is just 0.13 m wider than the wheelchair. Our system should not only be able to navigate corridors effectively, but also travel through doorways and accomplish other tasks. We are using a subsumption-like architecture [Brooks, 1986] to accomplish this. Our architecture differs from subsumption in that the user's input will also influence the behavior of the system. The NavChair system had problems with doorways. However, if the system had been told it was about to move through a doorway, it would be able to switch from hallway navigation mode to moving through doorway mode.

Another system that does not depend on environmental modifications is that of [Ojala et al., 1991]. This system is intended for wheelchair users who can not see their environment. However, the work has only been done in simulation. While simulation can provide useful design information, a simulated wheelchair can not assist anyone but a simulated user.

Future Work

As the work reported in this paper progresses, we will continue the development of the user interface. All input to the system from the user is now taken through a point-and-click user interface running on a notebook computer. This system has limitations for people with limited upper body mobility since the use of a mouse may be as difficult as controlling a joystick. We envision a system that will incorporate voice commands into the user interface so that the user can speak to the computer. While we could change from a mouse-based system to a system tailor-made for the user of a particular robotic wheelchair system, this research is focused on a general system rather than specialized systems for each person's particular needs. However, we recognize that these systems would require customization before they would be truly useful to a real user.

In addition to the further development of the user interface, we will continue to develop the control routines running on-board the robotic wheelchair system. We will move from issuing simple commands such as "go through door" when the door is directly ahead to commands such as "move to the door on the right and go through it." These commands will require planning on the part of the robot, but should greatly reduce the effort required by the user of the system.

Summary

This research project is aimed towards developed a usable, low-cost assistive robotic wheelchair system for disabled people. In our initial work towards this goal, we have developed a graphical user interface which allows the user to communicate with the wheelchair's on-board computer. The robotic wheelchair must work with the user to accomplish the user's goals, accepting input as the task progresses, while preventing damage to the user and the robot.

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