A WHEELCHAIR MOUNTED ASSISTIVE ROBOT

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Abstract

A robotic manipulator has been mounted to an electric wheelchair to assist people with disabilities. Particular emphasis has been given to the constraints and requirements for wheelchair mounting.

Background

Many different approaches to assistive robotics have been both suggested and implemented. Whilst in some situations (for example a vocational setting) a fixed site workstation is suitable [1], in other cases (for example someone living independently in their own home) a mobile device [2] is more appropriate.

An earlier project at our Institute implemented a low cost mobile robot by mounting a manipulator on a simple non-powered trolley base, which could be moved around the home by a carer.

In order to extend the flexibility of this system, the same manipulator is now mounted onto an electric wheelchair as described in the current paper.

Methods

Central to the Institute's design philosophy [3] is the involvement of users at all stages of a device's development. In the case of the wheelchair-mounted robot project we have been in contact with about 30 volunteers, covering 5 disability groups. Of these a smaller number of local volunteers have been involved in more detailed discussions. We have also tried to involve disabled volunteer's carers wherever possible, because they too are users of the device.

In order to gauge volunteers' reactions to a device before investing time and expense in producing a working prototype it is often valuable to build a model or full scale non-working mock up. In the case of this project, this was a valuable way of gaining an insight into how users might react to having a large robotic device mounted to their wheelchair.

A fully working prototype is necessary to evaluate the functionality of a device. However, the prototype is not an end in itself but is only the first stage in making finished devices available to those who need them.

Specification

Many surveys [4] have reported different tasks which a disabled user might use an assistive robot for. Other papers [5] have described the use of robots in real life situations. It is not appropriate to repeat these statistics. However it is useful to divide the tasks briefly into groupings.

- Eating and drinking
- Personal hygiene
- Work
- Leisure
- Mobility

Many of these task areas are common to all assistive robot systems. However some tasks are more appropriate for a fixed site workstation, perhaps used for a vocational application, while others, are more specific to a wheelchair-mounted robot. These tasks include general reaching operations as well as more specific tasks related to mobility such as opening doors and windows and operating switches (e.g. light switches, lift call buttons).

Discussions with users identified some of the specific requirements and constraints for a wheelchair-mounted manipulator:

Requirements

It must be able to:

- reach to floor level;
- reach to head height.

Constraints

It must not:

- compromise manoeuvrability;
- obstruct the wheelchair user's vision;
- create a negative visual impact;
- affect the steering or control of the wheelchair;
- affect seat adjustment (or any similar facilities of the chair);
- affect transfers into or out of the wheelchair;
- cause an unacceptable drain on the wheelchair batteries.

Design Description

Vertical actuator & wheelchair mounting

The vertical actuator and how to mount it to a wheelchair are the most critical design aspects of the project. Some of the initial concepts have already been reported [6]. Use of a non-working mock up allowed evaluation of these concepts.

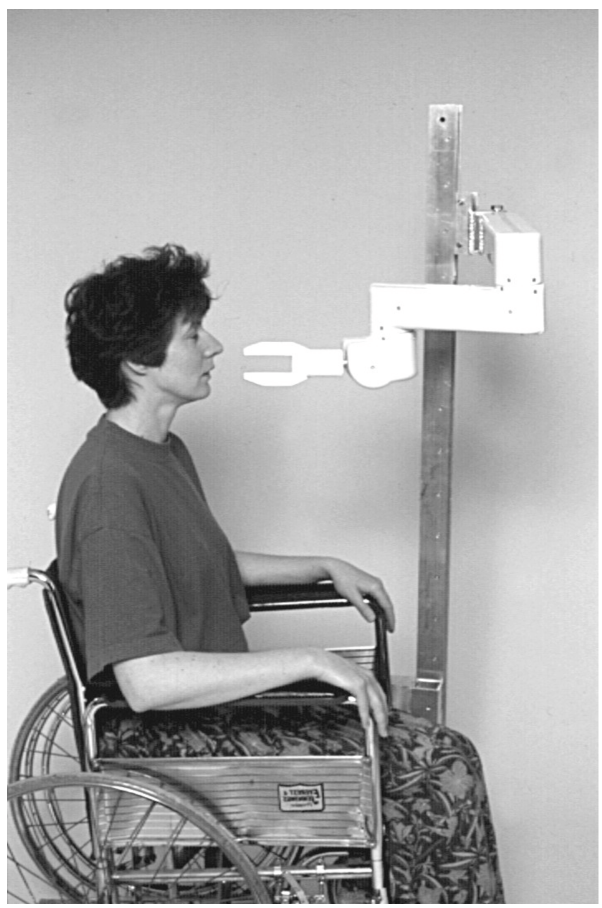

Figure 1. Mock-up manipulator

Both wheelchair users and others who saw the mock-up thought that the single stage actuator was too obtrusive. In order to overcome this, an extending mechanism was used which, in its parked (lower) position, does not extend noticeably above head height.

The mechanism is based around two parallel vertical tracks, linked by a pulley. As the moving section of the actuator moves upwards relative to the fixed section, the upper arm mounting point moves upwards relative to the moving section. Two constant tension springs counterbalance the weight of the arm so that a small motor of only 6W may raise the whole arm.

The mock-up mounted the manipulator on a hinged mounting point towards the rear of the wheelchair, allowing the manipulator to be swung forwards when required. It was found that the use of a hinged mounting required too much clearance to the side of the wheelchair, often not possible in a small room. The manipulator is therefore now mounted in a fixed position above the rear wheels. While not giving quite as much forward reach as had been originally specified this seems a good compromise solution.

Mounting the manipulator at the side, close to the shoulder of the user, decreases the visual impact of the device and does not obstruct the wheelchair approaching a table or desk. Since the weight is over the fixed, rather than castoring, wheels the device does not greatly effect the steering. The following photograph (Figure 2) shows the prototype (without cosmetic covers) mounted on a "Scandinavian Mobility" electric wheelchair.

Figure 2. Manipulator mounted to wheelchair.

<u>Upper arm</u>
The basic design of the upper arm is copied from the earlier trolley-mounted manipulator. The main rotary joints (identified as shoulder, elbow and wrist yaw) all move in a horizontal plane. Vertical movement comes from the vertical actuator described above. At the wrist there are roll and pitch movements. The basic design comprises an aluminium structure,

within which the motors are mounted, covered by a vacuum-formed cosmetic moulding.

The opportunity was taken to improve the design, particularly in the area of access for maintenance. The motors are now mounted within modules, which may be easily removed for maintenance. The cosmetic covers are also redesigned for easier removal and improved aesthetics.

Gripper

The earlier trolley-mounted robot used a prosthetic hand end effector. This never proved totally effective as a robot gripper. A purpose made gripper has been designed specifically for the current device. It has the following features:

- Two parallel moving jaws;
- Slim profile to allow good visibility of the item being gripped;
- Compliant elements in the drive train to allow variable force gripping;
- Non backdrivable gearing and compliance to maintain grip force when power is removed from the drive motor.

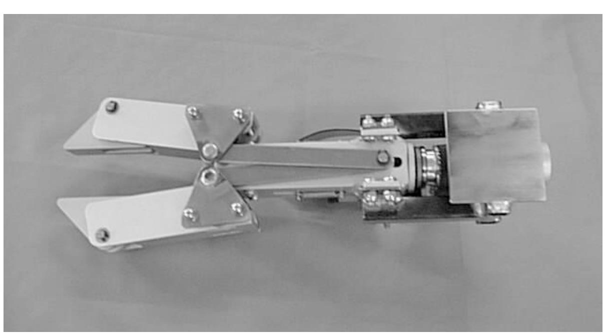

Figure 3. Gripper (without covers)

Electronics

The electronics design is based around an I^2C serial link running through the length of the manipulator. There are also 5v (for digital electronics) and 24v (for motor power) power supplies running through the manipulator. A single board PC compatible processor (GCAT from DSP Design, London, UK) mounted at the base of the manipulator sends command signals to motor control boards mounted within the manipulator. On the control boards (size only 50mm x 50mm) the serial signal is converted to a parallel signal for the proprietary HCTL1100 motor control chips. Motor control uses pulse width modulation.

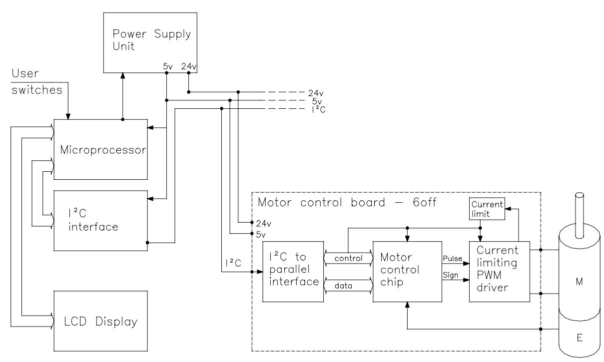

Figure 4. Electronics block diagram

User Interface

There are two main approaches to user interface design for an assistive robot.

- Task command: This works well in the structured environment of a workstation. It may be less appropriate in the undefined environment within which a wheelchair-mounted robot will be required to operate.

- Direct control: This allows the user to control the manipulator in an undefined environment. It does, however, make a greater demand on the user and may be time consuming and tedious.

The main approach used for the wheelchair-mounted robot is direct control, although there are also functions to allow the manipulator to be moved easily to certain pre-set orientations.

Users of electric wheelchairs are generally able to use a two-degree of freedom input, either a conventional joystick or a head or chin operated joystick. It was decided that this would be the most appropriate input for a wheelchair-mounted robot (although a switch-operated system will also be available as an option). The use of a two-degree of freedom joystick provides an intuitive form of control of a manipulator in real time. In the long term we envisage the user being able to use the same joystick to control both wheelchair and manipulator.

Control of a six-degree of freedom device with a two-degree of freedom input requires mode switching. The scheme used for the wheelchair-mounted robot uses the joystick movements to navigate around a map (Figure 5), displayed on a small LCD screen, or to switch to an alternative mode.

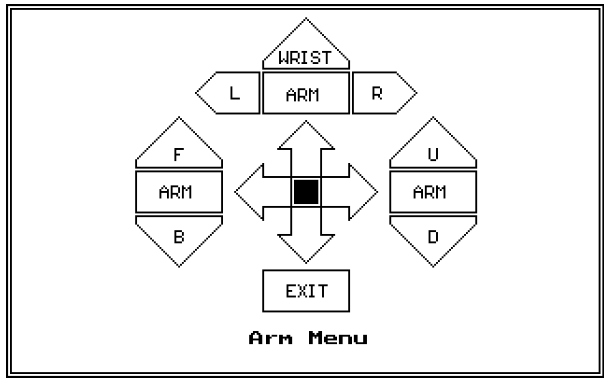

Figure 5. User interface display.

Conclusions

At the time of writing (Jan 99), the system is at the stage of final assembly and debugging of software. Brief evaluations are due to start in April 99. A mobile base has been designed, onto which the manipulator can be mounted. This can be wheeled up close to a user's wheelchair and will enable evaluations to be carried out from the user's own wheelchair.

Further developments are planned including the facility to integrate the system with a range of wheelchairs. This will enable longer term evaluations to take place towards the end of the year.

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