NAVIGATIONAL ASSISTANCE FOR WHEELCHAIR USERS

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Abstract

Previous low cost systems of navigational assistance for disabled wheelchair users have provided simple obstacle and collision avoidance, or have followed a pre-defined fixed route defined by a white line or a buried wire. Other research has used complex high cost multi-sensor mode systems resembling industrial, military or space exploration applications. Such systems have required modification of the operating environment and have provided little overall control by the user. Whilst proving the technical feasibility their cost and complexity has not resulted in practical and affordable solutions for the wheelchair user. The purpose of the present study was to bridge the gap between these two previous areas of research and to provide navigational assistance at an affordable cost.

Wheelchairs and Wheelchair Users

This paper describes work carried out at the University of Portsmouth during an investigation into the provision of navigational assistance for disabled users of powered wheelchairs.

It has been estimated that 10% of the worlds population will suffer from some form of disability during the course of their life, and an estimated 4% will be severely disabled [Busby, 1997]. For many severely disabled people a wheelchair provides an essential means of mobility.

Dependent upon the degree of disability a wheelchair may be manually propelled by the disabled person or by a helper, or increasingly a powered wheelchair may offer a better alternative. The ability to move about within the home and in the wider environment, under their own control and without reliance upon a helper, is of major benefit in terms of the self-respect, independence, and quality of life of the user.

A typical powered wheelchair consists of an electrically driven, battery powered vehicle that is steered by means of a joystick coupled to a proprietary controller that independently varies the current to the electric motors coupled to the driven wheels, as shown in Fig. 1.

Whilst a joystick is the most common means of steering such a vehicle other forms of input device, including ultrasonic head-movement detectors, infra-red devices that detect eye movements (i.e. 'winking'), and suck-blow tubes, may be utilised to provide signals for steering the wheelchair.

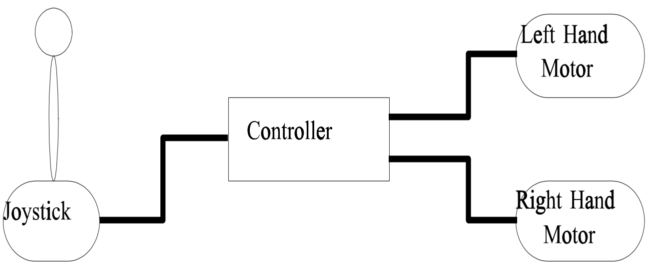


Fig.1 Typical powered wheelchair control system

Advances in medical techniques and improved paramedical care have significantly increased accident survival rates, but many survivors suffer from high level spinal injuries and paralysis that prevents the use of a joystick. Alternative input devices tend to be less precise and their use requires a longer learning cycle.

Cerebral palsy may cause sudden uncontrolled hand tremors that could result in a joystick-controlled wheelchair taking an erratic course. For young children, the recently disabled and elderly patients, learning to use a powered wheelchair can be a stressful and potentially dangerous experience. The confidence and personal safety of the user may be improved, and the risk of damage to the operating environment and the wheelchair minimised, by technical innovation.

Various schemes such as Motability in the U.K. have been established to provide specially adapted motor vehicles for disabled users. By contrast the type of wheelchair that is provided for many disabled people is often very basic. Most powered wheelchairs are purchased either by the disabled person or by a charitable organisation. With the cost of a powered wheelchair often approaching that of a conventional motor vehicle it is essential that any additional facilities provided must be at a low and affordable cost if widespread benefit is to be achieved.

Unique Characteristics of a Wheelchair Application

The navigational requirements for a powered wheelchair were considered to differ significantly with those of other types of autonomous vehicles [Goodwin, 1997].

- The vehicle is 'manned'.
- The human user is already equipped with an extremely reliable sensor system.
- Additional sensors are needed to compensate for physical and not sensory impairments.
- The user seeks assistance and not full automation.
- The assistance provided should be non-intrusive.
- The user should be given a veto to disregard or over-rule any navigational assistance offered.
- The system should operate in an unknown and unmodified environment.
- The system should be low cost.
- The system should operate in real time.

3. Objectives of the Research Program

The previous areas of research into navigational assistance for disabled wheelchair users were considered to approximate to the extreme values in the classical 'Law of diminishing returns' as represented in Fig. 2.

The objectives of the research described in this paper were to attempt to bridge the gap between the two previous areas of research, and to investigate the possibilities of providing true real time navigational assistance in a previously unknown environment at an affordable cost

The one extreme consisting of affordable low cost but low functionality collision avoidance systems, and the other extreme with technically feasible but practically unaffordable and complex multi-sensor systems.

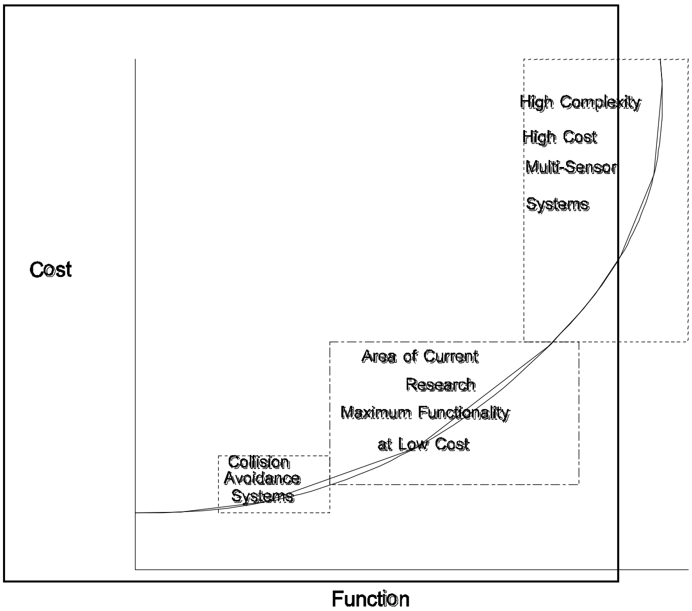


Fig. 2. The area of the current research

4. Research Completed

Fig. 3 shows a flow diagram of the completed research.

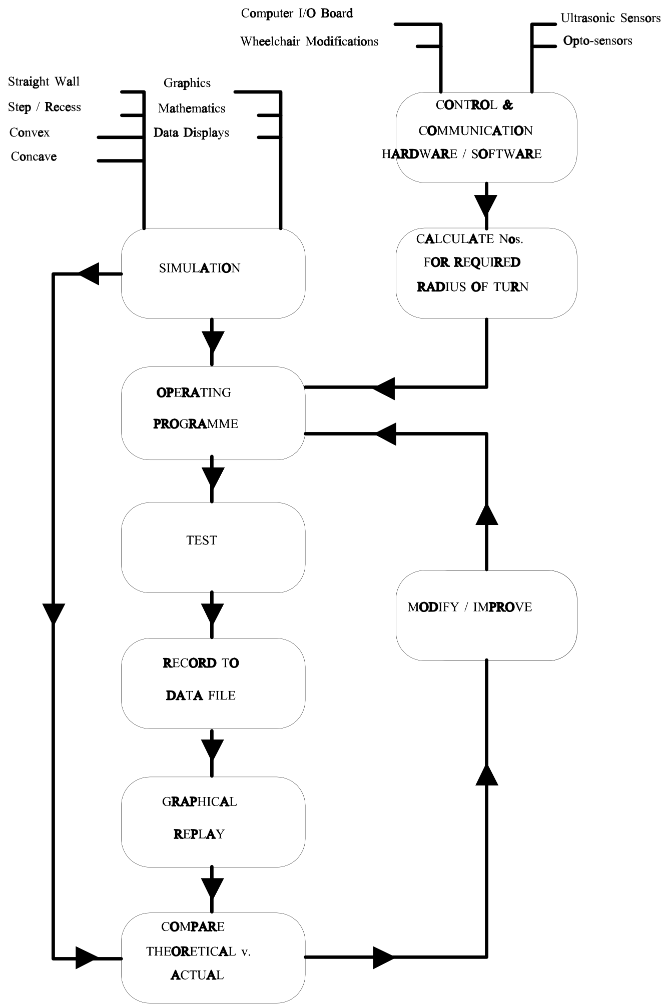


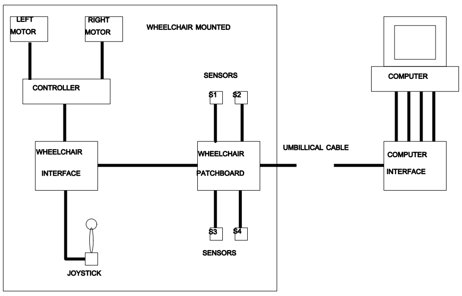
Fig. 3. Flow diagram of the completed research.

To achieve the previously defined objectives the following research was completed:

- A new simulation system was created to investigate new control algorithms for navigating a wheelchair in a previously unknown environment. Different environmental conditions were simulated and appropriate theoretical courses to be taken by a wheelchair were determined.
- New control algorithms for wheelchair navigation were devised. The algorithms were based on using ranging data derived from two sets of sensors located at a fixed distance from one another on the side of the vehicle.

The initial algorithm determined the turning action required to move the wheelchair from any initial starting position onto a desired target line that was parallel to and at a fixed distance from a perfectly straight wall. From certain initial starting positions, and in order to achieve the desired final position within a defined travel distance, an S-curve route planning technique was devised.

- Hardware was constructed enabling the signals derived from the users joystick and additional low-cost sensors to be interrogated by a computer and, where appropriate, to be modified so as to achieve the desired turning action by the



wheelchair, as shown in Fig. 4.

Fig. 4. Modified hardware system

A second algorithm considered the actions required where localised projections and recesses in the wall, curving walls etc. were encountered that more closely matched the environmental conditions for a wheelchair operating in the real world.

- A new system to provide navigational assistance was devised that enabled the recognition of various environmental features and eliminated the need for detailed mapping of the environment.

  The required radius of turn through which the wheelchair needed to be moved in order to achieve particular turning actions was calculated theoretically. The actions to be taken by the wheelchair in encountering a variety of different environmental features were investigated and developed. The new simulation program incorporated provision to minimise unnecessary changes in course to correct for minor temporary changes in the environment. Additional changes to the control algorithms enabled the wheelchair to complete course corrections within a pre-defined travel distance. The various actions necessary to navigate the individual environmental features were combined into a total control algorithm as a basis for the final operating system.

- Algorithms developed from the simulation programme were incorporated in an actual operating programme used in conducting a series of practical trials.
- The need for complex odometric calculations to determine the wheelchair's location was eliminated by using simple opto-sensors to initiate the updating of ranging data at fixed distances, independent of the speed of the wheelchair.
- A short-term memory technique was devised enabling the wheelchair to disregard temporary changes in the environment and to follow a smoother more natural trajectory. The ability to recognise various environmental features by using the short-term memory technique enabled appropriate navigational actions to be determined.
- The final system demonstrated the wheelchair's ability to maintain a parallel course at a fixed distance from a wall, to move from a remote position onto a predetermined course, to successfully navigate projections and recesses in the wall surface and to follow a curved wall.

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