A ROBOTIC MOBILITY AID FOR FRAIL VISUALLY IMPAIRED PEOPLE

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ABSTRACT

This paper discusses the design of a smart mobility aid for frail, visually-impaired people. The device is based on the concept of a walker or rollator - a walking frame with wheels. The device, which is called the PAMAID (Personal Adaptive Mobility Aid) has two modes of operation – manual and assistive. In manual mode the device behaves very much like a normal walker. In assistive mode, the PAMAID assumes control of the steering and will navigate safely inside buildings, giving the user feedback on the immediate environment via a speech interface. The PAMAID was evaluated in a nursing home in Ireland and the results of these tests will be briefly presented.

INTRODUCTION

Comprehensive statistics on dual disabilities are rare. Some studies do provide compelling evidence that there is a substantial group of elderly people with both a visual-impairment and mobility difficulties. Ficke[1] estimated that of the 1.5 million people in nursing homes in the United States around 23% have some sort of visual impairment and 71% required some form of mobility assistance. Both visual impairments and mobility impairments increase substantially with age. Rubin and Salive[2] have shown that a strong correlation exists between sensory impairment and physical disabilities.

The people in this target group have difficulty using conventional navigational aids in conjunction with standard mobility aids. Their lifestyle can thus be severely curtailed because of their heavy dependence on carers. Increased mobility would lead to more independence and a more active, healthier lifestyle.

A number of electronic travel aids for the visually impaired already exist. Farmer [3] provides a comprehensive overview. A small number of devices have reached the stage of extensive user trials, notably the Laser Cane[4], the Pathsounder[5] and the Sonicguide[6]. None of these devices provide any physical support for the user however. A full review of assistive technology for the blind is provided in [7].

DESIGN CRITERIA

A number of considerations had to be taken into account when designing the device. The device has to be constructed such that the cognitive load on the user is kept to a minimum. Thus the user interface has to be very simple and intuitive.

The device has to be safe and reliable to use and the user must have immediate control over the speed. For this reason, it was decided that the device should not have motorised locomotion, only the steering is motor controlled. This also reduces the power requirements of the mobility aid substantially. The one disadvantage of giving the user control over the speed is that from a control perspective, the system becomes under-determined. One of the two control parameters is lost and the system is more difficult to control. As a consequence, the control loops must be tight so that the system can react to unexpected changes such as the user accelarating when close to an obstacle.

To make the device as inexpensive as possible, most of the components are available off-the–shelf. Ultrasonic range sensors were chosen over a laser scanning rangefinder to further reduce the potential cost of the device.

MECHANICAL DESIGN

The mechanical design of the device is very similar to that of a conventional walker with a few important differences. The two castor wheels at the front of the walker have been replaced by two wheels controlled by motors. The motors are solely for adjusting the steering angle of the device, they do not in any way propel the device. Absolute encoders return the angular position of each of the front wheels. The device thus has kinematic constraints similar to those of an automobile.

Fig 1. Photograph of mobility device

Handlebars are used for steering the device in manual mode and indicating an approximate desired direction in assistive mode. They can rotate approximately +/-15 degrees and are spring loaded to return them to the central position. In the manual mode of operation, the handlebar rotation is converted to a steering angle and the device can be used in the same way as a conventional walker. The two wheels are controlled independently because of the highly non-linear relationship between them at larger steering angles. It is desirable to achieve these large steering angles for greater manoeuvrability. Rotation on the spot can even be achieved as shown in fig 2. To slow the vehicle down, the wheels are "toed in" by a few degrees from their current alignment. The exact misalignment angle used will depend on the severity of the braking required.

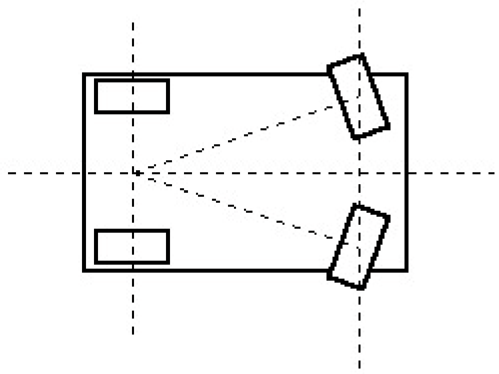

Fig 2. The steered wheels can be positioned so that rotation on the spot is possible.

HARDWARE

Control of the device is distributed through a number of separate modules. An embedded PC (Ampro LittleBoard P5i, 233MHz) is used for high-level reasoning. The motion control module is custom built around a singleboard micro-controller (Motorola MC68332). Communication between the PC and the motion controller is via serial line. This motion control board also deals with general I/O. Optical absolute encoders (US Digital) are used for monitoring the steering angles of the two front wheels. A pair of incremental encoders are used for odometry. These are mounted on the rear wheels. All the encoder information reaches the motion controller via a single serial bus (SEI Bus, US Digital). The handlebar steering angle is monitored by a linear hall-effect sensor positioned between 2 magnets.

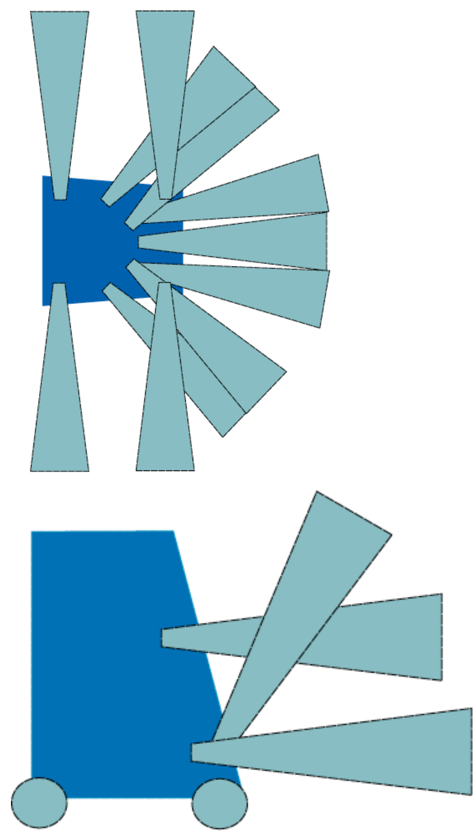

Fig 3. Sonar configuration in plan and elevation

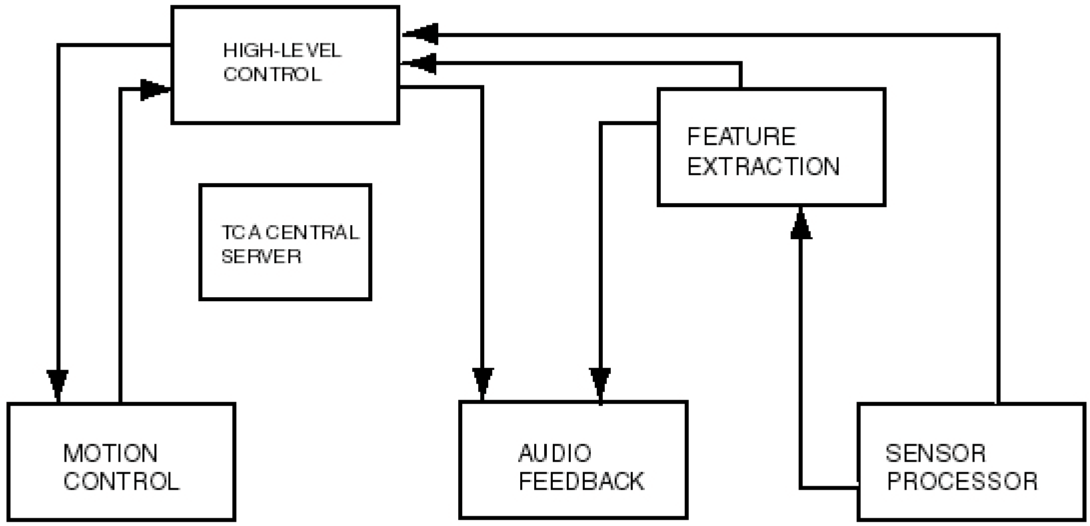

Fig 4. Software Architecture. Each module is implemented within the TCA framework. The central server mediates communication between individual modules.

Ultrasonic sensors (Helpmate Robotics Inc.) are used for object detection and ranging. Fifteen sonar transducers are used in total. This provides degree of sensor redundancy which is appropriate for the current application. The arrangement of the sonars around the mobility aid is shown in fig 3. The arrangement is very similar to that proposed by Nourbakhsh in [8]. There are seven groups of sonars in all. Four sonars point sideways (One group, composed of two sonars, on each side) and are used to determine the presence of any adjacent walls. Two groups point approximately straight ahead. One of the groups is at a height of approximately 40cm and contains 3 sonars. The second group contains 2 sonars and is at a height of 25cm and used for detecting obstacles closer to the ground. Two more groups are set at angles of approximately 45 degrees and –45 degrees. The fifth group comprises of two sonar at a height of 30cm from the ground pointing upwards at an angle of approximately 60 degrees. This group is used predominantly for detecting head-height obstacles, tables etc. The PC is equipped with a sound card so audio feedback can be provided where appropriate. The sound samples are pre-recorded and contain messages such as " Object left", "Object ahead" and "Head-height obstacle"

SOFTWARE

Due to the high demands on reliability, the mobility aid uses the Linux operating system. Its extensive configurability means also that it possible to tailor the system to the requirements of the application. The Task Control Architecture[9] was used as a framework for the software design. TCA is essentially an operating system for task-level robot control. The control can be transparently distributed across multiple machines as TCA can handle all the interprocess communication. A central server is used to pass messages between individual software modules. Other services provided include scheduling, resource management and error handling. Communication between modules is via UNIX sockets. Currently, there are five modules running on the device – motion control, sensing, feature extraction, audio output and high-level control (see fig. 4). All processes run on the same processor. If required however, processes can be moved transparently to other processors and connected together via a small hub.

The feature extraction module uses the sonar returns to determine simple features in the indoor environment such as corridors, junctions and dead ends. The four sideways-pointing sonars (see fig 3.) are predominantly used for this feature extraction. Evidences for the existence of walls on either side of the device is accumulated. A histogram representation of feature evidences is used. If a particular feature is detected from one set of sonar returns, its evidence is incremented by one, otherwise its evidence is decremented. The feature with the highest histogram score is then the most probable feature in the local environment. For instance, the criteria for a positive corridor identification is that evidence of a wall either side of device is strong and that the measured angles to the left and right walls are parallel within a certain tolerance. Once a positive feature has been identified, the robot will switch into the mode associated with that feature. For example, if the device detects that it is in a corridor, the 'follow_corridor' mode will steer the device to the centre of the corridor. Similarly, if a left junction has been detected, the device will query the user on how to proceed. A rule-based obstacle avoidance routine is located within the high-level control module. The rule-based system is more suitable than a potential field algorithm for the current sonar layout adopted.

RESULTS

The device was evaluated on-site on seven persons (all male) registered as visually impaired. The average age of the test participants was 82. They suffered from a variety of other physical problems such as arthritis, balance problems, frailty, nervousness and general ill-health. After testing the device, the users were questioned on its performance.
The results are summarised in the table below. The results were compiled using a 5 point Likert scale.

User's sense of safety while using device	4.4 / 5
Ease of use	4.2 / 5
Usefulness	3.8 / 5

Table 1. User Feedback on device performance

FUTURE WORK

Work is continuing on improving the autonomy of the device indoors. An inexpensive vision system is being developed for detecting features such as doors. Sensors which can reliably detect down-drops are also being developed.

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