Personal Adaptive Mobility Aid for the Infirm and Elderly Blind

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Technical Report TR-CS-95-18,
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Abstract

This technical report describes ongoing research into the development of a robotic mobility aid (PAM-AID) for people with a visually impairment who also require support during walking. These disabilities coincide most often in the elderly and as the elderly constitute almost two thirds of all blind people (due to the fact that blindness occurs most often in the over 65's) we feel that this attention is justified. Some of the elderly blind have difficulty in using the common mobility aids such as the long cane or guide dog and consequently have little opportunity for independent exercise. PAM-AID will provide both a physical support during walking and a mobility aid thus providing an opportunity for independent activity.

This report examines issues related to mobility for the blind and pays particular attention to the needs of the elderly or frail. We overview some of the currently available mobility aids for the blind and detail current research in this area. We describe PAM-AID, a robot-type device which senses the environment to ensure that the user is safe and can avoid obstacles. We examine the factors important to the operation of PAM-AID and give a overview of its design. Finally we describe the current status of the project and indicate our future direction.

1 Introduction

This report describes some of the ongoing work in the area of Assistive Technology (AT) in Trinity College Dublin, Department of Computer Science. The focus of our research has been to apply Artificial Intelligence (AI) and robot technology in a manner which improves the quality of life for all people. The research work described in this report aims at improving the quality of life for the visually impaired who also require support during walking. Due to their infirmity common mobility aids such as guide dogs and long canes are difficult or impossible to use. This results in a severe curtailment of their ability for independent locomotion. The coincidence of visual impairment with infirmity occurs most often in the elderly. This dual disability results in an extremely sedentary and dependent lifestyle which has an adverse affect on the persons physical and mental well being. We aim to construct a device which will provide a physical support for walking and also give the user guidance so that safe travel is ensured.

It is easy to approach Assistive Technology (AT) in a naive manner and produce an aid which while being technically excellent does not meet needs the real of the intended users in a practical manner. Before embarking on this research we have attempted to examine the needs of potential users and in this we have been aided by the staff of the National Council for the Blind of Ireland (NCBI).

Initially we examined the state of the art in mobility aids for the blind and identify some guiding principles for design of our mobility aid. In this report we will examine the unique mobility and navigational needs of the elderly and infirm. We go on to examine the technical issues associated with building a mobility aid for the elderly blind and identify those areas in which research is required. Finally we outline our work towards building a prototype device called PAM-AID and describe our plans for future work in the area.

2 Mobility and Navigation for the Visually Impaired

Blind and visually impaired people experience difficulties in moving around dynamic environments. Two general classes of problems occur, mobility problems and navigational problems. Mobility is the ability to avoid obstacles and move through a known space with confidence while navigation is knowing where you are, where you are going and how to get there. There is a certain degree of overlap between these two functions, however they represent two different ways of thinking about the space through which the person is moving. In mobility it is not strictly necessary to recognise the various objects which are being avoided, their size and position is all that is required. To navigate on the other hand it is necessary to identify a sequence of landmarks to allow the person to recognise their route.

The sighted person has an enormous quantity of information with which to achieve dynamic obstacle avoidance and landmark recognition. For the visually impaired person this information is diminished to a large extent or is totally absent. Without some form of mobility aid the blind person's movement will be severely restricted. Even when using current mobility aids a very limited preview of the terrain is afforded and accidents can easily occur. Navigation for the blind person is also difficult as the ability to detect landmarks and reliably follow a route is seriously reduced. Even with these difficulties blind and visually impaired people can and do successfully venture into the outside world.

3 Mobility Aids

Mobility aids, advance route planning using tactile maps and occasional assistance from sighted people afford the able-bodied blind person a great deal of personal freedom. We will examine the currently available mobility aids and identify how they work in general. We will also try to identify their limitations particularly in the case of the elderly and infirm.

3.1 The Long Cane

By far the most common mobility aid for the visually impaired is the long cane. Techniques for the use of the long cane were developed by the Veteran's Administration in the US during the 1960's [2]. At its most simplistic the cane is swept from left to right synchronised to the stride of the user. The synchronisation is such that the cane sweeps the space in front of next stride. The length of the cane is the distance from the base of the sternum to the ground, thus the blind person is given approximately one stride preview of the terrain directly ahead. If an obstacle is detected the cane user must be able to react quickly to avoid a collision.

Ascending and descending steps are negotiated using specialised techniques. The dimensions of the step are determined on the first step and when ascending the person holds the cane tip approximately 3cm above the edge of the next step. As the person moves forward the cane tip will come into contact with each successive step, when no contact occurs the person knows that the flight of steps is at an end. For descending stairs a similar approach is used. The cane tip is held 5cm beyond the edge of the next step thus the cane will detect when level ground is encountered.

The limitations of the long cane are such that overhanging obstacles such as the rear of parked trucks, rubbish skips and holes in the ground cannot be detected reliably. Sophisticated use of the long cane is possible by using the sound of echos from the tapping of the cane or by following walls, kerbs and other environmental features. However it can be very difficult for users to detect slowly curving paths and thus orientation can be lost. Noises from the environment and smells also play a part in helping the visually impaired cane user move around an environment. There can however be a high degree of stress associated with cane use due to the limited preview of the terrain and the limited amount of information it provides.

3.2 Guide Dogs

The other most common mobility aid is the guide dog. Dogs have been used as a guide for the blind since at least Roman times. However systematic training of guide dogs began in the 18th century. Guide dogs became wide-spread after the first world war when the German army began training German Shepherd dogs to guide war veterans [2]. The typical guide dog begins training at 2 years of age and has a working life of roughly nine years. Guide dogs cost approximately £10,000 to train and about £20 per month to maintain. Guide dogs are not suitable as a mobility aid for all blind people. The blind person's visual impairment must be so severe at to prevent the anticipation of stops or turns before receiving this information from the dog. If the guide dog user could anticipate such events the dog would not have the opportunity to put its training into practice and without sufficient reinforcement the guide dog may no longer function effectively. The speed at which the guide dog travels must be acceptable to the user. A typical walking speed is 5 to 6 kilometres per hour. The user must have an active lifestyle to provide the dog with sufficient exercise and reinforcement. The training process is physically strenuous and the users must have good coordination and balance.

The guide dog enhances the mobility of the user greatly, dogs are taught to avoid overhanging obstacles such as tree limbs and awnings and to give adequate clearance from trees, parking meters, ladders and other things typically found cluttering the pavement. Often the dog will be so skilled the user may not have noticed the complexity of the environment that has been negotiated. The basic commands are "forward", "right", "left" ,"stop", "steady" to slow the dog and "hup-hup" to speed up. The dog must be given constant correction if it disobeys a command or does not perform correctly except in the case of *intelligent disobedience*. This is where the dog disobeys the command if it would cause danger to the person and is particularly important for crossing roads. When the dog and owner are familiar with a particular area the dog can learn more complex activities such as finding particular shops or buildings.

The guide dogs provide the owners with a effective mobility aid, companionship and security (although guide dogs are trained to curb their natural defence behaviour their presence tends to deter possible attack). Guide dogs also allow the blind person to integrate into society to a much larger extent, not alone by aiding increased mobility but also because of the reaction of the general public. People are often drawn to the dog and it can be a topic of conversation, thus providing positive reinforcement for some blind people.

3.3 Electronic Mobility Aids

Even though the long cane is a very cheap and reliable mobility aid it does have the drawback that all the space through which the body travels is not scanned. This leaves the upper body particularly vulnerable to collisions with overhanging obstacles or with other people. This deficit of the long cane has prompted much research into electronic mobility aids. Several reviews have been done such as Nye & Bliss [20], Boyce [5] which contains a good overview and Welsh & Blasch [2] which reviews mobility devices in depth. This is an active research area and there are regular conferences on topics related to mobility and navigation for the blind particularly under the aegis of the Telematics for the Integration of the Disabled and Elderly (TIDE) program of the European Union.

Electronic mobility aids are not used by the majority of blind users, primarily due to the excessive cost, poor user interfaces and poor cosmetic design. If a mobility aid is to be successful the device must provide the user with a great deal more information about the environment than the long cane. It must also present this information in a manner that does not occlude the remaining senses. For example requiring the user to wear a pair of headphones which would exclude noises from the environment. The device must be affordable, robust and not draw undue attention to the user's blindness. This is a difficult specification to achieve and because of this fact emphasis has remained on mobility training using the long cane and guide dog.

Many interfaces to mobility devices have been proposed including stereo headphones, vibrating pads on the forehead, chest or back, however none have been very successful. One mobility device currently under development in the ASMONC [1] TIDE project proposes to use a moving handle to give the user directional information. The ASMONC system is primarily designed for use in outdoor urban environments.

4 The Visually Impaired Elderly

A number of surveys indicate that as many as two-thirds of the blind population are 65 years of age or older [2]. Forecasts of the age profile of the European population show that by 2020, 25% of the population will be over 60 years old. They also show that the largest increase will be in the over 75 age group in which disability is most common. Despite these facts the majority of the effort in mobility has been focussed on integrating the employable and the young into society. Social attitudes concerning the elderly coupled with the higher incidence of hearing loss, balance problems, gait problems, memory loss and general ill health among the elderly discourages the provision of mobility training or specialised mobility aids for those with a visual impairment.

Vision loss in later life can be crippling particularly for those in long term care. Psychological problems associated with lack of motivation and lessened expectations make mobility training difficult [2]. This difficulty is compounded by memory loss, the need for a support during walking and an increased fear of falling. If the cane is used both for support and mobility it can be quite heavy and lead to fatigue quite quickly. Using a long cane and a walking aid in tandem would result in both hands being occupied and an increased fear of falling. In long term care facilities practical concerns discourage independent mobility for the aged visually impaired as long canes pose a risk of tripping the other residents.

The difficulties of providing the elderly visually impaired with independent locomotion results in their being confined to their beds or to chairs supposedly for their own safety. In this sedentary state a rapid deterioration in the cardio-pulmonary systems occurs. The link between inactivity and the deterioration of health in older persons has been noted in various studies [3], [6], [17]. The psychological effect of increased dependence also has an adverse effect on the persons quality of life and even limited independent mobility can greatly increase the quality of life of the elderly.

5 The PAM-AID Concept

We aim to develop an robot-type mobility aid which will be a primary mobility aid to the aged or infirm visually impaired for use in the home or in a residential care facility. The (Personal Adaptive Mobility Aid for the Elderly and Infirm)PAM-AID guide at its most basic will provide obstacle avoidance to a visually impaired person as shown in Figure 1. This will be achieved by a combination of warning messages and direction control provided by PAM-AID. The control strategy aims to combine the control input of the user with the sensor information to provide a safe path. The degree to which PAM-AID assumes control over the direction of the device will be configurable.

We propose a modular set of technologies which can expand the capabilities of PAM-AID so that they can be tailored to meet the needs of a particular individual. For example it could be fitted with a module to allow it navigate from point to point in the building, in a nursing home it could lead the person from their bedroom to the dining room. Other enhancements proposed include a

[1] Autonomous System for Mobility, Orientation, Navigation and Communication

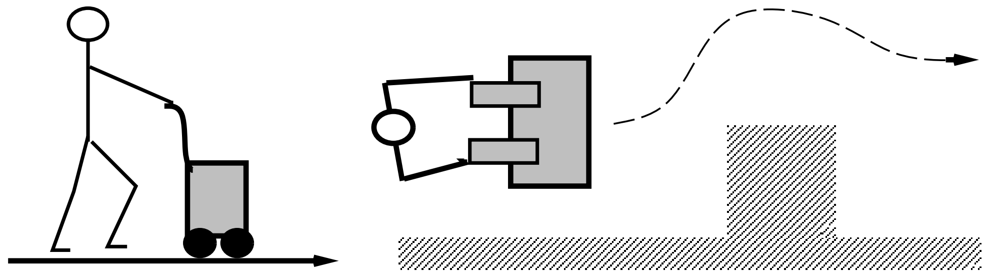

Figure 1: Schematic of PAM-AID guide in use

wide variety of user interface configurations tailored to suit the individual needs and preferences of the user. In particular the type and frequency of warning messages, the type of control algorithm used and panic buttons etc. could be fitted to the device. Other enhancements include interfaces to navigation aids currently under development (e.g. ASMONC, MOBIC, OPEN) will be provided thus allowing for expansion of its capabilities.

As a primary mobility aid PAM-AID must address the needs of the users by providing both a support for walking and a mobility aid. To ensure user confidence in what is effectively "a rollator with a mind of its own" a fail safe strategy must be incorporated into the operation of the base unit. The operation of the guide should be as simple as possible and should not require any specialised user input. While operating as a mobility aid the direction of motion should be primarily determined by the user. PAM-AID should only modify the user's direction when it is likely to cause a collision. Similar technology could also be used in providing smart wheel chairs for people with multiple handicaps.

6 Operational Specification of PAM-AID

To ensure the acceptance of the guide we need to have a clear profile of our potential user, their needs and the potential difficulties of introducing new technology. Firstly we will examine the medical issues of the user population, the sensory deficit, the origin of the infirmity and any related factors which may affect the design of the guide. Secondly we will examine the needs of the users and in what areas their quality of life could potentially be improved. Lastly we will render down the user needs and profile to produce a operational specification for the PAM-AID guide. The operational specification will describe the performance expectations and the environment in which the guide will operate.

6.1 User Profile

There are a wide range of people who may benefit from a intelligent walking aid such as people with physical disabilities or neurological disorders. Because the elderly are the group of people in whom a visual impairment is most frequently combined with a difficulty in walking unaided we have chosen to focus on them. We will try to identify their needs and develop a clear understanding of their disabilities.

Statistical data

A study in the United States in 1985 [10] estimated that their were 1.5 million residents of nursing homes, 88% of whom were over 65 years old and 40% were 85 years old and over. Of the total number of residents 22.7% had a visual impairment and 70.7% required assistance in mobility. If these figures are examined in more detail we find that of the visually impaired 64.4% are partially impaired, 24.6% severely impaired and 11% profoundly blind. The incidence of visual impairment increases with age, 14.3% of the 65 to 74 year olds are visually impaired but this rises to 30.8% of people 85 and over. There is also a corresponding rise in the severity of the impairment with age.

The mobility data shows that the number of people with mobility impairment rises from 60% of 65 to 74 year olds to 81.6% of people aged 85 and over. When the data is examined by the nature of the mobility impairment we find that 35% of people require assistance to walk, 55.8% are confined to a chair and 9.1% were confined to bed. Somewhat counter intuitively there is a slightly

Age of Onset	Percentage of Total
Under 45	12.5%
45-64	31.5%
65 and over	56.0%

Table 0.1: Age and onset of Blindness in California 1956

greater proportion of people in the less severe impairment among the older age groups possibly due better mortality rates of the more active residents.

From the data we see that a very large proportion require assistance with mobility (70%) and a significant number (22%) have a visual impairment. We can also see that as people get older (over 85) the incidence of visual impairment increases to 30% while the ability for limited mobility is maintained.

Causes of Blindness

Visual impairment often occurs in later life as a consequence of disease or as a result of a progressive degeneration related to aging. Table 0.1 [2] which shows the results of a study into the relationship between age and blindness confirms this fact. The most common causes of visual impairment in later life are cataracts, diabetes related diseases, macular degeneration and glaucoma. These conditions often leave the person with some useful vision. The characteristics of each of these visual impairment are as follows.

- **Cataracts**
  Cataracts are opacities and clouding of the lens which block the light entering the eye. The incidence of cataracts increases with age. They affect vision by blurring or dimming the vision or by producing double vision. Treatments are available using laser surgery which is generally quite successful.
- **Diabetic Retinopathy**
  Circulation problems are quite common in diabetics and sometimes the blood supply to the retina can deteriorate. If severe the retina can detach causing blindness. Early surgery can sometimes help this condition.
- **Glaucoma**
  Glaucoma occurs when the fluid in the eye cannot drain correctly causing damage to the eye. Early symptoms may include blurred vision, halos around lights and reduced peripheral vision. This condition can sometimes be controlled by medication if it is detected in the early stages.
- **Macular Degeneration**
  Macular Degeneration is the degeneration of the macula, that area of highest resolution in the eye and may occur due to aging. The peripheral vision usually remains and magnifiers may help. Some surgical techniques can partially repair the damage.
- **Retinitis Pigmentosa**
  Frequently called "Night Blindness" it is produced by the degeneration of the retina and choroid (the related vascular area). It is hereditary with a variety of different patterns of inheritance. The deterioration is usually progressive leading to tunnel vision and eventual total blindness. There is currently no treatment available.

Apart from people who develop blindness in their later years the proposed aid would also be relevant to people who have been profoundly blind from a young age and who in old age need a support while walking.

General Issues

Some special considerations relevant to the design of PAM-AID include the fact that some elderly may not be able to endure stress or pressure on their cardio-pulmonary system for long periods.

[2] source Belloc 1956 page 504 in [1]

Medication may affect the co-ordination of users or may make the users less aware of environmental information during their route. Memory loss and difficulty in retaining information in some elderly people may make complex tasks impossible. The reaction times of elderly people compare favourably with those of younger people for simple tasks however as the complexity of the co-ordination required increases the reaction time deteriorates dramatically [1].

User profile summary

To summarise, the elderly represent the majority of blind people, as with all elderly they suffer a degeneration in sensory-motor capabilities. While data on the combination of visual impairment with frailty is difficult to find, it is possible that some of those recorded as "confined to a chair" in the data given earlier were so described because they had a visual impairment in conjunction with a frailty which prohibited independent mobility. Data on the use of walking frames or walking aids by the population of elderly is also difficult to find. However Welford in [1] studying agricultural accidents identifies a significant increase in falls and collisions with age. This suggests that balance and judgement of moving obstacles undergoes a progressive deterioration with age. From the statistical data it is reasonable to assume that their is a significant and growing population of aged with both a visual impairment and a mobility problem. This indicates a real need for a device which provides physical support during walking and environmental information such as PAM-AID.

6.2 User Needs

In this section we will attempt to identify the needs of our potential users by identifying the manner in which walking frames and walking supports are currently being used by sighted and visually impaired people. We will also attempt to identify activities in which the elderly would practically undertake but cannot due to a combination of infirmity and visual impairment. In this process of identification of needs we are paying particular attention to the relevance of our proposed design to the quality of life of the elderly person.

Walking frames

Although there are many different models of walking frame they fall into three distinct categories, standard walking frames, rollators and reciprocal walking frames. The features of each are summarised below.

- **Standard Walking Frames**
  Commonly known as "Zimmer" frames they are designed to provide a larger based of support to a person with lower limb weakness. Most are adjustable in height and some models can be folded away. The frame is used by lifting, placing it forwards, bearing weight through the grips and taking two strides to the centre of the frame. Particular attention must be paid to the height of the frame to ensure good posture during walking.

- **Rollators**
  These are walking frames with wheels attached, there are many different configuration of base. Rollators are used where balance is the major problem rather than weight bearing. They are also used where upper limb strength is not sufficient to lift the walking frame on a regular basis. Rollators are often attached with brakes to prevent "run away", baskets for carrying things and seats in case of tiredness. A great deal of attention is paid to the cosmetic design of Rollators as they are often used out of doors.

- **Reciprocal Frames**
  These are similar to the standard frames except that the frame is hinged on either side allowing the sides of the frame to be moved alternately. They are designed to accommodate a normal walking pattern with opposite arm and leg moving together. They are also used in domestic homes where space is confined.

Quality of life for the Frail Elderly

In the absence of in depth research into the issue of autonomy and age authors Birren et. al. in [13] assert that it is "self-evident" that the desire to be independent is fundamentally connected with quality of life. The onset of disability is seen as a serious threat to the sense of control in ones life. Spirduso and Gilliam-MacRae in [13] examine the relationship between physical activity and quality of life in the frail elderly. They show a clear link between physical activity and morale and argue for integrated exercise programs for the elderly.

Elsewhere in [13] Chon and Sugar conducted a survey of the perceptions of residents and carers as to the determinants of quality of life. The residents chose morale and social-emotional environment as the key determinants of quality of life. The carers generally chose the quality of care and the morale as the key determinants of quality of life. The conclusion drawn was that a tension existed between the needs of the residents and the limitations of the institution and an expansion of resident choice in as many areas as practicable was recommended. Quality of life is a very difficult thing to measure. Measures that are currently used are often only related to the medical condition of the person. Quality of life can be seen to be a complex relationship of physical activity and social contacts as well as a purely medical definition.

Interface Issues

Wellford in [1] reports that the speed and accuracy of elderly people for simple motor tasks is quite good but this deteriorates rapidly as the complexity increases. This is particularly true if there is a extended time between the stimulus and the taking of the responding action. This result is attributed to a poor short term memory. In general where possible the elderly shift concentration from speed to accuracy in an attempt to maximise the use of limited physical resources. This can often result in lower error rates than younger people.

Kay in [1] examines learning and the effects of aging. Short term memory is very dependent on the speed of perception and thus deterioration in perception skills will produce a consequent deterioration in short term memory. Learning in older people consists of the modification of earlier experiences as opposed to from new stimuli. This situation consists of a process of un-learning and results in continuous error repetition. The major factor in learning is motivation. In the elderly motivation for learning is much reduced as the acquisition of a new skill is not seen to be worth the effort given the limited time they may have left.

Simplicity and flexibility will be the key elements required in the design of the interface. Simplicity to ensure that no complex learning is required and that PAM-AID's operation is as intuitive as possible. Flexible to allow modification of the operation of the PAM-AID control strategy to meet personal preferences. It is vital that it can change to meet the needs of the users and not require them to undergo extensive training.

6.3 Operational Specification

The operational specification is a somewhat idealistic list of the functionality of the device. It is derived from the current needs of the user community and the expressed preferences of themselves and their carers on the various issues of performance. At the pre-prototype stage many of the comments and recommendations which are given can be self contradictory and ultimately wrong. If user input is maintained through out the project the recommendations become more and more relevant. Care must be taken however not to design a device solely meet the needs of the user panel. For this reason the recommendations of professionals in the care of the elderly play a large part in the design process.

Interface

This general title covers all aspects of the users experience of PAM-AID. As PAM-AID in an electro-mechanical device the manner in which it moves and responds to user input as well as its computer interface to users and carers must be included. It is not possible to build and test the myriad of possibilities for computer interfaces, control strategies and mechanical designs. For this reason we will highlight those aspects of the interface which have been adjudged to be important. It is these aspects that the prototype will attempt to address.

- Electrical Specification
  The device must be suitable for a domestic environment i.e. no additional electrical installation must be required, it must not present a danger to the user or others if it becomes wet. Relevant safety standards will need to be applied.

- Mechanical Specification
  The device must be as light as possible i.e. it should not represent a large load to pushed by the user. Manoeuvrability must be a major component of the design.

- Control Strategy Specification
  The users need to feel in control of the device. Control strategies must perform in such a manner as to enhance this feeling. Override buttons or On/Off control should be provided. Brakes and fail safe operation must also be a feature of the design.

- Sensor Specification
  It would be preferable for the user to be able to gain a information about the environment from the device. This information should be supplied in as intuitive a manner as possible requiring little training. One possibility would be force feedback similar to that provided by the long cane.

- Computer Interface
  An interface to the device to make adjustments to the control strategies etc. should be supplied. This must require no previous computer knowledge so that a carer or user can select strategies based on their personal preferences.

Capability & Performance

This section covers the users expectations from the device related to its general use. It is mainly concerned with the activities which people will wish to perform while using the device.

- Cosmetic Concerns
  The PAM-AID device should be as attractive as possible and not stigmatise the individual. It should not be noisy or obtrusive and ideally, if it is giving voice feedback, a capability for volume control and silent running must be possible.

- Environmental Information
  Where possible PAM-AID should provide information on the environment. What information and its manner of presentation is not known at this time.

- Maintenance
  The device should be as maintenance free as possible. It should provide an extended period of operation before requiring a re-charge. A target time of 6 hours between recharges is projected as the minimum. It also should be possible to wipe down the device after spills etc.

- Portability
  The device should be portable with the target concern being its ability to be transferred by a family car.

- Operational Concerns
  The device must be manoeuvrable and allow the user to perform such operations as opening doors etc. It must not become an obstruction to the activity of the person.

Cost

The cost of the device is difficult to ascertain at this point in time when the final specification remains unclear. A target cost can be guessed at as being in the region of £1000 to £1500.

Safety

The safety of the device is of major concern to both the carers and the users themselves. The most important factor in the design is the detection of descending stairs. In the words of one mobility expert "If the device fails to detect descending stairs it will be useless". The device must not drag the users after it or exert any force on them which might upset their balance.

Robustness

The device must be physically robust and able to tolerate minor accidents such as spills, things falling on it, and grandchildren! It must also be operationally robust having a long mean time before failure. The behaviour of the system during operation should be as free from error as possible, an error detection and correction mechanism should be incorporated where possible.

7 Technical Specification of the PAM-AID Guide

This constitutes a list of the technical requirements of the system and the manner in which they may be achieved. The aim is to meet the operational specification and identify where tradeoffs exist. The specification will also address technical issues which are independent of the operational specification such as expandability, modularity and conformance with standards.

Many of the specifications relate to the delivery of a finished product and cannot be addressed by the PAM-AID prototype. They are mentioned here as they remain valid specifications for a PAM-AID type device.

7.1 Conformance with Relevant Standards

There are few standards affecting the design of robots or assistive devices for the domestic environments. There are however several standard communications protocols for communication between robotic devices. One relevant standard is the proposed Multiple Master Multiple Slave (M3S) bus standard. This is a general-purpose interface standard for the rehabilitation environment. It allows the addition of devices from different manufacturers to a system ensuring expandability. An example would be the addition of a home automation system to PAM-AID to automatically open doors etc. PAM-AID will endeavour to use this standard.

7.2 Electrical Specification

The system is required to be autonomous which implies that it must be battery powered. The runtime of the final system is to be of the order of six hours. Batteries are cumbersome and heavy so the power consumption of the system will be of paramount importance. Although this will not be of primary concern to the rapid prototype design it is an issue for the final system.

For safety the electrical system will have to be isolated from the environment in an enclosure to prevent damage from liquid spills etc. The re-charge time should not be longer that eight hours to achieve full charge thus allowing re-charge overnight. The re-charge system should be trivial to connect and monitor. The system should give status messages regarding its power status to the user in an easy to understand manner possibly by voice synthesis. To ensure extended battery life power saving strategies should be incorporated into the operation of PAM-AID e.g. when not moving go into a low power mode.

7.3 Mechanical Specification

The mechanical design of the system will be a key factor in the operation of the system. The starting point for the design is currently available rollators. If the device is too heavy for the person to push unaided motors will have to be added to assist the user.

7.4 User Interface Specification

During normal operation the user inputs information to the device about their speed and direction of walking. There are numerous possibilities for gathering this information including a joystick, force sensing handles or detecting motion in the wheels. These different methods will have to be evaluated as the project progresses.

Information on the presence of obstacles in the environment will be required from PAM-AID. The amount of information and its means of presentation will have to be determined. Several possibilities exist, tonal information, which would require quite comprehensive user training, voice synthesis relating to the location and direction of an obstacle or force feedback through the PAM-AID base. As with the user input devices the various options will have to be evaluated as the project progresses.

7.5 Operational Specification

The primary role of PAM-AID is to detect the presence of obstacles in the environment and guide the user past them. To do this PAM-AID may provide warnings or steer around the object or some combination of both. Ultimately PAM-AID requires the ability to sense the environment. This sensing must be as error free as possible. Given that the powerful human sensory system makes mistakes we have to assume that the PAM-AID sensors will miss-classify sensory information on occasion. Error detection and correction must be an integral part of the sensor system and must ensure safe operation at all times.

As the device will be used in a wide variety of environments the sensor system must as redundant as possible to prevent the necessity of tailoring the device to specific domains. The application environments are domestic and residential care facilities and the dangers to the users are collisions with fixed objects, collisions with moving objects, falls down descending stairs and collisions with overhangs. The sensor system must detect each of these dangers and the control system must develop a fail safe strategy to protect the user.

PAM-AID must not represent a burden to the users i.e. it should not represent a significant load to be pushed by the users. If the weight of the system is significant a motor assist will have to be provided. The device must keep pace with the users, it must not drag the users after it or slow the users unduly. Sensing the user speed and direction must be an integral component of the system. PAM-AID must be manoeuvrable in an enclosed space and must not be unduly large. The device should be portable, fitting into the common family car.

The control system must be configurable by someone without in-depth training (a user or carer) to allow for personal preferences to be selected e.g. silent running in church. A facility of learning the users responses to sensor data may be useful to improve performance over time.

7.6 Robustness

The device must be physically robust and able to tolerate rigourous usage on a regular basis. It must be able to carry small loads (shopping etc.) with out incurring a significant loss of performance. It must tolerate small accidents without being damaged. The life span of the device must be of the order of seven years and require minimal service in that time.

8 Related Work

Assistive technology is a dynamic research area and much work which is relevant to the design of PAM-AID has been done. In this section we will review some of the relevant material and identify the context of the PAM-AID project. Much relevant work has also been done in the field of robotics and signal processing. We will summarise that work which is relevant to the control and sensor processing problems of PAM-AID.

8.1 Related Work in Assistive Technology

Electronic Mobility Aids

As mentioned in section 3.3 we discussed the development of electronic mobility aids. The main reasons for their lack of success to date has been their lack of cosmetic appeal and the masking of other environmental information. The cosmetics of PAM-AID will be a primary concern. However as we are dealing with the elderly who would be using a rollator or walking frame in any event the use of a device which draws attention to the users disability will not be as critical. In addition the elderly tend not to react to the fickle dictates of of fashion world quite as much as their younger counterparts. The mechanism of presenting environmental information has yet to be finalised however we will not be requiring the users to wear headphones or other devices which may mask information.

Technology and the Elderly

Firnie [13] reviews assistive devices for the elderly and their affect on their quality of life. He focusses attention on the need to retain the ability of the individual to make choices and on the need to pursue the real problems as the describes them of falls, incontinence and cognitive disfunction. In the design of technology for the elderly Nicolle et al [19] advise a broadly based approach to the specification of new technology involving carers, observation of potential users as well as user interviews.

Karlsson in [16] notes that usability or "perceived ease of use" is not the only concern in the adoption of new technology by elderly people. "Perceived usefulness" is the prime factor in the adoption of a new routine and is influenced by information, motivation and sustained by the evaluation of "service quality" parameters. "Perceived ease of use" influences the adoption of new sub-systems technology and is in turn influenced by hardware and software design, user experiences and by training and support. Introducing new technology into the domestic area affects that environment and this impact must also be considered when assessing the design of the system.

Solutions for mobility impairments

Their are a wide range of projects aimed at improving the mobility of persons using wheelchairs but very few which concentrate on assisting people use their remaining ability. Projects such as OMNI [8] and SENARIO [9] focus on improving the operation of conventional electric wheelchairs. OMNI is building a very high manoeuvrability wheelchair for confined domestic and office environments. SENARIO is improving on conventional wheelchairs by the introduction of intelligence, the user is able to select from manual control to fully autonomous navigation. The MANUS project is fitting a robot arm to the wheelchair to facilitate manipulation of objects by persons with quadraplegia.

Another projects are attempting to replace the functions lost by those persons who are bed ridden. MOVAID/URMAD project [7]and WALKY [18] are projects which aim to assist the bedridden person be as independent as possible by performing the common daily tasks remotely from their bed by means of a mobile robot fitted with an arm.

8.2 Relevant work in robotics and signal processing

Mobile robotics and signal processing research is undergoing a period of rapid advancement due to a number of factors, not least due to the availability of cheap, portable and powerful computing. This has brought the possibility of viable applications for mobile robot technology ever closer. In [12] Horswill showed that a robot guide could be constructed which used only visually sensed data. This robot guided people around the floor of a building giving a running commentary on the surroundings. He also noted that when moved to a new environment the robot detected false obstacles due to shadows and colour changes. Garibotto et. al.[11] have built a robot guide for public spaces such as theatres and museums. They have reported that the robot guide required human intervention every 10 minutes. While these applications have experienced some minor difficulties they show that the potential for harnessing this technology.

Signal processing techniques have been developed to use cheap sensors for mobile robot navigation. Leonard [15] showed that sonar, despite having some limitations, can be used to reliably detect features such a corners and walls etc. using a-priori feature maps. This allows the robot to successfully navigate around a complex environment.

The control of mobile robots has undergone the most radical change in the recent past. Systems with multiple competing behaviours have proven to be successful in dynamic environments [21]. The relationship of these behaviours can perform tasks such as hall following etc. However in cases several behaviours my be invoked simultaneously and arbitration is required. The arbitration can be a fixed hierarchy as in [21] or by inter-behavioural bidding as in [14] or by a variety of other schemes. A fixed hierarchy can be quite brittle especially when the robot is tested in an environment different to the one in which it was developed.

Of particular relevance to our work are techniques for shared control between robot and user. This research is common in tele-operated robots which are used for bomb disposal or other hazardous environments. Borenstein in [4] describes a system of tele-autonomous guidance which allows for the gradual sharing of control between the user and the robot for obstacle avoidance.

9 The PAM-AID Design Parameters

In the design of PAM-AID we have pursued two parallel streams of research. Firstly we have developed a mobile robot test bed shown in Figure 9. This has allowed us to experiment with sensing and control required of the device. Secondly we have researched the user requirements and needs. This has allowed us to design a rapid prototype of the PAM-AID device. The rapid prototype will allow us to test the different interfaces and control strategies with potential users.

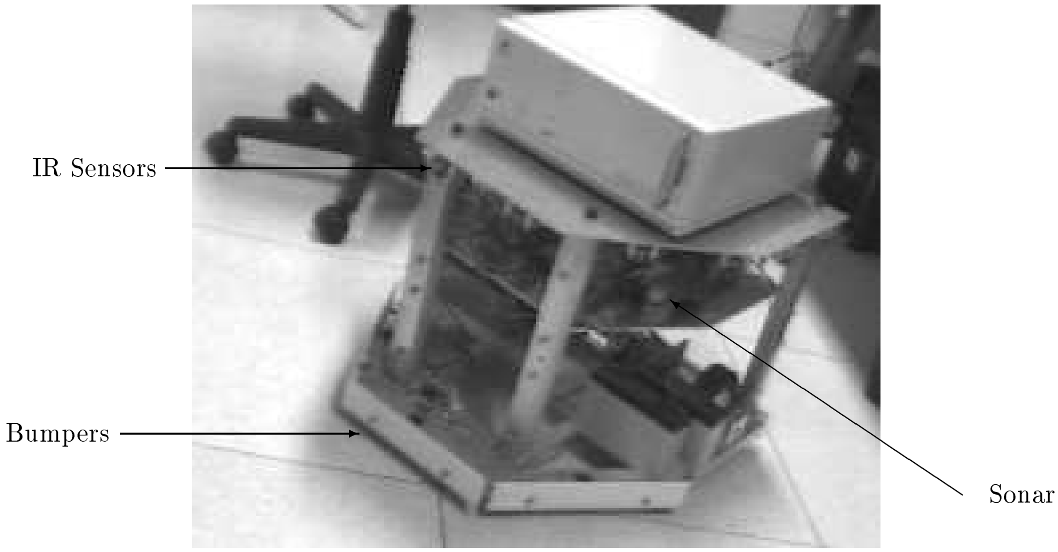

Figure 2: Current PAM-AID Test-bed

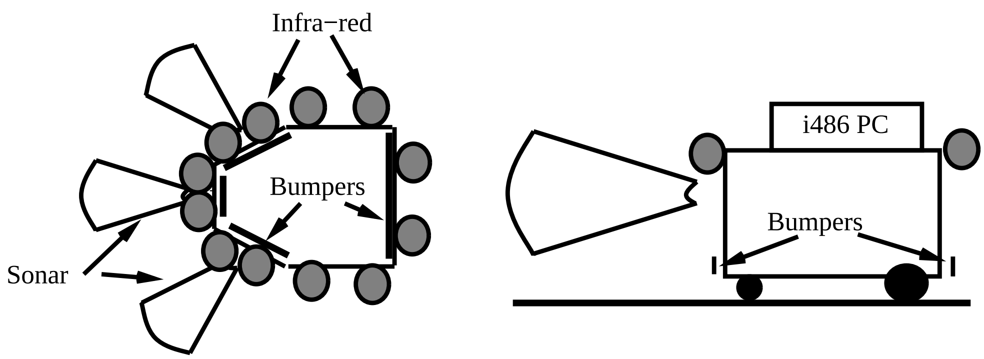

Figure 3: Sensor Map of PAM-AID Test-bed

9.1 Mobile Robot test-bed

Our work to date has been concerned with the construction of the mobile robot base which is currently being used as the prototype for PAM-AID. Three types of sensor are used to provide information on the environment : sonar, infra-red proximity sensors and bumpers switches. The data gathered is sufficient for obstacle avoidance and is simple enough to allow rapid processing. This fast reaction time ensures reliable obstacle avoidance. The sensors chosen complement each other in their range and characteristics as shown in Table 0.2. The layout of the sensors on the robot base is shown in Figure 3. The sensor data is processed using an on-board micro-controller to provide reactive obstacle avoidance. The reactive control system is based on a subsumption architecture [21]. This architecture provides an efficient means of integrating the multiple sensors to provide robust obstacle avoidance without the overhead of maintaining a large central representation of the world around the robot. The robot base micro-controller is connected to the master P.C. via a serial link. The PC contains the vision system, the text-to-speech card and performs the navigation. Currently odometery is used for dead reckoning navigation however its accuracy is very limited due to wheel slippage.

Sensor	Range	Purpose
Sonar	$0.15m - 10m$	Range Measurement and Collision avoidance
Infra-Red	$0m - 0.2m$	Proximity Detection
Bumpers	contact	Collision Detection

Table 0.2: Table of Sensor Characteristics

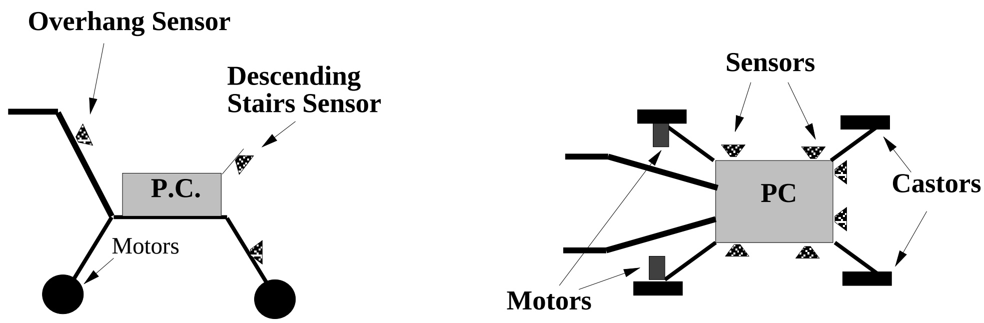

Figure 4: PAM-AID Prototype Schematic

10 PAM-AID Rapid Prototype Design

The next stage of the project involves the construction of a rapid prototype. This prototype will implement as many of the functions as practicable and will provide a means of user evaluation. The PAM-AID rapid prototype will be based on a commercially available rollator as shown in Figure 4. Initially we aim to fit this with motors on the rear wheels. The motors will be fitted with optical encoders to detect motion in any direction. Several different types of sensors will be used, most likely sonar and infra-red sensors. A vision based sensor is likely to be used for the descending stairs sensor. The control system is likely to be similar to that on the robot test bed i.e. micro-controller for sensor and motor control with P.C. for high level control and signal processing.

11 Future Work

This project must solve several technical problems to build a reliable device. These are sensory, mechanical, electrical and human factors.

11.1 Sensor Issues

It will be possible to address several of the sensory issues on the robot test-bed. The results of this work will then be incorporated onto the PAM-AID device. Some of the major sensor problems to be solved are :

- Descending Stairs Sensor
  A sensor system which reliably detects descending stairs, in a variety of domains and for a sufficiently wide area needs to be developed.

- Overhang Sensor
  A system for the detection of overhanging obstructions likely to collide with the user of PAM-AID has to be developed.

- User Direction Sensor
  A method of detecting on an ongoing basis the desired direction of the user must be developed.

- Object Sensors
  A set of object sensors to be used for path planning have to be selected.

11.2 Mechanical Design Issues

The design of the motion control system will need significant work. The relative merits of rear wheel differential drive as opposed to front wheel steering can only be determined after testing with a prototype. The mass of the final system and the specification of the motors will also have to be addressed.

11.3 Electrical Design Issues

The isolation of the electrical parts of the system and the development of a user friendly re-charge interface are required. Power supply issues involving continuity of supply, power saving strategies and run time will also have to be addressed.

11.4 Human Factors

Possibly the largest and most complex part of the project the development of a suitable interface for the PAM-AID device which satisfies the needs of the users while working within the technical limitations of the project. We will endeavour to engage user input throughout the project in the from of interviews and user trials to ensure that the device meets the real needs of the users.

12 Conclusions

This work is seen as part of a long term effort to apply Artificial Intelligence and robot technology to the needs of the wider community. We have chosen a well focussed project such as PAM-AID as it represents both a concrete need and a significant challenge. The needs of the infirm blind and visually impaired are quite different from those of the able-bodied blind. This manifests itself in the need to combine both a walking support and a mobility device. We are in the early stages of this work and are concentrating on developing the sensor technology required to provide reliable mobility in a dynamic environment. We aim to develop a modular robot design in which complex tasks and user interfaces can be customised to meet the needs of individual users. To gain acceptance as a viable application the robot must be robust, reliable and require little or no supervision.

In this work we are trying to provide limited independent mobility to a group of people who would otherwise be bed-ridden. We are not attempting to build a robotic guide dog which will work in all environments and for all people. Our aim is to harness advanced technology to return some limited independence to people who currently lead very dependent lives. To do this we are integrating current sensing technologies with Artificial Intelligence techniques provide a support for the persons existing abilities. We do not aim to remove the necessary human contact involved in the care of the elderly however we hope to facilitate the greater independence of the person within a caring environment.

13 Acknowledgements

We would like to acknowledge Des Kenney, Tim Gunning and Heather Hunter of the National Council for the Blind of Ireland for their continuing advice and encouragement and to the NRB for access to their library. This work has been funded by the Computer Science Dept. Trinity College and by the EU “SMART” network for Autonomous and Semi-Autonomous robots.

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