Compsci705 Seminar Report

Robotic assistant for elderly and disabled people

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ABSTRACT

Artificial intelligence has made an extremely significant contribution to our community, moreover its function has exerted incisively in various domains, especially in the robotic field, and robots already had the very tremendous influence to our life. For example: In the industry, to avoid human beings being injured, some hazardous jobs have to be completed by the robot. While, the dramatic increase of the disabled and elderly in need of care is a major social problem we need to face, therefore the role of robots in aiding the disabled and elderly is becoming very important with growing health care cost. Numerous studies dedicated to the research of technological solutions have been done for allowing robotic solutions to be applied to assist disabled and elderly people and improve their quality of life. In my report I will describe the needs and challenges for assisting disabled and elderly people and then present an overview of robotic systems had been developed for helping them.

INTRODUCTION

The structure of population in the world is changing at the turn of the millennium. Many countries are facing the reality of an increase in the proportion of the aged population. New Zealand is in addressing the implications of population ageing. As the ageing of the baby born generation, by 2051, there will be 1.18 million people aged 65 and over in New Zealand, making up 26% of the New Zealand population of 4.63 million (Cornwall& Davey, 2004). Further more, in New Zealand, 20 percent of the total population is suffering restricted daily activities because of the long-term effects of disabilities and the disability issue in New Zealand is becoming increasingly important as population ages (Statistics New Zealand, 2001). The significant increase of the elderly and disabled population along with the costs explosion pose cruel challenges to our society. The current care for the particular part of population is already insufficient. No doubt, the financial strain on the country and individuals is extreme, increasing tax rates to cover large future liabilities is not the solution, governments must find an alternative way to reduce the costs for care, meanwhile preserving and improving the quality of life for the special group.

Over the last 30 years development, AI has obtained widespread implementation in multi-disciplinary domains and has yielded significant results. The major area of AI concerned is the practical use of robots. A robot is an electromechanical machine that attempts to duplicate certain functions of the human anatomy (Jackson, 1993). Our technologies are now closer than ever to the goal of intelligent service robots which can assist people in their activities. With the help of rehabilitation technology, service robots attend to the problems of visual, hearing, speech, moving and cognitive impairment. The primary objectives of such robotics is to assist elderly and disabled users in an unstructured environment and fully or partly restore their manipulative function, finally enable impaired people to reach an optimal mental, physical and social functional level, thus providing them with the opportunities to change their own life (Jackson,1993).

Unlike industrial robots, assistant robots require cooperation with human, human-machine interaction is very important in these systems. A human-machine interactive system is based on the harmonious symbiotic existence of human and robots and various implementing methods such as appropriate cooperative sensing, planning, acting have been investigated (Yoon, 2001). There are three sections in my report: the first section concentrates on the needs and challenges for assisting disabled and elderly people. In the next section I will present an overview of robotic systems being developed, focusing upon system hardware configurations, implementation architectures like planning, sensing or navigation and human-machine interaction. The barriers of using those robotic systems will be briefly discussed in the last section.

NEEDS OF ELDERLY AND DISABLED PEOPLE

Nowadays, target of technology research and development is regularly narrowed on the young technically oriented generation, elderly or disabled people are rarely considered. Nevertheless, a particular research has been taken by Harmo et al. (2005) to find technical demands for assisting the elderly in independent living. They found out the elderly wished to have more contacts with other people, this concern also applies to disabled people. But with the loss of mobility they have to make severe changes in their life network. Naturally, regular contact with relatives or neighborhood is encouraged for the rehabilitation of handicapped people, but traditional transportation for them is impractical or costly. Moreover, elderly and disabled individuals have to weight their choices about doctors, hospitals, and social services depending on their access to the car. Clearly, mobility needs from the elderly and disabled population is a critical issue our robotic technology need to concern about.

When the elderly and the disabled need a constant attention from care givers, transition to an assisted living facility is the traditional and the only solution (Dubowsky et al., 2000). As elderly and disabled individuals move from their home to assisted living facilities, costs could be doubled while the quality of life could rapidly decrease. In assisted living facilities, residents' daily routines such as bathing, meal preparation, taking medicine can be taken care of by professional caregivers. However, most facilities are lack of labor, and some of them even cannot figure out what are the actual needs of their residents, providing labor-intensive support is pointless thus resulting in approximately 30 to 40 percent of residents in assisted living facilities suffer from some kind of senile dementia (ALFAA Advisor, 1995). Dubowsky et al. (2000) have exposed their findings that consistent guidance is required by residents with failing memory and disorientation issues, medication regulation and physical support are needed by people with muscular skeletal frailty and instability, health-condition monitoring is needed by residents with poor cardiovascular potential strokes and heart attacks, and scheduling daily activities is needed by various medicines coupled residents with failing memory. On the other side, care givers from the interview pointed out that the biggest problems or the hardest task in their job is rehabilitation training patients. This task takes most of the manual labor and is experienced troublesome in the assisted living facility.

Since most assisted living facilities can not supply effective support for elderly and disabled patients, it is more desirable and economical to live at home with certain robotic assistance. Although meeting the needs of the elderly and the disabled present technical challenges, robotic systems have been developed or under research in recent years try to provide mobility and rehabilitation assistance to aged and disabled people. Table I is a detailed presentation of several major problems facing by the elderly or disabled people and the robotic researches been taking place to fulfill corresponding problems. All information from table 1 is based on the research by Harmo et al. (2005).

Need, problem or difficulty	**Robotic technology or support available today**	**Robotic technology or support under research**
Loneliness and passivity	Entertainment robot	Emotion robot, Information home robot
Medicine dispensing control	Intelligent medicine dispensers	Rehabilitation robots
Walking (physical support)	Automated electric wheelchairs	Robotic walkers, electric canes
Memory losses, dementia	Information home robot	Rehabilitation robots
Heart attack, poor cardiovascular potential strokes	Tele-operated cameras	Intelligent home, Rehabilitation robots
Reduced vision and Reduced hearing	Speech recognition programs	Guidance robots, Information home robot.

Table 1. Robotic technology for elderly and disabled

AN OVERVIEW OF ASSISTANT ROBOTIC SYSTEMS

In this section, an overview of robotic systems for the elderly and the disabled is presented based upon system hardware and interactive software architectures.

ARPH

ARPH (Assistance Robotics to Handicapped Person) is a wheelchair-base assistance system designed by Colle, Rybawzyk, and Hoppenot (2002) for people with mobility handicaps. Simply, ARPH can cooperate with users to finish tasks like targets locating and objects grabbing.

Hardware design

In wheelchair-based systems, the environment changes with the placement of the wheelchair thus monitor and control mechanisms are required. Roughly ARPH is composed by a control station and a mobile robot with a manipulator arm mounted on as showing in figure1.

Figure 1. Control station and mobile robot

A. Control station

The control station is a medium that allows user to control the robot remotely. It is composed by control handles which is well adapted to the handicaps of the disabled person and a screen which displays video image of what is seen by the robot, virtual aids superimposed onto the video image, robot position on a 2D flat plan and robot operating indicators (Colle et al., 2005). Figure 2 is the visual feedback of ARPH's man-machine interface.

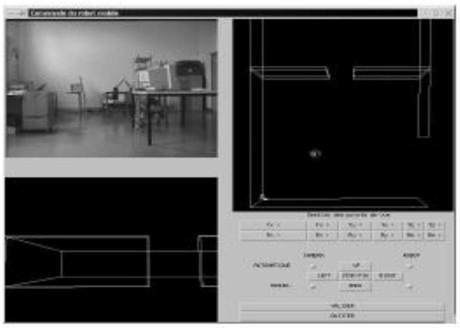

Figure 2. Visual feedback of man-machine interface

B. Mobile robot

The mobile robot is consisted by dead reckoning and ultrasonic ring as perception components, fiber glass as mobile robot body and MANUS arm as the manipulation device. At the perception point of view, dead reckoning gives the position and the orientation versus angular rotation of the wheels. The ultrasonic ring detects obstacle and measures the distance between the robot and obstacles. The camera mounted on the pan and tilt base is a perception device dedicated to common surveillance functionalities. The camera has an auto-tracking feature and it can used to provide video feedback during the robot movement and provide robot the direction to follow or the object to reach.

Implementation architecture

The approach to perform an autonomous operation such as target searching and obstacles avoiding requires three functions: planning, navigation and localization.

A. Planning

Planning is a process of selecting actions to achieve the desired goals. It is a familiar cognitive activity. Human decision making is characterized by this process of determining the actions to be taken in the future, a plan is setup in human brain to find a way to go or following a path he looks at to catch the target (Berti & Frassinetti, 2000). For the robotic approach, the robot can compute a path to reach the goal using the known plan or use camera in auto tracking mode. The user operates the camera to point out an object which is within sight of the camera. The robot moves in the direction pointed by the camera, and the camera can automatically track the object if it is a mobile target.

B. Navigation

Navigation is used to seek the goal and avoid obstacles on the path. Human's navigation can be divided into two aspects: goal-seeking and obstacle avoidance. Automatic navigation system of ARPH imitates the human's behavior. For goal-seeking, right direction is detected by relative position of the robot and the goal. If an obstacle is on the robot's path, it can be detected by ultrasonic sensors and the fuzzy logic controller will use specified rules to manage the behavior of obstacle avoidance. As a result, the robot will move smoothly in the middle of the detected free space like a human.

C. Localization

Localization technology is used to define the robot's position in a partially known environment. Two levels of system are used in the localization function: On-line localization system and off-line localization system. On-line localization system functions with the control of camera when the robot knows approximately its position and orientation. When the robot enters an unknown environment, the off-line localization function will be activated. The robot will start to locate some landmarks in the environment. If some landmarks are recognized, the robot will be able to calculate its location with the help of flat plan (Berti & Frassinetti, 2000). Walls and doors are landmarks which are highlighted in an indoor environment. Detection of walls and doors is typical pattern recognition issue; technologies like ultrasonic image segmentation, neural networks and statistical estimation are used in ARPH system for object recognition.

Interactive control

Existing robotic systems' primary objective is to maximally re-establish user's manipulative function, but these systems regularly supplant user's participation. It is especially necessary to develop control modes that share tasks between both user and system. ARPH's control mode presents aspects of human machine cooperation. It can be split into automatic, manual or shared mode. Shared mode sets up an appropriate cooperation between human and robot, disables are involved in the service and robot complexity is reduced by using human's perception and decision making. User controls the camera orientation and robot follows the direction indicated by camera with obstacle avoiding, or the user controls the robot and the camera is adjusted by expectant actions associated with the curvature radius of the path followed by the robot. ARPH's "controllability" to a human user is evaluated by a study of its requisition abilities. It consists of a set of experiments of comparing natural human performances with remote control performances during a task such as object grasping.

Pearl

Pearl is a rehabilitation robotic system (Martha et al., 2002). The goal of the system is to develop mobile rehabilitation assistance for elderly people, particularly those with mild cognitive impairment. Pearl serves like a cognitive orthotic, providing elderly people with reminders. This system has two basic functions: the first is to remind people about daily routines therefore to enhance their performance of cognition; the second function is to help elderly people navigate in their environment.

Hardware design

Pearl is equipped with two on-board Pentium PCs and they are connecting to the Internet via a wireless Ethernet link. Sonar sensors and SICK laser range finders are capable of measuring distances at an angular resolution of one degree and a spatial resolution of 5 cm. Microphones are equipped for speech recognition, speaker system is for synthesizing, stereo camera systems are white balanced color CCD cameras with an approximate aperture angle of 100 degrees. These cameras are connected with frame grabbers and JPEG encoders for image processing and high-bandwidth communication. A touch-sensitive graphical display is mounted at approximate eye height for sitting people. On top of the display is an actuated head units which could show different facial expressions.

Implementation architecture

Pearl features autonomous mobile robot navigation systems, multimedia information tracking and processing abilities. These features lead to two main implementation modules to support the primary tasks of providing reminders and assisting with navigation.

A. Cognitive orthotic functions

Computer system "Auto-minder" has been installed on Pearl and been taken to make decisions about what reminders to issue, when to issue, how to balance potentially competing objectives and ensure the client is aware of the certain expected activity, how to increase the chance that the compulsory activities is going to performed (Martha et al., 2002). Auto-minder has three components: a Plan Manager (PM), which stores and updates the client's daily activity plans. Client Modeller (CM), which observes client's activities to track the execution of the plan; and a Personal Cognitive Orthotic (PCO), which takes care of any inconsistencies between what the client is supposed to do and what she/he is doing, and makes decisions about when to issue reminders. The architecture of auto-minder is showing in figure 3.

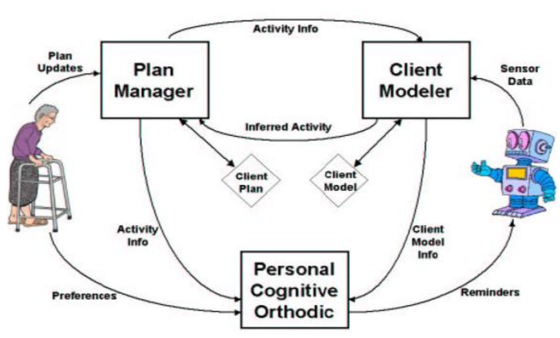

Figure 3. Architecture of auto-minder

B. Navigation

Another purpose of designing Pearl is to navigate elderly people. Navigations could be done by first learning a map of the environment, which is represented through a 2D occupancy grid map (Elfes, 1989). Once a real-time map has been acquired, Pearl will be able to maintain accurate state of its location and accurate heading direction in the space. With this ability, Pearl can move to any subjective targets and can direct cameras towards various items of interest. By comparing sensor readings and the learned map, the robot can detect changes in the environment, particularly the locations of people. In another word, Pearl detects people using map differencing; people are detected by significant deviations from the map. By known the location of a person, Pearl could facilitate the interaction with the person, detect patient's abnormal behaviors and analyze people's daily routines.

Interactive control

Pearl's control decision is based on the full probability distribution generated by the state estimator (Martha et al., 2002). This distribution includes several multi-valued probabilistic state and goal variables. From various distinct states, Pearl can select distinct actions, narrows down to communication actions like issue a reminder, check patient's status; movement actions like lead the client from one location to another, patrol around to seek patients need help; and miscellaneous actions like recharge the battery, entertain people. An actions hierarchy is showing in figure 4. Actions will invoke a pre-defined sequence of commands on the robot. The Martha et al., (2002) has presented an example, the action to tell the patient the weather tomorrow will map to command *SpeechSynthesis="Tomorrow's weather should be sunny, with a high of 80."*

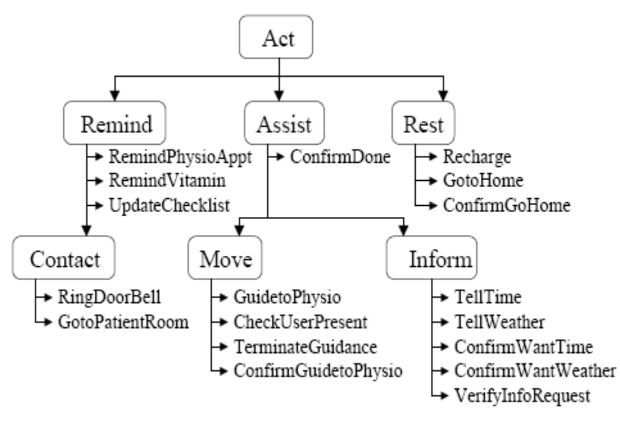

Figure 4. Action hierarchy sample

RoJi

RoJi is a robotic cane proposed by Yoon (2004) for blind or visually-impaired travelers to navigate; it aimed at improving the mobility of sight handicapped people. Instead of using white cane or the guide dog, users hold the robotic cane in front of him/her while walking and RoJi will guide them safely and quickly through obstacles or other hazards like uneven surfaces, holes or steps.

Hardware design

Much like the widely used white cane, RoJi consists of a long handle painted in white; two powered, rotatable wheels; a sensor unit is mounted above wheels; a user interface panel is combined at the end of the handle. A gyroscope sensor which could be tie on user's head is used to track user's head movement. An earphone could be worn by user to receive obstacle information as different audio tones. A manuscript of RoJi is demonstrated in figure 5.

Figure 5. Demonstration of Roji's components

Implementation architecture

A. Action Module

RoJi utilizes a PICBASIC 2000 microcontroller to process the information from sensors and also to generate control pulses for the DC servo motors. The two steering wheels of the cane are controlled independently by separate DC. These two powered motors could provide sufficient power to lead the user autonomously. Autonomous recharging methods, such as recharging batteries through solar energy can sustain enough power to be utilized for a full working day.

B. Sensing Module

The sensor head consists of an ultrasonic sensor unit, two antennas and three infrared (Figure 6). Ultrasonic sensor works as a sonic scanner and it is driven by a RC motor. The unit scans the area ahead of the cane to detect obstacles and then steer the device. Its scanning distance is 250 cm within a scanning angle ±90 wide and ±30° height (Yoon, 2004). Two steel antennas are equipped for short-range contact sensing, the length of each antenna is 22 cm and they are all connected to potentiometers which are utilized as contact sensor. By touching the surface, these antennas can detect irregularities or obstacles in front. Three infrared sensors are operated to detect the objects blocking the pathway. These three sensors are arranged in a semi-circle with 30° apart from each other, and result in detect any convex obstacles up 60 cm ahead.

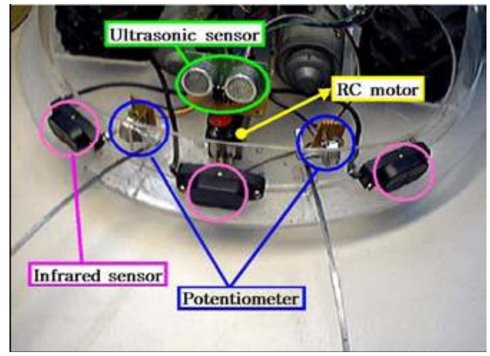

Figure 6. Sensor head of Roji

Interactive control

An interactive system requires cooperation between robots and human. Basically this robotic cane has the robot control mode (RCM) and the user control mode (UCM). The RCM model is an extended autonomous navigation mode with the user's intention. A flow showing of autonomous navigation mode is presented in Figure 7. The cane's UCM mode lets the user navigate safely when the cane and the user make conflicting and/or difficult decisions to follow. The button on the miniature panel allows the user to switch between modes. By pressing the button on the panel, the user can grab the control priorities and specify his desired direction of action. This module lets the user and the robotic cane share information to cooperate with and compensate for each other.

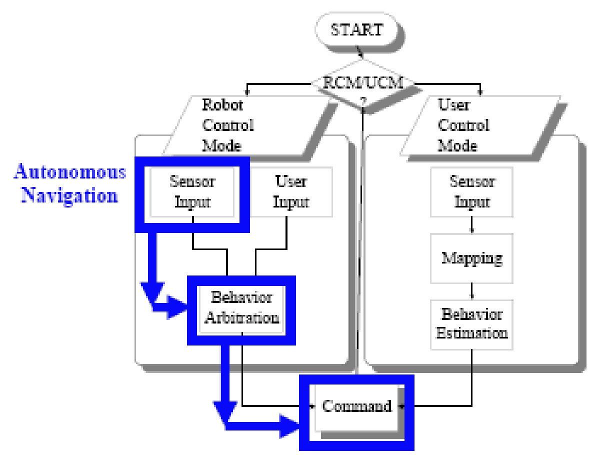

Figure 7. Control flow of Roji

SUMMARY

Robotic technology promises considerable help to elderly and disabled people, while, the approach to providing robotic assistance presents important technical challenges. The successful introduction of a robotic system requires system providers to possess the knowledge of potential users' environment and their needs, as well as specific robotic sensor, navigation and control technologies. Since robotic system's operation is participated by the user, the issue of human-machine interactive interface is very important. I have briefly described ARPH, Pearl and RoJi these three robotic systems being designed to assist elderly or disabled people in their daily activities. Various methods for implementing the sensing, planning, navigation and appropriate cooperative acting have been investigated in these three human-friendly interactive systems. They are good platforms for our current man-machine interaction study and future's autonomous applications.

FUTURE WORK

Robotic systems are walking out of the lab and going to apply to the real implementation. There seems to be interest towards using robotics to help the elderly and disabled people. However, high cost of the assistance and the fear of technology may cause people to reject using them; also it is important to admit the robot cannot be completely autonomous (Jackson, 1993). There are very few systems available on the market, the hardware, installation costs and service charges are remarkable, users were afraid that the device would harm them or they would break the expensive devices (Harmo et al., 2005). New appliances that old and disabled users were not used to use were suspicious and they are not pleased to learn, interact with and rely on them. Mechanical and impersonal reactions from robot may be annoying and irritating. Also different kind of sensors and surveillance equipments could make people feel uncomfortable. Recognizing the barriers of providing robotic assistance at current stage, robotics researchers would pay plentiful attentions on these challengers and conquer them in the future work.

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