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DESIGN OF PASSIVE ROBOT WALKER BY USER INTENTION USING FORCE SENSOR

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Abstract:

This paper describes a robotic walker designed as an assistive device for frail elderly people with cognitive impairment. Lo- comotion is most often the primary form of exercise for the elderly, and devices that provide mobility assistance are criti- cal for the health and well being of such individuals. Previous work on walkers focused primarily on safety but offered little or no assistance with navigation and global orientation. Our system provides these features in addition to the stability and support provided by conventional walkers. This capability is achieved by a software suite of robot localization and navi- gation combined with a shared-control haptic interface. The system has been tested in a retirement facility near Pittsburgh, PA, USA.

Keywords – Navgation, Haptic, Stablity.

1. INTRODUCTION

The elderly population is growing at a dramatic rate and caus- ing a greater demand for devices that extend independent liv- ing and promote improved health. Since inactivity among the elderly has been shown to be a significant cause of in- creased morbidity [1, 2] and premature mortality [3], devices that enable daily exercise are essential to the health and wel- fare of these individuals. As locomotion is most often the primary form of exercise for the elderly, this segment of the population dominates the users of devices that offer mobil- ity assistance [4]. Despite the dependence on such ambula- tory assisting devices, contemporary walkers and subsequent variants only provide assistance with user stability. Naviga- tional assistance, for those who suffer from senile dementia and frequently become disoriented, and motion-control aid, for those who possess deficiencies in motor skills and cannot properly control their walkers, are features not currently avail- able. These forms of aid, while critical to the functionality of the user, are only provided through direct human-to-human interaction. Escorting the elderly who reside in long term care settings to medical (doctor and therapy appointments), social (meeting friends), and cosmetic (manicure, getting a hair cut) activities, as well as such repetitive daily tasks as visits to dining facili- ties, is a necessary yet time-consuming task that requires hu- man assistance. With the growing disproportions between the Our research builds on a rich body of literature on robotic walkers and assistive devices [6, 7, 8, 9]. These mobility aids have provided safety and stability to their users through means of collision avoidance or velocity/acceleration limits for op- eration on uneven terrain [6]. Such features have been im- plemented in powered wheel chairs [8, 9] through local path planning. One of the first robotic mobility aid to incorporate guidance functionality was the PAMM cane [7]. It performed route fol- lowing by localizing to unique ceiling markers along a des- ignated path. Although not directly assisting human locomo- tion, tour-guide robots [10, 11, 12, 13] have been developedby various research groups over the past few years for maturing guidance systems in dynamic environments. Navigation has also been developedin other context as with wearable comput- ing [14]. This technology is leveraged into the present system, which is unique in its use of a haptic interface on a walker to mediate human and robot control.

2. PROPOSED SYSTEM

The physical system is depicted in Figure 1. Our present prototype has been built on top of a Nomad XR4000 mobile robot platform. This robotis equippedwith an omnidirectional drive, making it ideal for navigating through corridors in close proximity of a person. The robot is also sturdy enough to sup- ply sufficient physical support to its clients. The 0.61 meter diameter of the robot, however, prohibits navigation through narrow doorways; for this reason our experiments have been confined to hallways and larger doorways. The robot is equipped with two circular arrays of Polaroid ul- trasonic transducers, two circular arrays of Nomadics infrared near-range sensors, three large touch-sensitive doors, and a SICK

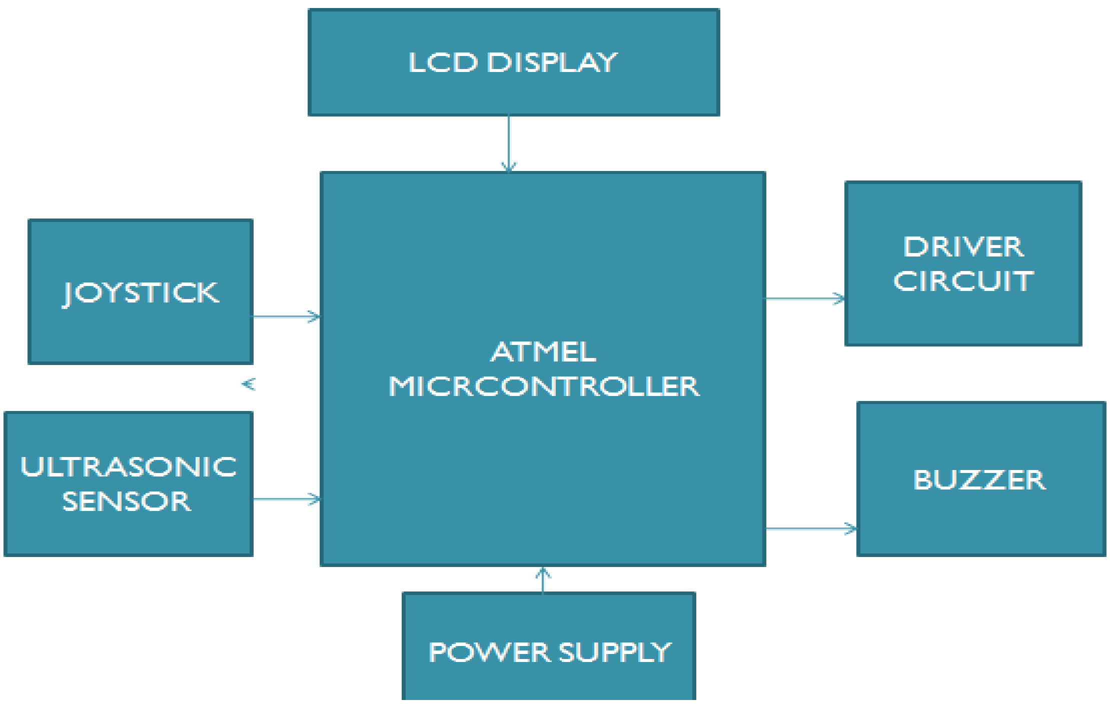

Fig.1.Block diagram

LMS laser range finder. These sensors enable our sys- tem to perceive obstacles at various heights, and the SICK laser range finder is used for navigation (mapping, localiza- tion, path planning).To function as a robotic walker, the platform has been equipped with two handlebars. Both handlebars are mounted in a fixed position relative to the robot's frame, to provide physical support and stability. The handlebars are also the loci of the haptic interface: Both bars are equipped with two independent force sensors each, en- abling the robot to measure forces asserted by the user. The interface provides sufficient information to navigate the robot into arbitrary directions. Additionally, the robot features a vi- sual LCD display panel that informs the user about the sys- tem's desired motion direction. The display is similar to ex- isting in-vehicle guidance systems used routinely in the auto- motive industry [17]. The display is updated several times a second, thereby always providing an accurate assessment of Our experiments, which will be reported further below, evaluate the effectiveness of our system in real-world situations under the premise that the user is unaware or mentally incapable of knowing her target location. Experiments investigate the fea- sibility of escorting people through their environments using our robotic walker, and the relative merits of the robot's indi- vidual components.

3. NAVGATION SYSTEM

The robot's navigation system is built on top of Carmen, which is short for Carnegie Mellon's Navigation Toolkit. Precursors to the Carmen system were used in dozens of robots world- wide, including the two museum tour-guide robots Rhino [12] and Minerva [13]. Building on these systems, Carmen has been developed into a full-fledged software system for au- tonomous mobile robot navigation in indoor environments. It contains software modules for collision avoidance, localiza- tion, mapping, path planning, navigation, and people tracking. Carmen is strictly a probabilistic software system, in that all essential information is represented via probability distribu- tions. At the core of Carmen's navigation routines are metric envi- ronment maps. Figure 2 depicts such a map taken from a re- tirement facility in Oakmont, PA, USA. The map represents an occupancy grid maps [18] with a resolution of 10 cm. It has been acquired in real-time using the probabilistic mapping software described in [19]. During the mapping process, en- vironment size is significant. The robot is manually driven through the environment using a joystick interface and, within a few minutes, a map is produced. Potential target locations are subsequently marked manually in these types of maps. The entire process takes no more than 30 minutes, making our robot system extremely portable to new environments.

4. ANALYSIS

Experimental trials of this walker robot system have been per- formed at a retirement facility in Oakmont, PA, USA. Four residents of the facility were asked to operate the walker in a navigation task under the various modes of control. Their trajectory data and haptic input were logged along with the

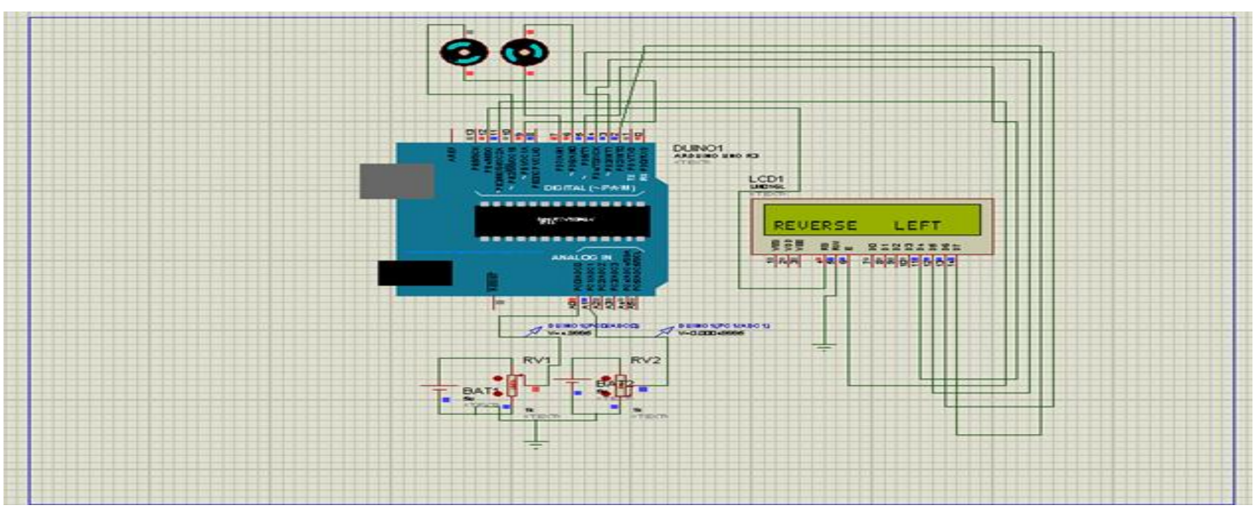

Fig.2.Simulation system

robot's trajectory input and projected path. The system was evaluated on its usability and capacity to keep the user moving toward the goal. The motion response of the system. For each mode of control, the user was informed to move to a goal position. Under passive control, large path deviations were witnessed since the navigational system of- fered no intervention. Under active control, the motion of the user was restricted to within 80 degrees of the intended orientation. The result was that the user was forced to remain much closer to the path After preliminary tests held at Carnegie Mellon University, a user interface was implemented to assist in directing motion. It was discovered that the participant became confused

Fig.3.Hardware construction

during active control whenever the robot stopped suddenly. Visual feedback was displayed on a laptop LCD screen and consisted of a large rotating arrow that pointed in the direction of the next waypoint. If the user was oriented in the correct direc- tion, the arrow pointed up; likewise, if the user began to drift, the arrow would rotate towards the next desired location. By seeing the arrow, the participant was fully aware of the robot's intended trajectory. In many cases, the visual representation was critical to effective navigation since it provided communi- cation between robot and human. Furthermore, the simplicity of an arrow was found to be far less confusing compared to displaying maps and goal locations.producing minimal deviation.

CONCLUSION

This paper presented a novel approach to the design and im- plementation of a mobility assistant device. By augmenting a commercial mobile robotic platform with haptic sensing, the Carmen navigational system, and a shared control scheme, a robotic walker was developed. Multiple modes of human to robot control were investigated in order to determine the best compromise between user freedom and completing a specified navigation task. This robotic system was then field tested in an assisted living facility with

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