A Rollator-Mounted Wayfinding System for the Elderly: Proof-of-Concept Design and Preliminary Technical Evaluation

Vladimir A. Kulyukin, Ph.D.[1], Edmund LoPresti, Ph.D.[2],

Aliasgar Kutiyanawala[1], M.S., Richard Simpson, Ph.D.[3],

Judith T. Matthews, Ph.D.[4]

[1] Utah State University, Logan, UT
[2] AT Sciences, LLC, Pittsburgh, PA
[3] University of Pittsburg, Pittsburgh, PA
[4] University of Pittsburg, Pittsburg, PA

ABSTRACT

Surveys show that a great number of U.S. residents would like to maintain their independent status in their homes and communities as long as possible. Intelligent walkers are the focus of research aimed at helping elderly individuals to maintain their independence. Several robotic walkers have been developed by investigators at Carnegie Mellon University and the University of Pittsburgh. This paper contributes to this research venue by describing the proof-of-concept design and preliminary technical evaluation of iWalker, a three-sensor rollator-mounted wayfinding system for the elderly. Unlike previous and ongoing research efforts, iWalker emphasizes a smart world (SW) perspective. A SW is a physical space equipped with embedded sensors. Two consequences of the SW perspective are simplified on-board machinery and low cost.

KEYWORDS:

intelligent walkers, indoor localization, cognitive impairments

BACKGROUND

Current demographic trends in the U.S. signify a demographic shift from a population where most people are relatively young to a population where most people are relatively old. In 2000, U.S. residents age 65 and older constituted approximately 12 percent of the population. It is projected that by 2030 people age 65 and older will make up 22 percent of the U.S. population [1]. Of considerable concern to aging adults is the decline in their sensory-motor abilities. Surveys show that a great number of U.S. residents would like to maintain their independent status in their homes and communities as long as possible.

Intelligent walkers are the focus of research aimed at helping aging individuals to maintain independence. Three robotic walkers have been developed by investigators at Carnegie Mellon University and the University of Pittsburgh [2]. One robotic walker was a self-powered walker with an intuitive haptic interface. A software control system enabled data from force-sensing resistors to direct actuators in a mobile robotic platform to move in the user's intended walking direction. The base was equipped with a laser range finder and ringed at the top and bottom with sonar sensors for obstacle detection and avoidance. The second robotic walker was developed by modifying a wheeled walker (rollator) to include autonomous navigation capability, as well as self-parking and retrieval functionality actuated through a remote control mechanism. Further modification of this walker has resulted in a third robotic walker which has been used in a series of experiments to successfully predict people's walking activities [3]. Several studies have involved prototype robots designed to assist older adults by augmenting rather than replacing human caregiving and support. One study investigated a mobile robotic personal assistant named Pearl [4], and the remaining studies pertain to several iterations of a robotic walker. These robots are the products of the Nursebot Project, a research and educational collaboration involving clinicians and technologists at the University of Pittsburgh, Carnegie Mellon University, Stanford University, and the University of Michigan [3].

This paper contributes to this research venue by presenting the proof-of-concept design and preliminary technical evaluation of iWalker, a three-sensor rollator-mounted wayfinding system for the elderly. Unlike previous and ongoing research efforts, iWalker emphasizes a smart world (SW) perspective [5, 6]. A SW is a physical space equipped with embedded sensors. Two consequences of the SW perspective are simplified on-board computing machinery and low cost.

METHODOLOGY

Figure 1.: iWalker Device.

The iWalker device and its components are shown in Figure 1. The sensor suite consists of three sensors: an encoder, a digital compass, and a radio-frequency (RFID) reader and antenna. The encoder and compass constitute the dead reckoning system. The encoder has a resolution of 60 cms, which appears to be sufficient in the initial technical evaluation described below. The encoder is connected to an OOPIC microcontroller that provides a serial interface with the laptop or any other computational device. The RFID reader is also connected via a serial interface to the laptop. All units are powered by an onboard rechargeable battery. The entire unit can be easily mounted on an standard rollator without any modifications to the latter.

Figure 2: An RFID Tag and a Carpet Strip with Embedded Tags.

The RFID antenna attaches to the bottom of the rollator. It detects small RFID tags embedded in RF-enabled carpet strip that can be placed on the floor anywhere in the environment. Figures 2 shows an RFID tag and an RF strip (2.5 meters by 0.9 meter) used in our experiments. Each tag can store up to 64 bits of data which allows for 264 (2 to the power of 64) unique tags in the environment. A strip has 15 tags separated by a distance of 20 cm from each other. The tags are passive, i.e., they do not require external power supplies. Such tags can be read through any non-metallic material, e.g., plastics, tiles, and carpets. The dimensions of one tag are 12mm by 6mm by 3mm. The weight is 0.4g and the cost is $4. The cost of one strip shown in Figure 2 is approximately $70.

The localization algorithm runs on the onboard laptop and fuses readings from the encoder, the compass, and the RFID reader to localize the walker. The algorithm requires a map of the environment in which the x-y position of each strip is recorded. In the beginning, the algorithm localizes the walker on the first strip it encounters. In between strips, the algorithm uses standard dead-reckoning from compass and encoder readings. When a tag in a strip is detected, the encoder error is reset to 0 and the walker's position is reset to the strips's x-y position. The strips are also used to discretize the compass readings. For example, in an East-West hallway, the compass output can be restricted to East and West. The discretization schema is associated with each strip at design time and is activated at run time through a simple lookup.

A series of experiments were performed on a 40 meter route in an office environment that consisted of four hallways that formed a square. The route was divided into 40 one meter segments marked with masking tape on the floor. Localization results were recorded and compared with the ground truth to generate the localization error every time the walker crossed one of these segments. The contribution of each sensor to the localization accuracy was measured as well. The main research hypothesis was that the RF strips have a positive impact on the localization accuracy. The following configurations were tested: dead-reckoning alone, dead-reckoning and 1 RF strip, dead-reckoning and 2 RF strips, dead-reckoning and 3 RF strips, and dead-reckoning and 4 RF strips. Each configuration was tested on 30 runs along the route.

RESULTS

number of mats	mean	standard deviation	maximum	minimum
0	4.2870	2.8550	8.8499	0.0185
1	3.0793	2.3772	8.6241	0
2	2.2643	1.7584	6.4840	0.0394
3	2.2150	1.8569	6.9585	0.0203
4	1.1124	0.5558	2.8616	0.2759

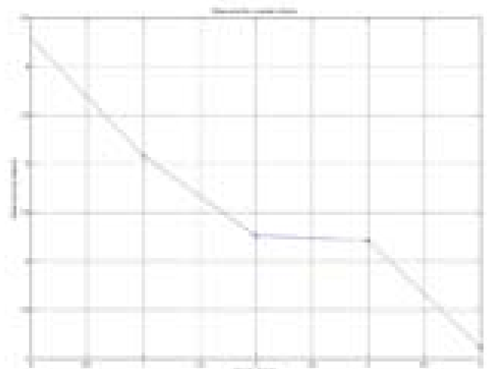

Figure 3: Graph of Localization Error Versus the Number of RF Strips.

Table 1 describes the localization results and Figure 3 shows a graph of localization error versus the number of RF strips. The results show that the average localization error drops from 4.5 meters (dead-reckoning only) to 1 meter (dead-reckoning and 4 strips). This suggests the validity of the research hypothesis that the average localization error drops as the number of RF strips increases. The compass is the noisiest of all the sensors on the walker and discretizing it at run time results in a reduction in the localization error by over a meter. Localization accuracy of 1 meter was found to be very satisfactory considering that the encoder resolution is only 60 cms.

DISCUSSION

Our future work will enhance iWalker with a reminder software system that will interact with the elderly as they navigate indoor environments. We will test the device with a group of frail, community-residing elders in Pittsburgh. Another venue of future research will focus on the automated design of RF surfaces to maximize the probability of detection while minimizing the number of RFID tags in the surface.

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Author Contact Information:

Vladimir A. Kulyukin, Ph.D.
Computer Science Assistive Technology Laboratory
Department of Computer Science
Utah State University
Logan, UT 84322
Phone (435) 797-8163
EMAIL: vladimir.kulyukin@usu.edu.