An Active Smart Walker for the Elderly

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***Abstract*—In this paper we present an implementation of an active smart walker, consisting of a differential-drive-like platform equipped with a 2D laser scanner and a control unit for the obstacle avoidance. The resulting behavior of the platform allows the user to effectively divert his/her path while using the walker, thus preventing bumps or collisions which may lead to the accidental fall of the user.**

***Index Terms*—obstacle avoidance, potential field method, actuated walker, fall prevention**

I. Introduction

The ability to walk is one of the most important and fundamental functions for humans to live high-quality lives. However, it is well-known how such a locomotion capability can be partially or entirely compromised, especially in the case of the elderly or in the case of the mobility impaired. Robotics research has been recently involved in proposing innovative solutions to assist the aforementioned categories of people in walking autonomously. Nowadays such solutions are extremely relevant as the average life expectancy is getting longer and longer in a very large number of countries all over the world. For all of the reasons above, several walking assistants have been proposed and developed in the literature [1]. Here we will focus on so-called *smart walkers* only. These are mainly conventional walkers integrated with sensing, actuation and control systems to ease the usage of such devices and, more importantly, to avoid collisions or hindrances while walking, which may result in dangerous falls. Moreover, thanks to the computing platforms embedded on the walkers, it is often possible to create a network of devices and sensors or to connect them to the Internet, which opens up a wide number of applications in the medical and nursing care.

Smart Walkers are usually classified as *passive* or *active* devices [1]. The former require the user to push the walker in order to move. In this case the obstacle avoidance is typically performed by a braking-based steering system [2]–[4]. On the other hand, active smart walkers help the elderly in moving the walker itself through the actuation of the wheels with motors [5]. Moreover, this allows the user to walk uphill with a smaller effort compared to the passive case.

This work has been developed under the PC Interreg V-A Italy Malta Grant, Project NATIFLife C1-1.1-90 – CUP E61I1600002005.

II. Proposed System

The work described in this paper consists in the control design and the realization of a differential-drive-like active smart walker capable of avoiding obstacles within the environment, thanks to the data coming from a 2D laser scanner. The *Potential Field Method* (PFM) has been adopted as obstacle avoidance approach. The basic idea of such method is to define a repulsive force, $\overrightarrow{F}_{rep}$, stemming from the obstacles such that:

- the walker path is strongly diverted when it is close to the obstacle;
- the walker path is not affected at all by far obstacles.

This is obtained by defining $\overrightarrow{F}_{rep}$ as follows:

$$\begin{aligned}\overrightarrow{F}_{rep} &= -\nabla U_{rep}(q) \\ &= \eta\left(\frac{1}{\rho(q)} - \frac{1}{\rho_0}\right)\left(\frac{1}{\rho^2(q)}\right)\nabla\rho(q)\end{aligned} \tag{1}$$

where:

- q is the current robot position
- $\rho(q)$ is the minimum distance from the closest obstacle;
- ρ_0 is a threshold;
- η is a positive scaling factor;
- $\nabla\rho(q) = (q - q_c)/\parallel q - q_c \parallel$ is the unit vector pointing outwards the closest obstacle.

A. Hardware Overview

The main component of the system is the myRIO board by National Instruments, which processes all the information coming from the sensors, generates control signals for the motor drivers and implements the control logic (i.e. the PFM). Two wheels with brushless DC motors have been used, while obstacle detection is performed by an RPLidar A1. It is a low-cost light-weight 360° laser range scanner with a scanning frequency of 6 Hz and a sample rate of 2 kHz. Its maximum detection range is 12 meters. A block scheme of the proposed system is shown in Fig. 1, whereas a picture of the implemented system is shown in Fig. 2.

B. Control Implementation

After several pilot tests, a fair compromise between computation burden and quality of the resulting path has been

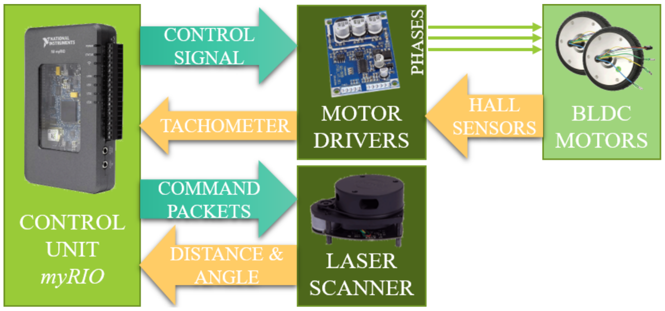

Fig. 1. Block scheme of the implemented system.

Fig. 2. The developed prototype of the smart walker.

obtained by reducing the scanning angle to 70° as sketched in Fig. 3. In this way not only the amount of data to be processed is decreased, but also the capability of the robot to move between obstacles appeared to be smoother compared to the full-angle scan case. Moreover, four critical regions have been identified, according to the distance of the walker from the obstacles as depicted in Fig. 4:

Case A There are no obstacles in the surrounding area: the walker can go straight with the maximum velocity (i.e., the control signal is $\mathrm{PWM}_{\mathrm{max}}$).

Case B The robot detects an obstacle below the threshold (ρ_0) but above the minimum distance. In this region the steering logic is driven by the Potential Field Method. We can distinguish two further sub-cases:

- left obstacle detection;
- right obstacle detection.

In both cases, the algorithmic implementation of the PFM is as follows:

1) fix the values of ρ_0, $\min_{\mathrm{distance}}$, η, and $\mathrm{PWM}_{\mathrm{max}}$;
2) compute $\overrightarrow{F}_{\mathrm{rep}}$ according to Eq. 1;
3) normalize $|\overrightarrow{F}_{\mathrm{rep}}|$ in the $[0,1]$ range according to Eq. 2 (*min-max normalization*):

$$|\overrightarrow{F}_{\mathrm{rep\ norm}}| = \frac{|\overrightarrow{F}_{\mathrm{rep}}| - |\overrightarrow{F}_{\mathrm{min}}|}{|\overrightarrow{F}_{\mathrm{max}}| - |\overrightarrow{F}_{\mathrm{min}}|}; \tag{2}$$

4) Compute $v' = |\overrightarrow{F}_{\mathrm{rep\ norm}}| \cdot \mathrm{PWM}_{\mathrm{max}}$ and assign:
   - $\mathrm{PWM}_{\mathrm{max}}$ to the wheel on the same side of the obstacle;
   - $\mathrm{PWM}_{\mathrm{max}}$-$v'$ to the other wheel.

This means that an obstacle on the left side (between 325°-360°), causes a steering to the right. The PFM acts reducing the $\mathrm{PWM}_{\mathrm{right}}$ proportionally to the obstacle distance (the closer the obstacle the lower the $\mathrm{PWM}_{\mathrm{right}}$). Similarly, when the walker detects an obstacle on the right side (between 0°-35°), it steers to the left.

Case C When the obstacle is detected between the minimum distance and the *critical distance*, the walker avoids the obstacle by rotating the proper wheel (namely the left or right one, according to the obstacle position) at the minimum velocity allowed by motor drivers, while the other wheel is kept still and acts as a pivot.

Case D Finally when an obstacle is detected in the region D (below the critical distance), the walker is stopped in order to avoid the collision.

III. Conclusion

We developed a smart walker, with active wheels and a 2D laser scanner, capable of avoiding obstacles through the potential field method. Although such an approach has been widely adopted in the literature of mobile robotics, it has been scarcely employed in the technology of walking assistants. This work suggests how many other paradigms and methodologies can be translated from mobile robotics to assistive technology research.

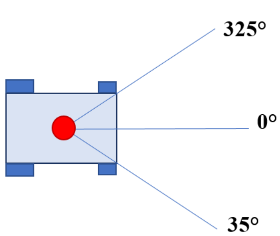

Fig. 3. Reduced scanning angle of the 2D laser on board the walker.

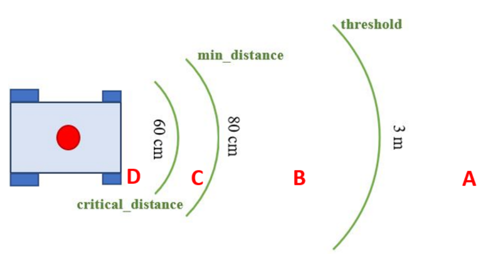

Fig. 4. The four regions identified.

IV. Acknowledgment

Authors would like to thank M. Beninato, G. Caruso, A. Cottone, V. Sipione, and A. Spurio for the development of the smart walker prototype.

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