An Obstacle Avoidance Strategy Using an Indoor Localization System

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Abstract In this paper an assistive device for the mobility support of the elderly and people with impairments is presented. The device is a Smart Walker developed for the Assistive Technology context, within the framework of the NATIFLife project. The hardware architecture of the system, the algorithm implemented for both static and dynamic obstacles avoidance and the experimental results are reported.

1 Introduction

The trend towards a gradual demographic aging of the population has been confirmed by several studies. With reference to European Union, a study by Eurostat [1] shows how the proportion of elders to working age population is gradually reducing, while the number of pensioners is growing, due to a substantial reduction in birth rates and the increase in life expectancy.

One of the consequences of demographic aging is the growth of the share of elderly people living alone. This implies the need to provide more support to guarantee independence and autonomy of life to this category of people. On the other hand, there are some safety issues since elderly people are more vulnerable to domestic accidents. In fact, the cases of domestic accidents occurring to people aged between 65 and 80, represent the 80% of the total [2]. Moreover, falls are the main cause of accidental injuries [3]. Fall-related injuries can have a substantial impact on the lives of the elderly, as they can lead to both a decrease in motor skills and to a considerable increase in health care costs.

The availability of technological solutions capable of contributing to the improvement of the safety, health and quality of life of the elderly represents an enabling step towards implementation of new social assistance models. The main idea of such

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models is to decentralize part of the social-assistance activities from healthcare facilities to the users' residences. According to the definition provided by the World Health Organization, assistive devices and technologies are those whose primary purpose is to maintain or to improve an individual's functioning and independence to facilitate participation and to enhance overall well-being. They can also help prevent impairments and secondary health conditions [4].

Many research efforts by the authors have been focused, in recent years, on the development of reliable solutions for Activities of Daily Living (ADL) monitoring and for the recognition and classification of critical events to the user, such as falls [5–9].

In this paper, part of the research activities developed within the NATIFLife project "A Network of Assistive Technology for an Independent and Functional Life" are presented [10]. The project is funded by the INTERREG V-A Italy Malta Cooperation Programme and involves the Universities of Catania and Malta, and several public entities and enterprises located both in Sicily and Malta [11]. The Project aims at providing effective technological solutions to the needs of independency and autonomy of elderly and people with impairments. Its main objective is the development of an innovative framework of assistive technology in the domestic environment, supporting elderly and people with disabilities, by a joint, cross-border action between research, industrial, institutional and social stakeholders.

In particular, a smart walker, i.e. an assistive device for mobility support, will be presented here. The main features and functionalities which make such a walker *smart* rely on the solutions provided within the framework of the NATIFLife project.

2 Related Work

Several research activities have investigated the enhancement of commercial walkers through actuators, sensors and high-level functionalities. In the related literature, such improved walkers are typically referred to as *smart walkers* [12]. These devices are usually classified according to their autonomy, shared-control degree, sit-to-stand support, monitoring of the user's status, and wheel actuation. Walkers with actuated wheels ease the mobility of the user, by navigating in the environment. On the other hand, passive walkers guide the users by means of brakes acting on the wheels, while the user is still responsible for the motion. Some examples are available in the literature on such a brake-based approach [13, 14], however they usually adopt expensive servo motors for the brakes and costly obstacle detection systems.

3 The Proposed Solution

An obstacle avoidance solution has been implemented on a commercial walker. Such a solution can handle both static and dynamic obstacles. Static obstacles are managed

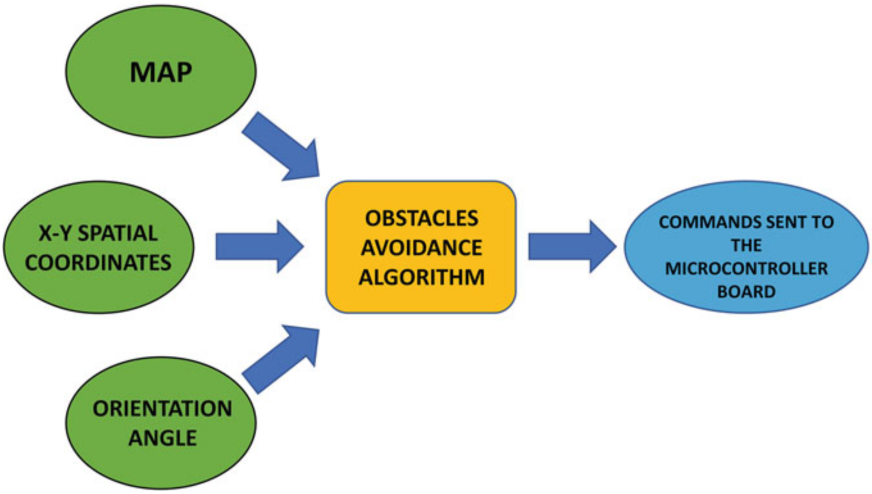

Fig. 1 Input and output of the control algorithm for static obstacles

by a control algorithm requiring three inputs, as schematically shown in Fig. 1, and they are:

- The 2-D binary map of the operating environment, including obstacles and free areas;
- The 2-D coordinates of the walker within the map;
- The orientation angle of the walker.

The map must be provided a priori and, in our case, has been manually realized. This is the main limitation of the current version of our work.

Whenever the algorithm identifies an obstacle within the minimum allowed distance from current position and orientation within the map, it sends a command to a microcontroller board in order to actuate the braking system, in order to steer the elder walking to avoid the collision.

Dynamic obstacles (i.e. not present in the map) are detected through three Time-of-Flight (ToF) ranging sensors (one frontal, one towards the right and one towards the left). Whenever an obstacle is closer to the minimum safety distance, a suitable control signal is triggered also in this case to actuate the braking system.

The main novelties in our solution are the low-cost hardware implementation and the monitoring of the elderly status.

4 Hardware Architecture of the System

The algorithm for the static obstacle avoidance is executed by a Raspberry Pi 3, a popular single-board low-cost low-power computer. The map of the environment is

Fig. 2 The Smart Walker developed

pre-loaded into the computer mass memory. The walker heading is obtained using a board called Sense Hat, an expansion board for the Raspberry Pi 3, which integrates a set of heterogeneous sensors and devices, including a LED display, which allows the user to view the data detected through icons or messages, and an Inertial Measurement Unit (IMU), that integrates an accelerometer, gyroscope and magnetometer in a single chip. It also includes some environmental sensors such as a barometric pressure sensor, a temperature sensor and a humidity sensor. Furthermore, a 5-button joystick is present, which can be used as an input device.

The 2-D coordinates are provided by the indoor location system described in [15], through a wireless sensor network based on the ZigBee-IEEE 802.15.4 protocol. An XBee module has been used to interface the Raspberry Pi to the localization system. Such system is a solution belonging to the NATIFLife framework.

The control board integrated in the walker is a NUCLEO-L476RG board, which is equipped with a low-power ARM Cortex M4 STM32L476RGT6 microcontroller. Raspberry Pi and Nucleo board communicate through a serial channel. The two servomotors MG946R Towerpro are driven independently by PWM signals provided by the Nucleo Board. These signals switch the servo from the free to hold position of the two wheels' brakes. The result is an on-off control approach. The integrated system obtained is shown in Fig. 2.

5 Obstacle Avoidance Algorithm

Once position and orientation of the walker are known, the static obstacle avoidance algorithm probes the map to detect the presence of obstacles in the surrounding environment and, if needed, to avoid them.

In order to do this, the algorithm calculates the distances to the obstacles in the map (static objects or walls) over an arc of 181 degrees in front of the walker. The

Table 1 Threshold command control

Distance_left	Distance_front	Distance_right	Brake activation
0	0	0	None
0	0	1	Left
0	1	0	Both
0	1	1	Left
1	0	0	Right
1	0	1	None
1	1	0	Right
1	1	1	Both

arc is then divided into three equal sectors and the algorithm verifies for each sector if the distance from the obstacles is lower than a given threshold. Depending on the output of this check, the control action on the braking system is established. The three control variables, Distance_Left, Distance_Front and Distance_Right, shown in Table 1, represent the presence of obstacles respectively in the left, front and right sectors in the arc. The values of 1 and 0 indicate respectively the presence or absence of obstacles within the threshold distance. The basic principle is to produce (through the brakes) a difference in the speed of rotation of the two rear wheels, thus resulting in a steering of the walker. If the presence of an obstacle requires that the walker should stop, the control algorithm blocks both wheels.

The same approach is used with the ranging data acquired by the three ToF sensor to avoid unexpected or dynamic obstacles, with an equivalent consequent actuation of the brakes.

6 Results

Experimental tests carried out in the laboratory have shown that the developed system improves the ability to identify obstacles and therefore to avoid them automatically and intuitively. Then volunteers performed pilot tests for the qualitative usability assessment of the proposed smart walker.

The integration between data provided by ToF laser sensors and localization system greatly improves the ability of the system to avoid collisions with obstacles and consequent potential falls.

Moreover, the monitoring functionality of the smart walker, like the one provided by the NATIFLife infrastructure, allows exploiting potential advantages coming from processing data to observe the status of the elderly.

As a future development, we plan to carry out a wider and quantitative testing campaign on the platform.

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References

1. Population Structure and ageing, Statistics Explained, Eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php/Population_structure_and_ageing
2. Lee VMS et al (1999) Home accidents in elderly patients presenting to an emergency department. Accid Emerg Nurs 7(2):96–102
3. Gudnadottir M et al (2018) Accidental injuries among older adults: an incidence study. Int Emerg Nurs 40(9):12–17
4. World Health Organization, Assistive devices and technologies. https://www.who.int/disabilities/technology/en/
5. Andò B. et al (2014) An advanced tracking solution fully based on native sensing features of smartphone. In: 2014 IEEE sensors applications symposium (SAS), 2014. Queenstown, pp 141–144
6. Andò B et al (2016) A multisensor data-fusion approach for ADL and fall classification. IEEE Trans Instrum Meas 65(9):1960–1967
7. Andò B et al (2017) A NeuroFuzzy approach for fall detection. In: 2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC), June 27–29, 2017. Madeira Island, Portugal, pp 1312–1316
8. Andò B et al (2018) A RFID approach to help frail users in indoor orientation task. In: 2018 IEEE sensors applications symposium (SAS), 2018. Seoul, pp 1–4
9. Andò B et al A measurement strategy to assess the optimal design of an RFID-based navigation aid. IEEE Trans Instrum Meas
10. https://natiflife-project.eu/
11. https://www.italiamalta.eu/en/pc-interreg-v-a-italia-malta.html
12. Martins M, Santos C, Frizera A, Ceres R (2015) A review of the functionalities of smart walkers. Med Eng Phys 37(10):917–928
13. Hirata Y, Hara A, Kosuge K (2007) Motion control of passive intelligent walker using servo brakes. IEEE Trans Rob 23(5):981–990
14. Fontanelli D, Giannitrapani A, Palopoli L, Prattichizzo D (2015) A passive guidance system for a robotic walking assistant using brakes. In: 2015 54th IEEE conference on decision and control (CDC). IEEE, pp 829–834
15. Andò B, Baglio S, Lombardo CO (2014) RESIMA: an assistive paradigm to support weak people in indoor environments. IEEE Trans Instrum Meas 63(11):2522–2528