Mechatronic Design and Experimentation of a Mecanum Four Wheeled Mobile Robot

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Abstract. Autonomous robots with omnidirectional wheels are useful in the environments where maneuvers can be complicated and risky, in the movement of loads. In this research, the implementation of the Dijkstra's algorithm has been used in order to test the correct functionality of the wheels and significant results are shown by using Matlab.

Keywords: Mecanum four-wheeled mobile robot · Dijkstra's algorithm · Mechatronic design

1 Introduction

The Mecanum wheel has been used on utility vehicles such as forklifts and materials handling vehicles [1]. Mecanum mobile wheeled robots are suitable for applications in congested environments as they allow greater flexibility in mobility [2, 3]. The mobile platform equipped with wheels of type mecanum allows omni-directional movements. The mobile platform offers greater maneuverability in highly congested situations. The mobile platform is equipped with four Mecanum wheels. Each wheel has six symmetric bodies of revolution. Rollers are placed at an angle around its periphery. The angle between the roller axes and the wheel plane is 45°. The control of the movements depends on the slip due to the type of surface, the reduced contact between the floor and the wheels. Previous studies have been developed regarding to kinematics analysis of planar and spatial mechanisms [4, 5] mechatronic design [6] and vibration [7].

A wheeled platform exhibits good performance providing fast and reliable locomotion, with efficient-low energy consumption and a relatively simple motion control as shown in [8–10]. In general terms the motion control of a wheeled vehicle is based on the vehicle kinematics and the type of wheel being used [11–14]. Hence, the platform of the Mecanum four wheeled mobile robot satisfy the requirements of various fields, such as: industrial, military, naval, educational and medical [15]. Autonomous behavior requires that the mobile robot choose the optimum vehicle motion in different situations for object/collision avoidance and task achievement [16].

A suitable test bed of Mecanum four wheeled mobile robot has been design and built at LARM: Laboratory of Robotics and Mechatronics in Cassino with the aim of testing the correct functionality of the wheels. In particular, for the selection of the shortest paths in known environment, the Dijkstra algorithm has been implemented and significant results are shown by using Matlab.

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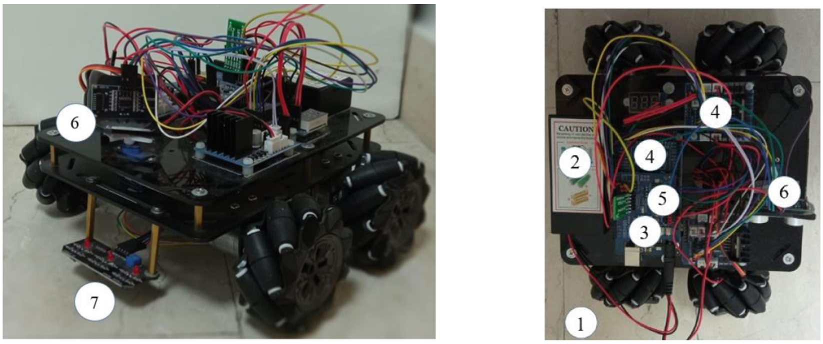
2 Mechatronic Design

Referring to the scheme of Fig. 1, the Mecanum four wheeled mobile robot presents several rollers arranged around a hub at a predefined angle, usually 45°, relative to the plane of rotation of the wheel, [17]. Each wheel is driven by a DC motor and contains 9 symmetrical revolution bodies that are oriented with an angle of 45° concerning the axis of rotation of the wheel, [18]. The rotation axis of the wheel is the imaginary line passing through the center of the wheel. The orientation of the 45° of rollers permits the robot to move in different directions from those simply forward and backward. Another thing to note is that the rubber rollers of the Mecanum four wheeled mobile robot are oriented like an X which allows it to move in any direction. The proposed test bed was built and tested at LARM (Lab. of Robotics and Mechatronics) of the University of Cassino and Southern Lazio, shown in Fig. 1a. The mechatronic design of the proposed test bed consists of power, DC motors, controllers, sensors, and communication devices, Fig. 1b. In particular, an Arduino Mega Electronic Card (3) powered by power supply (2), allows to control the movement of the four wheels (1), by two drivers (4) in order to describe an assigned path. A wi-fi module (5) controlled the robot and an ultrasonic sensor (6) was mounted on the platform to avoid obstacles and a 3-point tracking sensor module (7) to move the robot along the black track line in the white ground. The architecture of motor control for the test bed in Fig. 1b has been reported in Fig. 2 which includes: a Arduino Mega, two motor drivers, a wifi-shield, a Bluetooth module, a tracking sensor and an ultrasonic sensor.



a) b)

Fig. 1. The prototype of Mecanum four wheeled mobile robot: a) 3D view; b) mechatronic design, (1) - Four-Mechanum Wheel; (2) - Power Supply; (3) - Arduino Mega Electronic Card; (4) - Motor Driver; (5) - Wi-Fi Shield; (6) - Ultrasonic Sensor; (7) - 3-point tracking sensor.

3 Experimental Test

The proposed Mecanum four wheeled mobile robot of Fig. 1 has been tested by using Dijkstra algorithm which has been implemented by using Matlab. Figure 3 shows the flow chart of the Dijkstra algorithm which is used to solve optimization problems.

Dijkstra's algorithm is used to search and planning the shortest path to from a starting point to an endpoint avoiding collision with obstacles in the path. This algorithm is used to find the shortest path between nodes with weighted edges. The weight indicates the cost to move from one node to the other. The algorithm is divided into some steps to find the shortest path between any couple of nodes, building a set of nodes that have a minimum distance from the source. By considering a couple of nodes indicated with v and u, and weighted edges that represent the connection between nodes; an edge is denoted as (u,v) and $w(u,v)$ indicated as the weight.

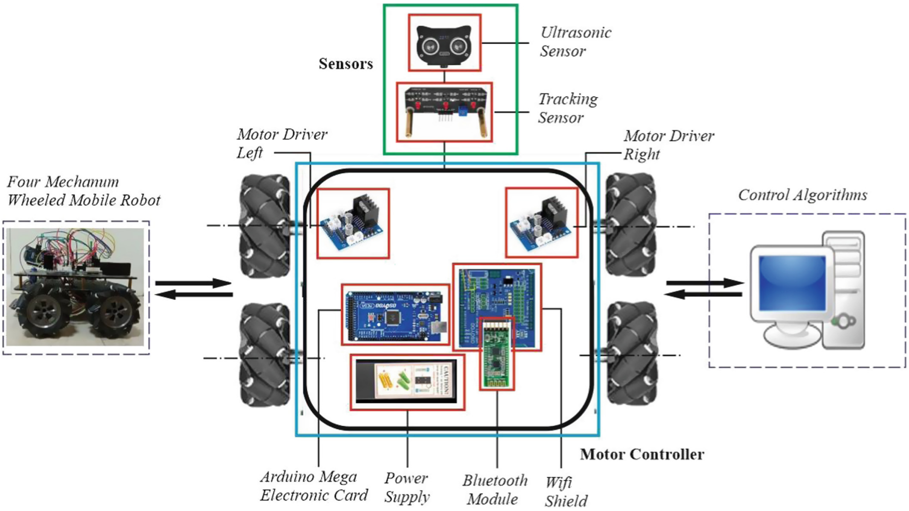


Fig. 2. The architecture of motor control for the test bed in Fig. 1.

Referring to Fig. 3, Q represents a queue of all nodes, and at the end of the algorithm it will be empty; S, is initially an empty set, will contain the marked nodes that have been already visited; at the end of the algorithm it will contain all nodes of the graph; *dist*, is an array of distances that goes from the source node s to the other ones in the graph. At the beginning, $dist(s) = 0$ and all the other ones indicated with v are initialized as $dist(v) = \infty$. This is set at the starting point so that the distance from each node will be recalculated while the algorithm proceeds and ended when the shortest path is found. The algorithm proceeds as follows: 1) while Q is not empty, pop the node v that is not present in S, from Q with the smallest $dist(v)$. At the first run, the node s will be chosen. Subsequently the one with the smallest *dist* will be selected. 2) The node v has to be added to S to marke that it has been visited. 3) Update *dist* value of adjacent nodes of the current node v in a way that for each new node u: if $dist(v) + weight(u,v) < dist(u)$, update $dist(u)$ to the new minimal distance value because a new ones has been found, otherwise $dist(u)$ is not updated. In the end, when the algorithm has visited all nodes, the smallest distance to each node has been found with *dist* containing the shortest path from the source s.

The use of this algorithm for a mobile robot is done by transforming the problem into a grid method through the information of a grid cell map. It considers the nodes reachable by the robot denoting them as free spaces. In addition, the grid method allows data storage and processing by divides the workspace into squares. In this paper, four examples have been reported with the aim of testing the correct functionality of the wheels by applying the Dijkstra's algorithm summarized in Fig. 3.

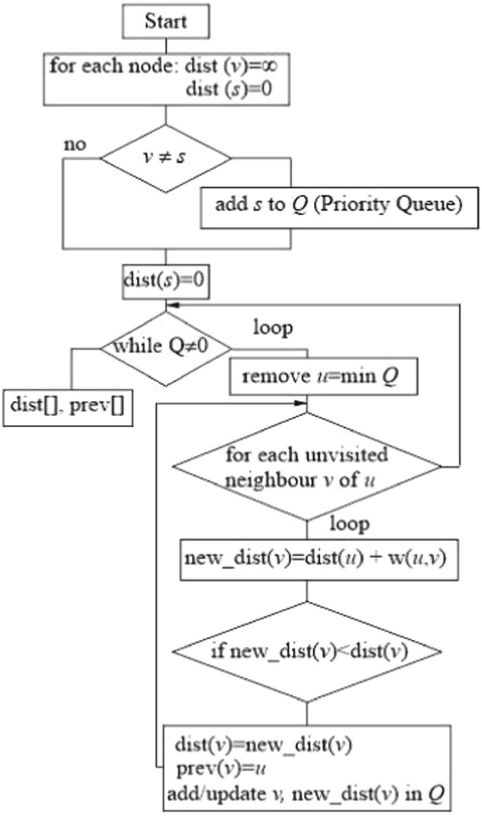


Fig. 3. The flow chart of the Dijkstra algorithm

In particular, as shown in Fig. 4, white grids are spaces where the robot can move freely. Black grids represent constraint areas or obstacles. The value 0 represented the white grid cell. The value 1 represented the black grid unit. The grid model consists of a two-dimensional coordinate system. Each node corresponds to the serial number. In the grid map, the green node represents the Start; the yellow node is the target node; the gray grids are the optimal path; the red grids are the cells visited.

As shown Fig. 4 there were in total $10 \times 10 = 100$ grids. The rear grilles represented obstacles. In particular, referring to Fig. 4a) and b), three obstacles have been fixed. The green grid expressed the initial position. The yellow grid represented the target point.

The robot only moved within white grids, where neither obstacles nor borders could gain access. The robot could move in four directions: up, down, left, and right.

In particular, if any obstacle is detected, the robot will stop, the ultrasonic module will turn from right to left to detect obstacles. The robot will decide to make left turn, right turn or backward according to obstacle sensor data. This algorithm proceeds by exploring the cells around both sides of the obstacle. Finally, the shortest path is shown in grey in the diagram at the bottom right and depends on the cost assigned to each cell.

Referring Fig. 4c) and d) obstacles have been fixed as composed by four grids, the shortest path is shown in grey.

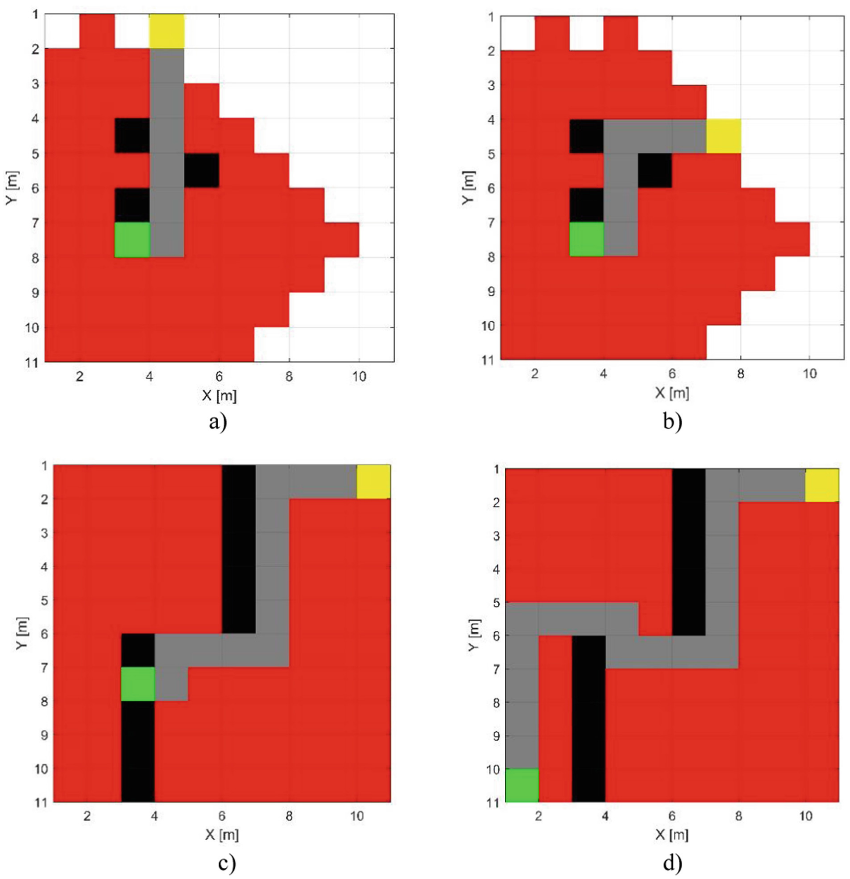


Fig. 4. The final grid map with the shortest path marked: a) simulation n.1; b) simulation n.2; c) simulation n. 3; d) simulation n.4.

4 Conclusions

The prototype of Mecanum four wheeled mobile robot was built and tested at the LARM (Lab. of Robotics and Mechatronics) of the University of Cassino and Southern Lazio.

Mecanum four wheeled mobile robot features wi-fi control via the Arduino Mega microcontroller. The main advantage of this type of wheel is the omni-directional property. The wheel provides extreme maneuverability and mobility in congested environments. The Dijkstra's algorithm has been implemented in order to test the correct functionality of the wheels and significant results are shown by using Matlab.

Future development of this research will include the experimental tests.

References

1. Tzafestas, S.G.: Introduction to Mobile Robot Control. Elsevier (2014)
2. Adăscăliţei, F., Doroftei, I.: Practical applications for mobile robots based on mecanum wheels-a systematic survey. Romanian Rev. Prec. Mech. Opt. Mechatron. **40**, 21–29 (2011)
3. Cavacece, M., Pennestri, E., Sinatra, R.: Experiences in teaching multibody dynamics. Multibody Sys. Dyn. **13**, 363–369 (2005)
4. Figliolini, G., Lanni, C., Kaur, R.: Kinematic synthesis of spherical four-bar link-ages for five-poses rigid body guidance. In: Uhl, T. (eds.) Advances in Mechanism and Machine Science. IFToMM WC 2019. Mechanisms and Machine Science, vol. 73, pp. 639–648. Springer, Cham. (2019). https://doi.org/10.1007/978-3-030-20131-9_64
5. Figliolini, G., Lanni, C., Angeles, J.: Kinematic analysis of the planar motion of vehicles when traveling along tractrix curves. ASME. J. Mech. Robot. **12**(5), 054502 (2020)
6. Figliolini, G., Lanni, C., Rea, P., Gallinelli, T.: Mechatronic design and dontrol of a 3-RPS parallel manipulator. In: Ferraresi, C., Quaglia, G. (eds.) Advances in Service and Industrial Robotics. RAAD 2017 Mechanisms and Machine Science, vol. 49, pp. 74–81. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-61276-8_9
7. Cavacece, M., Figliolini, G., Lanni, C.: Vertical vibrations of the vehicle excited by ride Test. In: Rao, Y.V.D., Amarnath, C., Regalla, S.P., Javed, A., Singh, K.K. (eds.) Advances in Industrial Machines and Mechanisms. LNME, pp. 631–642. Springer, Singapore (2021). https://doi.org/10.1007/978-981-16-1769-0_57
8. de Villiers, M., Tlale, N.S.: Development of a control model for a four-wheel mecanum vehicle. J. Dyn. Syst. Measure. Control **134**, 011007 (2012)
9. Zhang, L., Jongwon, K., Jie, S.: Energy modeling and experimental validation of four-wheel mecanum mobile robots for energy-optimal motion control. Symmetry **11**(11), 1372 (2019)
10. Wang, C., Liu, X., Yang, X., Hu, F., Jiang, A., Yang, C.: Trajectory tracking of an omni-directional wheeled mobile robot using a model predictive control strategy. Appl. Sci. **8**, 231 (2018)
11. Matsinos, E.: Modelling of the motion of a Mecanum-wheeled vehicle. Classical Physics. arXiv:1211.2323 (2012)
12. Gfrerrer, A.: Geometry and kinematics of the Mecanum wheel. Comput. Aided Geom. Des. **25**(9), 784–791 (2008)
13. Taheri, H., Bing, Q., Ghaeminezhad, N.: Kinematic model of a four mecanum wheeled mobile robot. Int. J. Comput. Appl. **113**(3), 6–9 (2015)
14. Yunwang, L., et al.: Kinematic modeling of a combined system of multiple mecanum-wheeled robots with velocity compensation. Sensors **20**(1), 75 (2020)
15. Abdelrahman, M., Zeidis, I., Bondarev, O., Adamov, B., Becker, F., Zimmermann, K.: A description of the dynamics of a four-wheel mecanum mobile system as a basis for a platform concept for special purpose vehicles for disabled persons. In: 58th Ilmenau Scientific Colloquium, pp. 1–10. Technische Universität Ilmenau (2014)
16. Xie, L., Scheifele, C., Xu, W., Stol, K.A.: Heavy-duty omni-directional Mecanum-wheeled robot for autonomous navigation: system development and simulation realization. In: 2015 IEEE International Conference on Mechatronics (ICM), pp. 256–261 (2015)

17. Orozco-Magdaleno, E.C., Cafolla, D., Castillo-Castañeda, E., Carbone, G.: A hybrid legged-wheeled obstacle avoidance strategy for service operations. SN Appl. Sci. **2**(3), 1–13 (2020). https://doi.org/10.1007/s42452-020-2141-5
18. Orozco-Magdaleno, E.C., Gómez-Bravo, F., Castillo-Castañeda, E., Carbone, G.: Evaluation of locomotion performances for a mecanum-wheeled hybrid hexapod robot. IEEE/ASME Trans. Mechatron. **26**(3), 1657–1667 (2021). https://doi.org/10.1109/TMECH.2020.3027259