A precise trajectory tracking scheme for mobile robots working in hospitals

[1]Rushikesh A. Deshmukh, [2]Meghana A. Hasamnis
[1,2] Shri Ramdeobaba College of Engineering and Management, Department of Electronics Engineering, Nagpur, Maharashtra, India
[1]deshmukhra@rknec.edu, [2]hasmnisma@rknec.edu
[1]0000-0003-0676-5648, [2]0000-0002-1492-4955

Abstract

Mobile robots are contributing medical field in various areas like waste handling, medical supply logistics, patient assistance, and telepresence. These applications need a mobile robot to navigate articulately between different locations in indoor environments. An odometry scheme proposed in this paper continuously tracks the distance travelled by the robot and its heading angle, and a go-to-goal controller enables it to manoeuvre to the desired location with minimum error. An in-house developed differential steering wheeled mobile robot (DSWMR) platform is used to assess the performance of the proposed trajectory tracking scheme. It uses a kinematic model to estimate the robot pose based on wheel speeds. The odometer precisely measures the distance travelled by the robot with the heading error of less than one degree. The proposed go-to-goal controller maintains a gracious gait traversing toward the target in all four quadrants with an error of less than one centimetre.

Keywords: Go-to-goal, Mobile robots, Odometry, Trajectory tracking
DOINumber:10.14704/NQ.2022.20.11.NQ66034 **NeuroQuantology 2022; 20(11): 317-323**

Introduction

The use of mobile robots in hospitals and clinics has increased during the COVID-19 pandemic. It helped doctors, technicians and healthcare workers by automating the manual, hazardous and time-consuming tasks such as disinfecting wards, reducing person-to-person contact, handling medical waste, and supplying medicines and other medical supplies. Mobile robots are also finding their application in services such as assisting patients in navigating the hospital, monitoring and helping patients and socializing with them for their emotional well-being. By delegating these responsibilities to mobile robots, doctors and hospital staff can focus more on patients, their treatments and other medical procedures [1]. Navigating effectively in indoor environments is the key feature of the mobile robots required for these applications. Several navigation methods [2-15] attempt to improve trajectory tracking in mobile robots.

Most trajectory controllers in [1, 2, 4, 6, 7, 9, 14] are based on the kinematic model as it is easy to implement. Only [8] reports a trajectory controller considering the robot dynamics. The remaining studies in [3, 10-13] use both kinematic and dynamic models of the system. The reported trajectory tracking schemes show promising results, but except for the controllers presented in [2, 4, 9, 10, 14], the rest are simulation-based. The navigation system in [2] combines 'go-to-goal', 'avoid-obstacle' and 'follow-wall' controllers. The resultant is not robust as the robot sometimes wanders before arriving at the desired location. The experiments carried out in [4, 9, 10, 14] report small position overshoots, errors in angles and deviations in tracking.

This paper presents a precise trajectory tracking scheme which uses target point distance and heading error. Odometry continuously measures the distance travelled by the robot and its heading angle.Turning more sharply for huge heading errors and softly for tiny heading errors, slowing as the robot approaches the target reduces the errors significantly.

This paper is organized as follows. It begins with the description of the mobile robotic platform used in this work in section 2. Section 3 presents the mathematical modelling used for the robot. Section 4 explains the proposed trajectory tracking strategy. Section 5 exhibits the experiments and examines the results to prove the effectiveness of the reported scheme, followed by the conclusions in Section 6.

2 Mobile Robot Platform

An in-house DSWMR called Sinbot (Fig. 1) evaluates the performance of the proposed controller. It is a two-wheeled differential steering mobile robot with quadrature shaft encoders mounted on each drive motor to measure the angular position of the wheels. The ATmega2560, an 8-bit AVR microcontroller, controls the robot's motion. A 3-cell LiPo battery with a rating of 11.1V and 2200mAH powers up the complete platform.

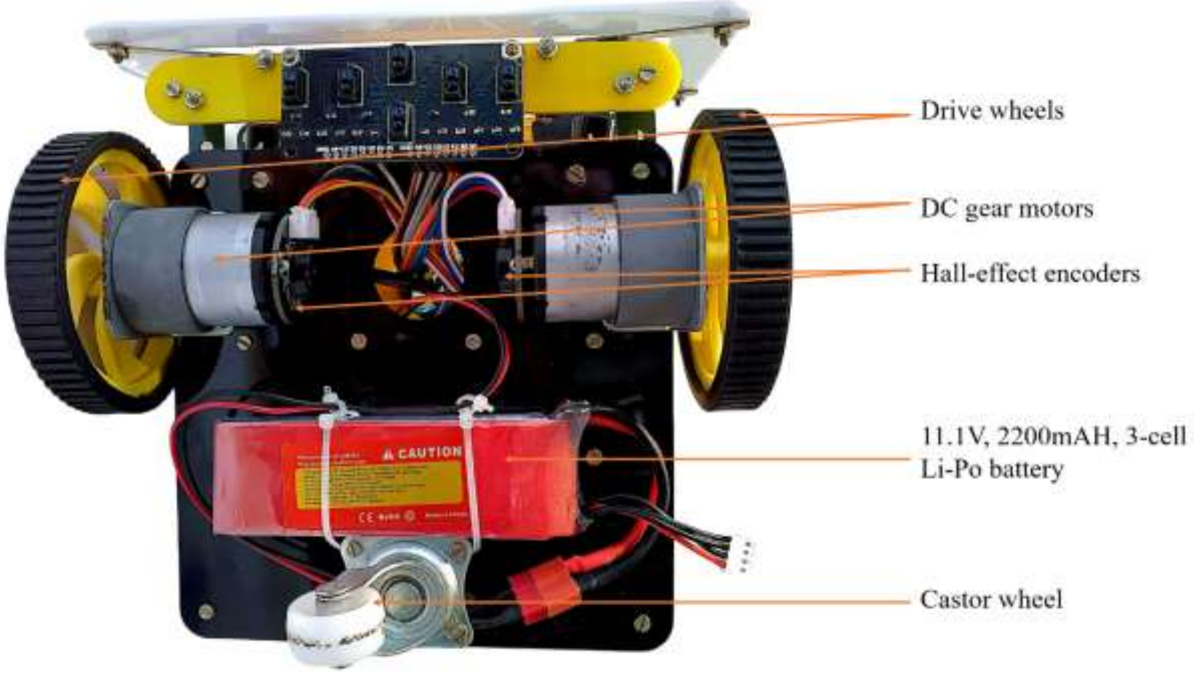


Fig. 1 Bottom view of Sinbot

3 Modeling of mobile robot

The kinematics model for a mobile robot estimates its position $(\dot{x}, \dot{y}, \dot{\theta})$ in the cartesian coordinate system based on the wheel speeds (V_L, V_R). Fig. 4 shows the kinematics of differential steering mobile robot.

Sinbot uses the following equations to determine each wheel's speed to move in the space with the required bearing.

$$V_R = \frac{2V+\omega L}{2R} \quad (1)$$

$$V_L = \frac{2V-\omega L}{2R} \quad (2)$$

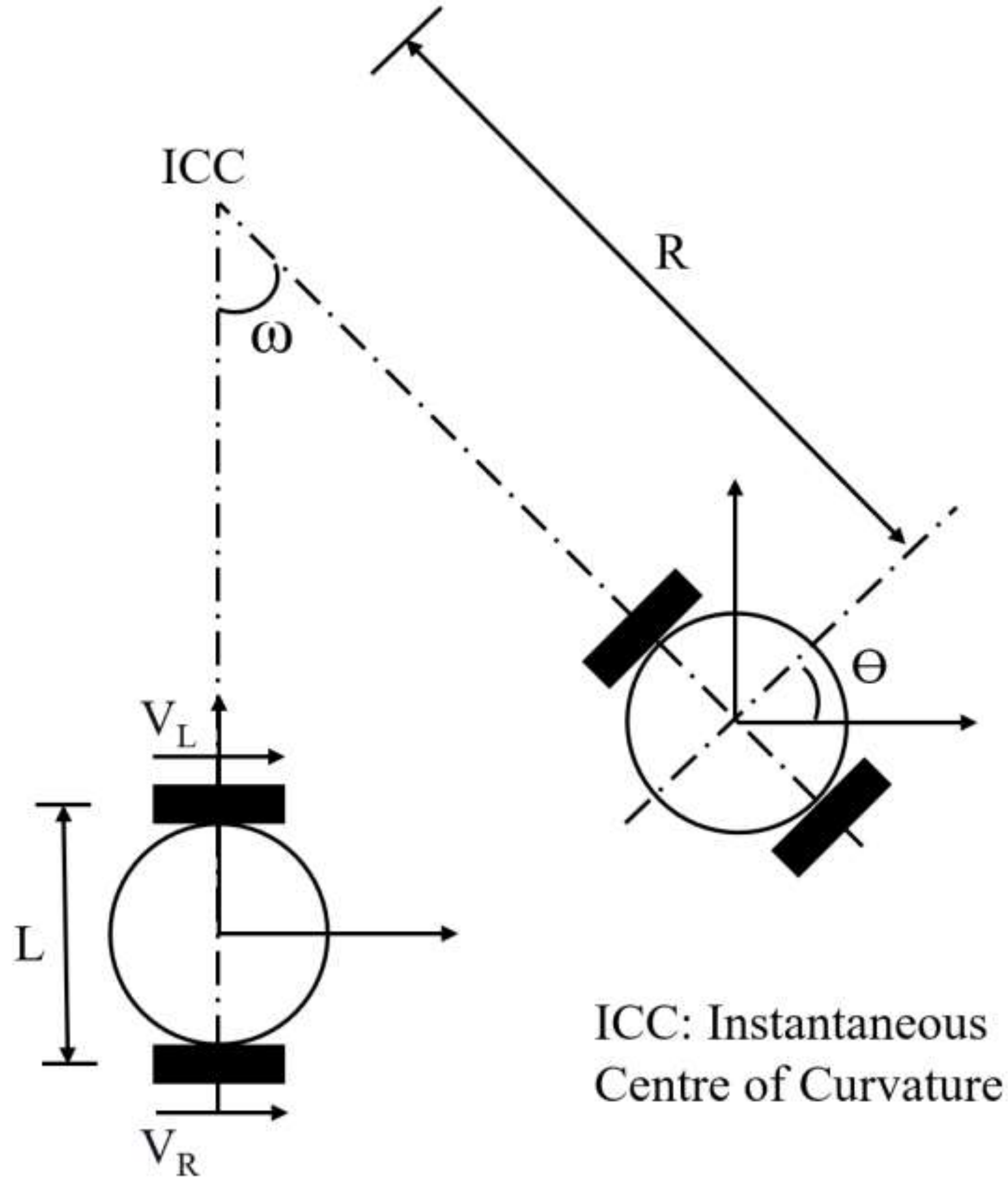


Fig. 2 Kinematics of differential steering mobile robot

4 Trajectory tracking

Odometry is a method by which a vehicle's pose is determined using the knowledge about the vehicle's course and speed over time without any external reference. If the robot's geometry and wheel revolutions are known, then the robot's position can be determined as follows.

Distance travelled by the robot:

$$Distance\ travelled = \frac{Distance\ travelled\ by\ left\ wheel + Distance\ travelled\ by\ right\ wheel}{2} \quad (3)$$

Steering angle for non-zero turning radius:

$$Steering\ angle\ (\theta) = \frac{Distance\ travelled}{Axle\ length} \quad (4)$$

Steering angle for zero turning radius:

$$Steering\ angle\ (\theta) = \frac{Distance\ travelled}{Axle\ length/2} \quad (5)$$

Co-ordinates of the robot:

$$x = Distance\ travelled\ \times \sin(Steering\ angle) \quad (6)$$

$$y = Distance\ travelled\ \times \cos(Steering\ angle) \qquad (7)$$

Sinbot's dimensions and encoder data tabulated in Table 1 are used to identify the distance travelled and heading.

Table 1 Sinbot parameters values

Sr. No.	**Parameter**	**Numerical Value**
1	Wheel diameter	8.5 cm
2	Axle length	18.3 cm
3	Ticks per revolution	136

Odometer maintains the track of the *x* and *y* coordinates and the heading angle *Ө*of the robot in cartesian space. Now for a mobile robot to navigate toward a pre-defined point in space requires two things 1) how far away is the target point, and 2) what is the bearing from the current heading. The robot steers knowing the angle, and it propels knowing the distance from the target. The target distance and required bearing are given by

$$x^{'} = x_{target} - x \qquad (8)$$

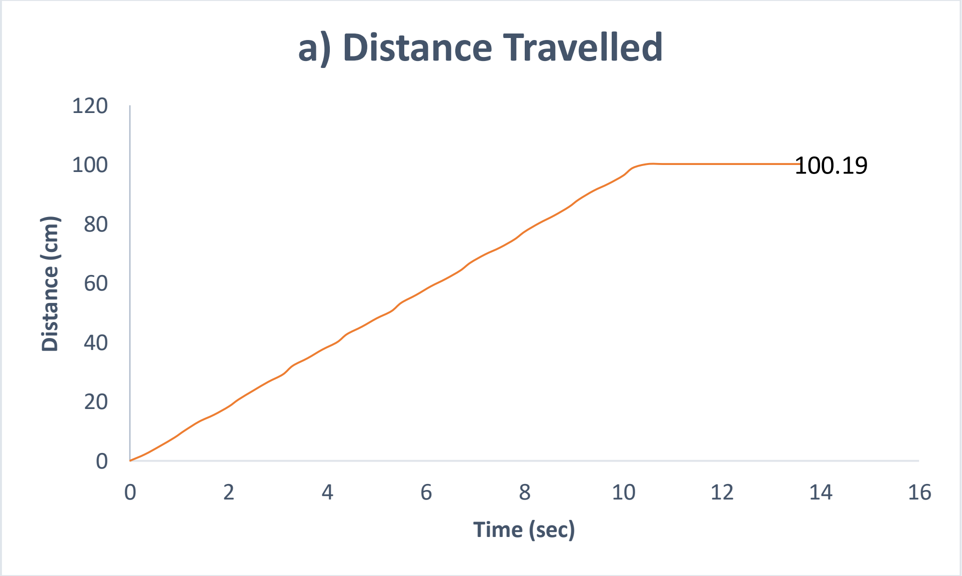
$$y^{'} = y_{target} - y \qquad (9)$$

$$Target\ distance = \sqrt{(x^{'})^2 + (y^{'})^2} \qquad (10)$$

$$Target\ bearing\ = \pm 90\ -\ arctan\left(\frac{y^{'}}{x^{'}}\right) \qquad (11)$$

5 Results and discussions

The odometry experiment sets the robot to follow a straight trajectory for 100 cm. The system provides precise distance measurement (Fig. 2a) with a heading error of less than one degree (Fig. 2b)



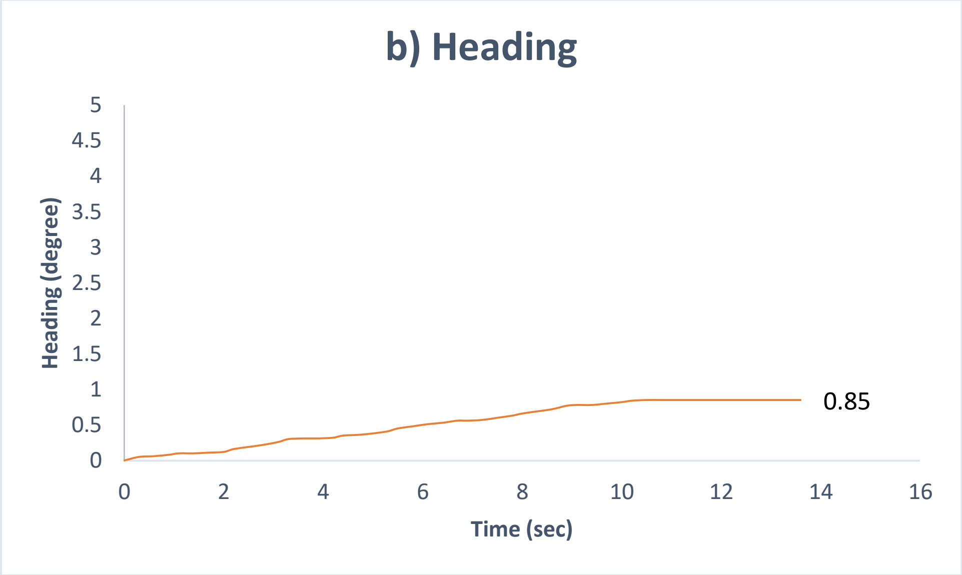


Fig. 3 Odometry results a) distance travelled, b) heading angle

Go-to-goal tests were performed for target locations (50, 50), (-50,50), (-50, -50) and (50, -50) to check the performance of the controller in all the four quadrants of the cartesian coordinate system. The robot traverses a smooth path reaching the target with error in the coordinates less than 1 cm. Fig. 4 shows the sinbot's trajectory approaching the goal.

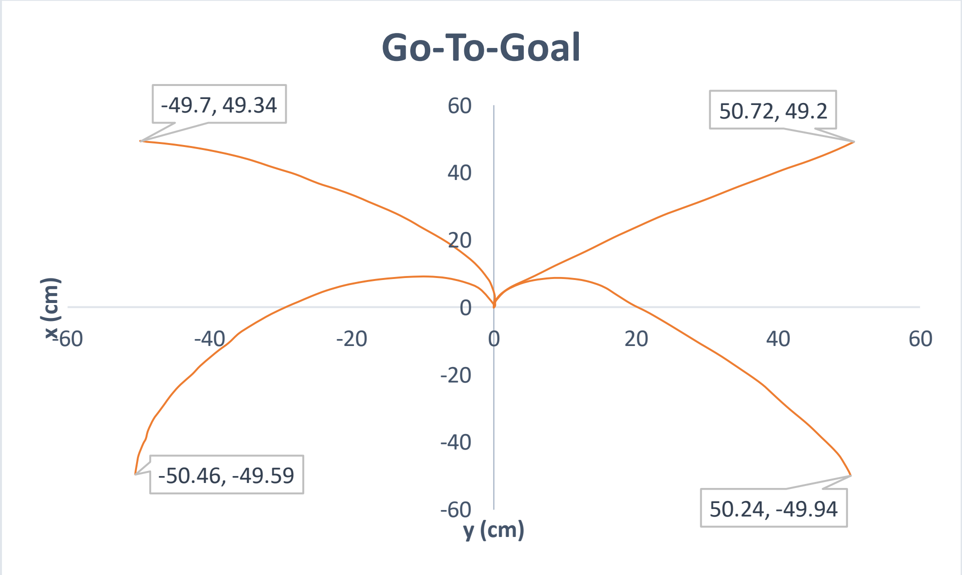


Fig. 4 Go-to-goal controller in cartesian coordinate system

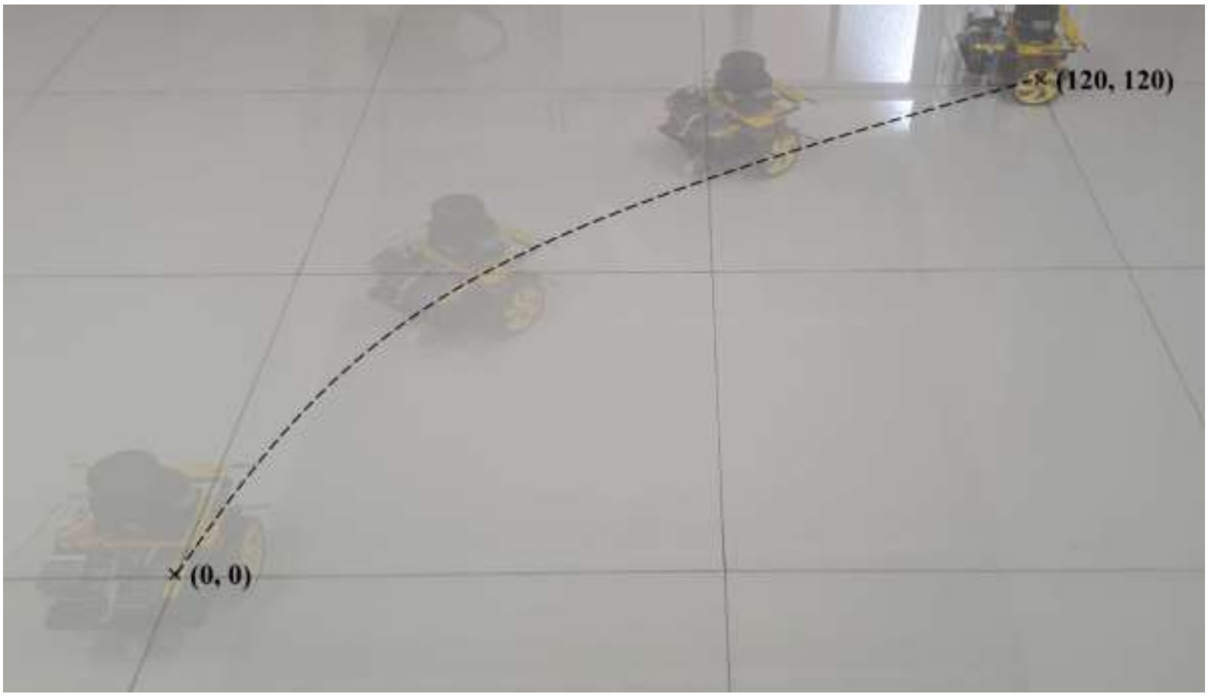


Fig. 5sinbot's trajectory approaching the target

6 Conclusion

A trajectory tracking strategy is developed in this paper to navigate a mobile robot in closed habitat. This work uses a kinematic model. A continuously running odometry logic maintains the distance travelled and pose of the robot, while a go-to-goal scheme manoeuvres the robot to the desired goal. The system performance is evaluated using an in-house developed mobile robotic platform. The odometry provides an accurate distance measurement with a heading error of less than one degree. The go-to-goal controller performs equally well in all the four quadrants of the cartesian system, offering an error of less than 1 cm in the target coordinates. The proposed scheme could be effective for mobile robots navigating indoor environments like hospitals and clinics.

References

1. Robotics in Healthcare: The Future of Robots in Medicine, https://www.intel.com/content/www/us/en/healthcare-it/robotics-in-healthcare.html
2. Stephen Armah, Sun Yi and Taher Abu-Lebdeh, "IMPLEMENTATION OF AUTONOMOUS NAVIGATION ALGORITHMS ON TWO-WHEELED GROUND MOBILE ROBOT", American Journal of Engineering and Applied Sciences 7 (1): 149-164, 2014.
3. Mohamed Khan Aftab Ahmed Khan, Irraivan Elamvazuthi, Suresh Muralidaran and Mathi Amudha, "Implementation of Controller Design and Navigation Algorithm for Sensor-Based Path Planning and Tracking Control Scheme for Non-Holonomic Wheeled Mobile Robot", UNISEL Journal of Sciences, Engineering and Technology 1(1): 24-38, 2014.
4. N.Leenaa, K.K.Saju, "Modelling and trajectory tracking of wheeled mobile robots", International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015).
5. Rigoberto Luis Silva Sousa, Marcus Davi do Nascimento Forte, Fabrício Gonzalez Nogueira, BismarkClaure Torrico, "Trajectory Tracking Control of a Nonholonomic Mobile Robot with Differential Drive",2016 IEEE Biennial Congress of Argentina (ARGENCON), Argentina, 15-17 June 2016.
6. Sparsh Gupta, "Autonomous Path Planning of Differential Drive Robots for Co-Ordinate Based Navigation", Proceedings of 2016 IEEEInternational Conference on Mechatronics and Automation, August 7 - 10, Harbin, China.

7. Cherry Myint, Nu Nu Win, "Position and Velocity control for Two-Wheel Differential Drive Mobile Robot", International Journal of Science, Engineering and Technology Research (IJSETR)Volume 5, Issue 9, September 2016.
8. Diana Diaz, Rafael Kelly, "On Modeling and Position Tracking Control of the Generalized Differential Driven Wheeled Mobile Robot",2016 IEEE International Conference on Automatica (ICA-ACCA), Chile, 19-21 October 2016.
9. Linjie Xin, Qinglin Wang, Jinhua She and Yuan Li, "Robust Adaptive Tracking Control of Wheeled Mobile Robot", Robotics and Autonomous Systems (2016),http://dx.doi.org/10.1016/j.robot. 2016.01.002.
10. Robins Mathewa, Somashekhar S Hiremath, "Trajectory tracking and control of differential drive robot for predefined regular geometrical path", Global Colloquium in Recent Advancement and Effectual Researches in Engineering, Science and Technology (RAEREST 2016).
11. Vinod Raj N, Abraham T Mathew, "Design, Simulation and Implementation of Cascaded Path Tracking Controller for a Differential Drive Mobile Robot", 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI), 10-13 August 2015.
12. Frida-Gail Rojas-Contreras, Alberto-Ismael Castillo-Lopez, Leonid Fridman and Victor-Javier Gonzalez-Villela, "Trajectory tracking using continuous sliding mode algorithms for differential drive robots", 2017 IEEE 56th Annual Conference on Decision and Control (CDC), December 12-15, 2017, Melbourne, Australia.
13. Mahesh Yallala, Mija S.J, "Path tracking of differential drive mobile robot using two step feedback linearization based on backstepping", 2017 International Conference on Innovations in Control, Communication and Information Systems (ICICCI), 12-13 August 2017.
14. Yasmine Koubaa, Mohamed Boukattaya & Tarak Damak, "Adaptive sliding mode control for trajectory tracking of nonholonomic mobile robot with uncertain kinematics and dynamics", Applied Artificial Intelligence, 2018, 32:9-10, 924-938, DOI: 10.1080/08839514.2018.1519100.
15. Ravinder singh, Gurpreet singh, Vijay Kumar, "Control of closed-loop differential drive mobile robot using forward and reverse Kinematics", Proceedings of the Third International Conference on Smart Systems and Inventive Technology (ICSSIT 2020).