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Modelling and trajectory tracking of wheeled mobile robots

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Abstract

Differential drive mobile robots are widely used due to their simplicity, easiness of control and flexibility. This paper discuss a detailed modeling of a differential drive robot taking into account the kinematics, actuator dynamics and rolling resistances of the wheels. Controllers have been designed for smooth trajectory tracking. Different trajectories similar to real life scenarios have been created and the model and control algorithm are seen to give accurate trajectory tracking.

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Keywords: Differential Drive mobile robot; Kinematic controller; actuator dynamics; trajectory tracking

1. Introduction

Autonomous mobile robots are finding widespread application is many areas like mining, space exploration and in service industry. The differential drive mobile robot (DDMR) is one such robot that has gained wide popularity due to its simplicity and ease of control [2]. The differential drive robot consists of two individually propelled wheels and a third wheel called castor wheel that can move freely in space. By adjusting the power applied to motors, the robot can be operated to go forward, rotate in place or perform movement on any arbitrary curve in plane.

Several research work on the modelling and control of such robots [1, 2, 3]. However most of these works handle the two aspects separately. Detailed modeling of the wheeled robot taking into account the actuator dynamics, rolling resistances and coupling constraints has not been attempted in most works when designing control schemes.

This paper discusses a detailed kinematic and dynamic model for the mobile robot which includes the chassis dynamics and actuator dynamics. Trajectory tracking is implemented using two controllers. A kinematic controller has been used for outer loop control to generate the reference velocities whereas a proportional

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controller has been used as inner loop controller to generate angular velocities for the wheels of the robot. Finally, several test trajectories were created and the simulation results are presented are seen to show excellent trajectory tracking.

2. Modeling of differential drive robot

The differential drive robot consists of a platform equipped with a front castor and a pair of rear co-axial drive wheels for isostatic equilibrium. Each of these drive wheels are independently driven by a DC motor which is in turn energized by a control voltage. By varying the power applied to the motors the differential wheeled mobile robot can be made to move in straight line or trace different trajectories like curves, circles etc. Deriving a precise mathematical model is a crucial part for designing any control system. Kinematic and dynamic model of the robot has been discussed below.

2.1. Kinematic modelling

Kinematic modeling deals with the geometric relationships that govern the system and studies the mathematics of motion without considering the affecting forces. For a differential drive which has two wheels with radius r paced at a distance L/2 from robot center. with θ be the robot orientation angle measured from the x-axis. From [1] and [2] the following equations are obtained:

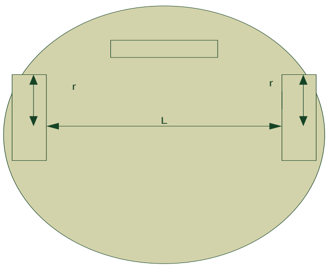

Fig. 1. Differential drive robot.

$$v = r\omega \tag{1}$$

$$w = \frac{d\theta}{dt} \tag{2}$$

The speed of each wheel in the robot frame is $r\omega$, therefore the translational speed in the robot frame is the average velocity

$$v_{mob} = \frac{r(\omega_R + \omega_L)}{2} \tag{3}$$

whereas the rotational velocity is given by $\omega = \dfrac{v_R - v_L}{L}$. (4)

The mapping between the inertia frame and the robot frame is done through the standard orthogonal transformation. Hence the robot velocity in the inertial or global frame is given by