IE415 : Control of Autonomous Systems

Project Report

Title : Simulation and Control of a Mobile Robot Using the Kinematic Model

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1. Introduction

Autonomous mobile robots play a crucial role in various fields, including logistics, exploration, and surveillance. The ability to simulate and control such systems effectively is fundamental for understanding their behavior and ensuring reliable operation. This project focuses on the simulation of a differential-drive mobile robot's kinematic model. The robot's trajectory is derived using predefined control inputs for linear and angular velocities.

Additionally, insights from the research paper "Selective Tracking Using Linear Trackability Analysis and Inversion-based Tracking Control" have been applied, particularly in understanding the role of input-output relationships in trajectory tracking and control design.

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2. System Model

The kinematic model of a differential-drive mobile robot governs the robot's motion under non-holonomic constraints. The robot's state variables (x, y, and θ) evolve over time as:

$\dot{x} = v\cos(\theta)$

$\dot{y} = v\sin(\theta)$

$\dot{\theta} = w$

Where:

- v: Linear velocity (m/s)
- ω: Angular velocity (rad/s)
- x,y : Position of the robot in the 2D plane (meters)
- Θ : Orientation of the robot (radians)

Assumptions:

- The robot operates in a flat, obstacle-free environment.
- No slippage occurs between the wheels and the ground.

These equations form the basis for simulating the trajectory of the robot.

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3. Control strategies

For this project open loop control was implemented by giving control inputs (v and w) as functions of time. The control strategies aims to demonstrate how robot responds to predefined velocities

Linear Velocity (v(t)): Kept constant at 0.5 m/s to ensure forward motion.

Angular Velocity (ω(t)): Varied sinusoidally ($\omega(t)=0.1\sin(0.5t)$) to induce smooth turning.

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4. Simulation Details

Software Used: MATLAB and Simulink

Simulation Time: $T=10$ s, with a time step of $\Delta t=0.1$ s.

Initial Conditions: $x=0, y=0, \theta=0$ (robot starts at the origin facing along the positive x-axis).

Numerical Integration: Euler’s method was used to compute the state variables iteratively.

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5. Results and Conclusions

The simulation results are summarized as follows:

- Trajectory:
  The robot followed a smooth, sinusoidal path in the x-y plane. The wavy nature of the trajectory reflects the sinusoidal angular velocity, causing periodic left-right turns.
- Plots:
  1. Trajectory Plot (x-y plane): Displays the robot's movement over time.
  2. State Variables vs. Time: Shows the evolution of x, y, and θ with respect to time.

Key Observations:

- The robot consistently moves forward due to the constant linear velocity.
- The trajectory shape aligns with the prescribed angular velocity profile.

Conclusion : This project successfully demonstrates the simulation of a mobile robot's kinematic model. The results validate the robot’s trajectory in response to predefined control inputs. Insights from the referenced research paper provide a foundation for future enhancements, such as incorporating feedback control or more advanced tracking methods.

6. References

1. *Selective Tracking Using Linear Trackability Analysis and Inversion-based Tracking Control*. [Reference details from the shared paper]
2. MATLAB Documentation: [Include relevant links]
3. Robotics: Modelling, Planning, and Control by Siciliano, Khatib, and others (for kinematic modeling basics).