Motion Control of an Underactuated Wheeled Mobile Robot: 
A Kinematic Input-Output Linearization Approach

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23rd International Congress of Mechanical Engineering
December, 6-11 2015 - Rio de Janeiro, RJ, Brazil.

1. INTRODUCTION

Basic problems:
• Path following and Trajectory tracking

This work addresses a Trajectory tracking controller for the kinematics of an underactuated wheeled mobile robot, in environments without obstacles, using input-output linearization and the Follow the Carrot algorithm. The use of input-output linearization allows the reduction of error dynamics into a linear order system. Different types of trajectories are devised in order to analyse the feasibility of the method. A specific trajectory consisting of a mix of smooth and sharp curvature sections is utilized in order to investigate the sensitivity of the control system in relation to gain variations. Some novelty is claimed by authors in relation to the use of kinematic input-output linearization combined to the Follow the Carrot algorithm.

Keywords: wheeled mobile robots, trajectory tracking, motion control, nonlinear control system, input-output linearization.

2. THE KINEMATIC MODEL

3. THE CONTROL SYSTEM

Follow the Carrot

Feedback Linearization

4. EXPERIMENTAL RESULTS

Some reference trajectories with the controller tuned as $K = \left[ \begin{array}{cc} 0 & 0 \\ 0 & 0 \end{array} \right]$. $K_1$ sensitivity analysis ($K_1 = -0.1$):
- The $v_1$ and $v_2$ dynamics are decoupled;
- The $v_2$ increases with the decreasing of $v_1$;
- The $v_2$ oscillates in the sharp sections;
- Increasing the module of $K_1$, the $v_2$ decreases;
- For high $K_1$, bounded chattering is observed.

$K_2$ sensitivity analysis ($K_2 = -1.0$):
- The $v_1$ increasing drives transient of $v_2$ faster;
- While the linear error gain $K_1$ increases the heading angle error $v_2$ increases and becomes oscillatory;
- Bounded high frequency chattering in heading angle error $v_2$ signals, specially for $K_1 = -0.5$ and $-1.0$.

5. CONCLUSIONS

• The main rationale is related to the use of the Feedback Linearization and the Follow the Carrot;
• The control system performance is defined by a 2-dimensional error vector $e = [e_1, e_2]^T$;
• The control system design is a choice of two parameters: $K_1$ and $K_2$;
• The trajectories are tracked very satisfactorily;
- It seems that the $v_1$ is decoupled from the $v_2$ but the opposite is not true.

REFERENCES:

Abiad, O. and Corana, G., 2013. “Control of pattern tracking nonholonomic mobile ro-
bot with feedback linearization”. IEEE International Conference on Electrical and Electronics
Engineering, No. 3, pp. 513-515.

Aston, M. 2003. Controller development and implementation for path planning and fol-
nowing in an autonomous urban vehicle. Thesis, University of Sydney.

a Backstepping-Like Feedback Linearization”. IEEE Transactions on Systems, Man, and

nonholonomic wheeled mobile robot”. In IEEE International Conference on Robotics and
Automation, pp. 2527-2532.


linearization: design, implementation, and experimental validation”. IEEE Transactions on


Bulch, P., Gani, S. and Stow, J. 2013. “Path evaluation of UAV path following algo-
rithms”. In International Conference on Control, Automation, Robotics and Vision, pp. 1-6.

motion prediction for unmanned surface vehicle operating in cluttered environment”. Autono-
mous Robots, Vol. 36, No. 4, pp. 343-416.

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BIBLIOGRAPHY

ABSTRACT

This work addresses a trajectory tracking controller for the kinematics of an underactuated wheeled mobile robot, in environments without obstacles, using input-output linearization and the Follow the Carrot algorithm. The use of input-output linearization allows the reduction of error dynamics into a linear order system. Different types of trajectories are devised in order to analyse the feasibility of the method. A specific trajectory consisting of a mix of smooth and sharp curvature sections is utilized in order to investigate the sensitivity of the control system in relation to gain variations. Some novelty is claimed by authors in relation to the use of kinematic input-output linearization combined to the Follow the Carrot algorithm.

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