

# Collision-free coordination of a group of unicycle mobile robots

**Citation for published version (APA):**

Kostic, D., Adinandra, S., Caarls, J., & Nijmeijer, H. (2009). Collision-free coordination of a group of unicycle mobile robots. In *Proceedings of the 28th Benelux Meeting on Systems and Control (BMSC 2009), 16-18 March 2009, Spa, Belgium* (pp. 119-)

**Document status and date:**

Published: 01/01/2009

**Document Version:**

Accepted manuscript including changes made at the peer-review stage

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

# Collision-free coordination of a group of unicycle mobile robots

Dragan Kostić,<sup>1</sup> Sisdamanto Adinandra,<sup>2</sup> Jurjen Caarls,<sup>3</sup> and Henk Nijmeijer<sup>4</sup>

Department of Mechanical Engineering

Technische Universiteit Eindhoven

P.O. Box 513, 5600 MB Eindhoven

The Netherlands

Email: {<sup>1</sup>D.Kostic, <sup>2</sup>S.Adinandra, <sup>3</sup>J.Caarls, <sup>4</sup>H.Nijmeijer}@tue.nl

## Abstract

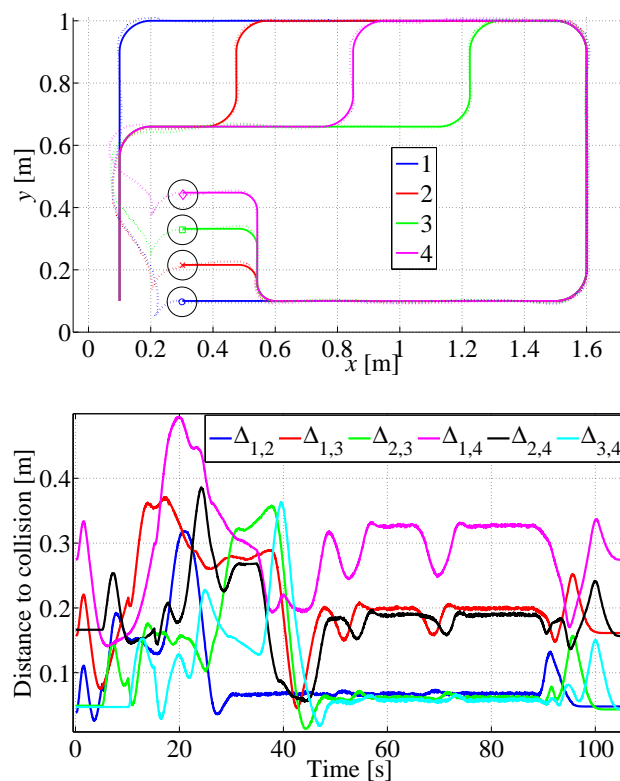
We propose a method for collision-free coordination of a group of unicycle mobile robots, which can be used for transportation tasks in large warehouses. A supervisory system assigns to each robot its reference path, together with the preferable velocity profile as a function of position along the path. The reference paths and velocity profiles do not necessarily prevent collisions among the robots. Feedback controllers of individual robots coordinate the robot motions along the assigned paths to ensure collision-free movements.

To design a collision-free tracking control scheme, we make use of a standard kinematic model of unicycle robots in Cartesian space [1]. From this model we derive equations of tracking error dynamics. Unlike the error equations that are often used in the literature, e.g. [1], we present equations such as to reveal some intrinsic properties of the error dynamics. By making use of these properties, we simplify derivation of tracking motion controllers using Lyapunov's direct method. While explicitly accounting for constraints on input signals, these controllers ensure global asymptotic convergence of the tracking errors to zero values. Although derivation of the control law mimics approach proposed in [2], in our work we modify Lyapunov function in order to improve performance of the resulting motion controllers.

To accommodate specific layouts of robot trajectories in the warehouses, we prove that our controller guarantees global asymptotic convergence of the tracking errors even if the reference angular robot speeds are discontinuous. This is relaxation with respect to [2], where the uniform continuity of the angular speeds was required.

We suggest an effective feedback method for collision-free robot coordination. This method employs penalty functions to reduce reference speeds of robots of lower priority. Feedback variables are the arguments of the penalty functions. To avoid deadlocks in the transportation, all mobile robots must have non-equal priorities during execution of their tasks. Quality of the collision-free robot coordination has been verified both in simulations and in experiments. At the top in Fig.1 we present a layout of robot paths that we used in the experiments. Apparently, starting robot positions were away of the reference paths. Despite the initial errors, all the

robots converge to their references and proceed along without collisions. Nonzero values of experimentally recorded distances to collision, shown at the bottom in Fig. 1, confirm collision avoidance.



**Figure 1:** Top: reference (solid) and actual (dotted) paths; bottom: evolution of measured distances to collision.

## References

- [1] Y. Kanayama, *et al.*, "A Stable Tracking Control Method for an Autonomous Mobile Robot," *Proc. IEEE Int. Conf. Robotics and Automation*, pp. 384-389, 1990.
- [2] Z.-P. Jiang, E. Lefeber, H. Nijmeijer, "Saturated Stabilization and Tracking of a Nonholonomic Mobile Robot," *Systems & Control Letters*, Vol. 42, pp. 327-332, 2001.