Improving Human-led Multi-robot Platoon Using Decentralized DSR

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Contribution

This work presents a new delayed-self-reinforcement (DSR) control approach for human-led multi-robot platooning through an area with obstacles.

Introduction

Recent works have shown that with the use of DSR-based approaches, the velocity cohesion and robustness of vehicle platooning can be improved [1] [2]. However, it only applies to the 1-dimensional longitudinal control. This work further extends the applications of the DSR-based approach in the 2-dimensional space on a mobile robot network, by combining the DSR approach with the trajectory planning based on Bézier Curve. With the 2-dimensional estimated trajectory of the predecessor projected to the 1-dimensional curve, the DSR approach greatly reduces the tracking error on the 1-dimensional space of the target trajectory. The proposed method only uses the local sensing information of the current and historical steps. Comparative simulation results show that both the longitudinal and lateral tracking errors are reduced by 99% and 85% with the use of DSR approach during transitions, compared to the case using standard dynamical feedback linearization but without the use of DSR.

System Description

The system consists of four mobile robots where only the leader is controlled by a human driver, as illustrated by Fig.1. The goal of the human driver is to control the robot network passing the area with obstacles safely and efficiently, while the goal of the followers is to maintain a constant spacing $s_0 = 0.5$ m to their predecessors on the target trajectory determined by the human leader. The target settling time of the followers is $T_s = 6$ s. The followers only utilize the relative position and orientation to their predecessors for control.

Trajectory Tracking and Spacing Error

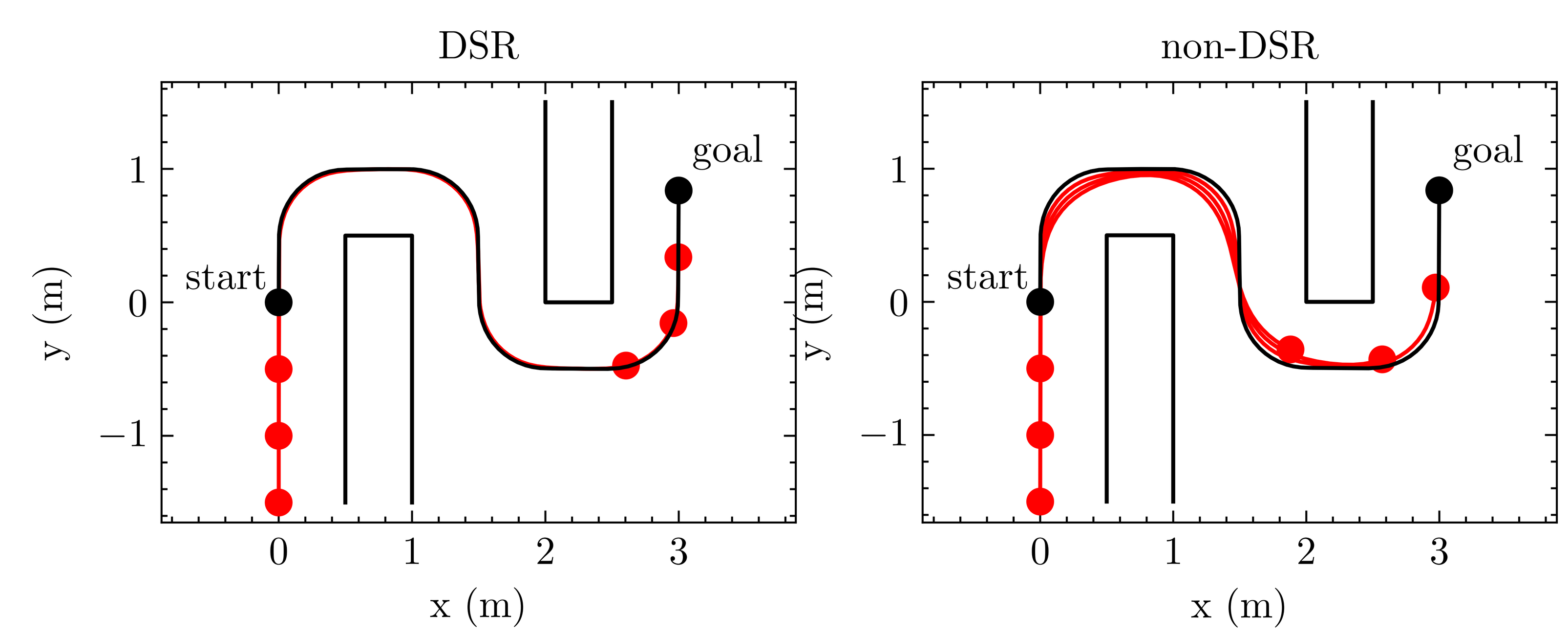

Figure: Using DSR results in less deviations to the target trajectory. With the use of DSR (left), the followers (red dots) stay on the leader trajectory (black dots) with maximum deviation d = 0.02 m, compared to the maximum deviation d = 0.13 m with non-DSR followers (right).

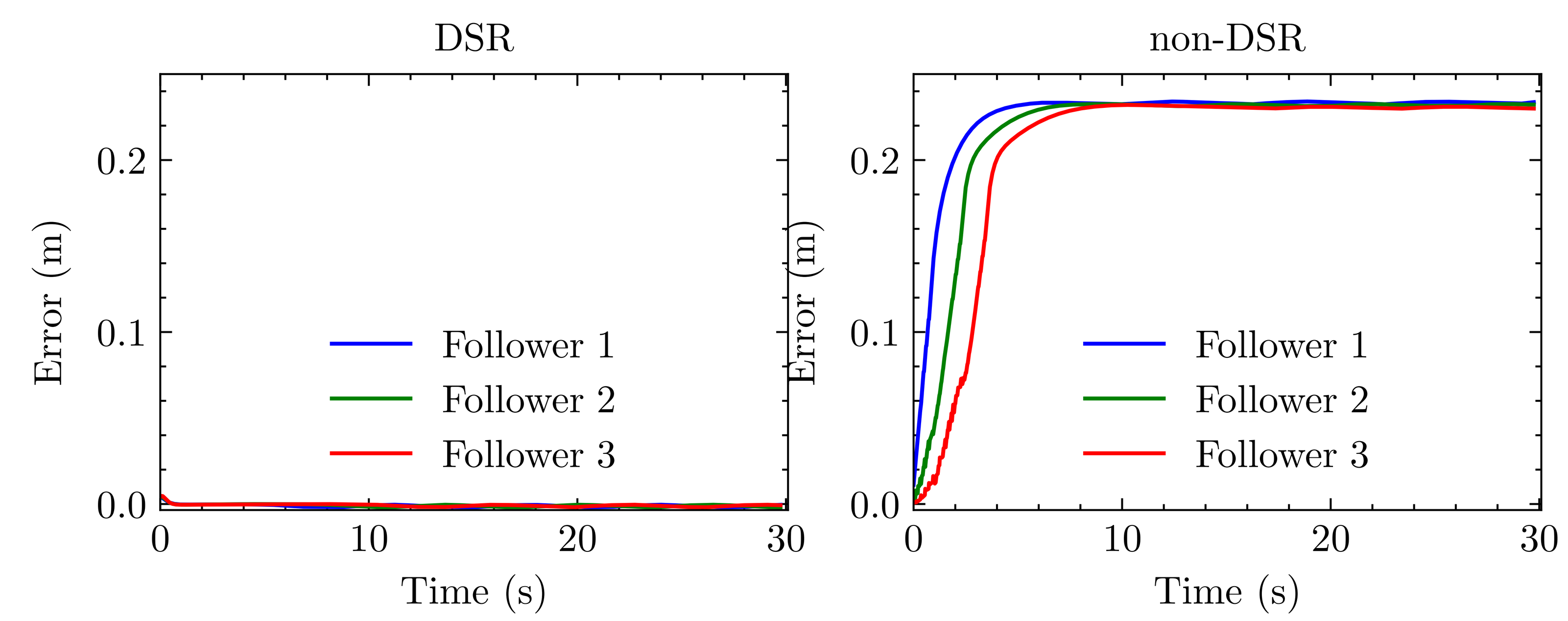

Figure: Using DSR reduces the relative spacing error along the trajectory. Left: with the DSR followers, the maximum relative spacing error of the network is 0.002 m. Right: with non-DSR followers and trajectory projection, the maximum relative spacing error of the network is 0.215 m.

Experimental Setup

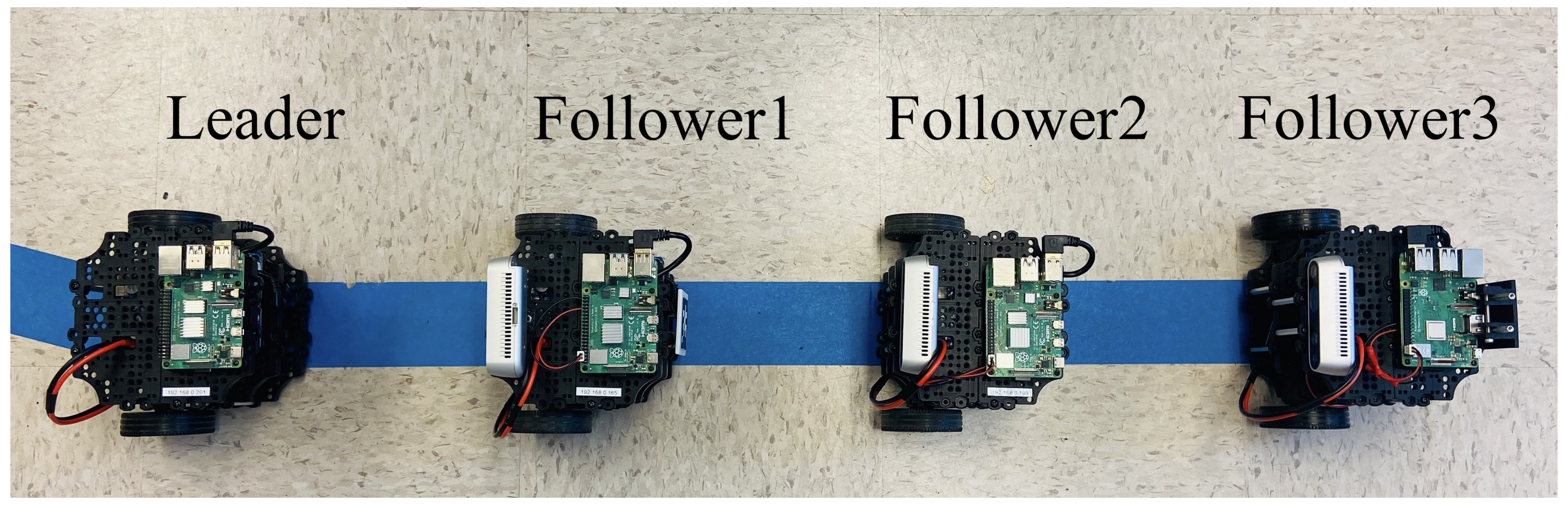

Figure: The leader Turtlebot3 is guided by a human operator, while three follower Turtlebot3 robots track their predecessor's trajectory and maintain a consistent spacing utilizing local camera information.

Conclusion

- **DSR reduces the deviation to the target trajectory.** With DSR and trajectory projection techniques, the maximum deviation of the network is 0.02 m, compared with 0.13 m for the case without DSR, as illustrated in Fig. 1. Therefore, using DSR reduces the lateral trajectory tracking error by 85%.
- **DSR reduces the relative spacing error during the transition.** With DSR and trajectory projection techniques, the maximum spacing error of the network along the trajectory is 0.002 m, compared with 0.215 m for the case without DSR, as illustrated in Fig. 3. Therefore, using DSR reduces the relative spacing error by 99%.

References

[1] Yudong Lin, Anuj Tiwari, Brian Fabien, and Santosh Devasia.
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[2] Yudong Lin, Anuj Tiwari, Brian Fabien, and Santosh Devasia.
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