

최소 자승법을 사용한 모바일 로봇의 선도로봇-추종로봇 군집 제어

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Leader-follower Formation Control of Mobile Robots using Least Square Method

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Abstract - The paper deals with leader-follower formations of nonholonomic mobile robots using least square method in order to maintain the formation constantly. The nonholonomic property of the mobile robot cause us to use the least square method. Then, the performance of the developed formation controller is verified by simulation results.

1. Introduction

In the last decade formation control became one of the leading research areas in mobile robotics[2]. By formation control we simply mean the problem of controlling the relative position and orientation of the robots in a group while allowing the group to move as a whole.

Formation control has wild applications such as security patrols, search and rescue in hazardous environments. Furthermore, varied robot formation typologies have been studied: ground vehicles, unmanned aerial vehicles, aircraft, surface and underwater autonomous vehicles. Three main approaches have been proposed: behavior based, virtual structure and leader-follower[2].

The most popular and intuitive approach is the leader-follower approach. In this approach, there are at least one leader and a follower robot stays at a specified distance and angle from a desired leader robot.

In this paper, we propose control method that easily apply to practical world. Then, to demonstrate the performance of the proposed formation controller we simulate for two scenarios.

2. Leader-follower Model for Mobile Robot

The configuration of the leader and the follower robot denoted by (x_L, y_L, Θ_L) and (x_F, y_F, Θ_F) is 3-D in the Earth fixed inertial coordinate system X-Y, where Θ is robot's heading angle measured from the x-axis. And ρ and ϕ are the leader's relative distance and angle with respect to the follower. Given the desired position and orientation denoted by ρ^d , ϕ^d are the leader's relative distance and angle measured from the follower. Generally the desired relative ρ^d and ϕ^d are given by the reference point as leader robot's position.

For the common local formation, however, the follower robot measures the leader robot's position. In this paper, we regard the position of the follower robot as the reference point of the desired relative distance. Furthermore, we consider the heading direction of the follower robot to be the baseline of the desired relative angle.

To achieve the desired formation, we need to control $\rho \rightarrow \rho^d$ and $\phi \rightarrow \phi^d$.

We define error state variable:

$$\begin{aligned} e_x &= \rho_x - \rho_x^d \\ e_y &= \rho_y - \rho_y^d \\ e_\theta &= \theta_F - \theta_L \end{aligned} \quad (1)$$

where (ρ_x^d, ρ_y^d) and (ρ_x, ρ_y) are the desired relative position and the real relative distance between the leader and follower along X, Y directions respectively and θ_F and θ_L is the follower and leader robot heading angles.

For the common formation, the desired relative distance ρ^d

and the relative angle ϕ^d usually needs to be a constant. Suppose ρ^d and ϕ^d be a constant value, then $\rho^d=0$ and $\phi^d=0$.

3. Main Result

3.1 Controller Design

By leader following approach, the angular and linear velocity of the leader are given, we will only need to control the follower' relative distance and angle between leader and follower to make the desired formation satisfied.

we use the least square method because the mobile robot has a nonholonomic property. we propose control inputs for follower robot to achieve the desired formation position and orientation with respect to leader robot.

4. Simulations and Results

To verify the presented controller in this paper, we simulate on team of 3 robots as shown in Figs. 1, 2, 3 and 4.

Simulations are carried out in MATLAB under tow scenarios. First, the leader robot moves only straight line. The leader linear velocity is 2 m/s and angular velocity is 0 m/s while the reference linear velocity is allowed to vary. The following initial positions are considered for the leader and follower robots:

<Table 1> initial position for the straight trajectory

	leader robot	follower robot 1	follower robot 2
x_0	0	7	-2
y_0	0	-5	5
Θ_0	$\pi/6$	$\pi/2$	0

Then, the leader robot makes a circle with two of the follower robots. The leader linear velocity is 1 m/s and angular velocity is 0.05 m/s. Table 2 shows the initial positions of the leader and follower robots.

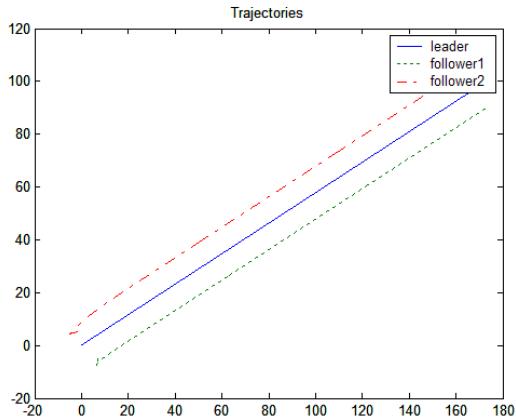
<Table 2> initial positions for the circle trajectory

	leader robot	follower robot 1	follower robot 2
x_0	0	-5	-2
y_0	0	-7	5
Θ_0	0	0	0

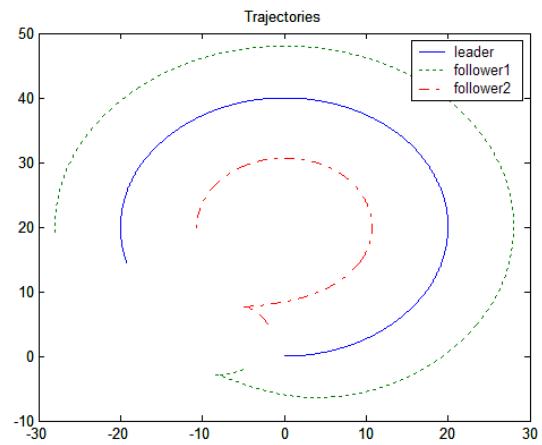
Under both scenarios, the desired position and angle between the leader robot and follower robot are 10 meter and $\pm\pi/3$. The following gains are utilized for the controllers: $K=[0.5 \ 0.5 \ 0.1]^T$.

Fig. 1 shows the resulting trajectories of the robot team composed by the leader robot and the follower robots. In straight scenario, the robots start in the bottom left corner of Fig. 1 and travel toward the top right corner of the figure. Fig. 2 displays the bearing and separation errors for the straight scenario.

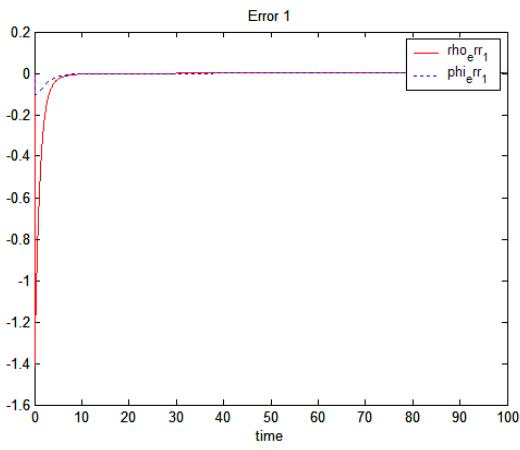
In Fig. 3, robots depict for the circle scenario while they maintain the desired formation. Furthermore, Fig. 4 illustrates the distance and angle errors of the first follower robot .



<Fig. 1> Trajectories for the straight line



<Fig. 3> Trajectories for the circle



<Fig. 2> Errors for the straight line

5. Conclusion

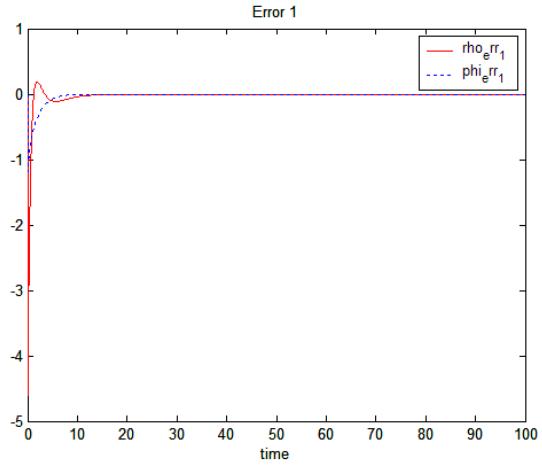
In this paper we have studied strategies for controlling formations of robots using leader-follower approach. The results presented in this paper apply to general formation controller. Numerical results were shown and the stability of the system was verified. Simulation results verify the theoretical conjecture.

6. Acknowledgement

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[Reference]

- [1] Z. Sun , M. J. Zhang , X. H. Liao , W. C. Cai and Y. D. Song, "Neuro-adaptive formation control of multi-mobile vehicles: virtual leader based path planning and tracking", Lecture Notes in Computer Science, vol. 4491, pp. 786-795, 2007.
- [2] L. Consolini, F. Morbidi, D. Prattichizzo, M. Tosques, "Leader-follower formation control of nonholonomic mobile robots with input constraints", Automatica, vol. 44, no. 5 , pp. 1343-1349, 2008.
- [3] T. Dierks and S. Jgannathan, "Control of nonholonomic mobile robot formations: backstepping kinematics into dynamics", Control Applications, 2007. CCA 2007. IEEE International Conference on, pp. 94-99, Oct. 2007.
- [4] R. Fierrro, and F. L. Lewis, "Control of a nonholonomic mobile robot: Backstepping kinematics into dynamics", Journal of Robotic System, vol. 14, no. 3, pp. 149-163, 1997.
- [5] Y. Q. Chen and Z Wang, "Formation control: A review and a new consideration", Intelligent Robots and Systems, 2005. (IROS 2005). 2005 IEEE/RSJ International Conference, pp. 3181- 3186, Aug. 2005.



<Fig. 4> Errors for the circle

[6] J. P. Desai, J. Ostrowski, and V. Kumar, "Controlling formations of multiple mobile robots", Proceedings of the IEEE International Conference on Robotics and Automation, vol. 4, pp. 2864-2869, May 1998.

[7] Z. Cao, L. Xie, B. Zhang, S. Wang, M. Tan, "Formation constrained multi-robot system in unknown environments", Proceedings of the IEEE International Conference on Robotics and Automation, vol.1, pp. 735-740, Sep.2003.