Fast and Efficient Formation Flocking for a Group of Autonomous Mobile Robots

Naixue Xiong, Yingshu Li, etc.

Depa. of Computer Science

Georgia State University, Atlanta, USA.

Formation Flocking

- Control and coordination of mobile robots in groups is a widely studied topic in distributed robotic application.
- Flocking: multiple robots move together to finish some kind of tasks coordinately
- Formation flocking: robots attain a desired formation and keep the formation stable while flocking…

GeorgiaStateUniversity

Applications of formation flocking

- Move some object from one place to another in the situations that human can not survive...
- Maintain formations for defense or herding
- ....

GeorgiaStateUniversity

Outline

- Problems and motivation
- System model
- Our scheme
- Simulation
- Conclusions

Problems and motivation

- Coordination motion of multiple robots in a plane to accomplish such tasks remains a challenging problem, especially in distributed way.

- Even many papers have addressed the flocking problem, few studies focus on efficiency (how fast and accuracy to keep formation during flocking) of flocking.

System model

- Robot: *asynchronous*, *anonymous*, *memory-less*, with *simple computational capability*, can *freely move* on the two-dimensional plane

- Two kinds of robots: *leader* robot and *follower* robot

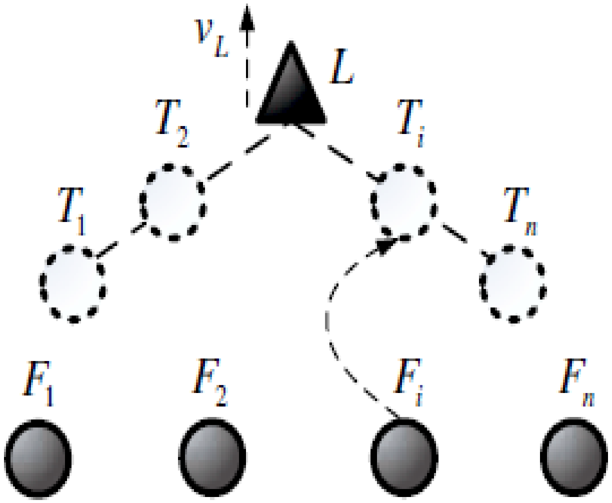


Figure 1. A basic robot model for directed targets[4].

System model (cont...)

- Leader robot can communicate with the followers
- Robots has local view of the world.
- Robots don't agree on the local coordinate systems.

Our flocking scheme

- Main idea: use the relative motion theory of motion of objects to solve the cooperative flocking of the mobile robots.
- In short, the follower can get its relative velocity to the leader by the equation:

$$v = \delta S / \delta t$$

where δS is the difference of the distance between the follower and the leader during the period δt.

Parameters used in algorithm

Parameter	Description
v_L	The velocity of the leader L
F	A follower robot
v_F	The velocity of the follower F
T	The target position of the follower robot F
v_{max}	The maximum available velocity for each follower

Our algorithm

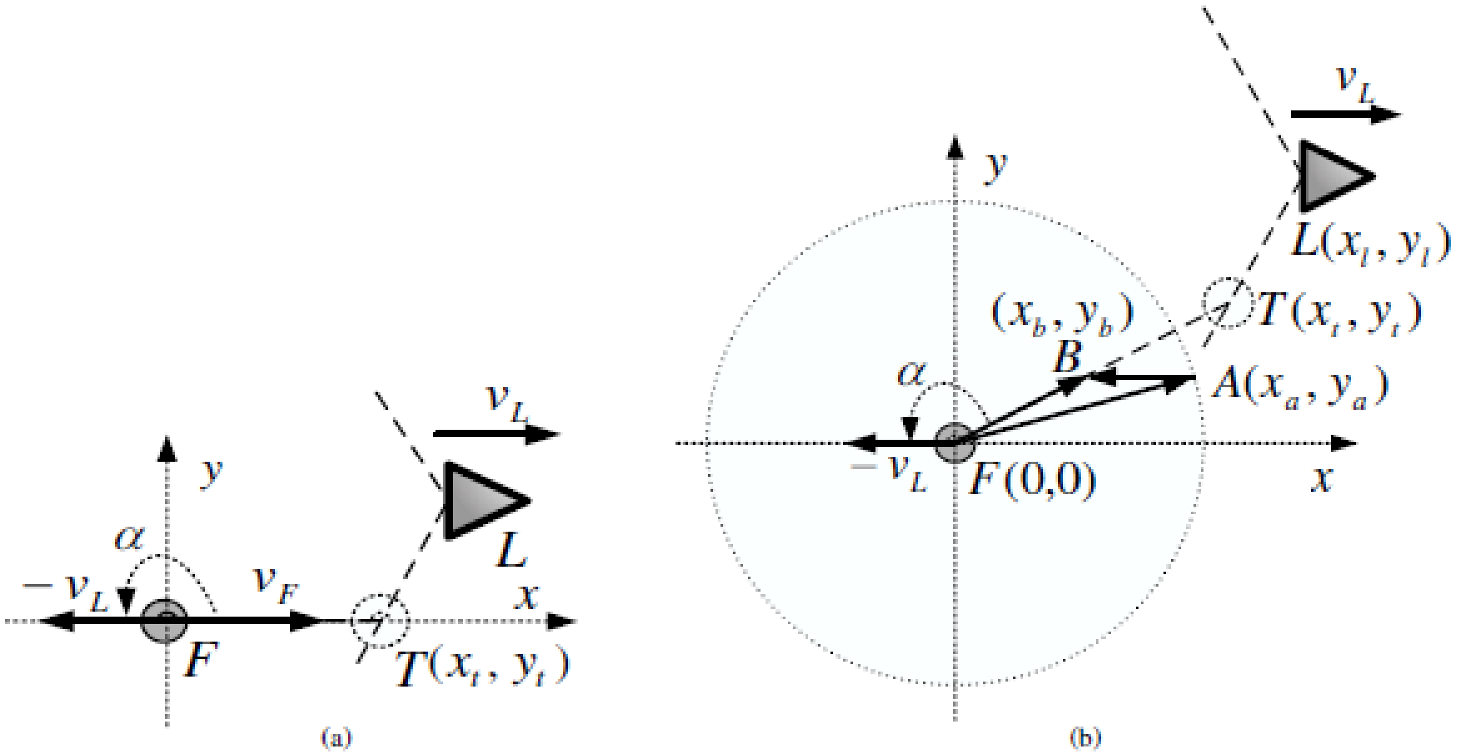


Figure 2. The presented fast flocking algorithm: (a) The orientation of the leader's velocity v_L is parallel with the vector $\overrightarrow{FT}$; (b) The orientation of the leader's velocity v_L is not parallel with the vector $\overrightarrow{FT}$.

GeorgiaStateUniversity

For Case (a)

- In Fig. 2(a), a coordinate system can be built using the position of the follower F as the origin.

- Assume the coordinate of the target T is (xt; yt), then the follower F will arrive at the target in the period $\sqrt{((x_t)^2 + (y_t)^2)}/(|v_{max} - v_L|)$.

GeorgiaStateUniversity

For Case (b)

- In Fig. 2(b), When the direction of the leader's rate is not parallel with the line FT.
- The time is

$$\frac{{x_t}^2 + {y_t}^2}{\sqrt{{x_t}^2 \cdot |v_F|^2 + {y_t}^2 \cdot (|v_F|^2 - |v_L|^2)} - x_t \cdot |v_L|}.$$

- the follower F moves with maximum velocity along the direction:

$$arctan(\frac{-x_t y_t |v_L| + y_t \sqrt{{x_t}^2 |v_F|^2 + {y_t}^2 (|v_F|^2 - |v_L|^2)}}{{y_t}^2 |v_L| + x_t \sqrt{{x_t}^2 |v_F|^2 + {y_t}^2 (|v_F|^2 - |v_L|^2)}}).$$

Performance evaluation

- Two parameters to consider: moving track & moving time

- Simulation settings:

  a) two followers and one leader

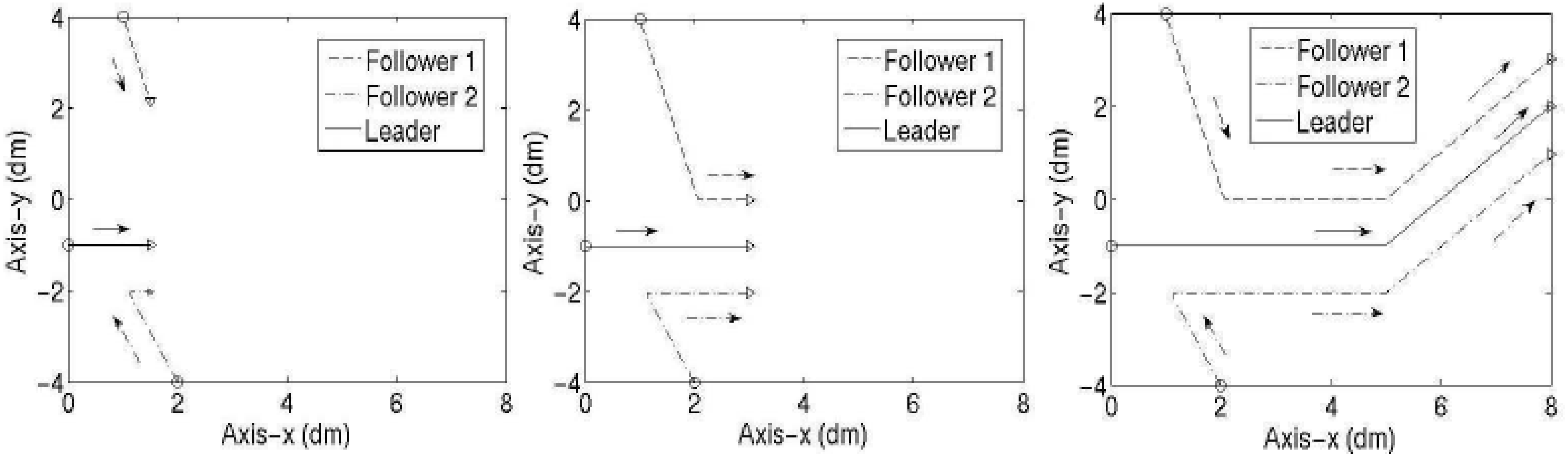
  b) the velocity of the leader is less than that of the followers

Requirements: the desired formation is a line formation and two follower are located in both sides of the leader.

Simulation

- Case 1: Before the two followers reach targets, the leader *doesn't* change direction.
- Case 2: Before the two followers reach targets, the leader *has* changed direction.

Simulation results of case 1

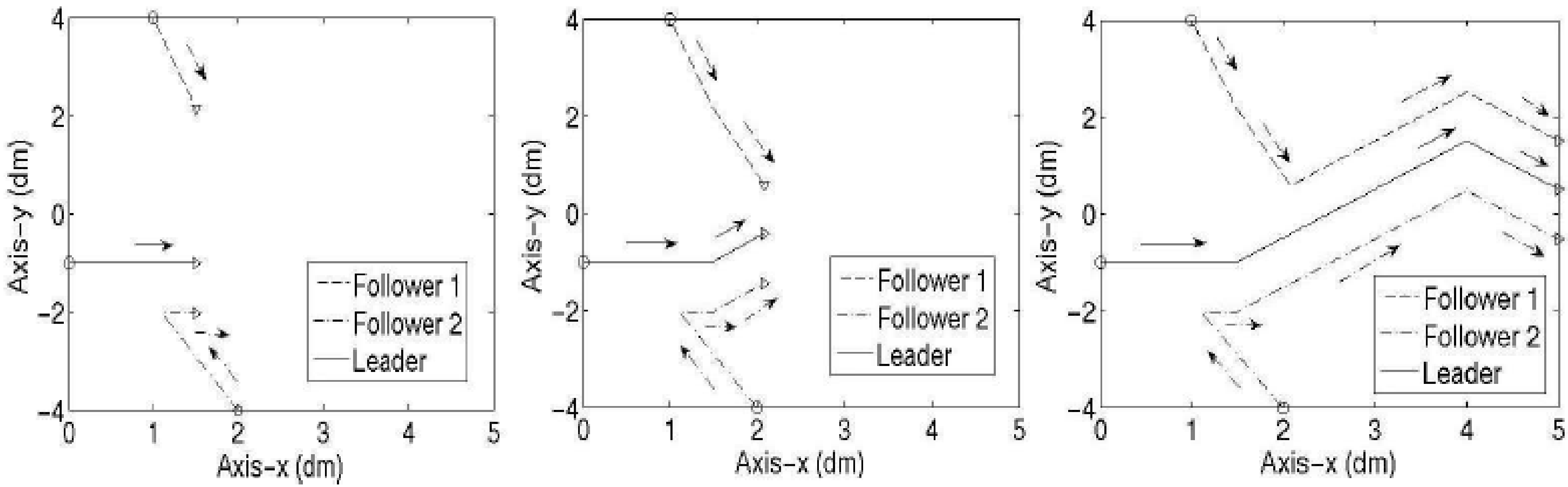


(a) 1.5 s (b) 3 s (c) 8 s

Figure 3. The navigation track of two followers and the leader.

GeorgiaStateUniversity

Simulation results of case 2



(a) 1.5 s (b) 2.1 s (c) 5 s

Figure 4. The navigation track of two followers and the leader.

Conclusion

- Present a novel efficient scheme for robot flocking
- The extensiveness theoretical analysis proves the effectiveness of the algorithms
- Simulation results demonstrate the algorithm can make robots flocking with shortest path and time.

Future work

- Test this scheme with real robots
- Considering more robots joining in the flocking, we need to consider the collision avoidance among robots.

Q & A

Thanks

Dr. Naixue Xiong
nxiong@cs.gsu.edu