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

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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...
Applications of formation flocking

- Move some object from one place to another in situations that human cannot survive...

- Maintain formations for defense or herding

...
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:

  \[ v = \frac{\delta S}{\delta t} \]

  where \( \delta S \) is the difference of the distance between the follower and the leader during the period \( \delta t \).
**Parameters used in algorithm**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$v_L$</td>
<td>The velocity of the leader $L$</td>
</tr>
<tr>
<td>$F$</td>
<td>A follower robot</td>
</tr>
<tr>
<td>$v_F$</td>
<td>The velocity of the follower $F$</td>
</tr>
<tr>
<td>$T$</td>
<td>The target position of the follower robot $F$</td>
</tr>
<tr>
<td>$v_{max}$</td>
<td>The maximum available velocity for each follower</td>
</tr>
</tbody>
</table>
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 $\overrightarrow{FT}$. 
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 \((x_t; y_t)\), then the follower F will arrive at the target in the period \(\sqrt{\frac{(x_t)^2 + (y_t)^2}{|v_{max} - v_L|}}\).
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:

\[
\arctan\left(\frac{-x_t y_t |v_L| + y_t \sqrt{x_t^2 |v_F|^2 + y_t^2 (|v_F|^2 - |v_L|^2)}}{y_t^2 |v_L| + x_t \sqrt{x_t^2 |v_F|^2 + y_t^2 (|v_F|^2 - |v_L|^2)}}\right).
\]
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

Figure 3. The navigation track of two followers and the leader.
Simulation results of case 2

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

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