Safe Robot Follow-the-Leader in the Plane

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Scenario

• Leader robot and follower robot
• Traveling in the 2D plane, with potential obstacles
• Various constraints on direction, velocity, and acceleration
Safety Properties

DISTANCE
- Minimum following distance
- Robots should not collide with each other

CLOSENESS
- Maximum following distance
- Robots should stay close together
Following Distances

[Diagram showing distances between an obstacle, leader, and follower]
Model Restrictions

- Leader has a maximum velocity
- Leader has a minimum obstacle clearance
- Leader makes wide turns
- Follower must be able to observe leader’s state at regular intervals
- Maximum system update interval
PROS

Collision avoidance
PROS

Obstacle avoidance
PROS

No shepherding
PROS

Limited follower sensing
PROS

Teamwork
USES

Robots traveling in a group (escort)
USES

Robots with different sensors or capabilities
USES
Path-following robot pairs
Robots tethered together

Image by NASA/Jet Propulsion Laboratory
USES

Robots pairs with wireless communication
USES

Search and rescue robot pairs

(e.g. scout and rescuer)
Intermediate Model

• Leader travels in circular arcs
• Leader can’t move down
• Follower travels in straight lines
• Follower uses a time-trigger, and can instantaneously adjust its velocity when making its control decision
• We were able to prove safety of this model
Intermediate Model

[Image of a diagram showing a proof tree and a KeYmaera proof window with a model expression and proof rules.]
Complete Model

• Follower and leader travel in circular arcs
• Leader cannot turn too sharply
• Safe control decisions are difficult
  • Follower must consider both its ending velocity and ending position
Leader’s future path

The point minfd behind the leader in the direction of its velocity

Follower travels path in time T (if uninterrupted)
NEXT

Extend to 3-D
NEXT

Multiple Followers
USES

UAVs
USES

Flocking
Q & A