Safe Robot Follow-the-Leader in the Plane

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15-424 FOUNDATIONS OF CYBER-PHYSICAL SYSTEMS
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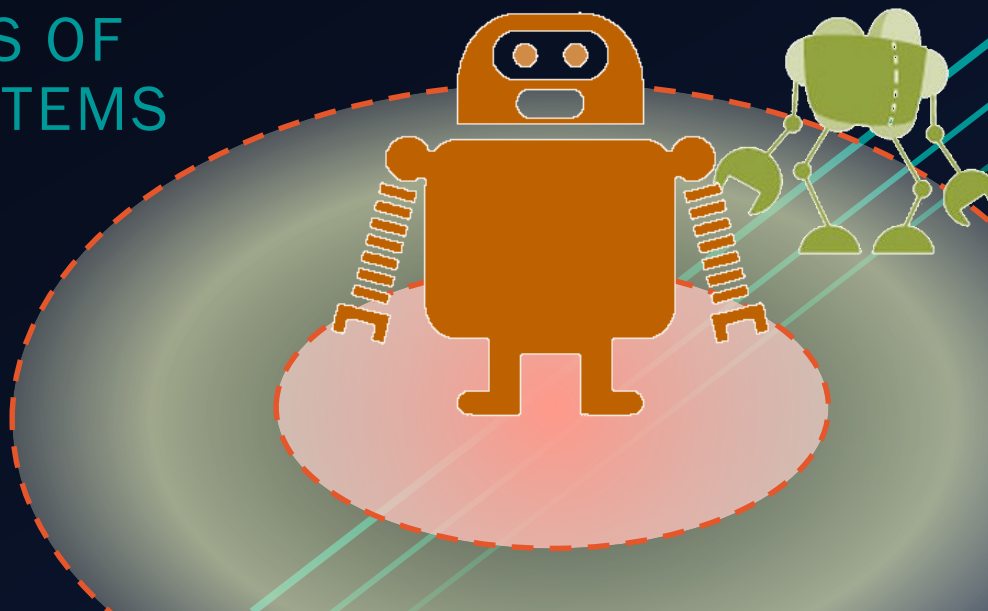
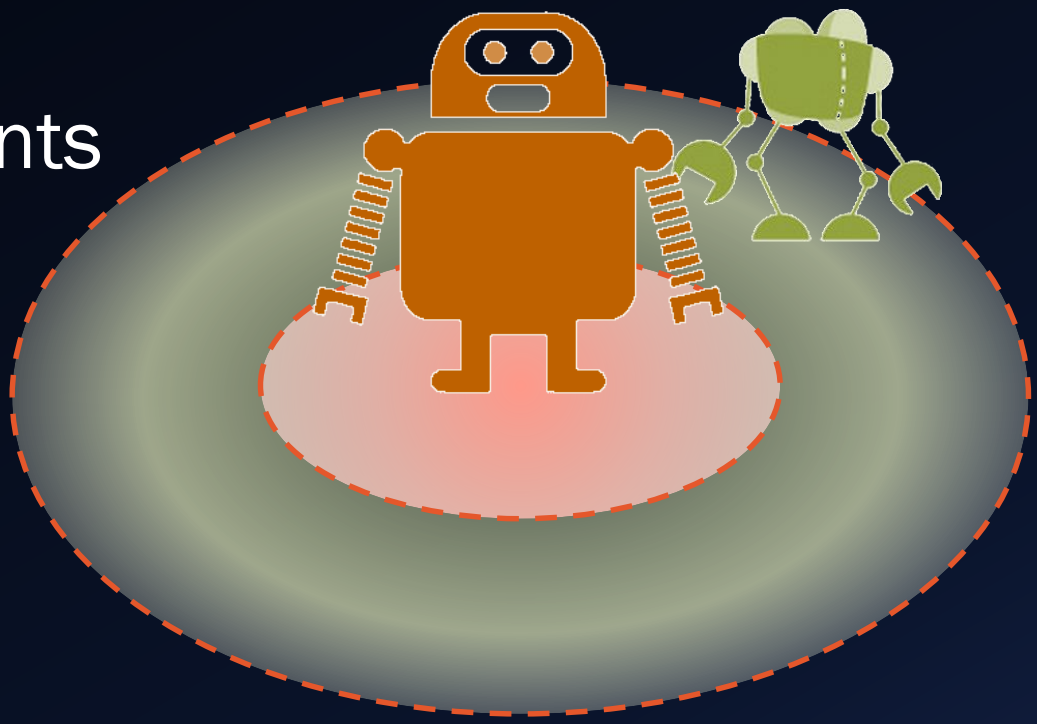


Scenario

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



Safety Properties

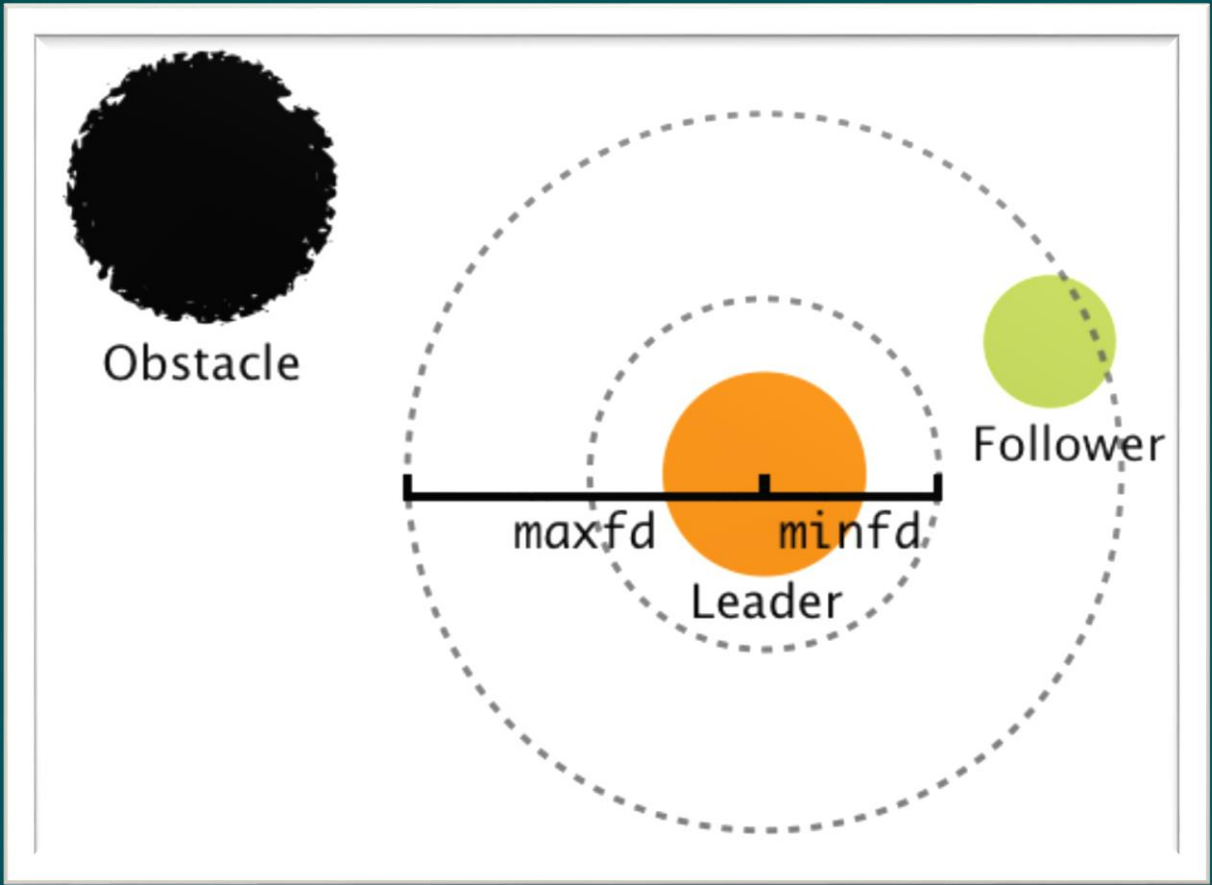
DISTANCE

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

CLOSENESS

- Maximum following distance
- Robots should stay close together

Following Distances



Model Restrictions

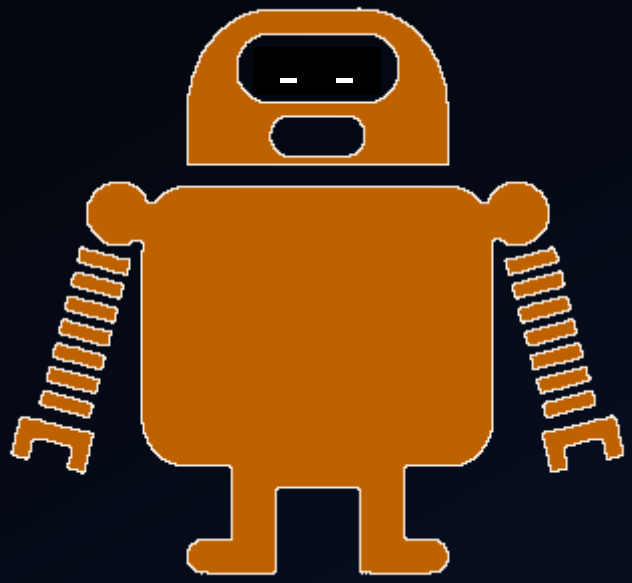
- Leader has a maximum velocity
- Leader has a minimum obstacle clearance
- Leader makes wide turns
- Follower must be able to observe leader's state at regular intervals
- Maximum system update interval

PROS

Collision avoidance

PROS

Obstacle avoidance

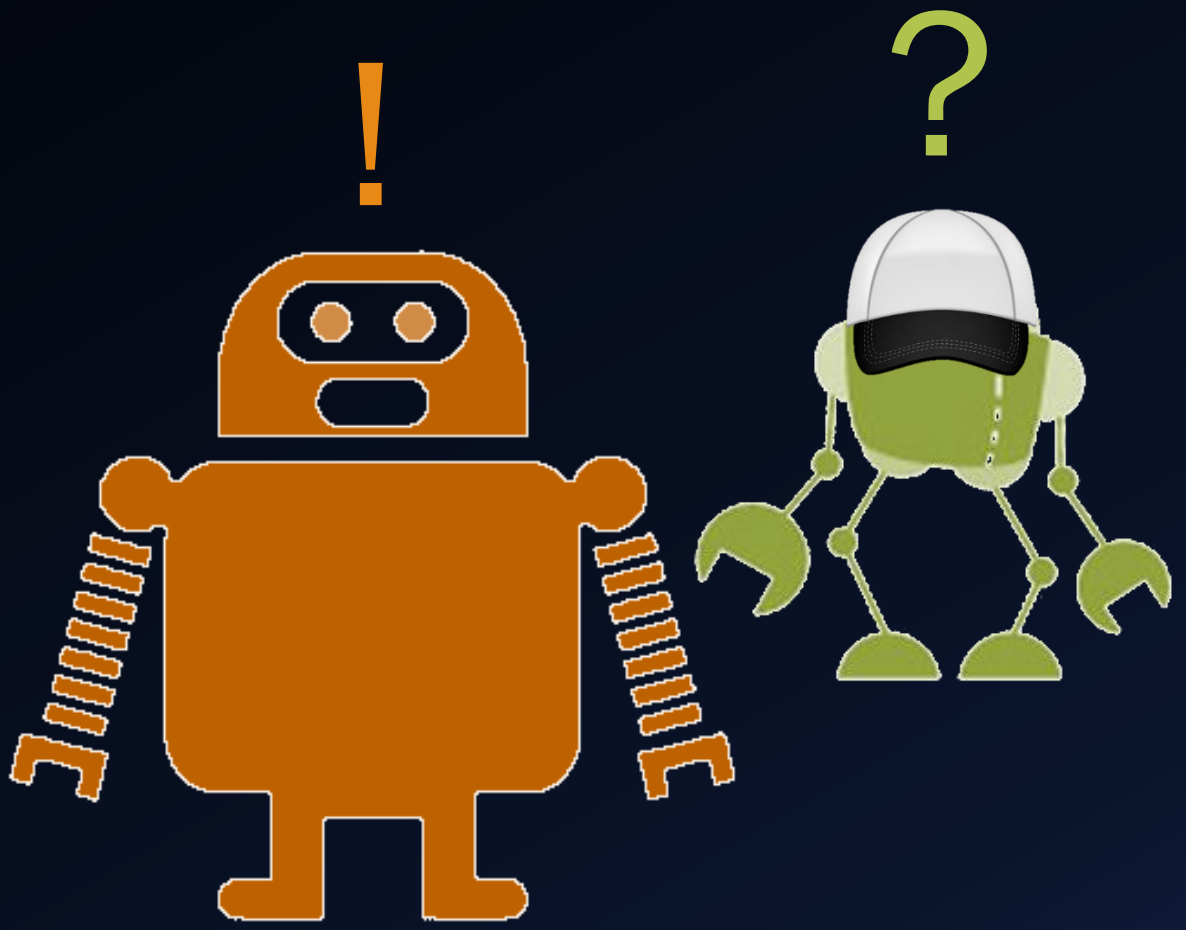


PROS

No shepherding

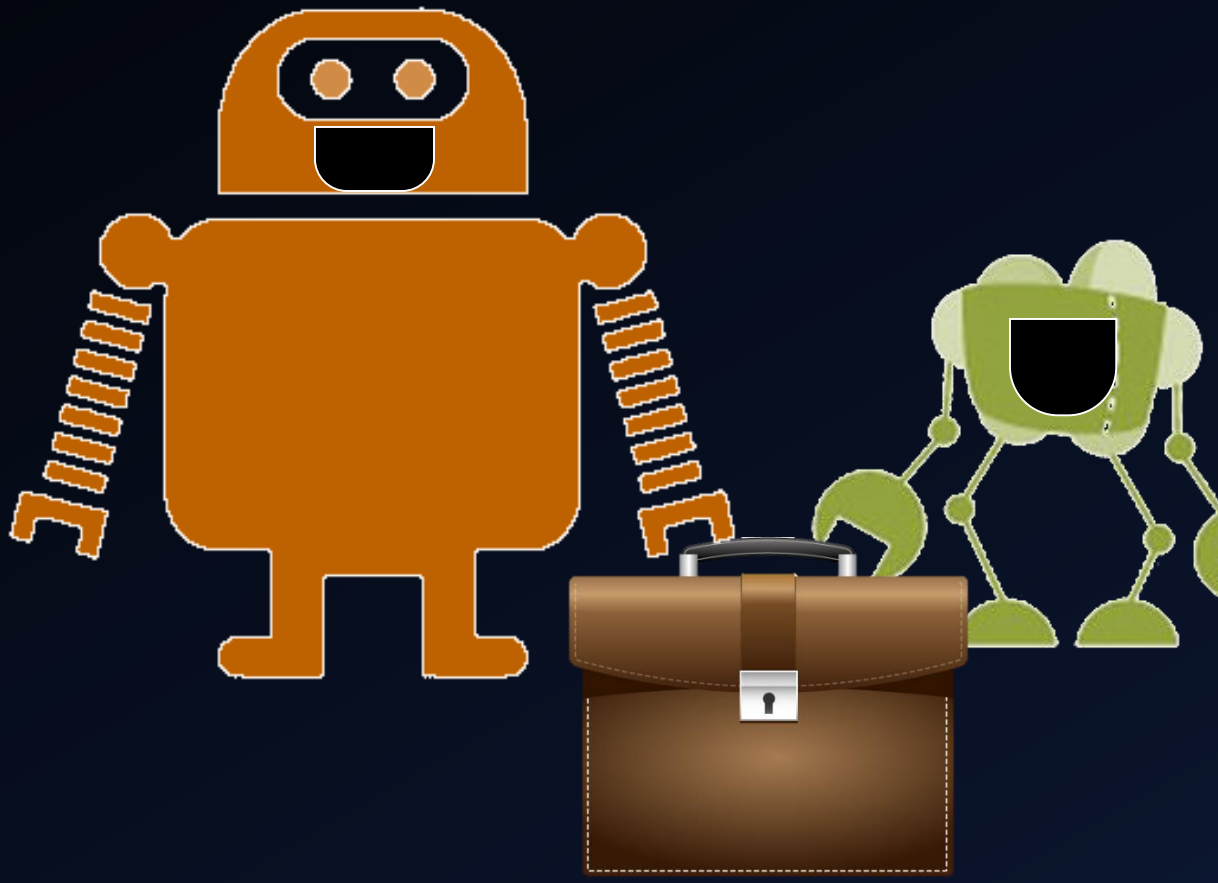
PROS

Limited follower sensing



PROS

Teamwork

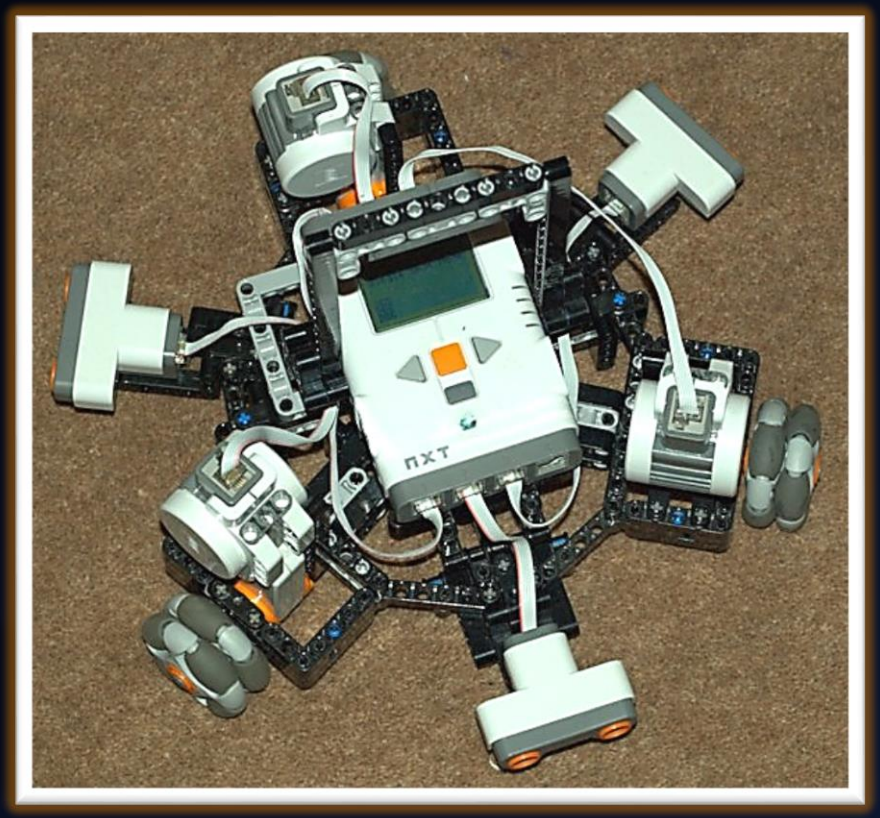


USES

Robots traveling
in a group (escort)

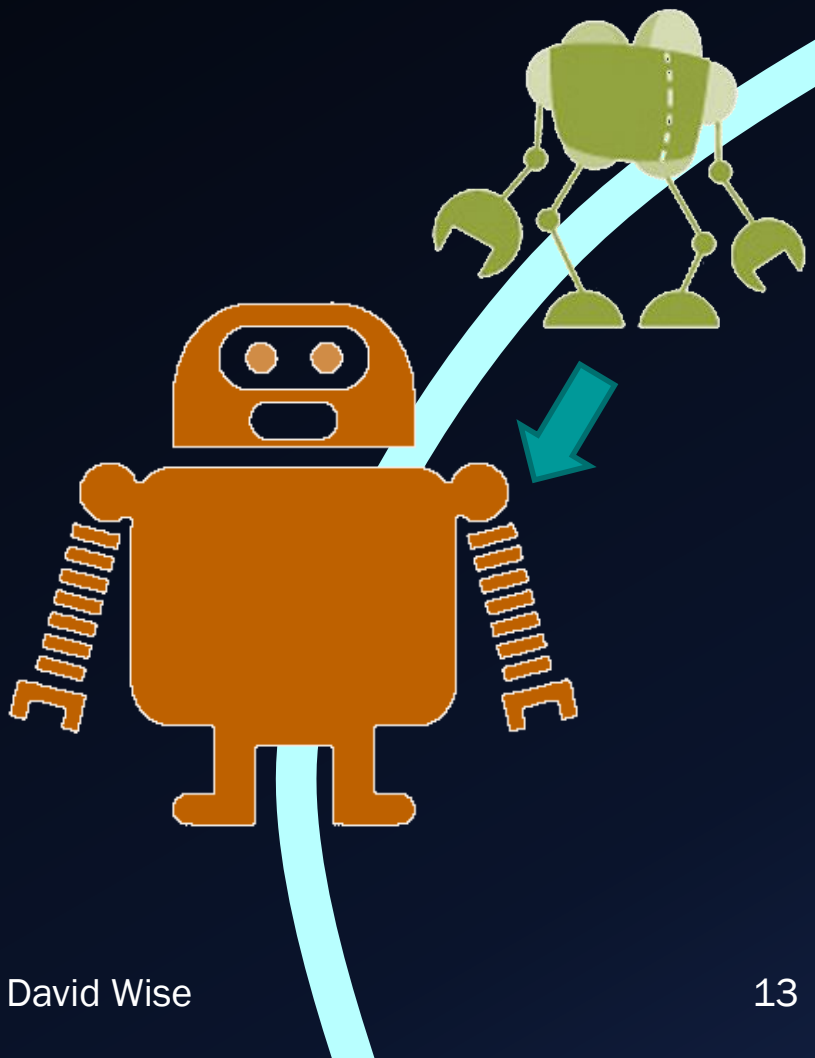
USES

Robots with different sensors or capabilities



USES

Path-following robot pairs



USES

Robots tethered together

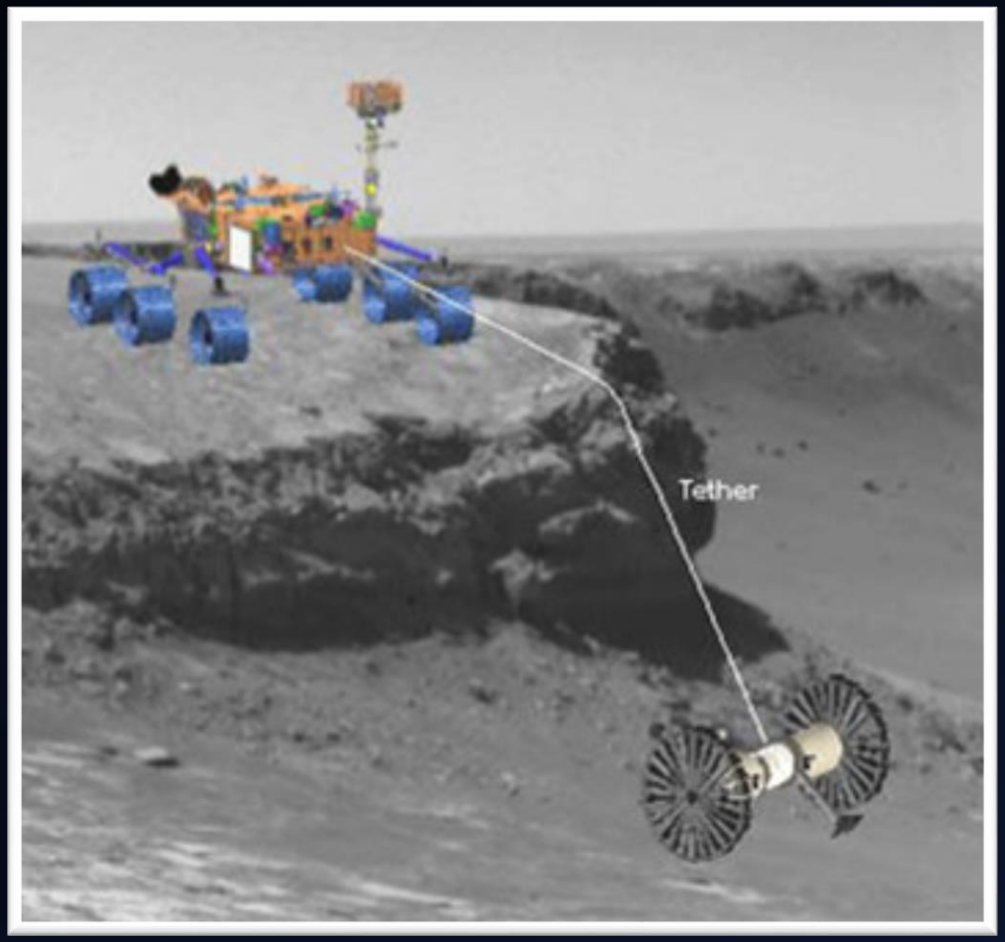
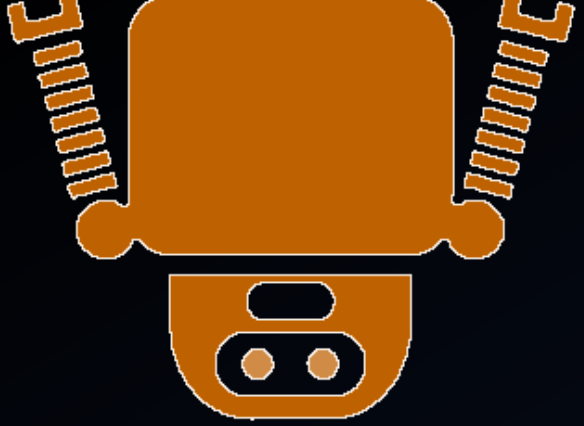
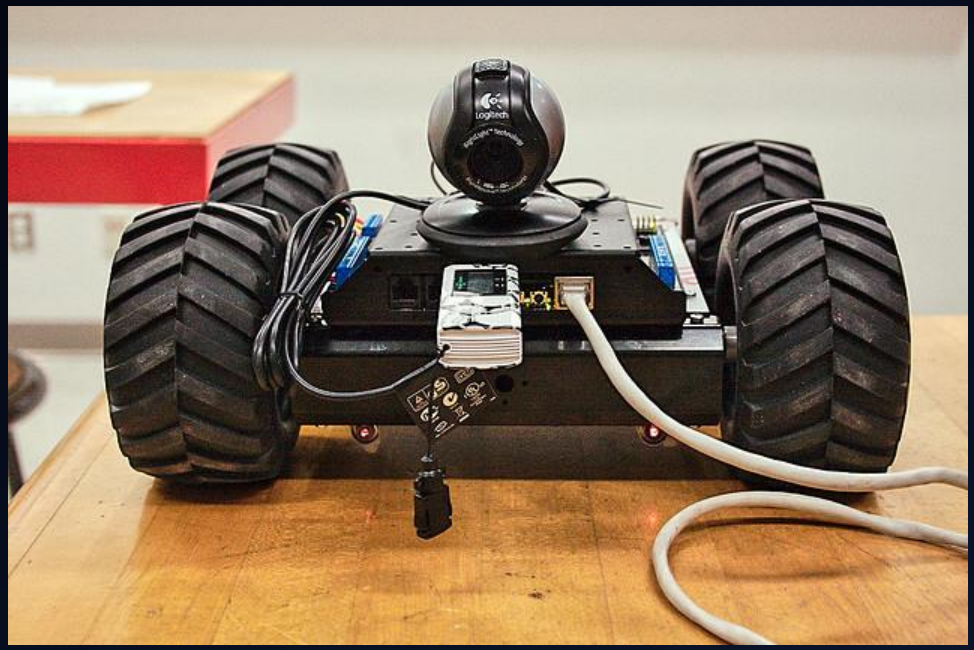


Image by NASA/Jet Propulsion Laboratory



USES

Robots pairs with wireless communication



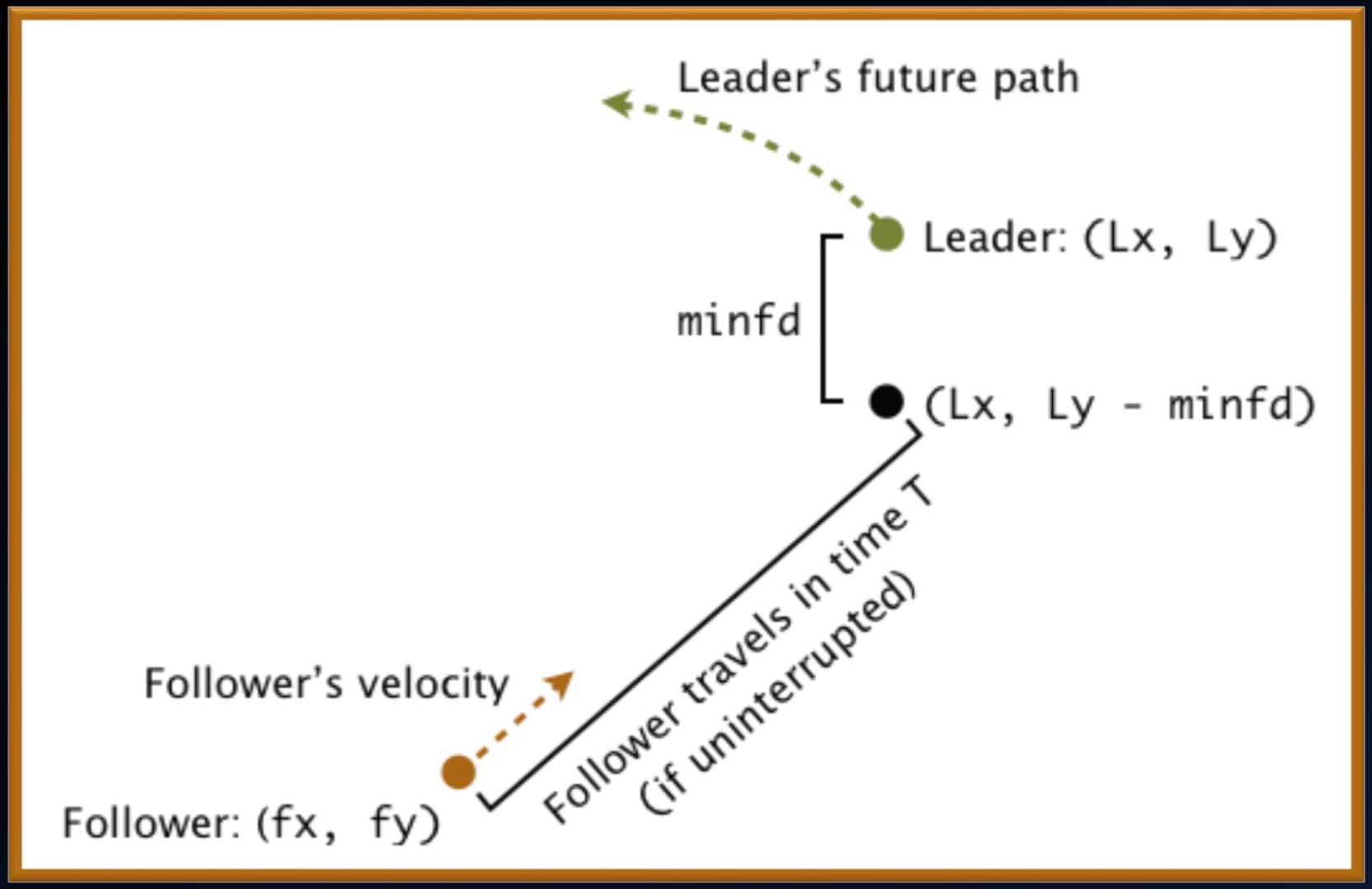
USES

Search and rescue robot pairs

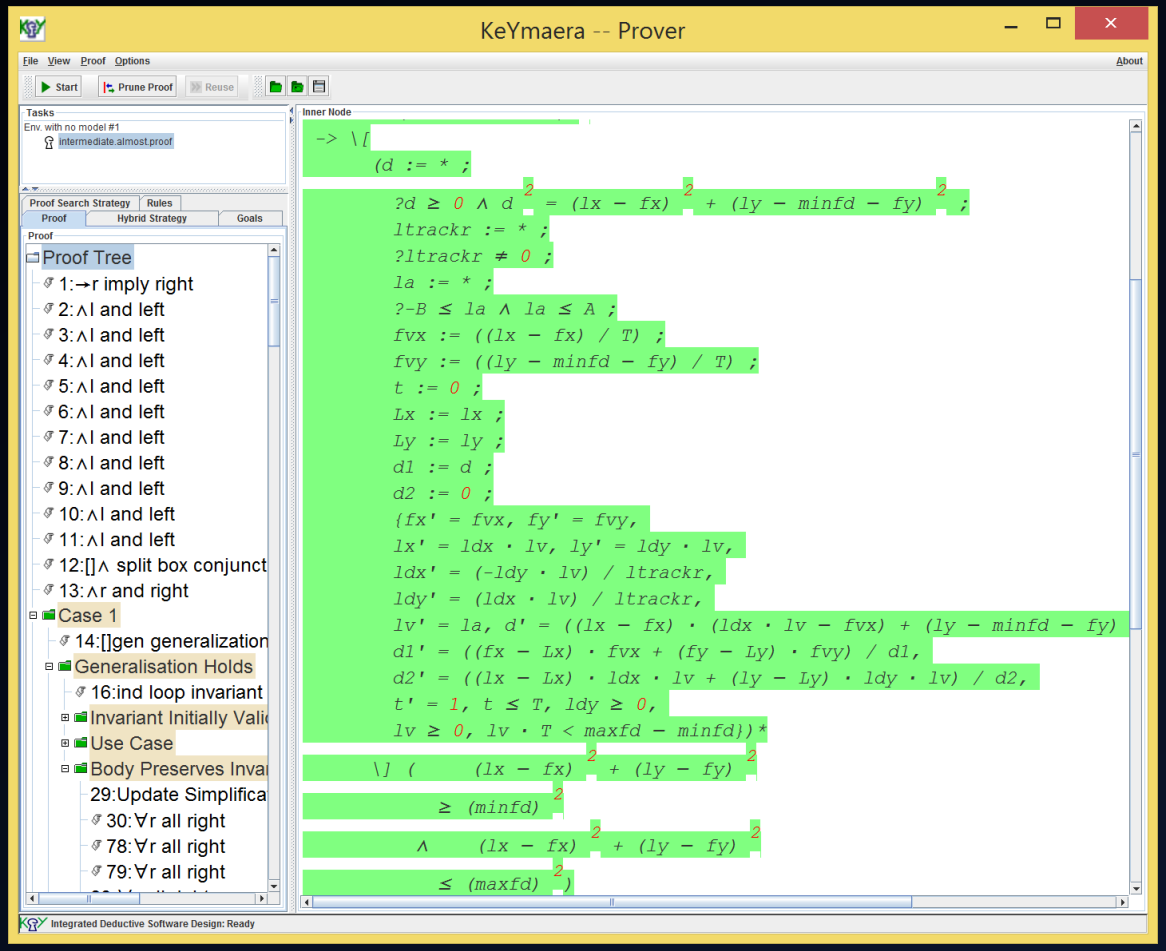
(e.g. scout and rescuer)

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

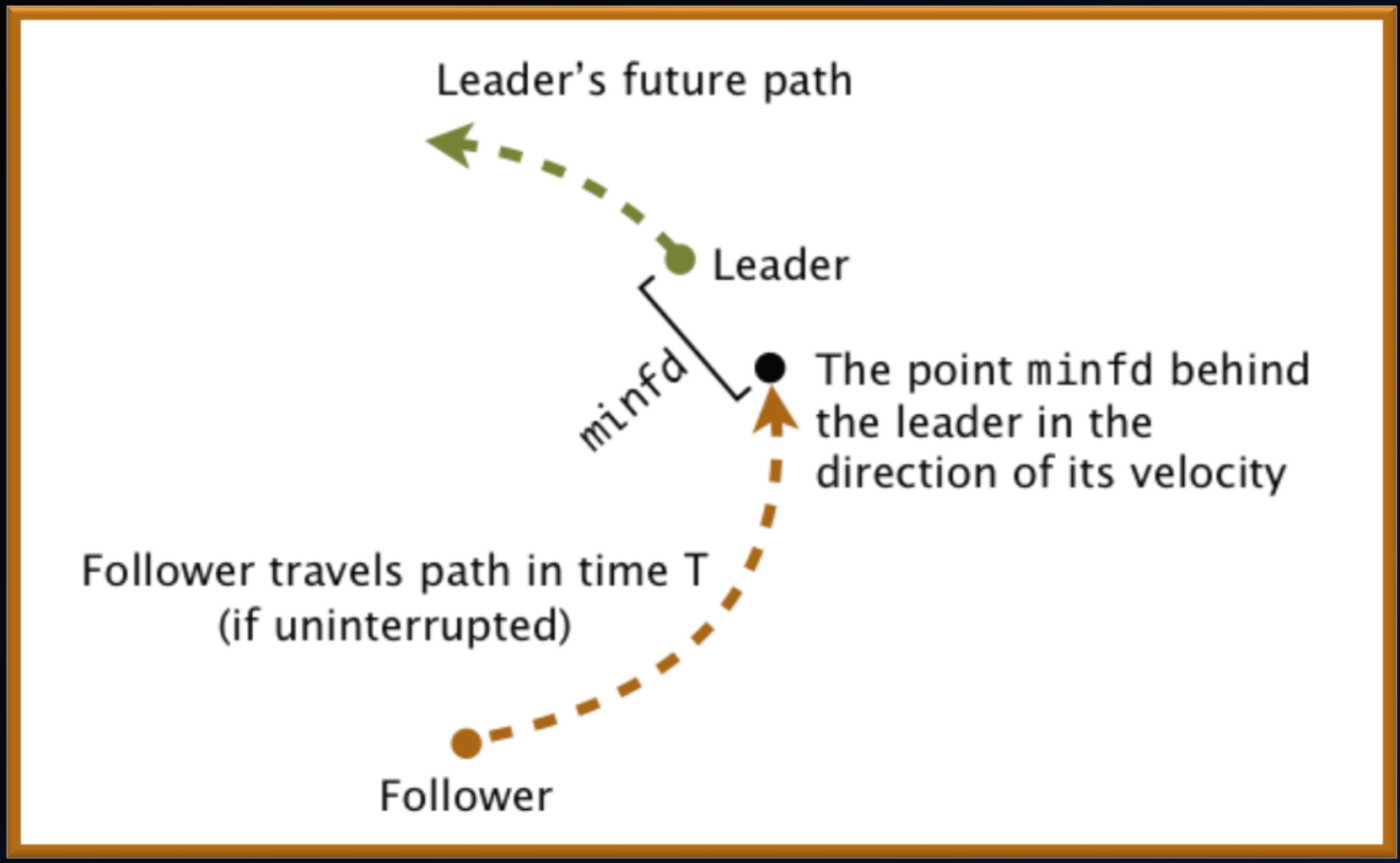

Leader's future path
Leader: (Lx, Ly)
minfd
(Lx, Ly - minfd)
Follower travels in time T
(if uninterrupted)
Follower's velocity
Follower: (fx, fy)

Intermediate Model



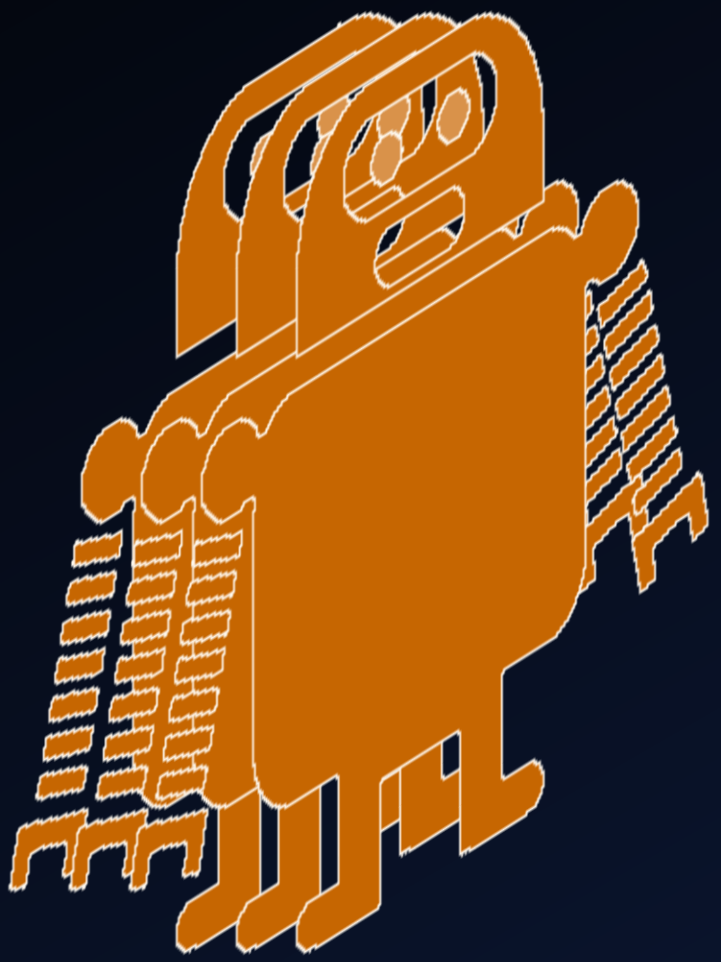
Complete Model

- 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
Leader
minfd
The point minfd behind
the leader in the
direction of its velocity
Follower travels path in time T
(if uninterrupted)
Follower

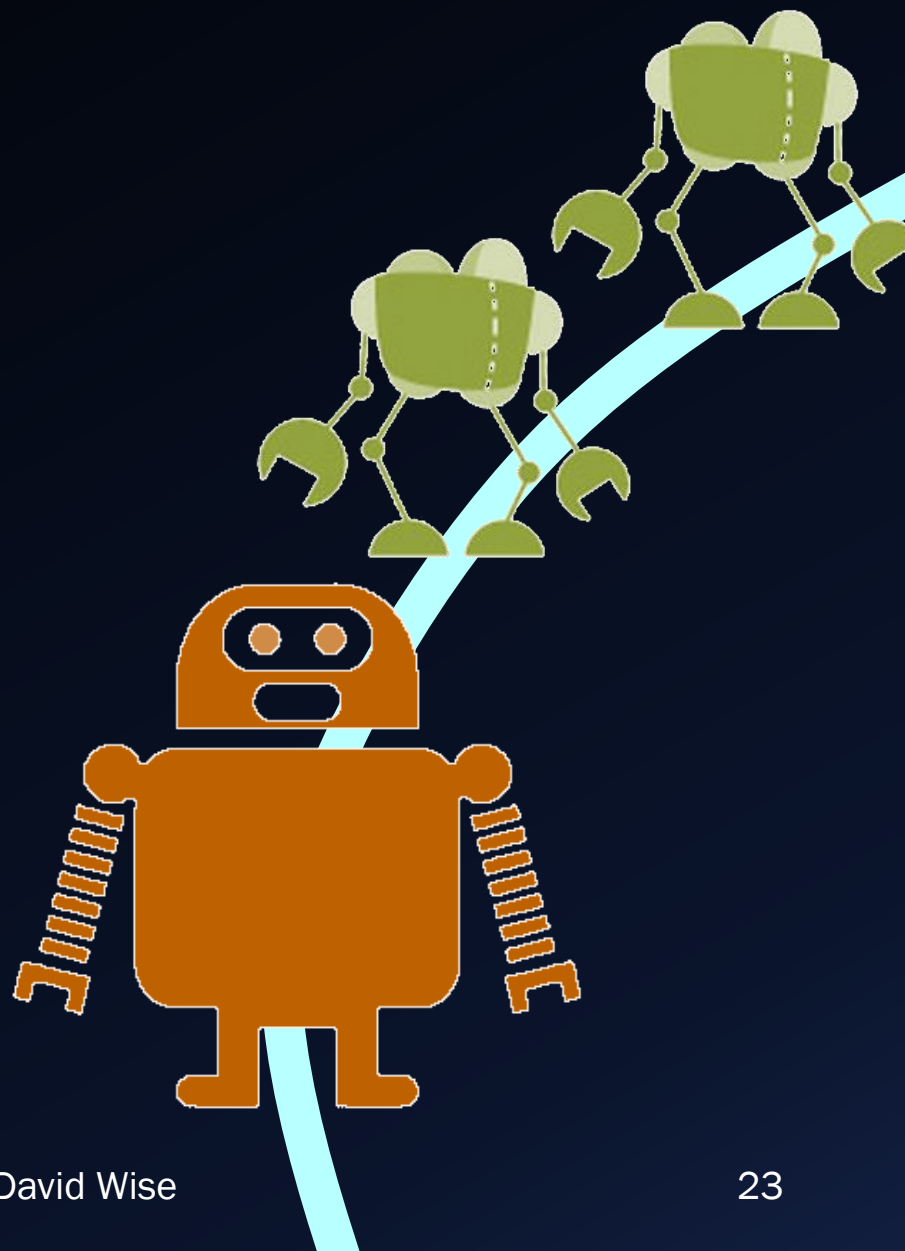
NEXT

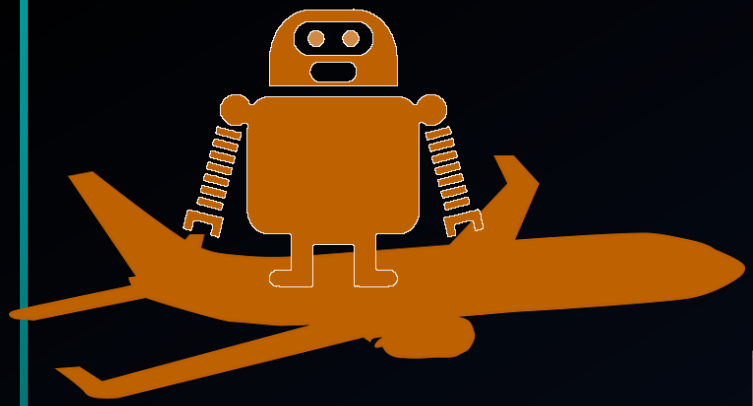
Extend to 3-D



NEXT

Multiple Followers





USES

UAVs

USES

Flocking

Q & A