Shaping a Swarm Using Wall Friction and a Shared Control Input

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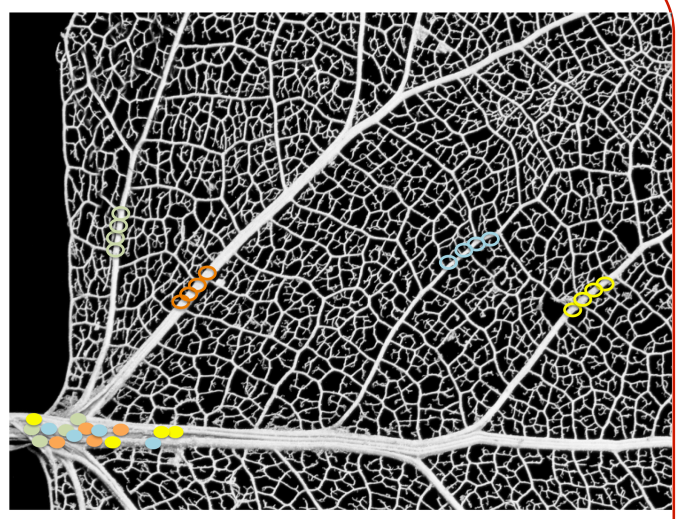
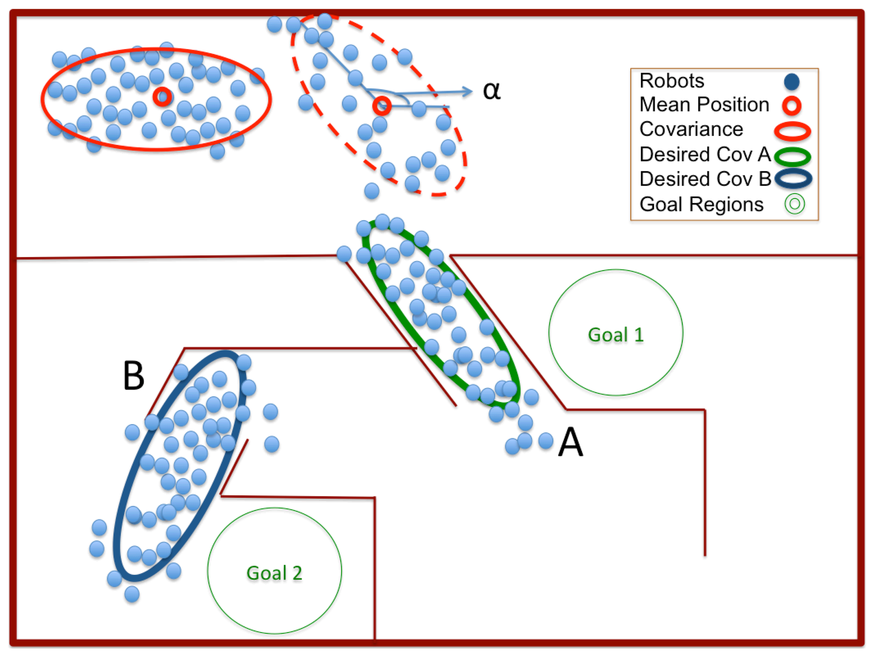
Why Covariance Control?

Vascular networks are common in biology



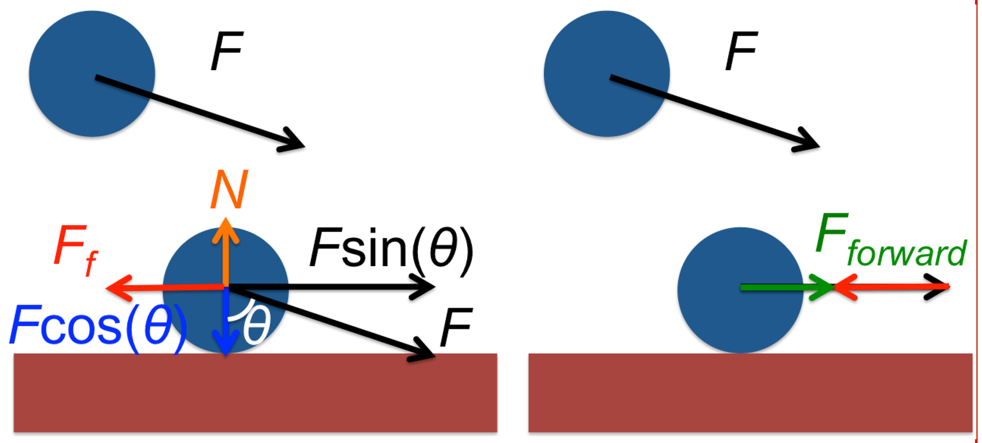
- *Shared inputs* means each member of the swarm receives the same control input
- Navigating a swarm using shared inputs is challenging due to obstacles and symmetry



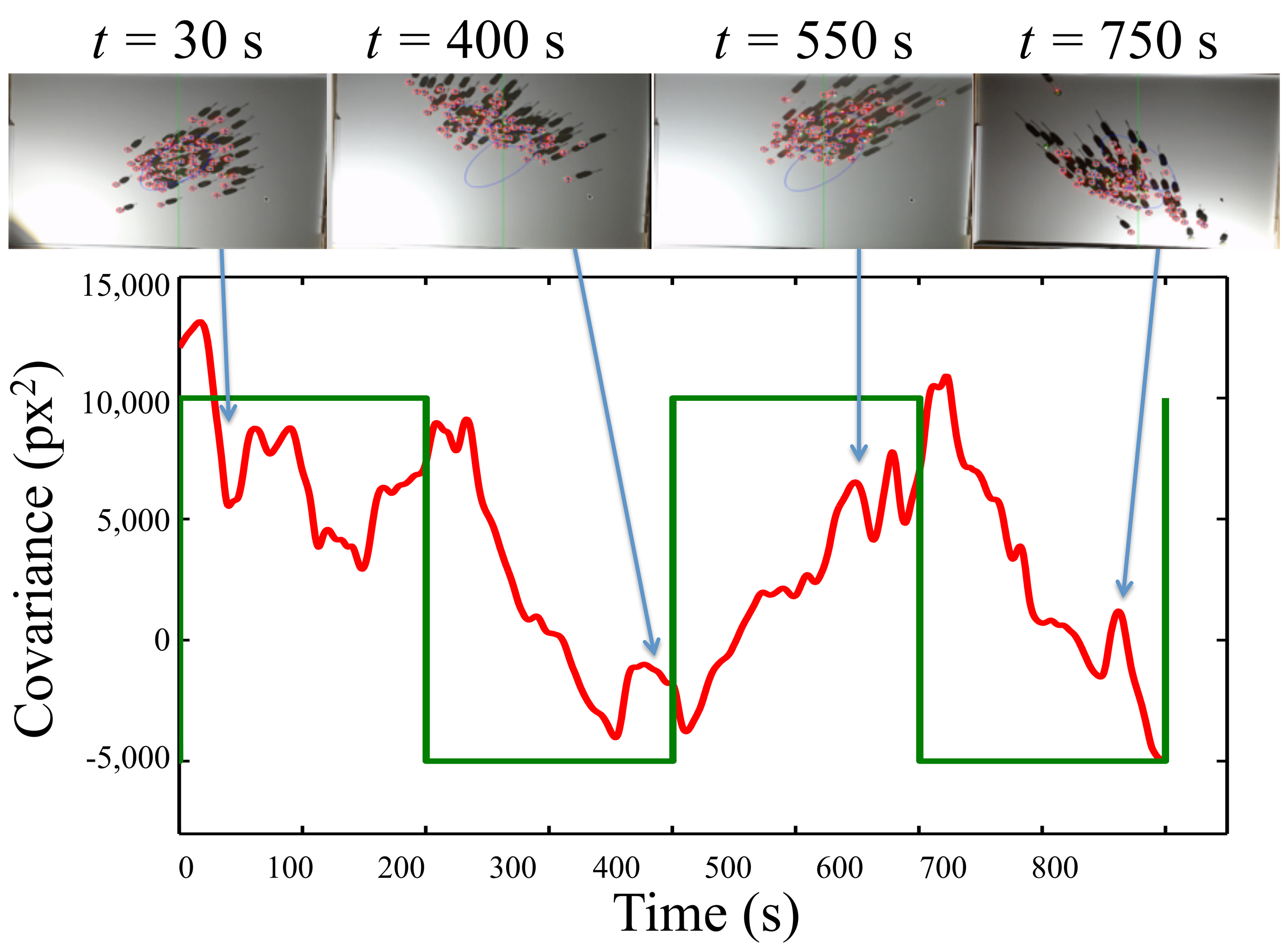
- Maintaining group cohesion while steering a swarm through an arbitrary maze requires covariance control
- Pushing swarm into vertical walls does not change *x* and *y* position correlation
- We need to break this symmetry

Using Friction to Break Symmetry

- Friction is sufficient to break the symmetry
- Wall friction reduces forward force for robots near a wall, but not for free robots



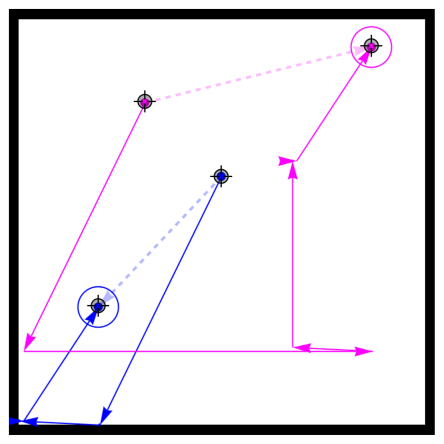
Results

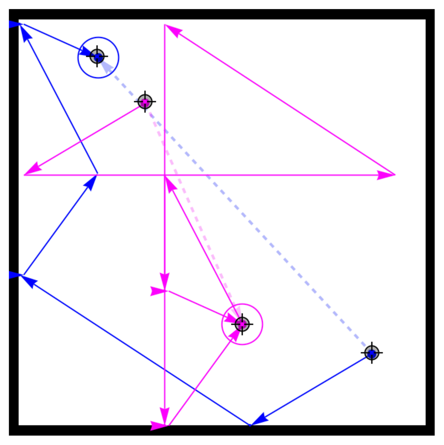


- We used *kilobots* to show that wall friction enables covariance control
- Global Input: kilobots go to the brightest light source in the room
- Plot shows covariance control is possible

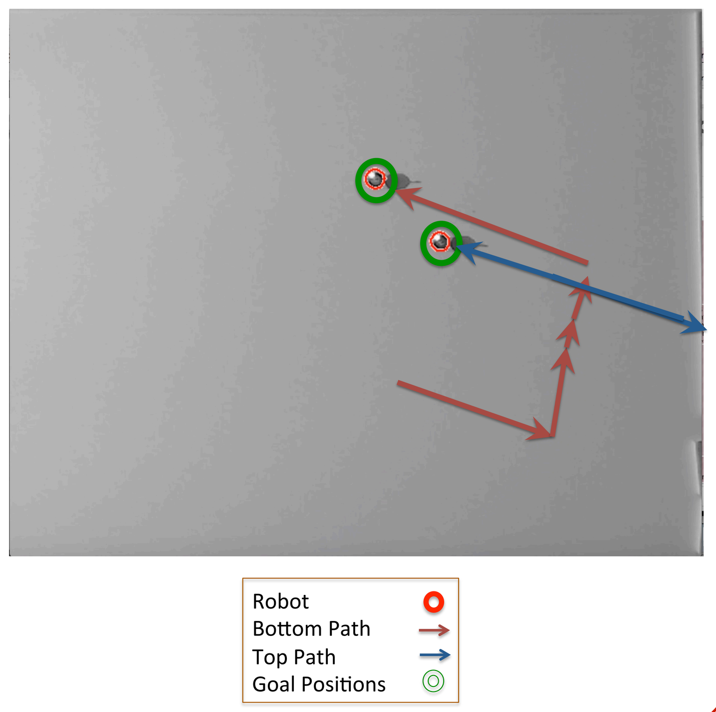
Position Control using Wall Friction

- We designed an algorithm for controlling the position of two robots
- For simplicity, we assume that friction is infinite
- Following this path we can get to the ending points when getting the same input.
- Two robot positioning: switching positions using walls with infinite friction





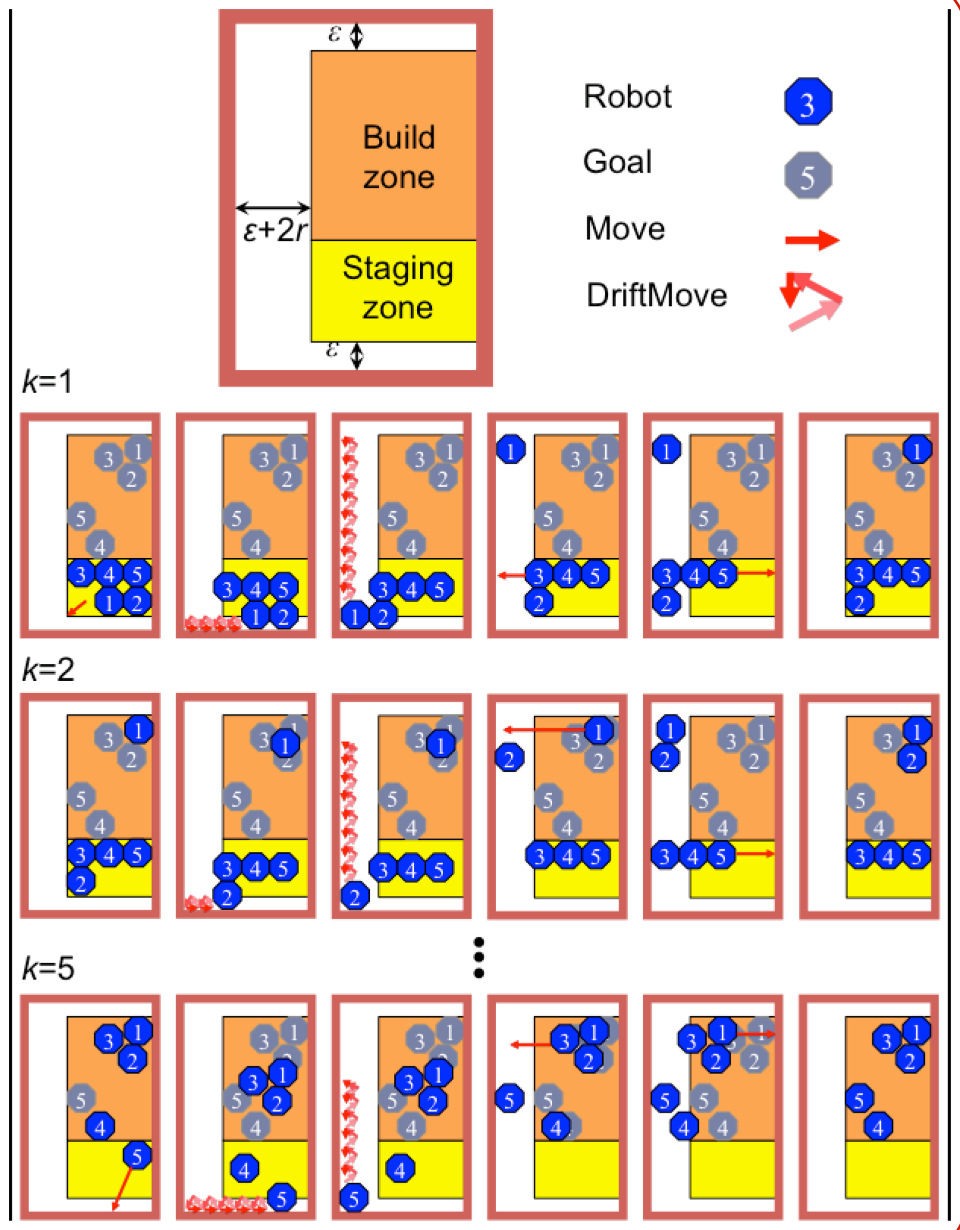
Two robot positioning using hardware setup with two kilobot robots



- Walls have *nearly* infinite friction
- Robot with blue path is stopped by the wall until the light changes orientation
- The orange robot in free-space is unhindered

Multi Robot Control

- We can extend this algorithm to control the position of *n* robots
- Algorithm has *n* iterations
- Iteration *k* assumes *k*-1 robots are at goal positions and moves *k*th robot to desired position



Future Opportunities

- Efficiently steer robot swarm through a maze
- Use obstacles and wall friction to partition swarm
- Implementing *n* robot position algorithm with kilobots
- Solving position control algorithm with finite friction
- Automatic covariance control law using wall friction