



How AI and robotics will accelerate research in social animal behavior

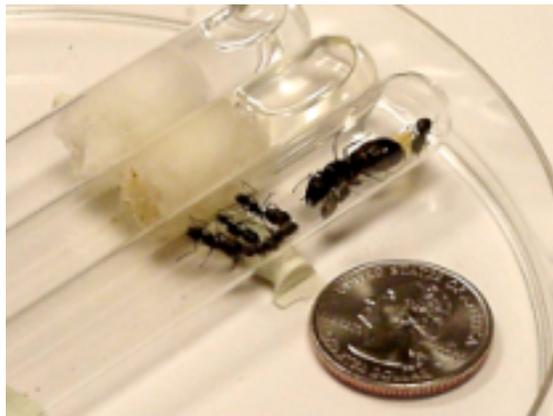
Tucker Balch

College of Computing

Georgia Institute of Technology

Challenges for AI

- What does it mean to *understand* the behavior of physical multi-agent systems?
- How can AI and robotics help?

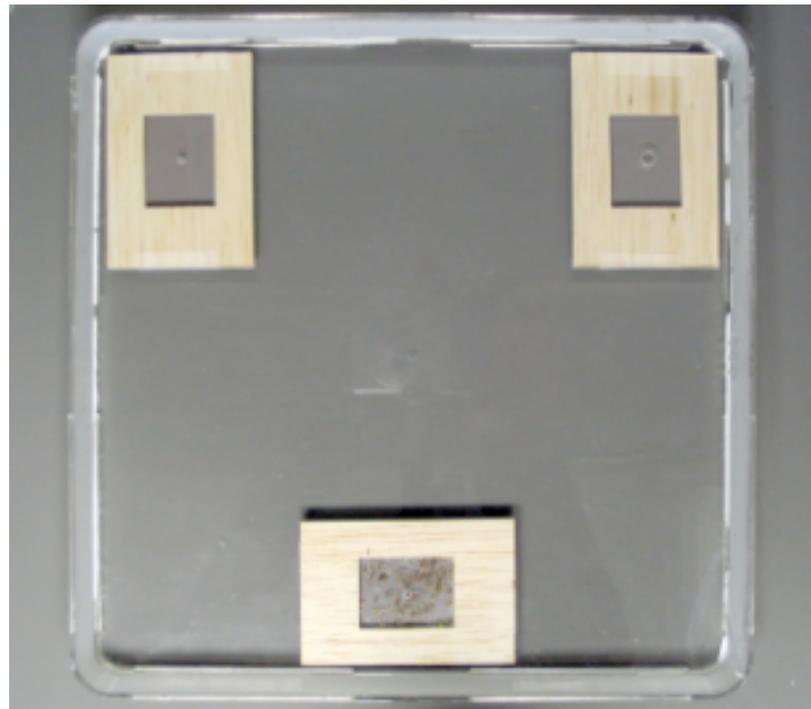


Thanks

- Frank Dellaert
- Adam Feldman
- Zia Khan
- Andrew Guillory
- Sangmin Oh
- James Rehg
- Stephen Pratt, Princeton
- Andrew Stein, Carnegie Mellon
- Hank Wilde

- NSF

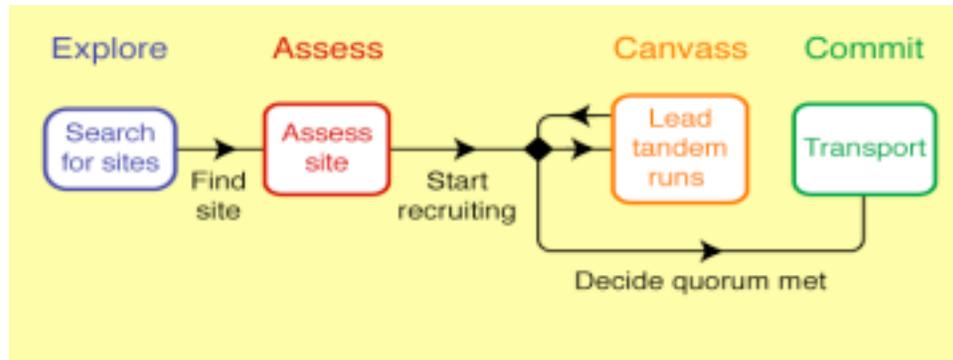
Example 1: Ant colony migration



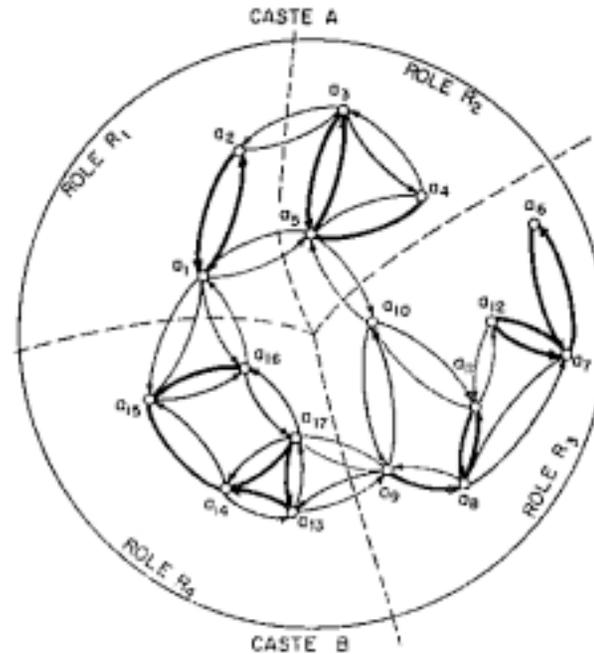
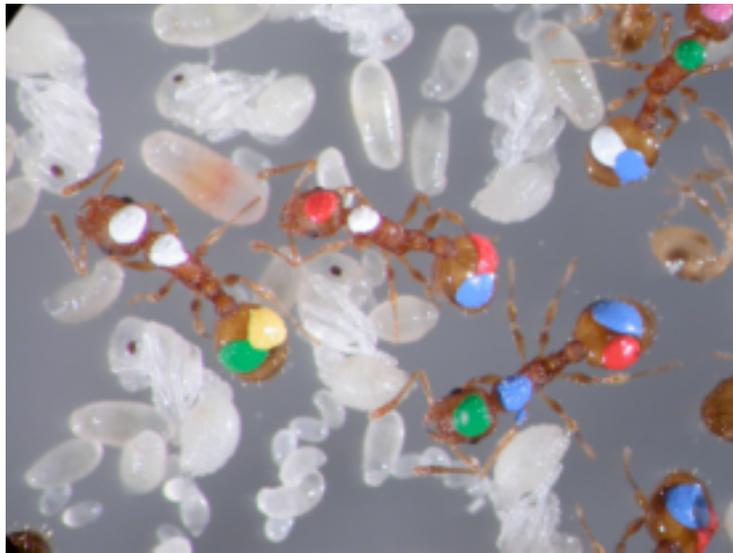
Stephen Pratt, Princeton University

Nest exploration/evaluation

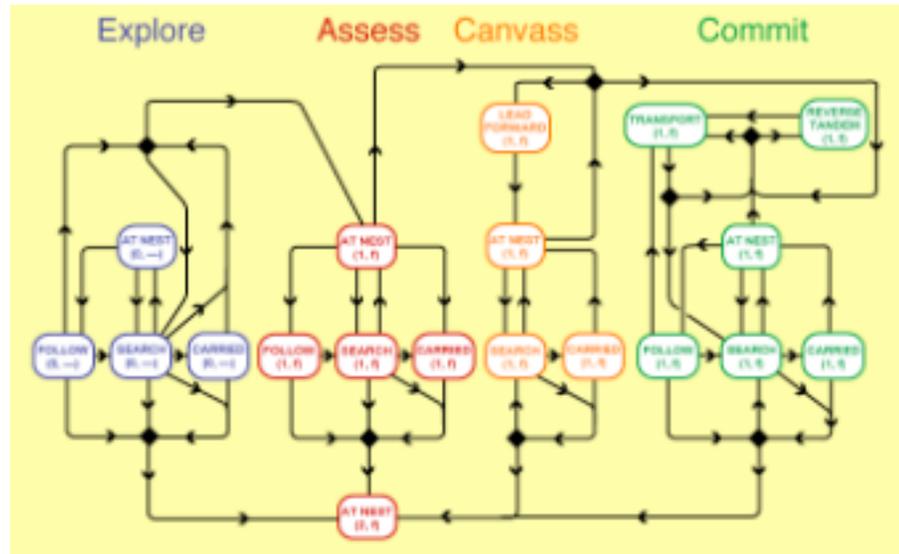
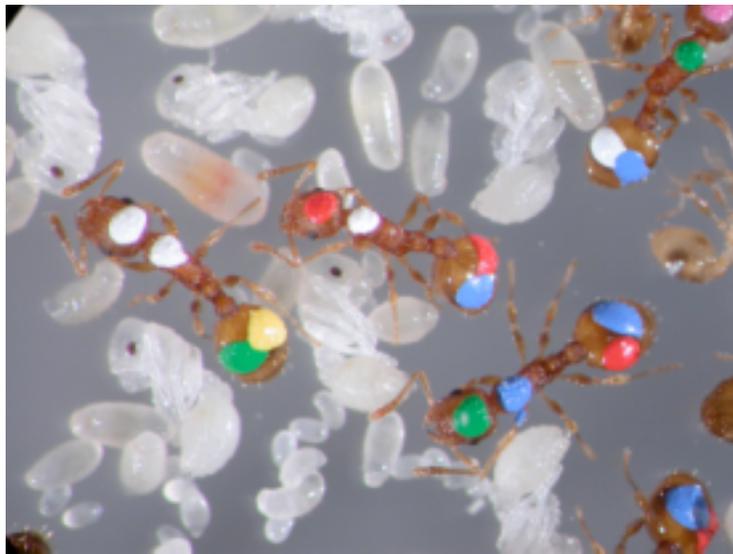




Methods & results ca. 1990

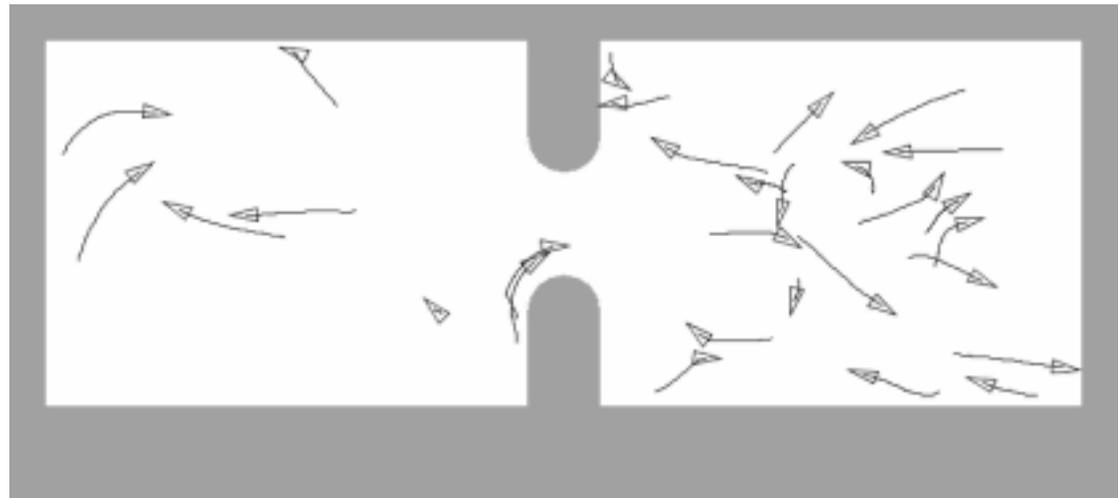


Methods & results ca. 2005

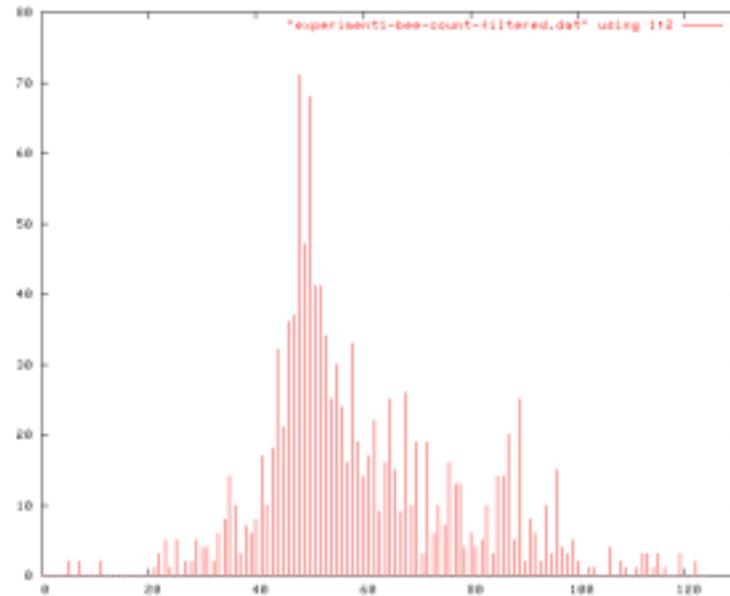


Pratt and Sumpter, 2005

Methods & results ca. near future...



Example 2: Task allocation in honey bees

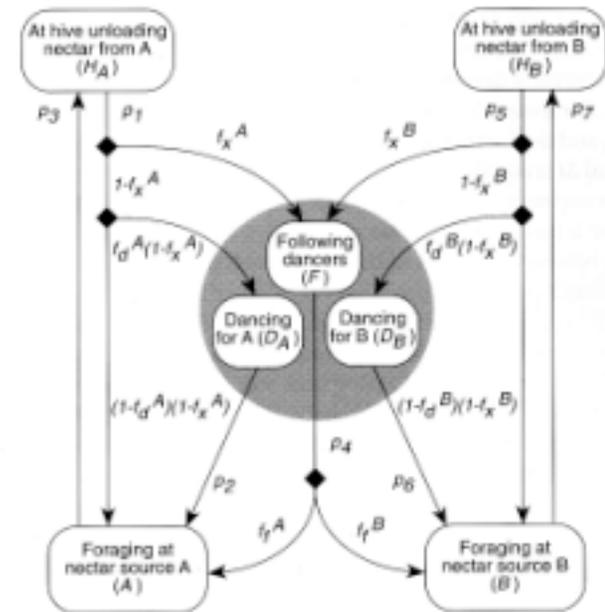
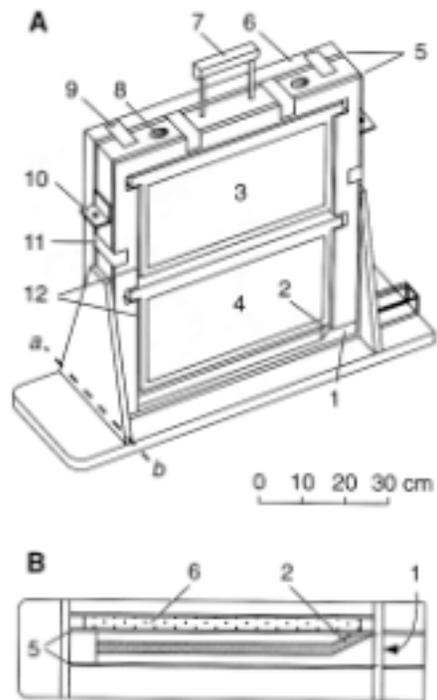


How they do it: The waggle dance



Von Frisch (1940s), Seeley et al (1980s-90s)

Methods & results ca. 1995



Seeley, et al

Revisiting our questions...

- What does it mean to *understand* the behavior of physical multi-agent systems?
 - Track
 - Label
 - Quantify
 - Model



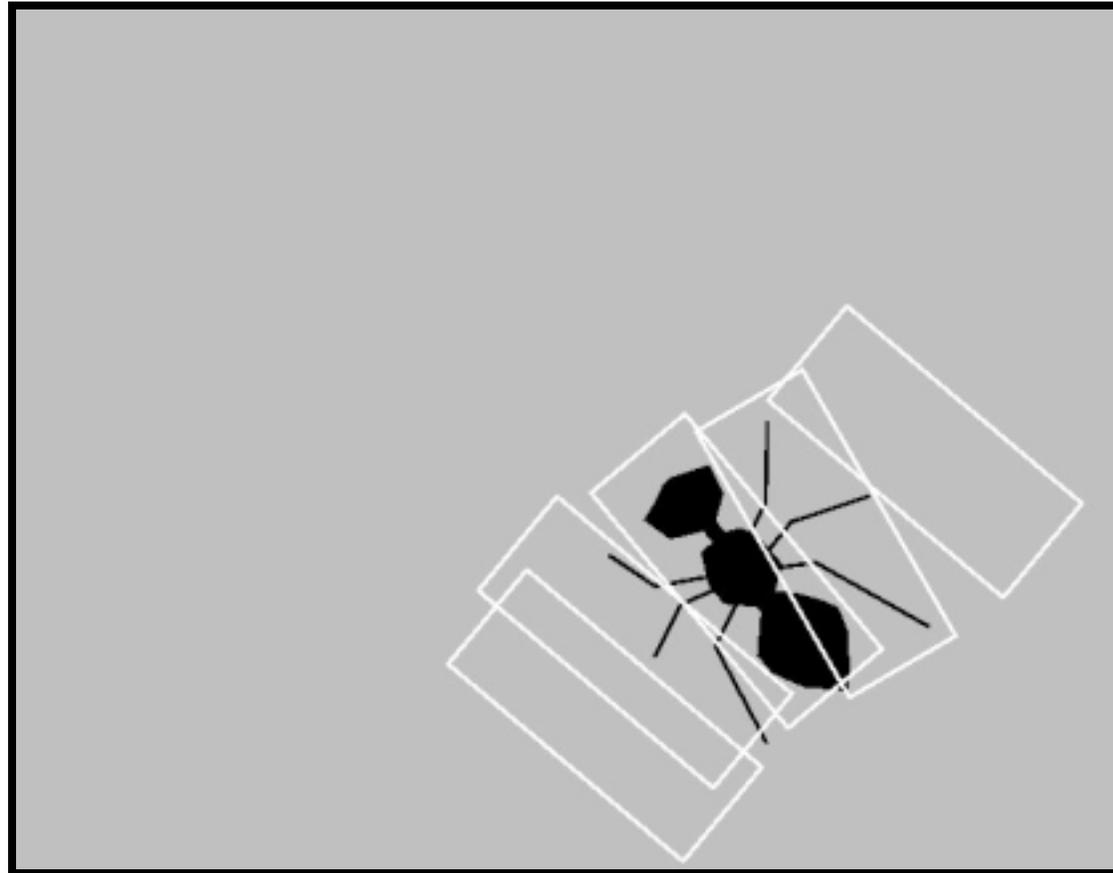
- Why is this research important?
- Why is this research difficult?



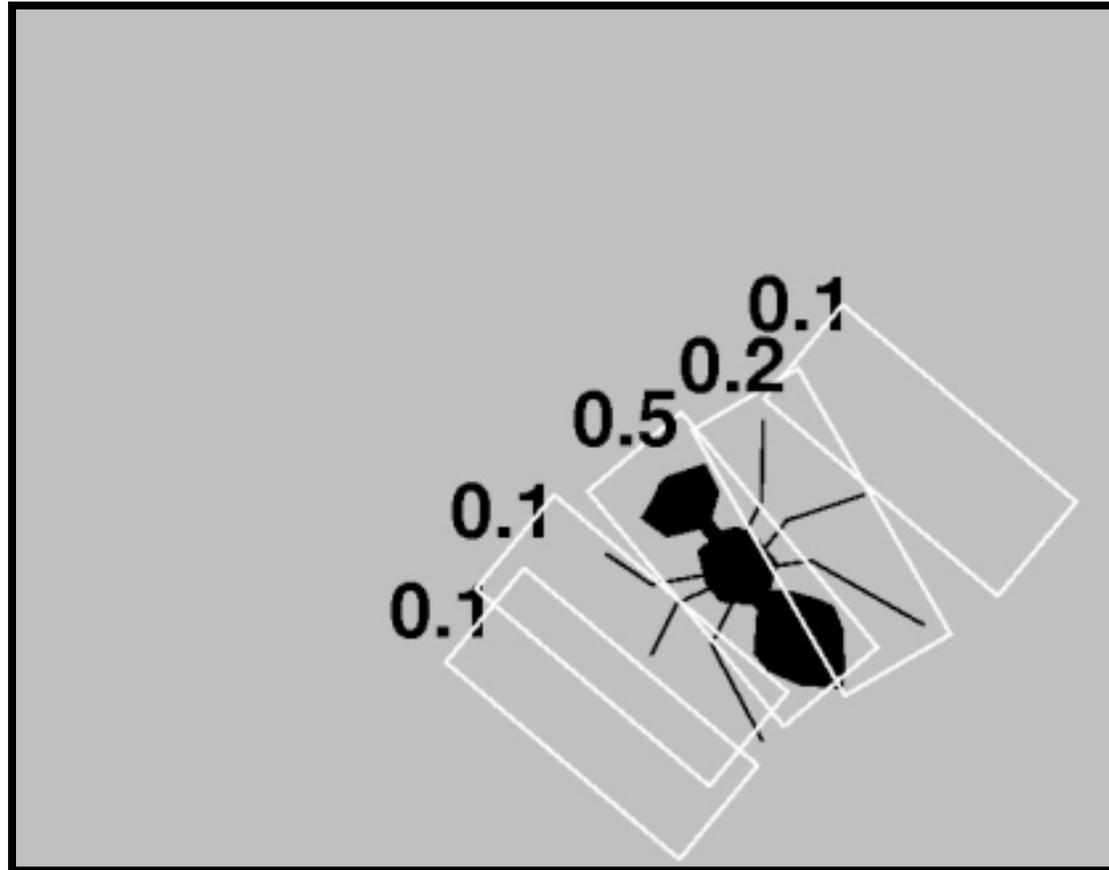
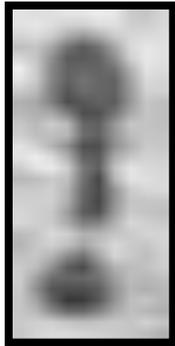
Tracking: Problem statement

- Given:
 - Examples of the appearance of animals to track.
- Compute:
 - Positions of the animals over time, including association with a unique ID.
- Assumptions:
 - Animals appear identical,
 - Lighting is stable,
 - Background is stable.

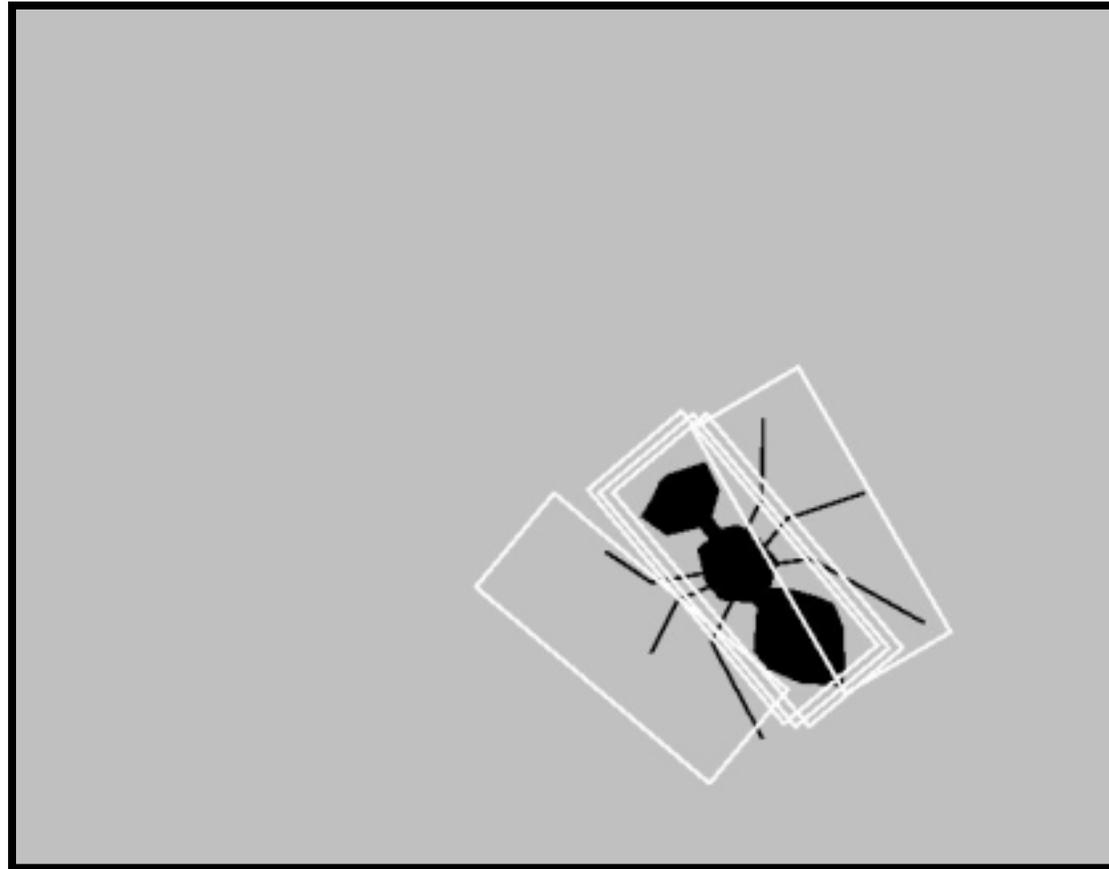
Tracking: Appearance-based particle filter



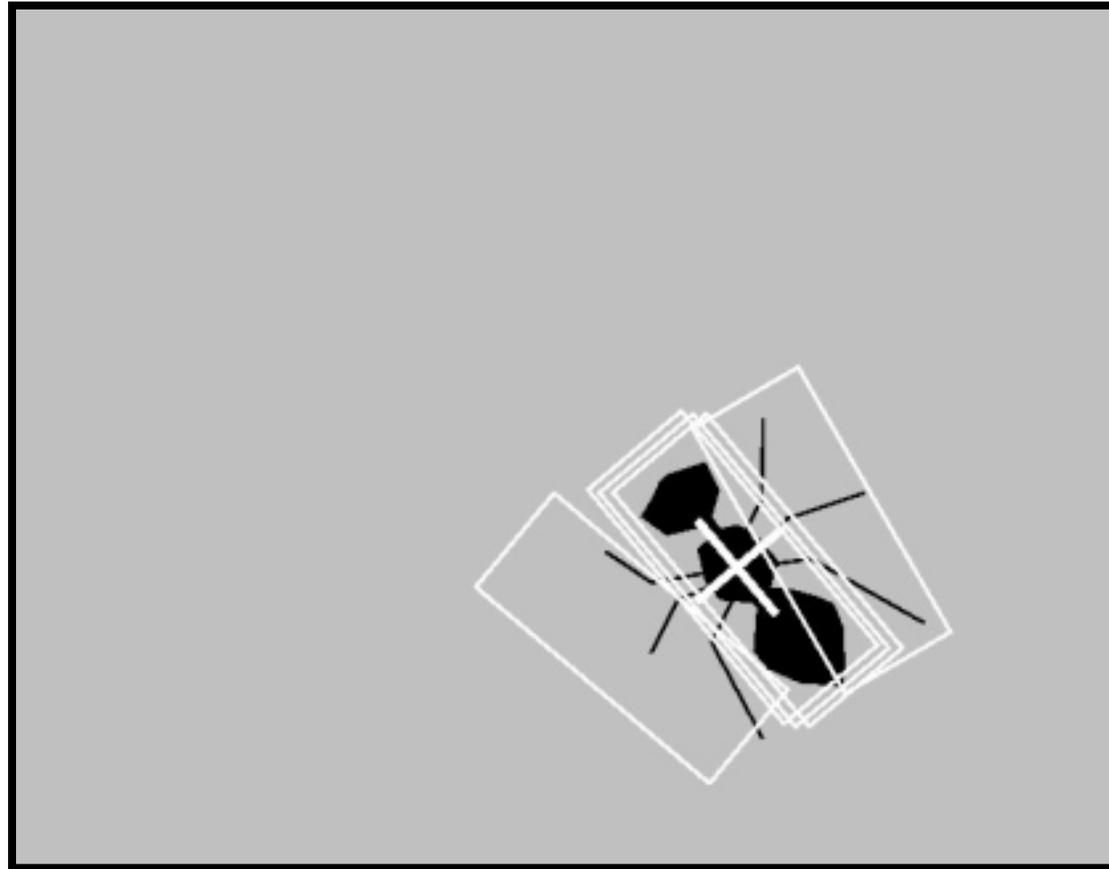
Score



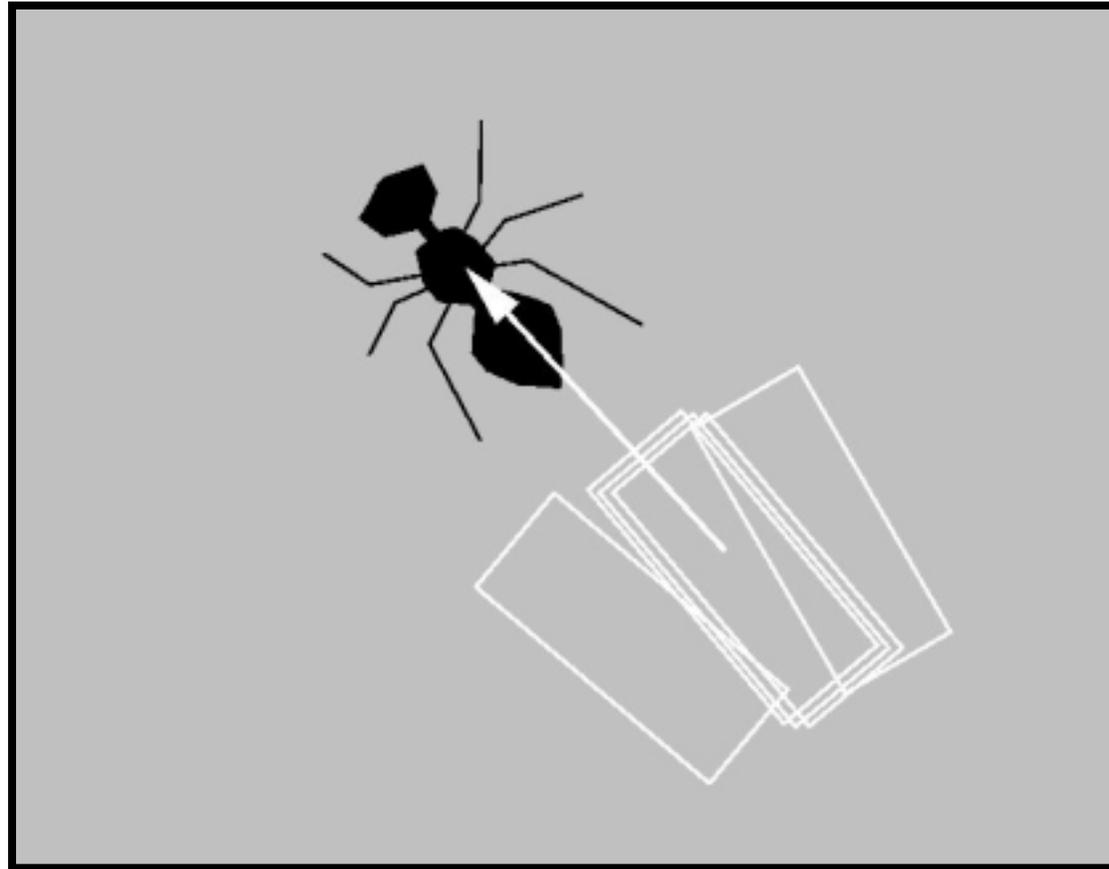
Resample



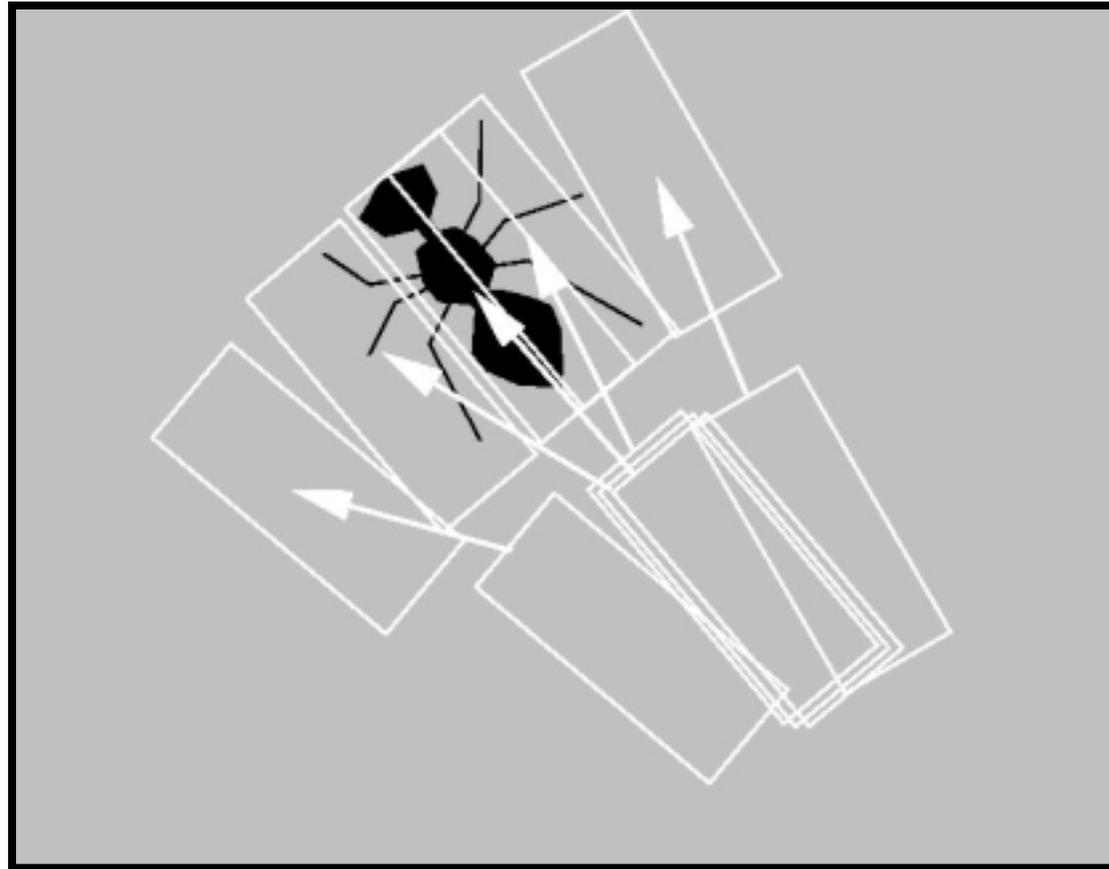
Position estimate



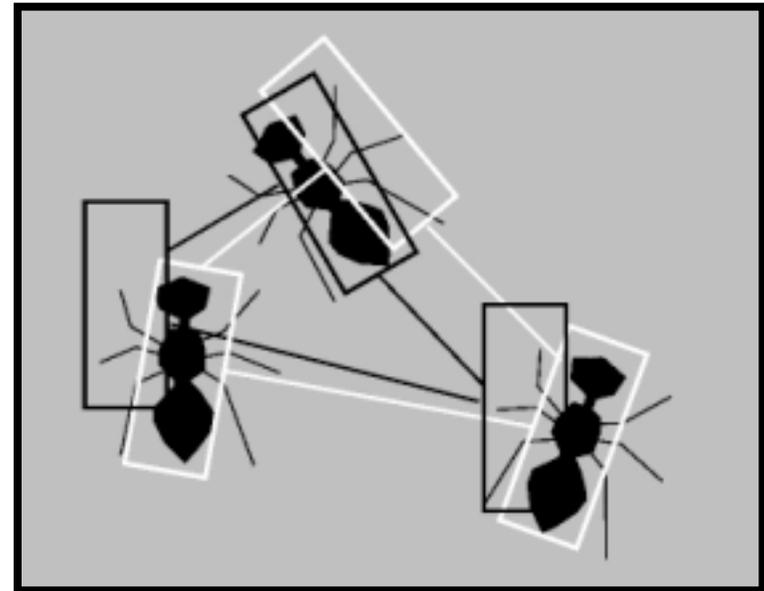
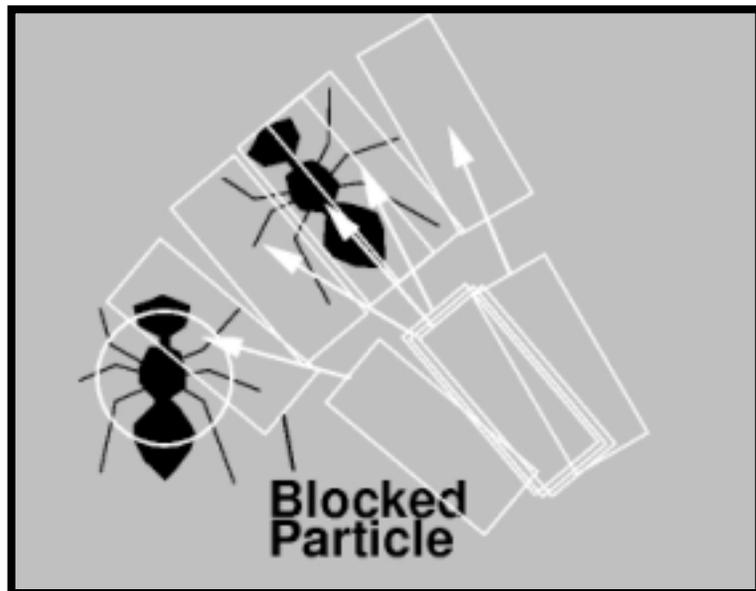
Target Movement



Apply motion model



Refinements



Khan, Balch, Dellaert, CVPR-04, CVPR-05, PAMI

Tracking results



Other appearance-based techniques



Eigenbees: Khan & Dellaert; Parts: Schindler & Dellaert

Detection-based tracking

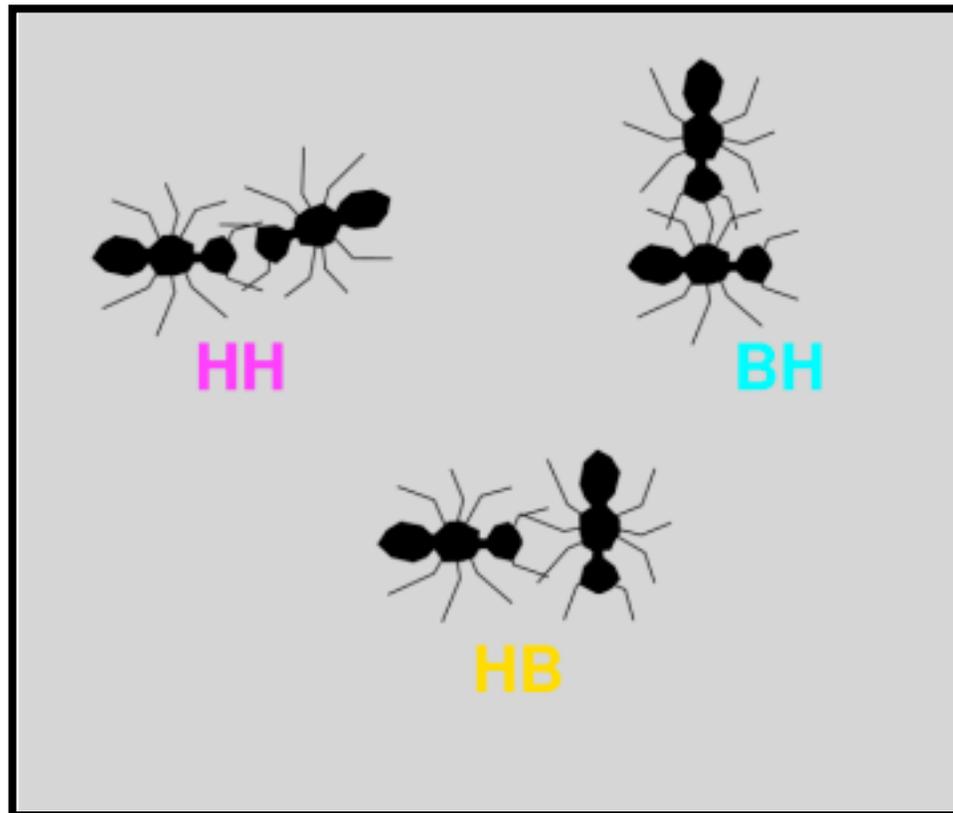


Khan, Balch & Dellaert

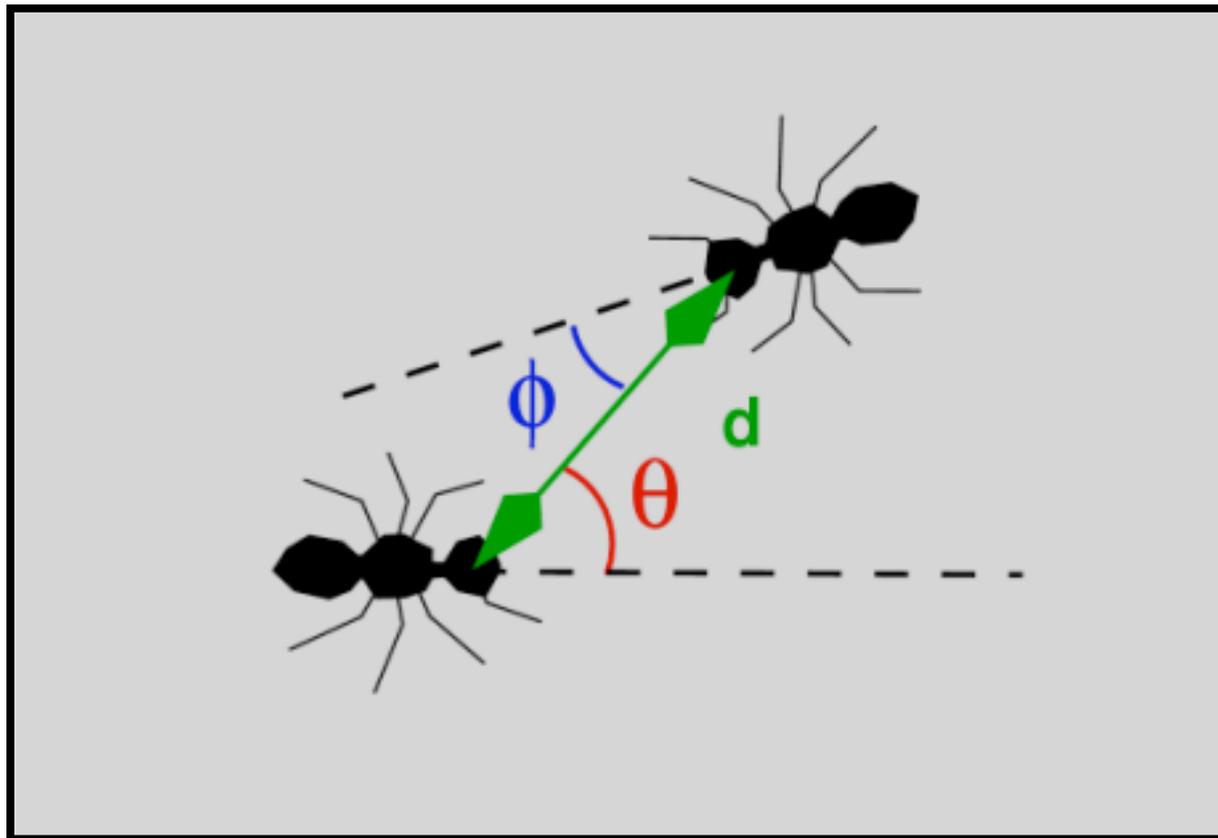
Labeling: Problem statement

- Given:
 - Animal trajectories over time
 - Quantitative features over trajectories
 - Example labeled data
- Compute:
 - Correct labeling (segmentation) of trajectories
- Assume:
 - Features are relevant
 - Example labels are correct

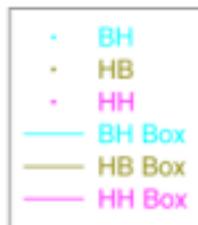
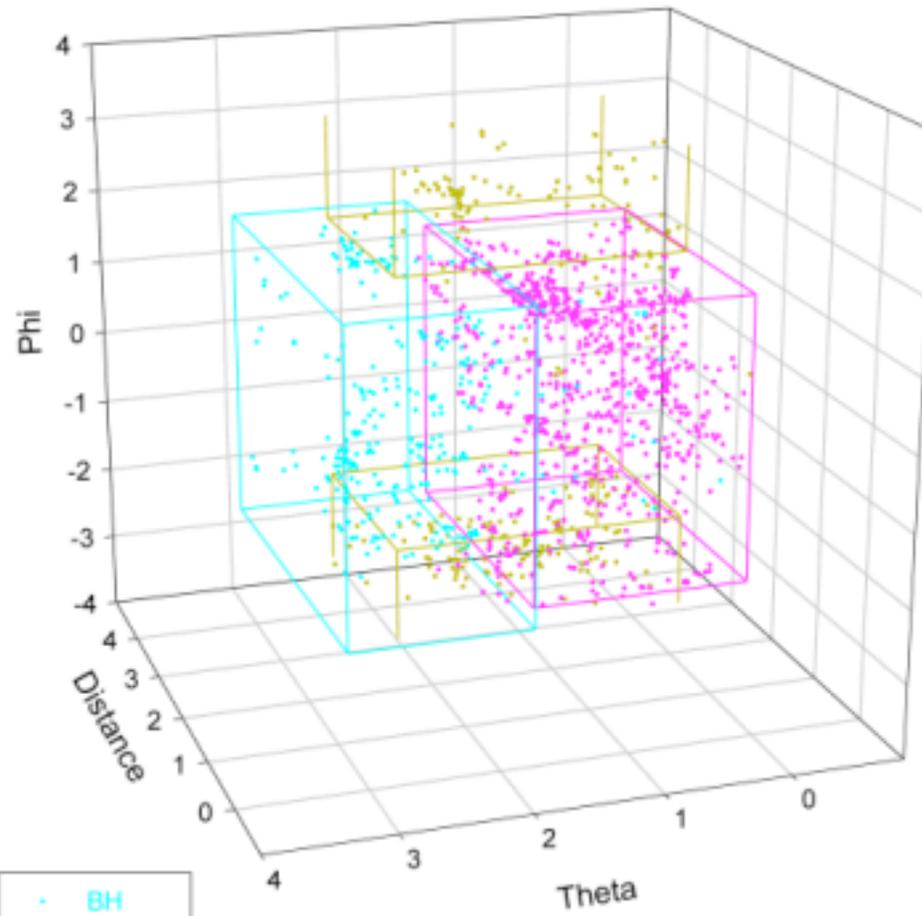
Detecting interactions



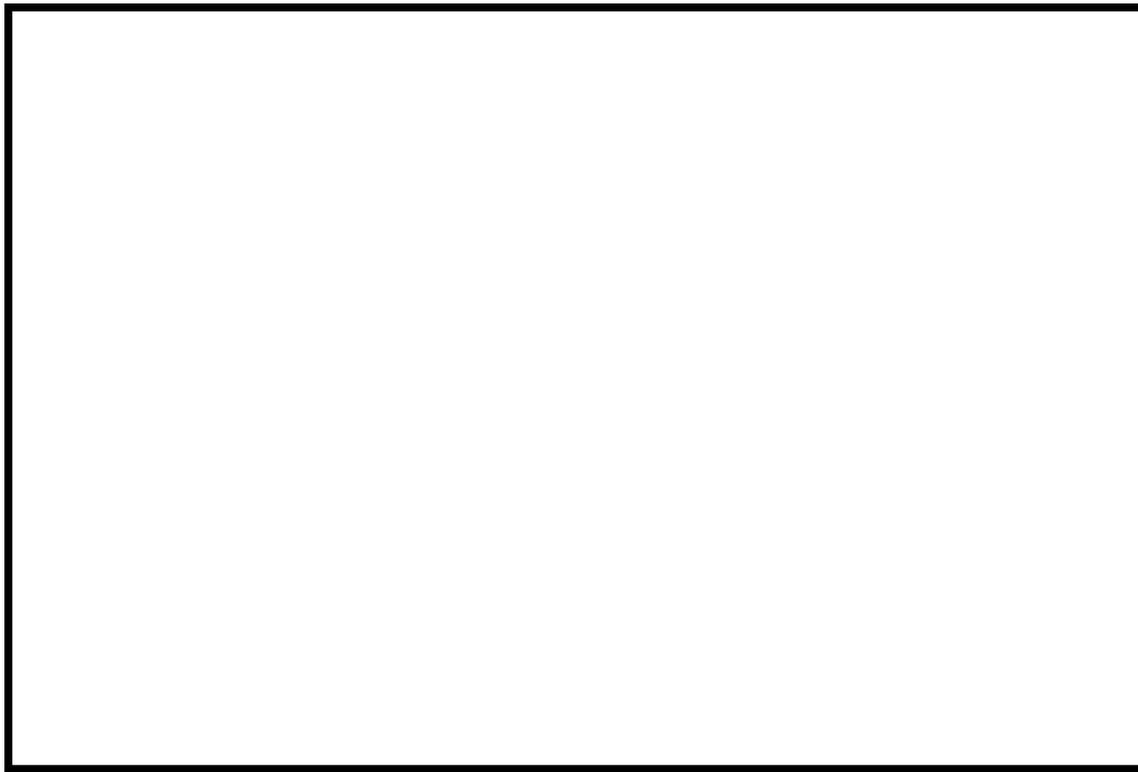
Interaction features



All Labels (with boxes)



Automatically labeled interactions



result

Model-based techniques

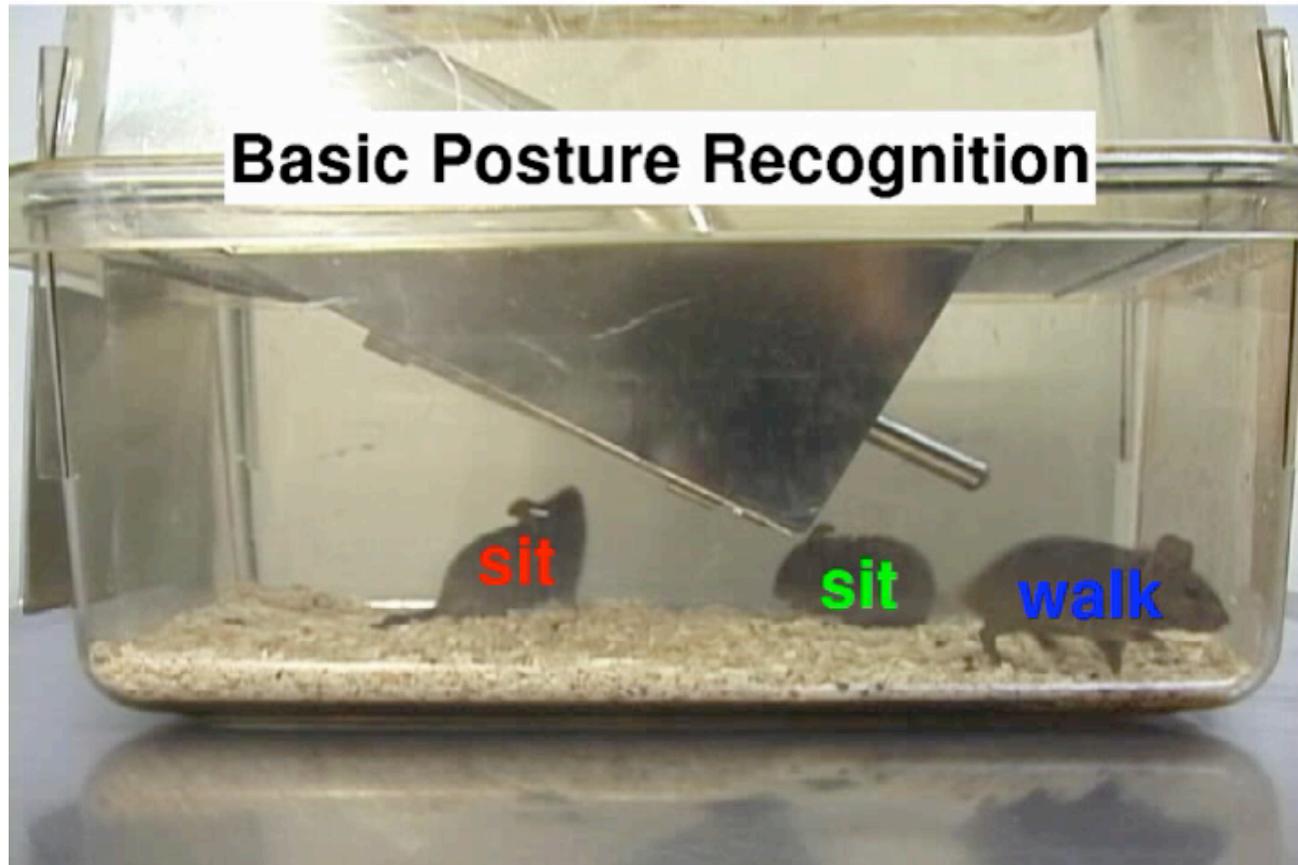


- HMMs: Feldman & Balch, *Adaptive Behavior*
- SLDSs: Oh, Balch, Rehg & Dellaert, *AAAI-05*

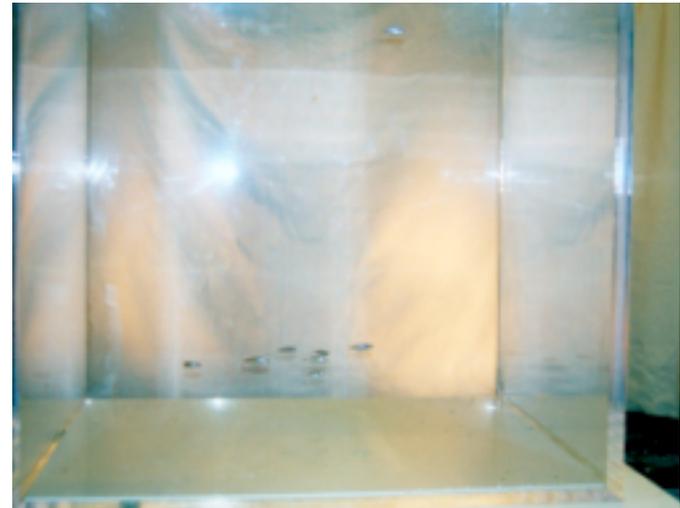
Others doing similar work

- Couzin, Oxford
- Parrish, Viscido & Grunbaum, Washington
- Belongie, UCSD
- Ratnieks, UK
- Franks, UK
- Theraulaz, France

Belongie: Smart vivarium



Parish & Grunbaum: Fish schools



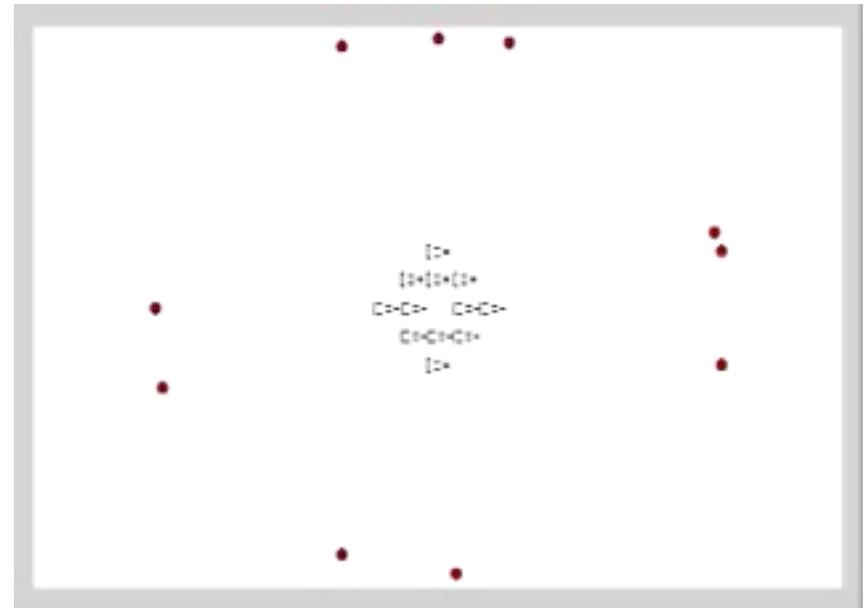
Parrish & Grunbaum



Labeling is not enough

- Labeling provides/supports:
 - Classification of movements, motions, activities
 - Role identification
 - Opponent strategy identification
- Labeling does not provide:
 - Explanation of how or why an animal chooses a motion
 - Testable models of behavior
- We need *executable models!*

Executable models

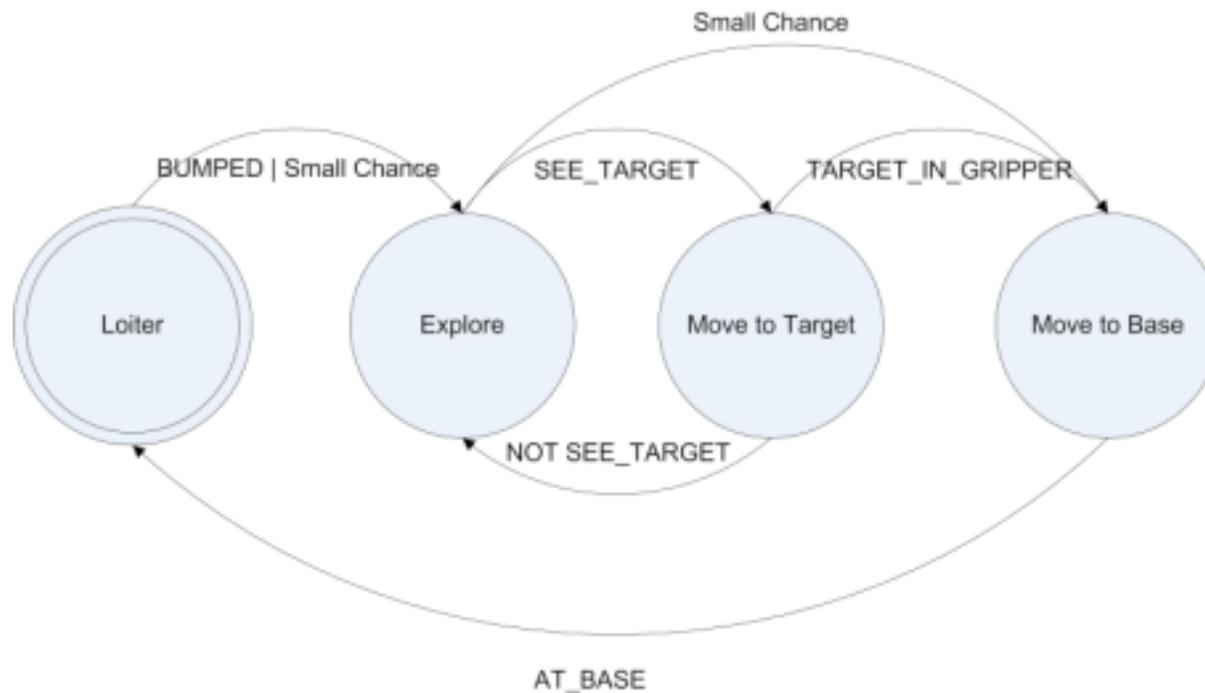


Learning executable models: Problem statement

- Given:
 - Low-level controllers (*or labeled trajectories*)
 - Animal trajectories over time
 - Perceptual features that cause transitions
- Find:
 - Most likely switched controller
- Assume:
 - Animal uses a switched controller

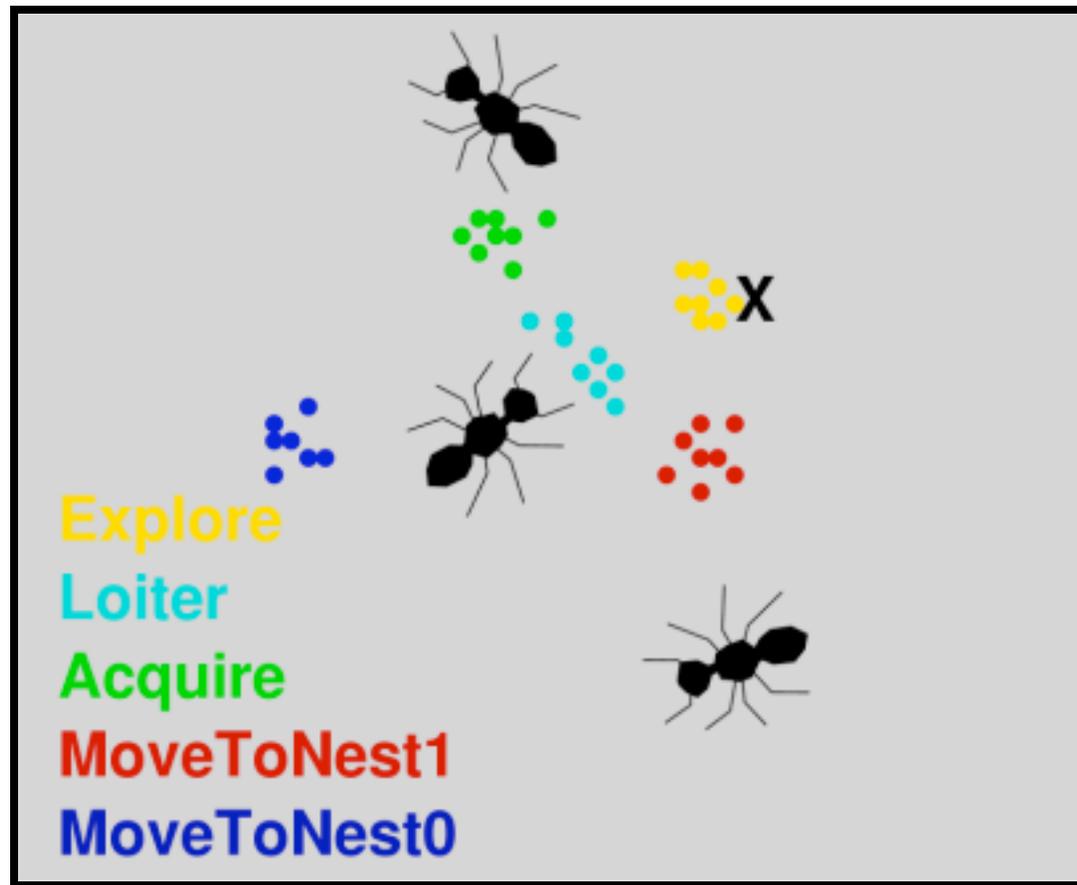


Approach: Treat as I/O HMM learning problem

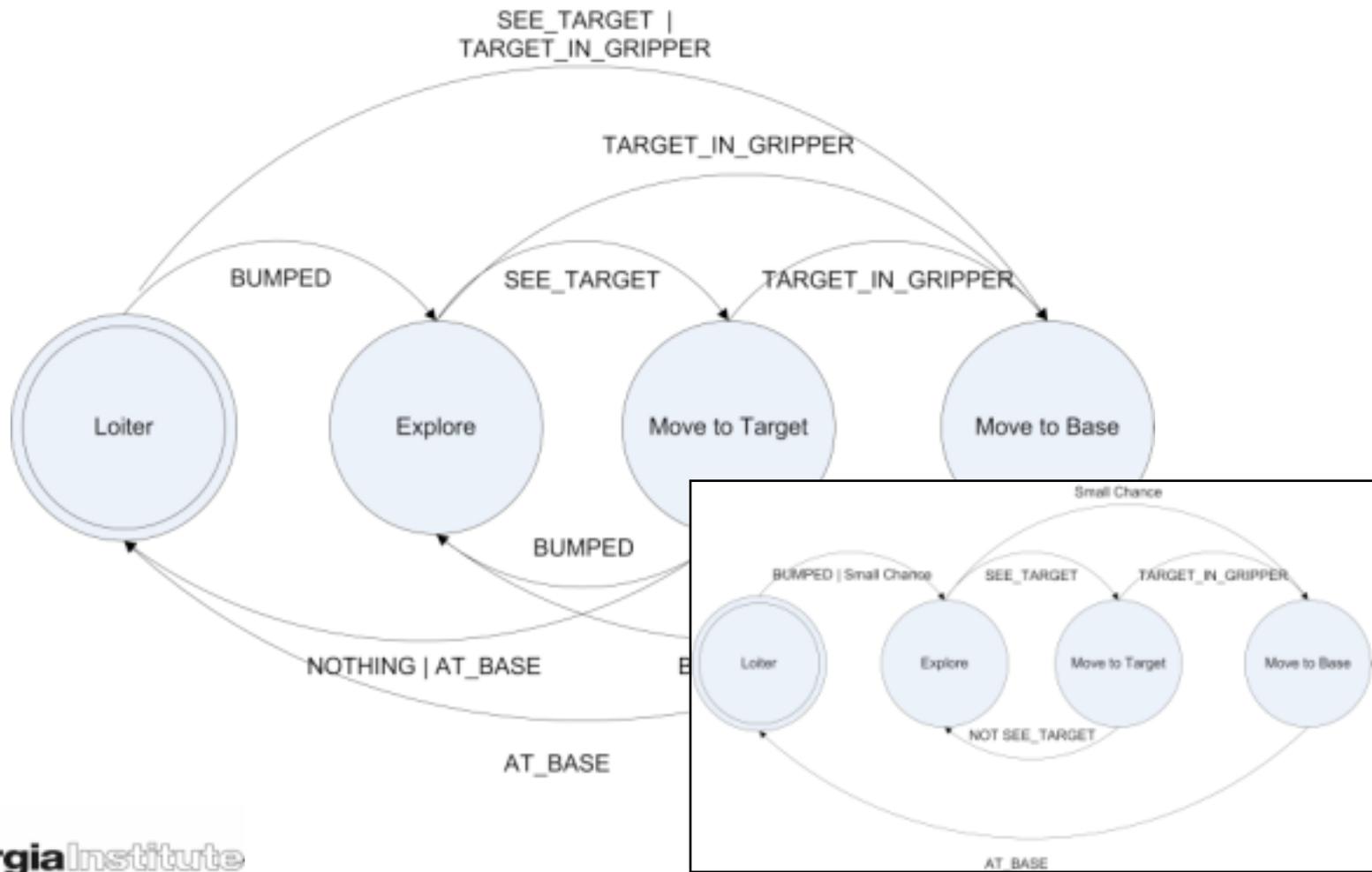


Guillory, Balch & Isbell, *submitted*

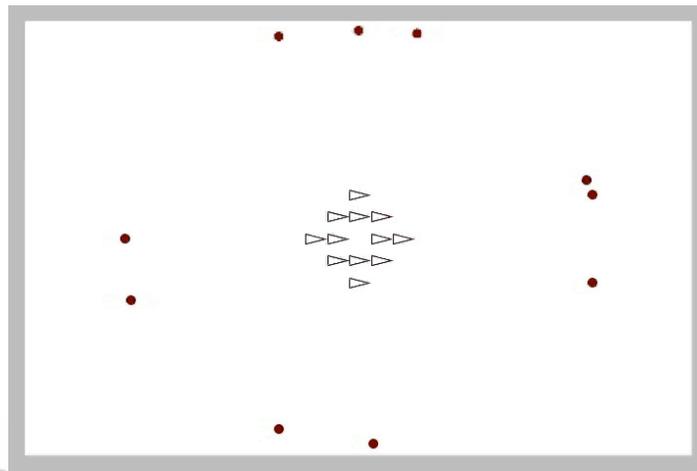
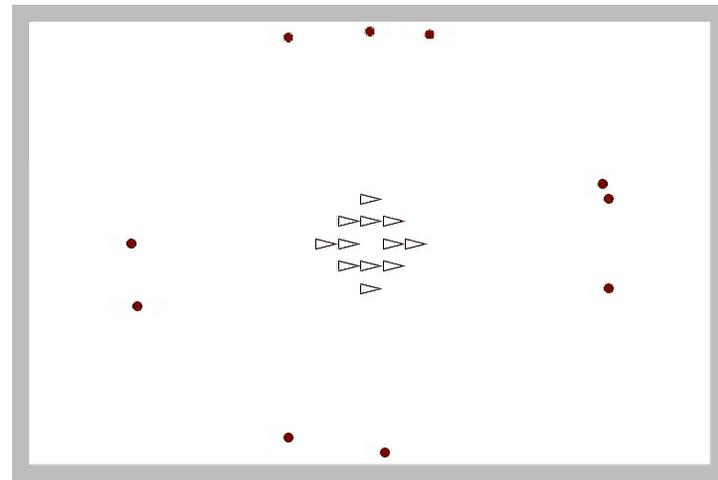
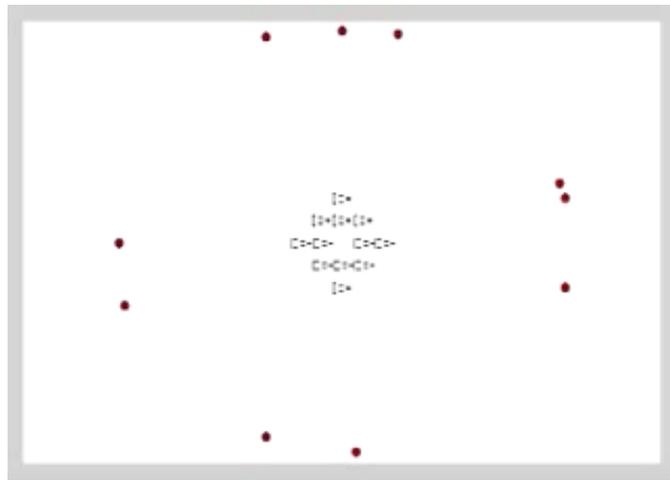
Idea: Sample from controllers as motion models



Learned controller

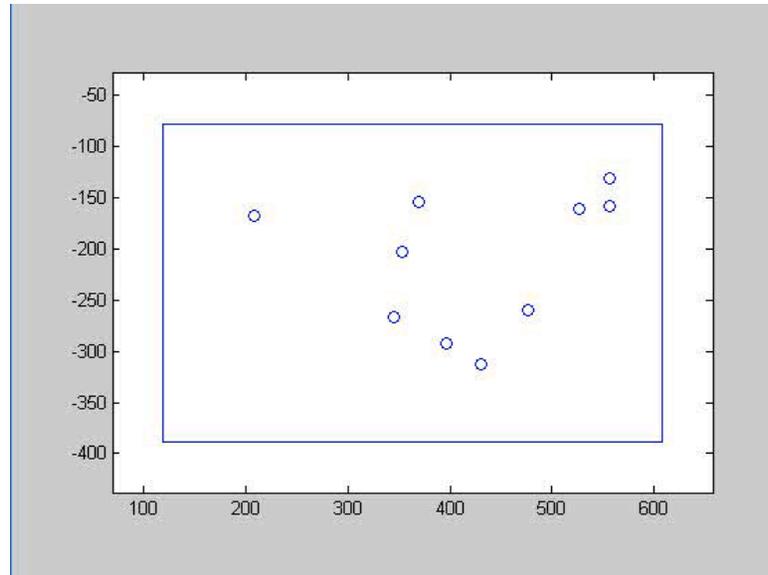


Qualitative comparison



What if you don't have the controllers?

- Learn them from labeled data



Egerstedt, Delmotte, Balch, Khan, Dellaert, ICRA 05

Summary and next steps

- Track, label, quantify, model
- Learn executable models from live animal data
 - Ants
 - Humans
 - Monkeys
- Test models experimentally
 - Do they correctly predict the performance of the real thing?

