Social Robot Navigation with Braids

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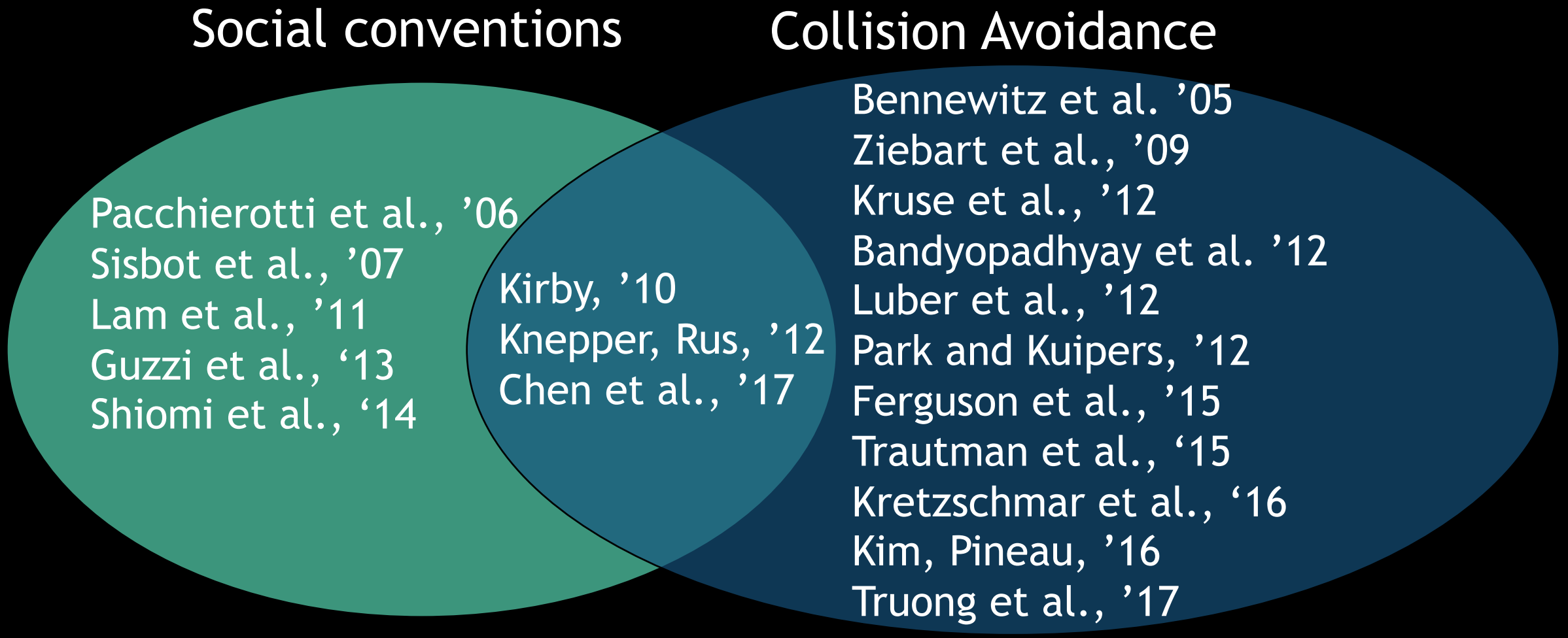
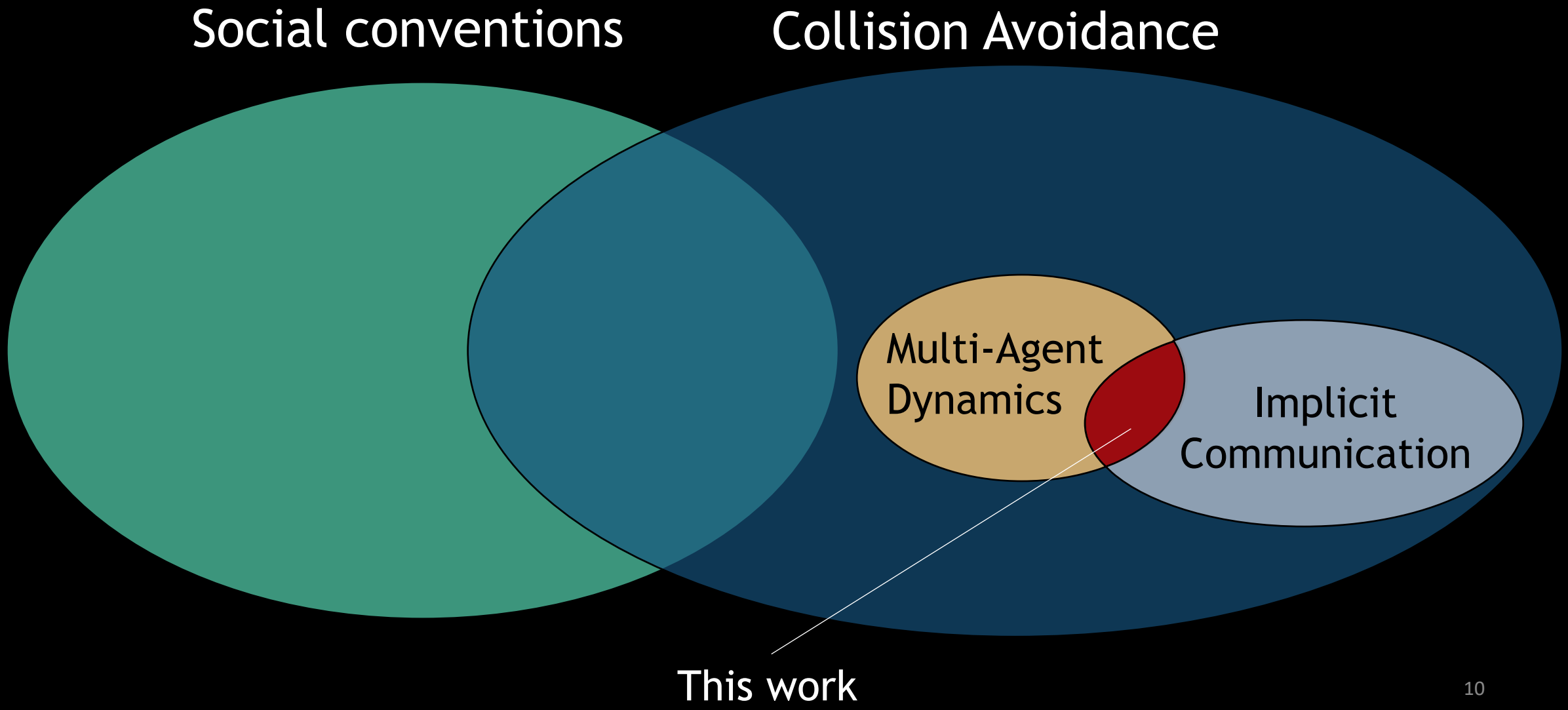
https://www.recode.net/2017/1/18/14306674/starship-robot-food-delivery-washington-dc-silicon-valley

Social Robot Navigation

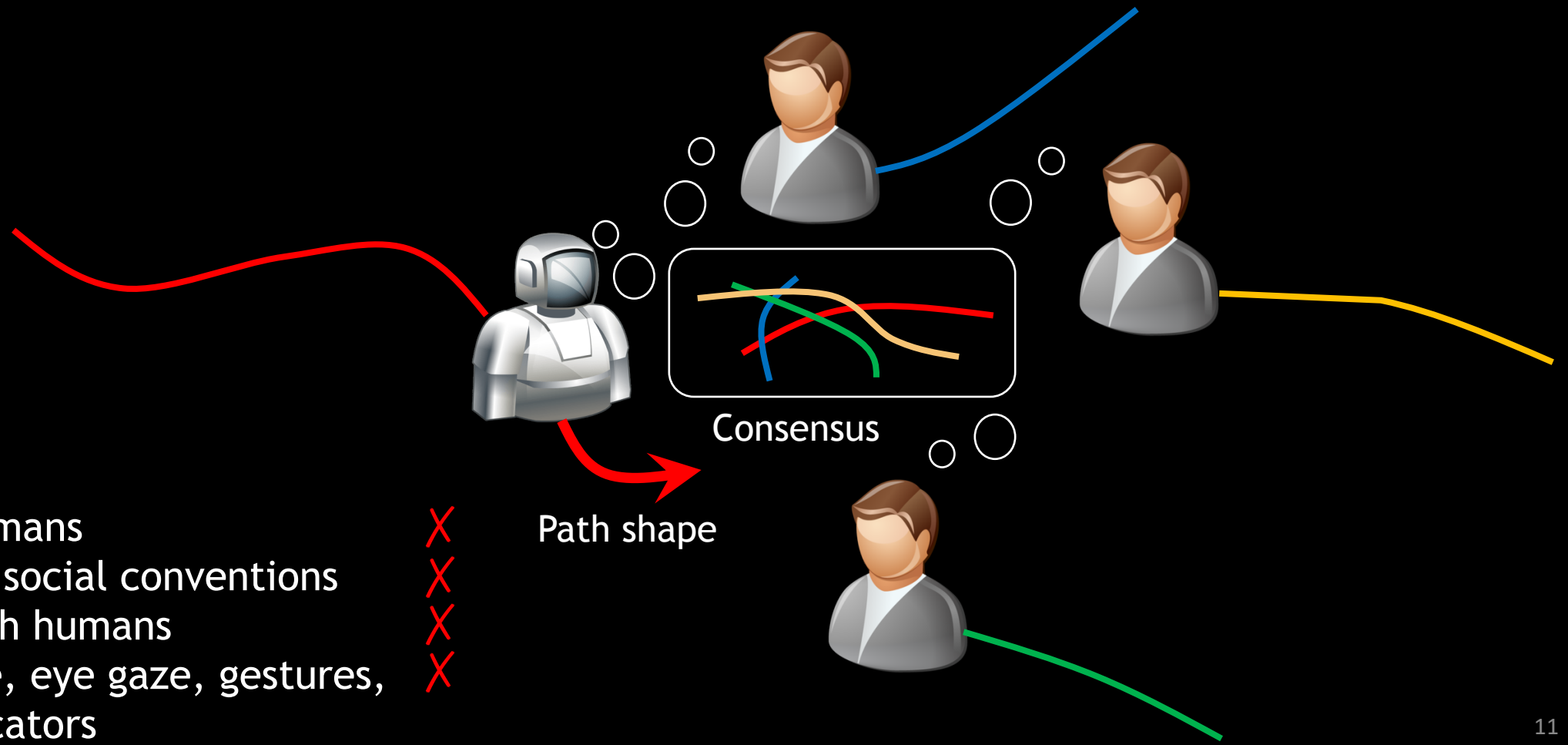
Related Work



Related Work



This Work



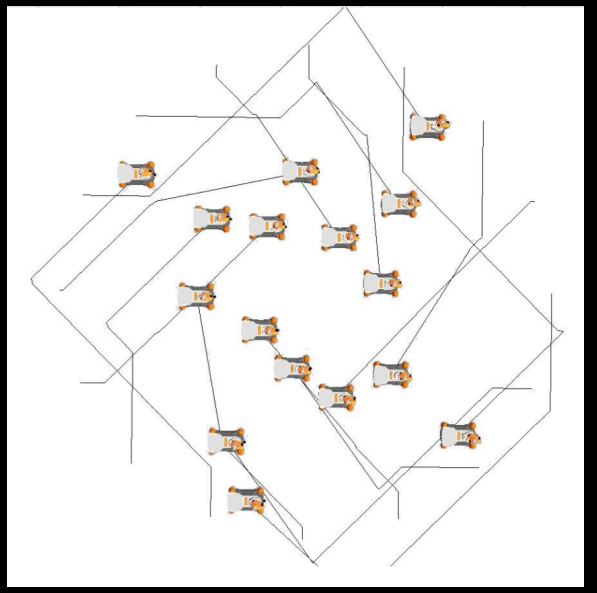
Imitating humans X
Reproducing social conventions X
Engaging with humans X
Body Posture, eye gaze, gestures, explicit indicators X

Foundations

Human Navigation is Cooperative

-People must behave like competent pedestrians.
-People must trust co-present others to behave like competent pedestrians.

Wolfinger, ’95

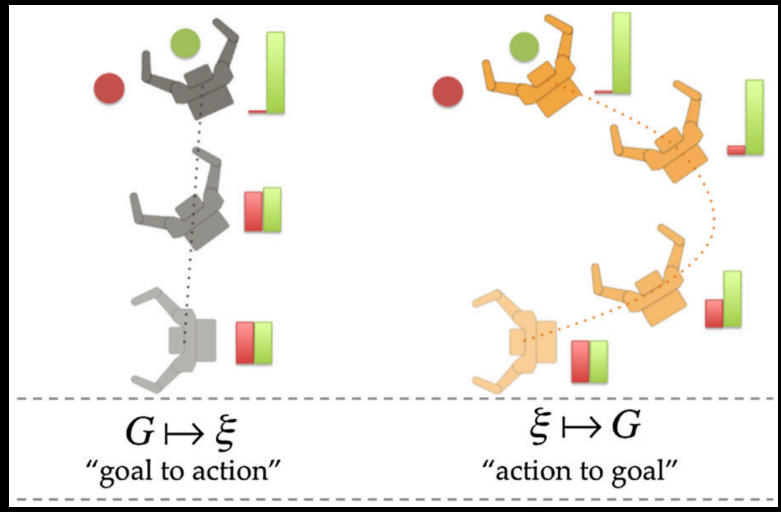


Knepper, Rus, ’12

Human Inference is Goal-directed

"Humans show a strong and early inclination to interpret observed behaviours of others as goal-directed actions".

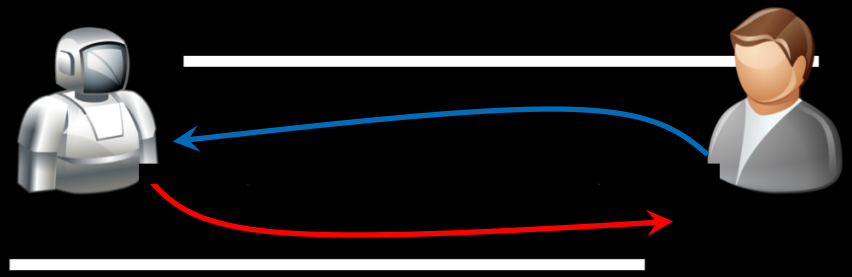
Csibra, Gergely, '07



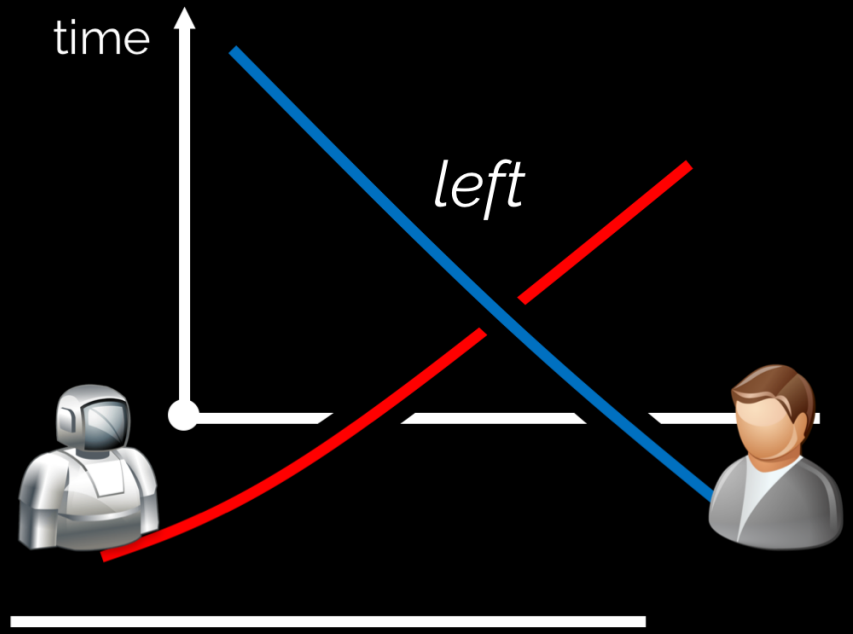
Dragan, Srinivasa, '13

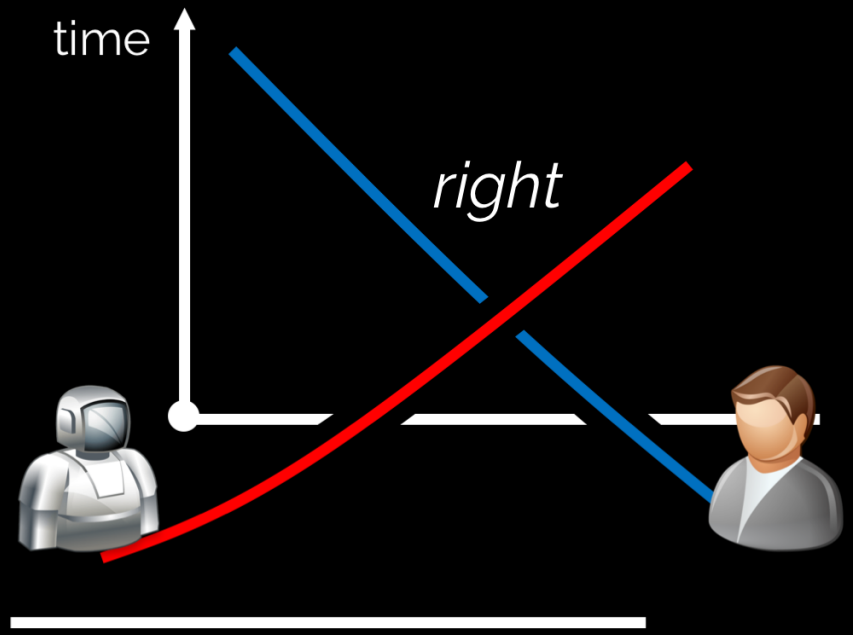
What is a Goal?

- Multi-agent dynamics
- Decision making is coupled
- Observers are also actors
- Not crucial to know destinations or trajectories
- Consensus is the goal!



Planning Legible Navigation Strategies


time
left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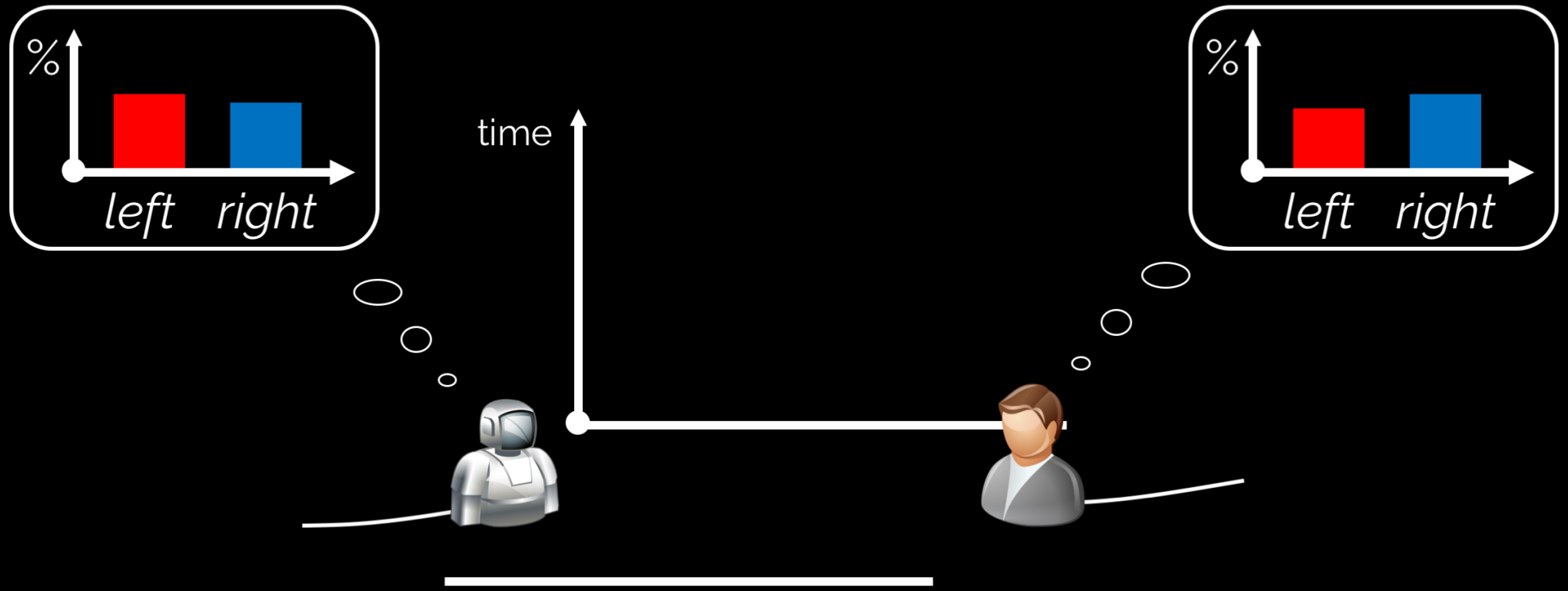
%
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time
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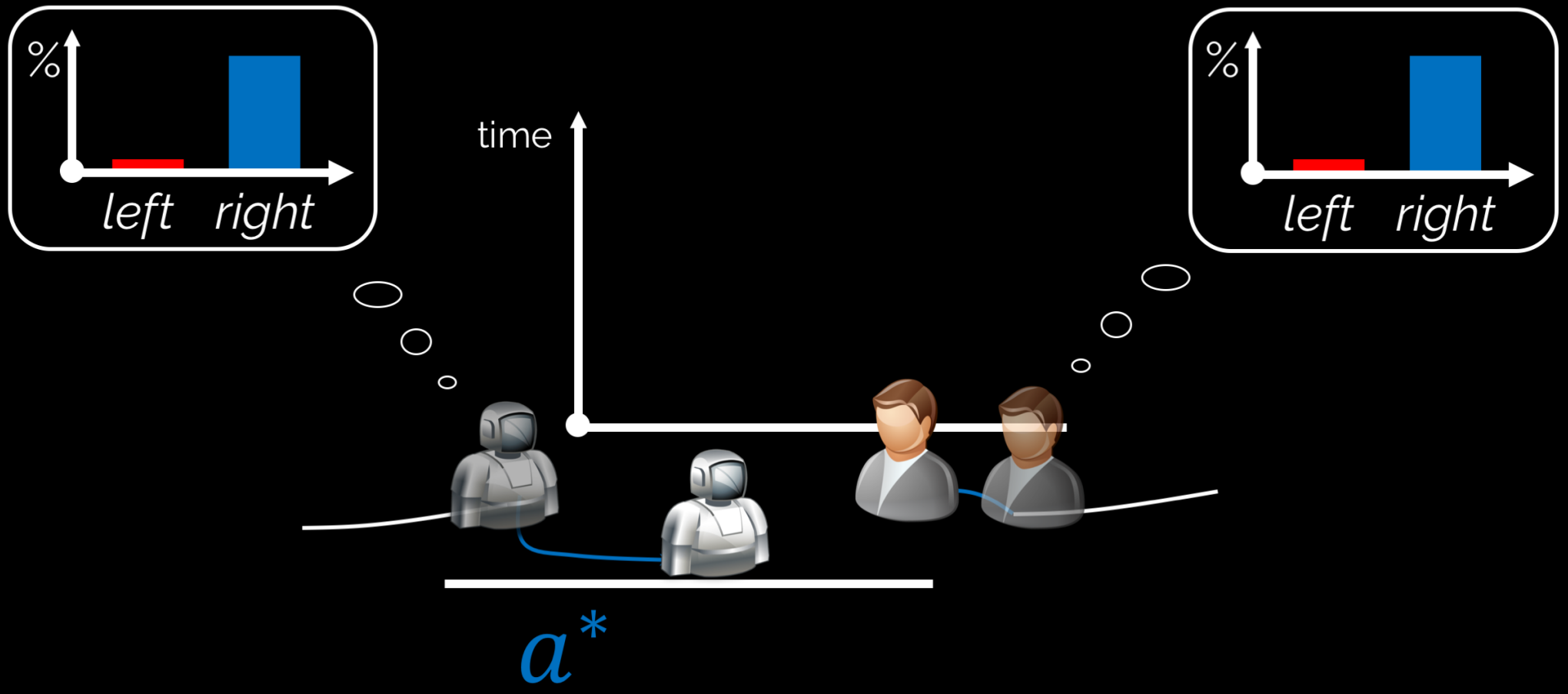
Legibility as *Entropy* minimization



What about *n* agents?

Insight: The maypole dance

https://www.flickr.com/photos/peteashton/174913998/in/set-72157594176644454/

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Insight Encouragement

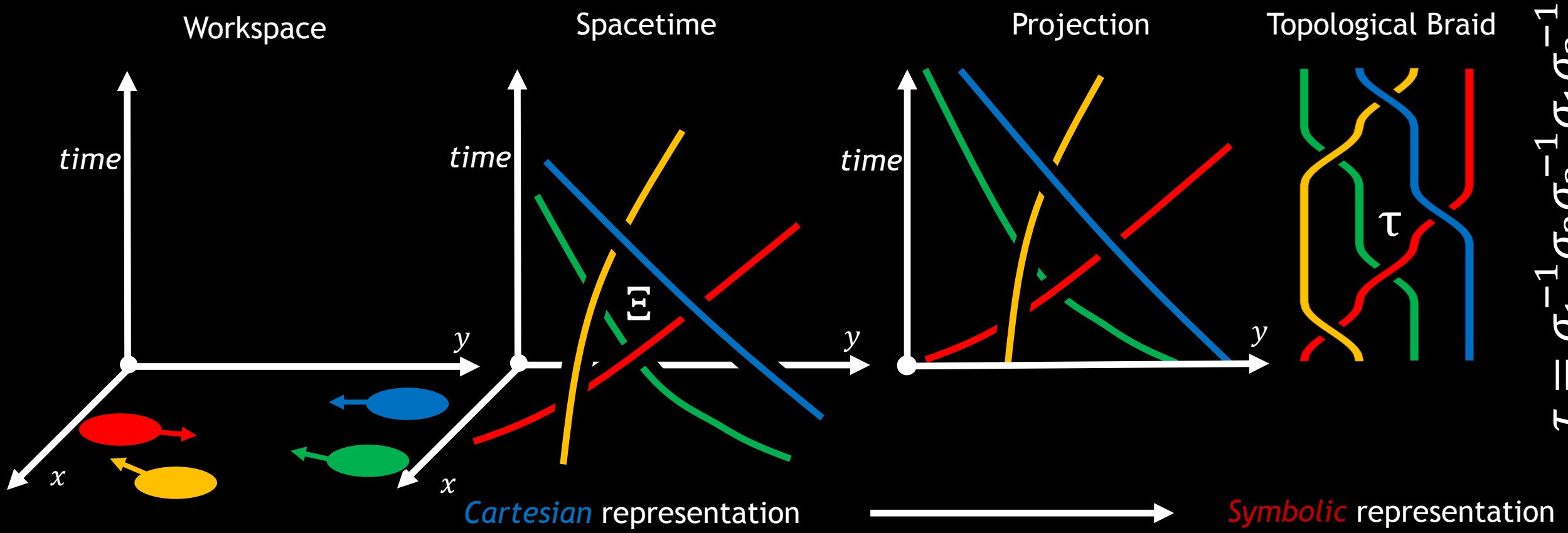
MATH

The maypole braid group

Posted by DAVE RICHESON *on* MAY 4, 2009

https://divisbyzero.com/2009/05/04/the-maypole-braid-group/

What about *n* agents?



The Braid Group B_n

σ_1 σ_2 σ_{n-1}

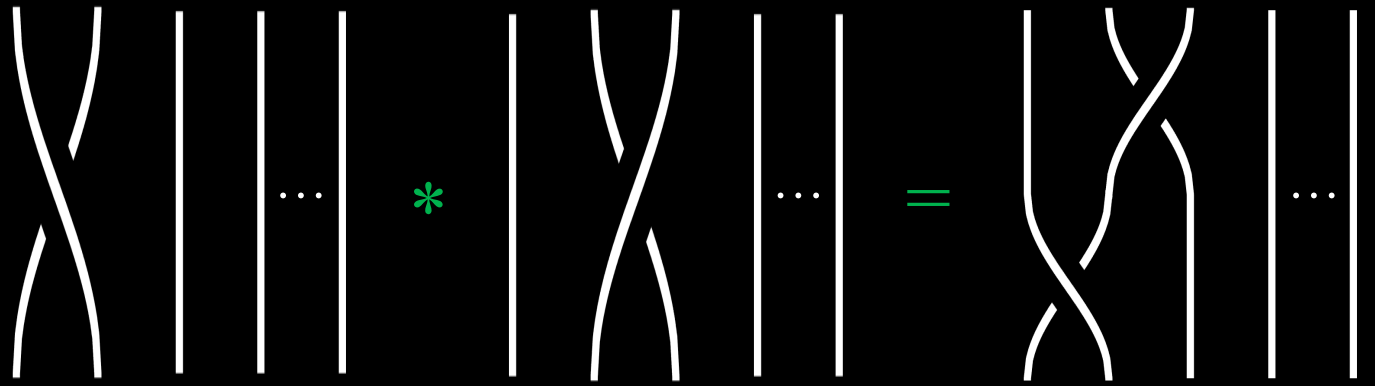
Relations

$\sigma_j \sigma_k = \sigma_k \sigma_j, |j-k| > 1$

$\sigma_j \sigma_k \sigma_j = \sigma_k \sigma_j \sigma_k, |j-k| = 1$

Composition

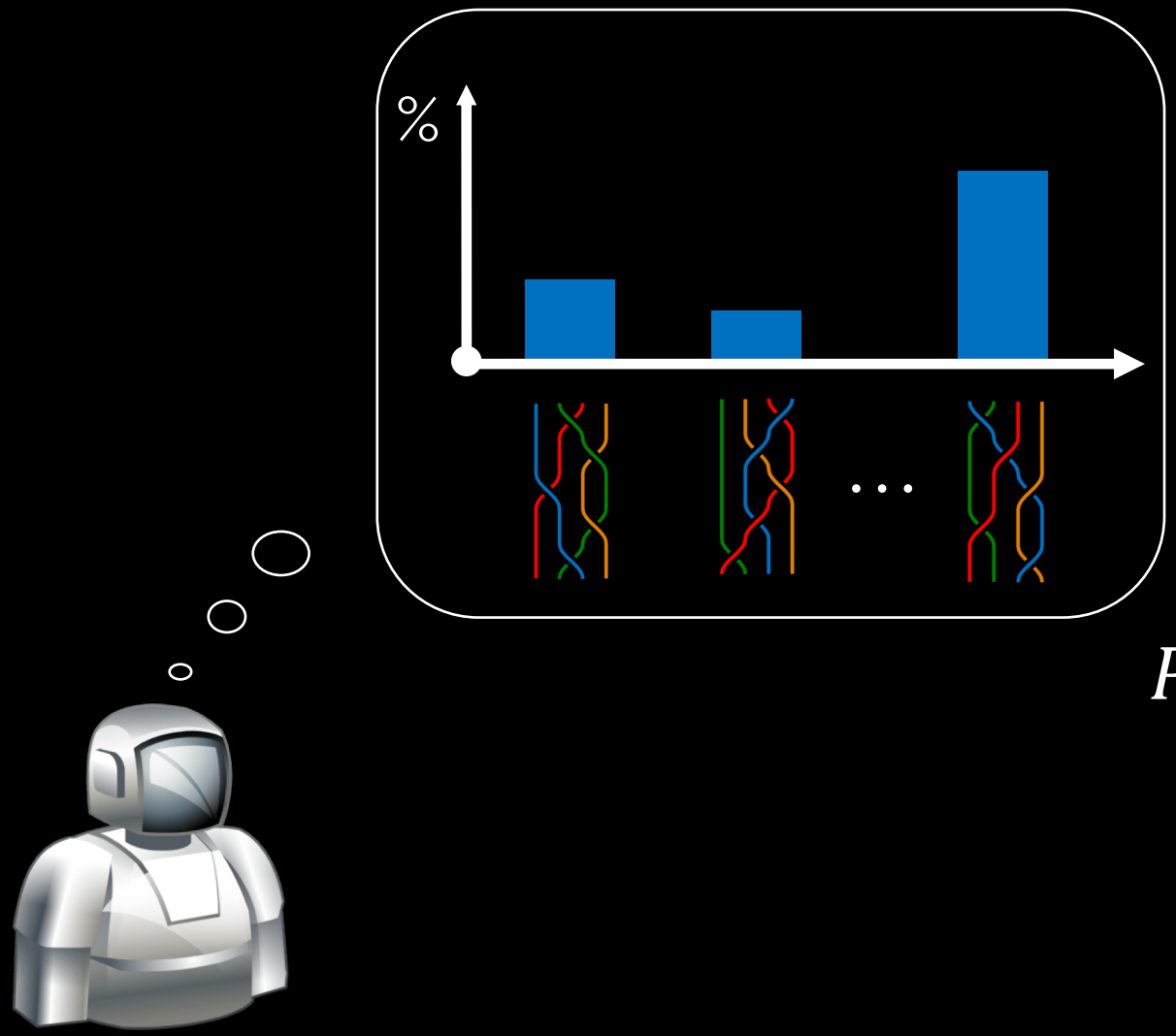
Inverse



σ_1^{-1} σ_2 $\sigma_1^{-1}\,\sigma_2$

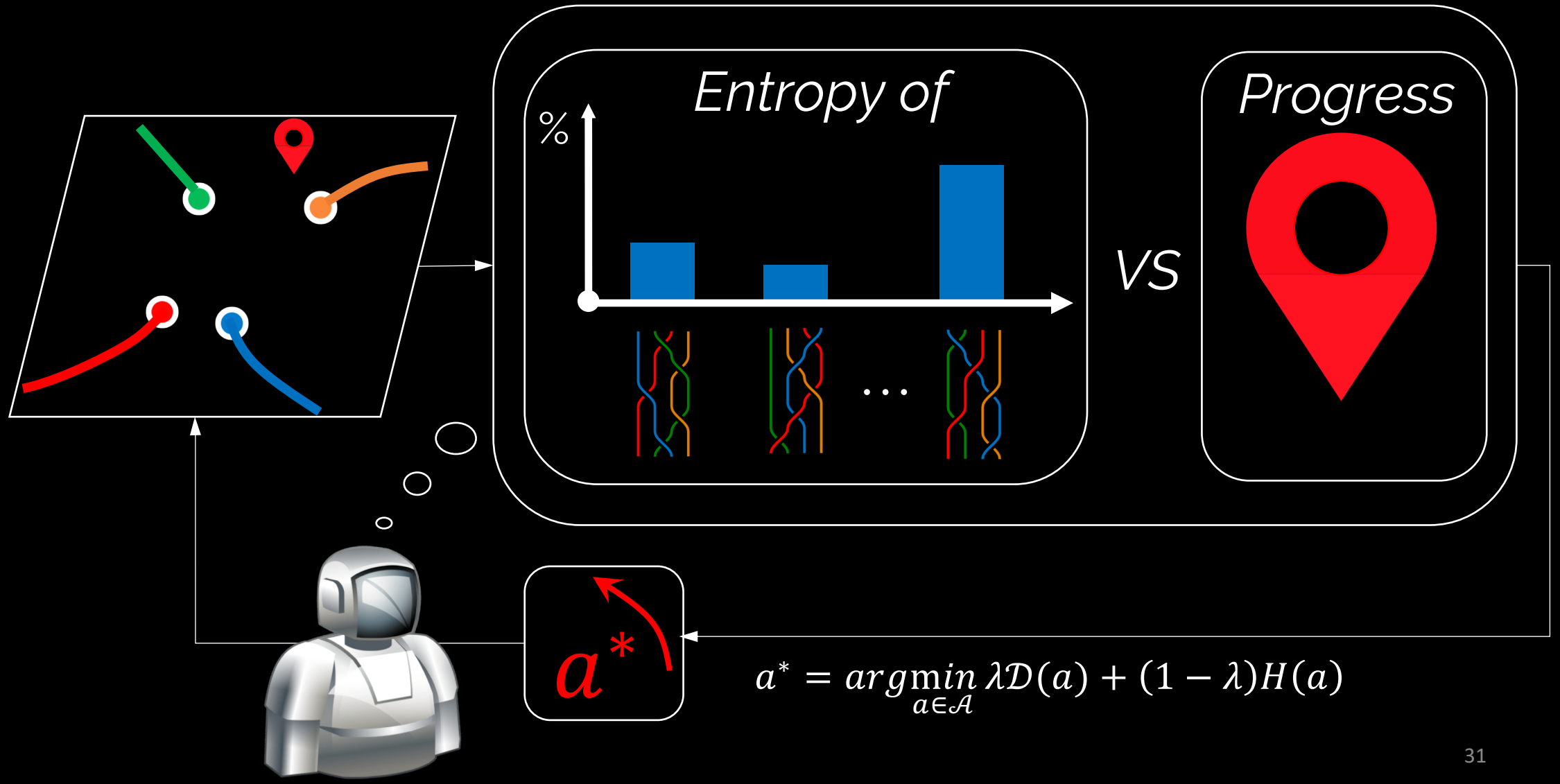
[Birman, ’75]

Reasoning about Joint Navigation Strategies



$P(\tau|\Xi, \alpha)$

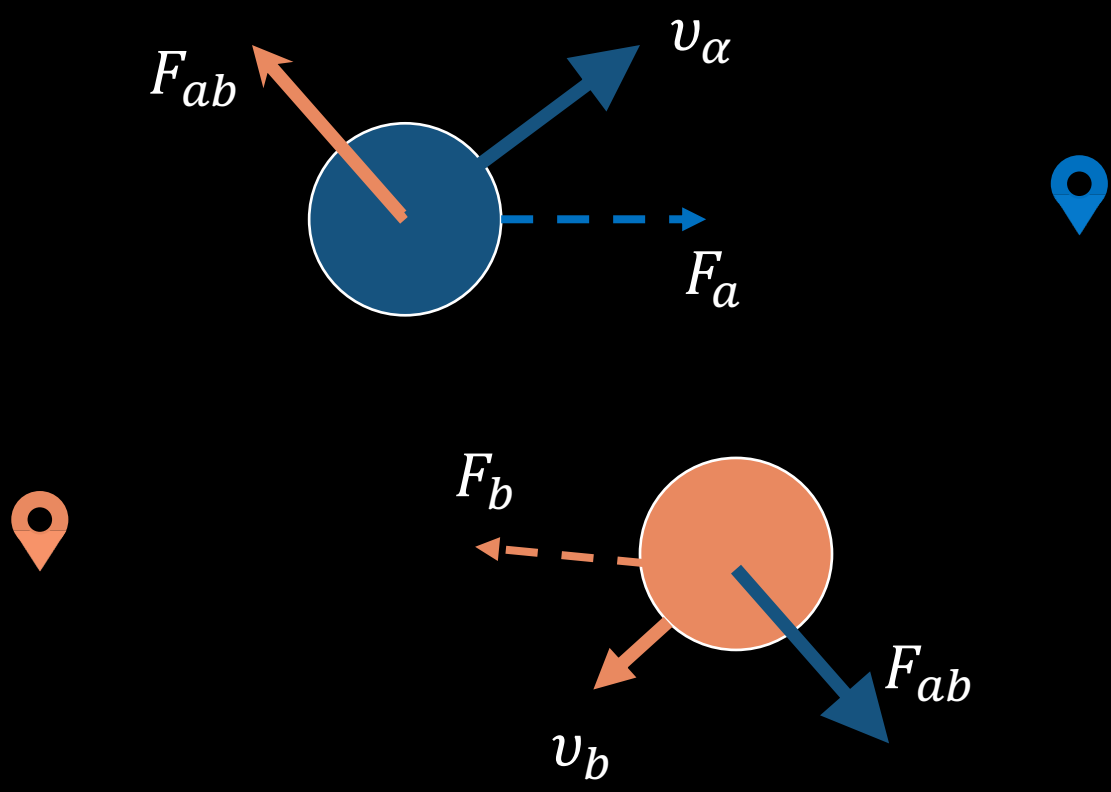
SCN: Socially Competent Navigation



Learning a Topology Prediction Model

- Multi-agent scenarios (2,3,4 agents)
- *Social Force* (*SF*) [Helbing, Molnár, ’95]

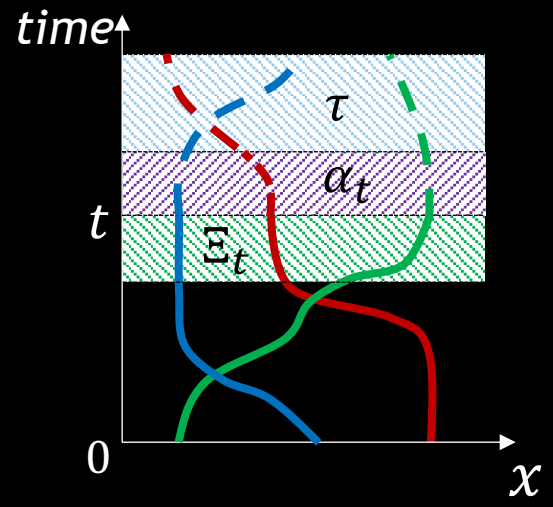
The Social Force Model

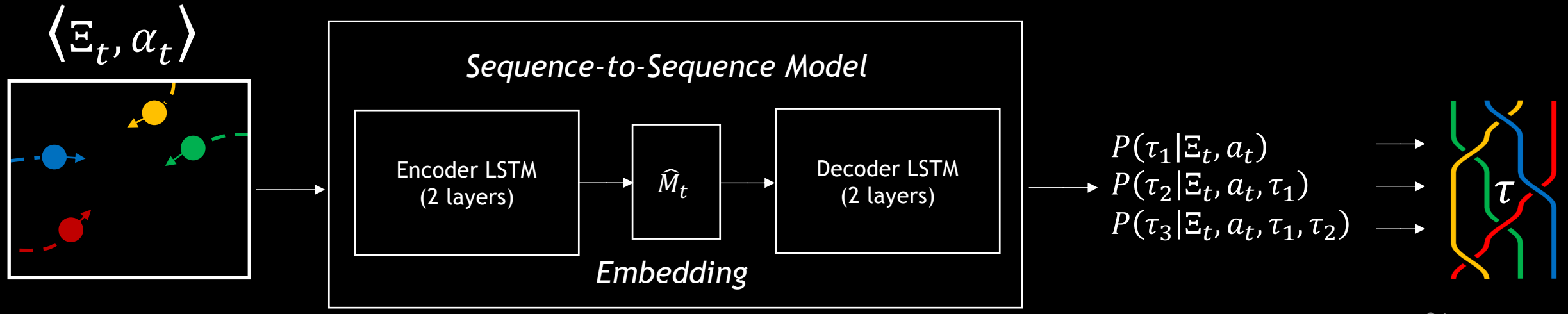


[Helbing, Molnár, ’95]

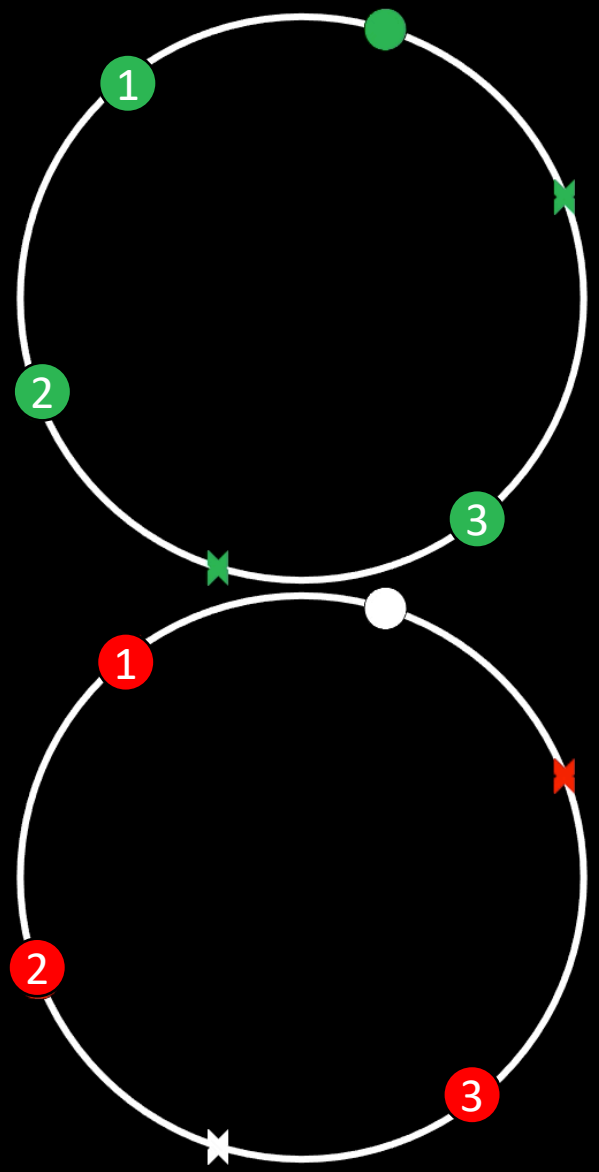
Learning a Topology Prediction Model

- Multi-agent scenarios (2,3,4 agents)
- *Social Force* (*SF*) [Helbing, Molnár, ’95]
- Rectangular/circular workspace

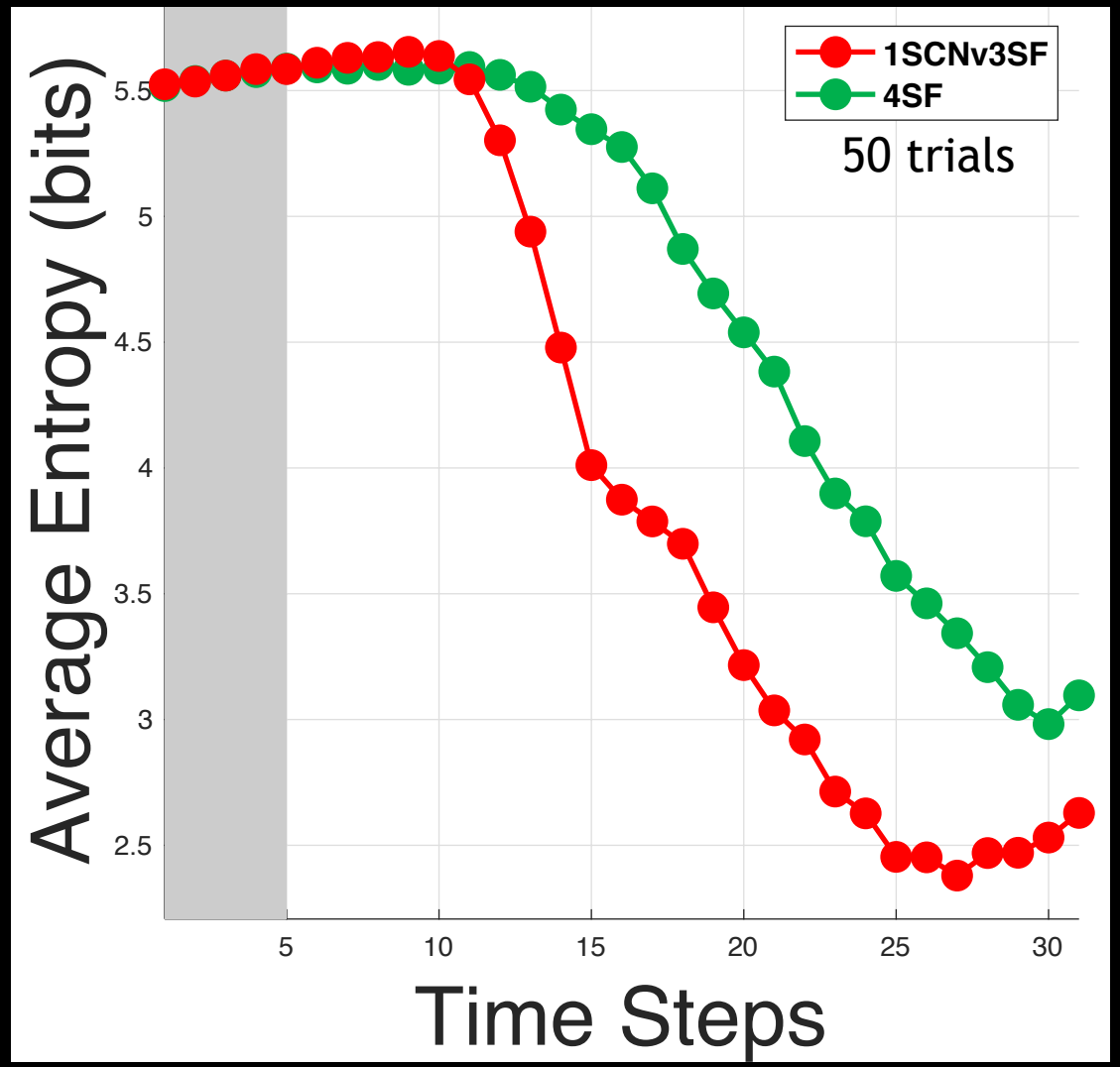




Topology Inference Accelerates Consensus



Low is better



Summary

- A symbolic representation for multi-agent navigation
- Legibility as entropy minimization
- Topology inference sufficient for effective coordination

- Computationally intense
- Projection results in loss of information
- Captures phenomena that are not necessarily useful
- Different numbers of agents, different models