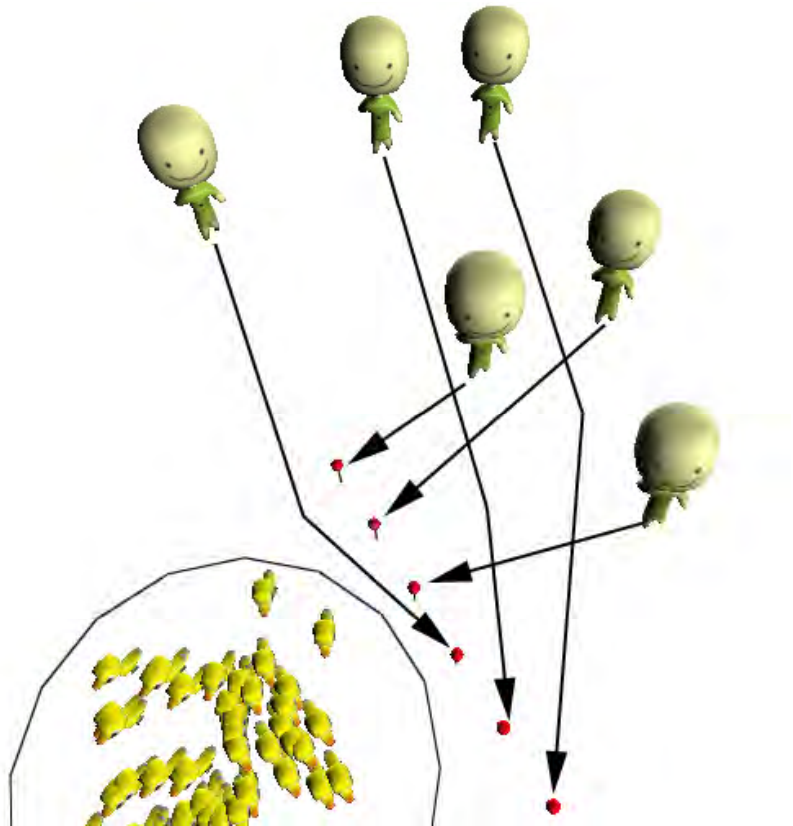
Behavior Based Motion Planning for Group Control

Christopher Vo **Joseph F. Harrison** **Jyh-Ming Lien**

Motion and Shape Computing Group (MASC)
Department of Computer Science
George Mason University
Fairfax, Virginia, USA



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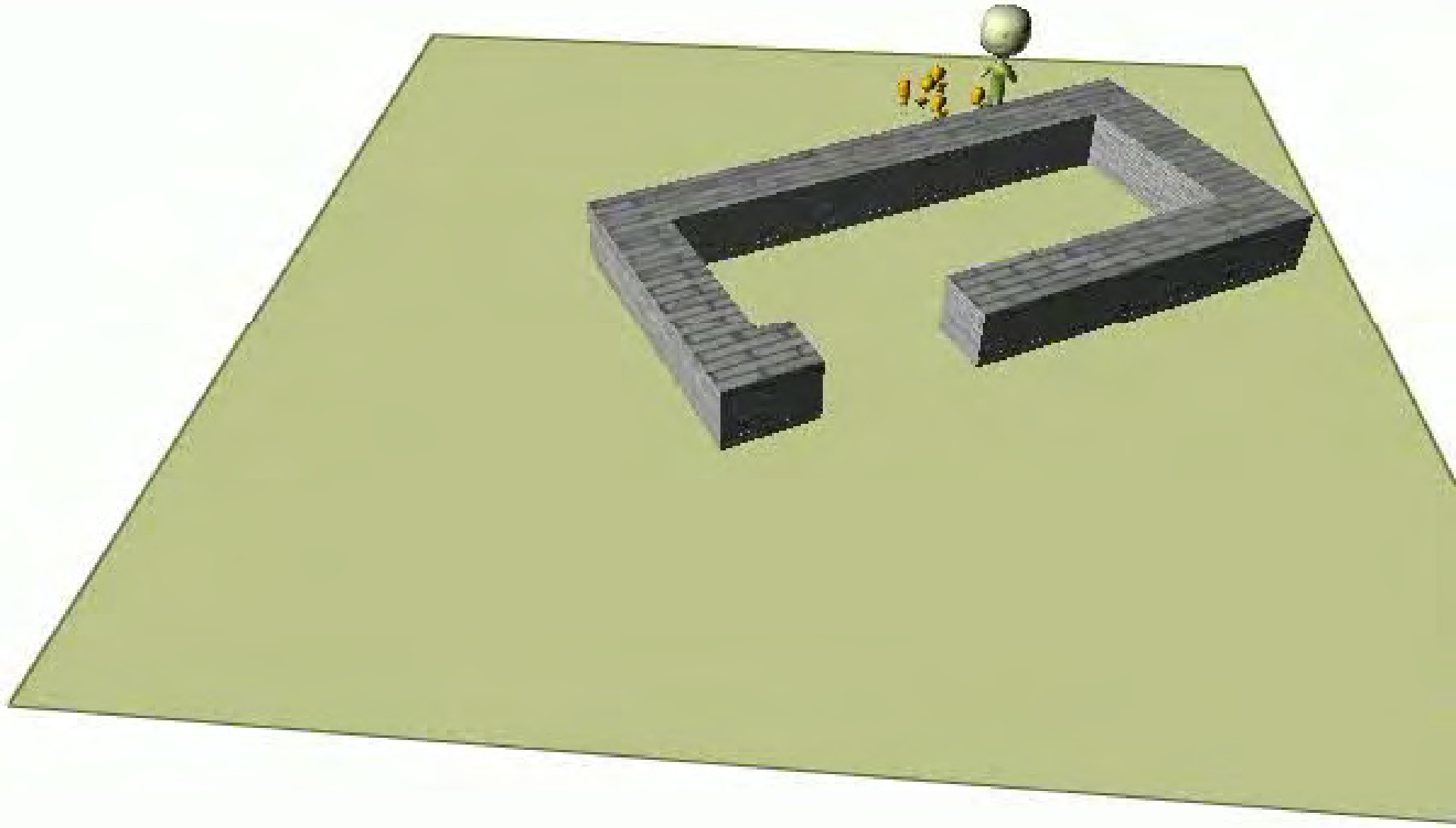
Group Control Problems

- **Agriculture** – Animal herding (sheep, goats, cattle)
- **Civil crowd control** – Barriers, signs, alarms, cooling
- **Manipulation** - Deformable or fragile objects
- **Pollution control** – Collecting oil spills
- **Video games** – Motion planning for game AI

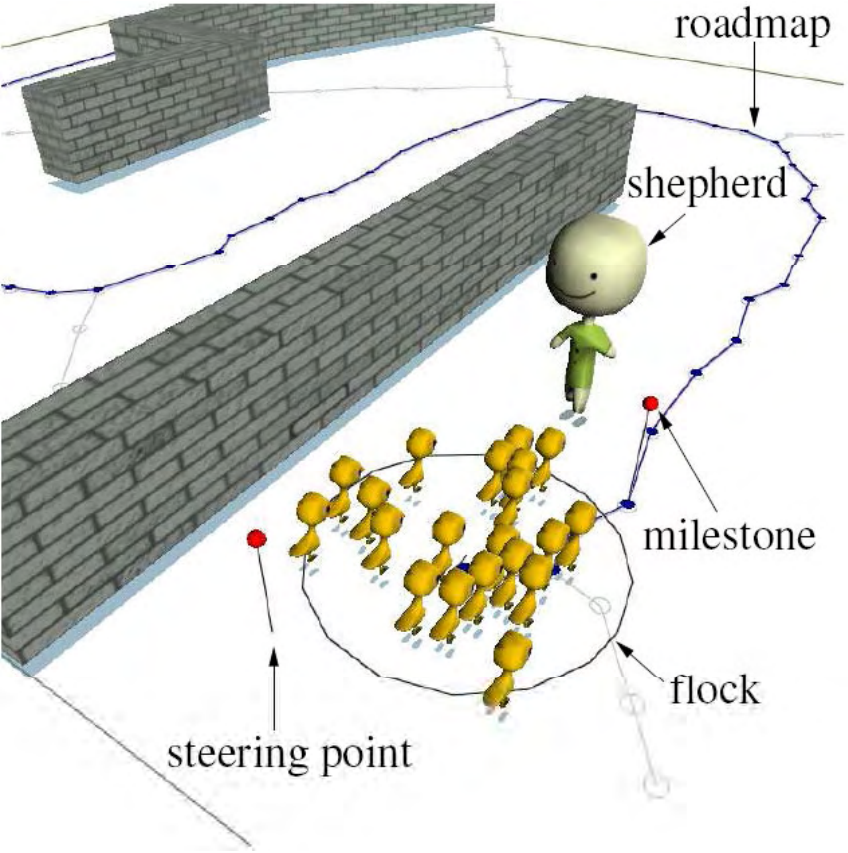
Group Control Challenges

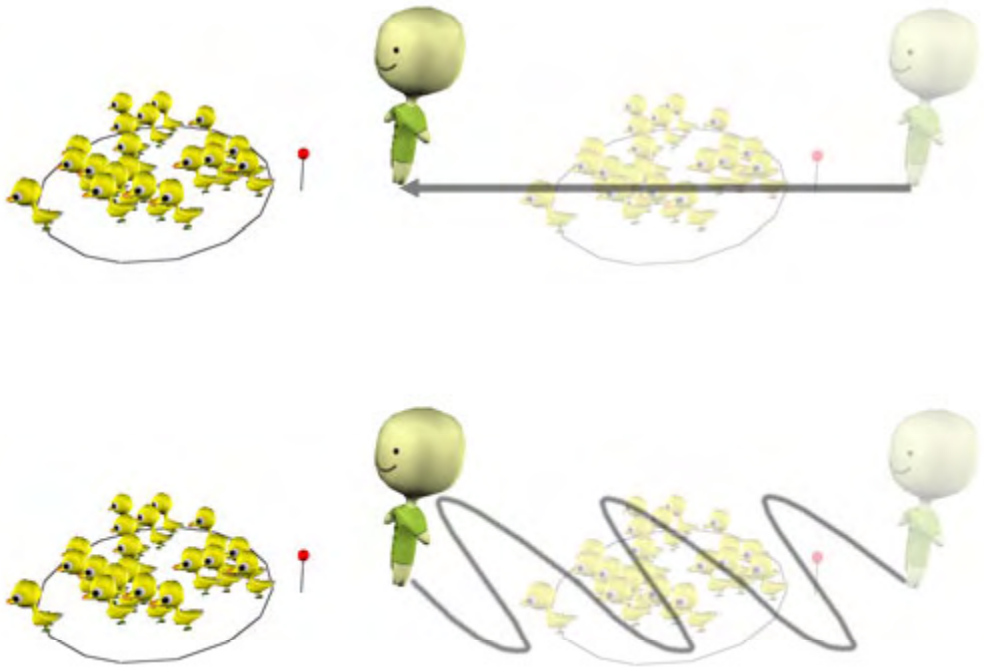
- Highly Underactuated
- Complex Dynamics
- Multi-Agent Coordination

Shepherding Simulation



Shepherding Simulation





Medial Axis-Based Shepherding (*Simulation-only*)

procedure SIMULATE(*G*, *p*, *g*, *simsteps*)

*"Simulate moving flock from **p** to **g** using **simsteps** steps."*

for i = 1 to *simsteps* **do**

for each shepherd *s* **do**

Find a path using the roadmap *G* from *p* to *g*

Select new milestone m on the path

Calculate a target *t* for *s*

Move *s* towards *t*

if flock is close to *q* **then**

return *Success*

High Level Planners – RRT and EST

procedure TREE-BUILD(q_{init})

"Build a tree in C_{space} rooted at q_{init}."

$G.init(q_{init})$

for $k = 1$ to K **do**

$g \leftarrow$ SELECT-INTERMEDIATE-GOAL

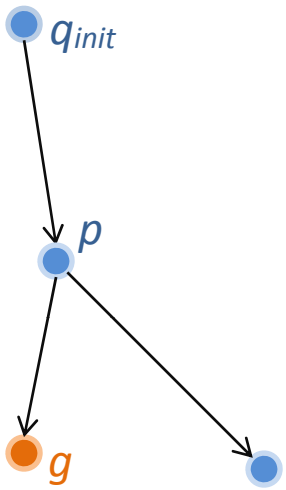
$p \leftarrow$ SELECT-NODE-TO-EXPAND(G)

$r \leftarrow$ SIMULATE(G, p, g, *simsteps*)

if r = *Success* **then**

⇨ $G.add\_edge(p, g)$

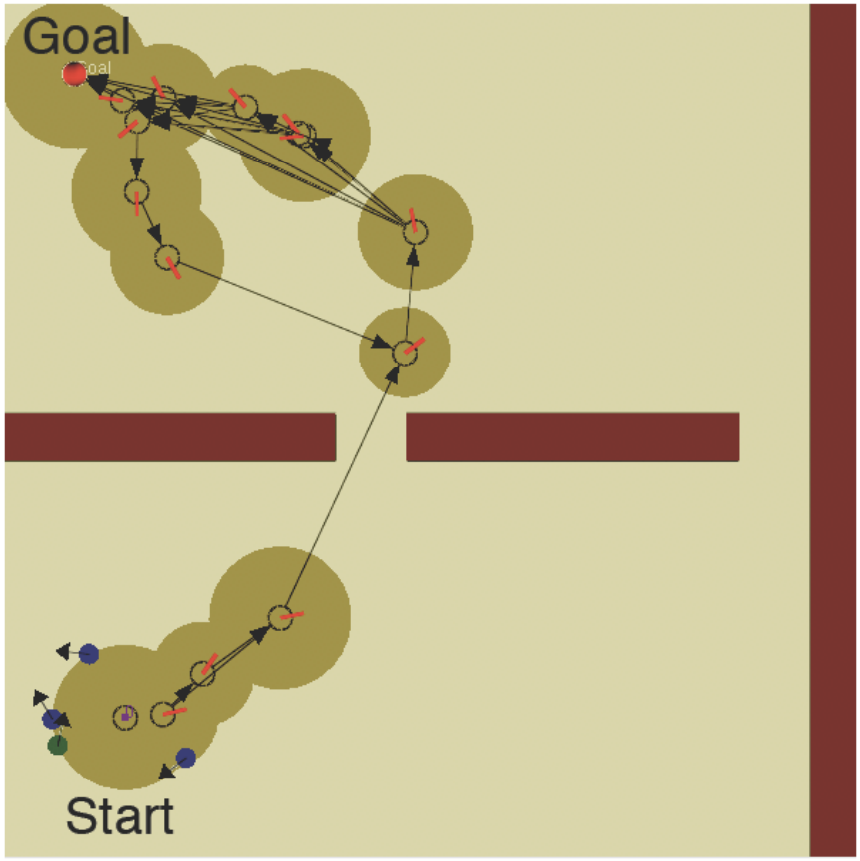
return G



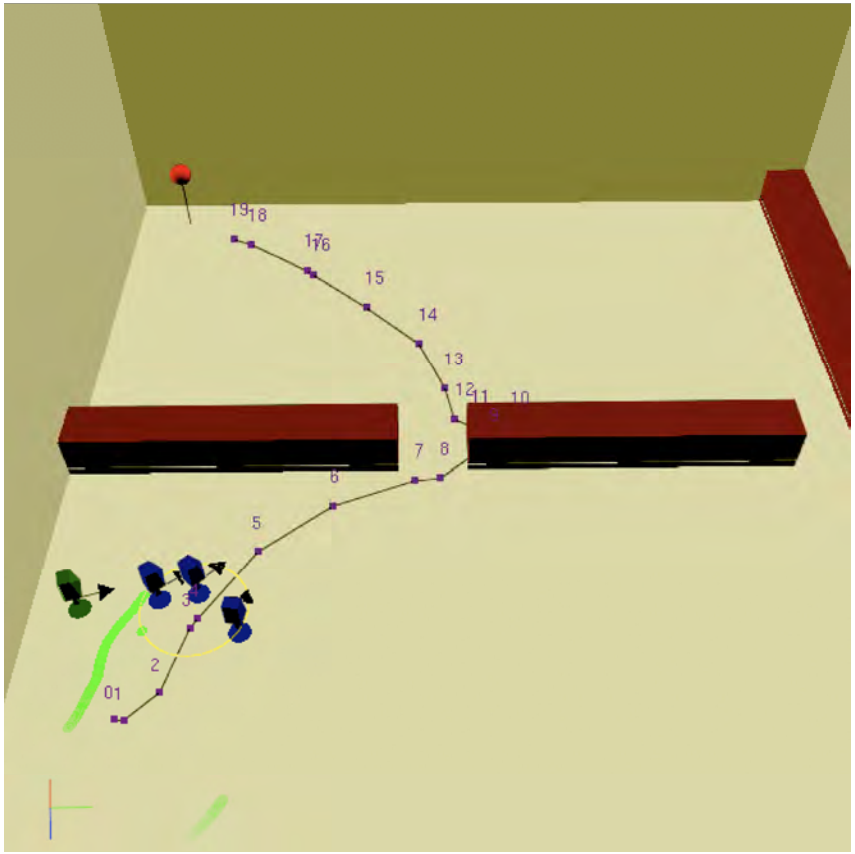
Fuzzy Meta-Graph Planner

- **Nodes:** sets of flock configurations (*Meta-configurations*)
  - represented by oriented discs
- **Edges:** directed with weights representing probability of success
  - probabilities could be computed by repeated trials
  - weights we use are simply based on the distance in position and orientation between nodes

Fuzzy Meta-Graph Planner

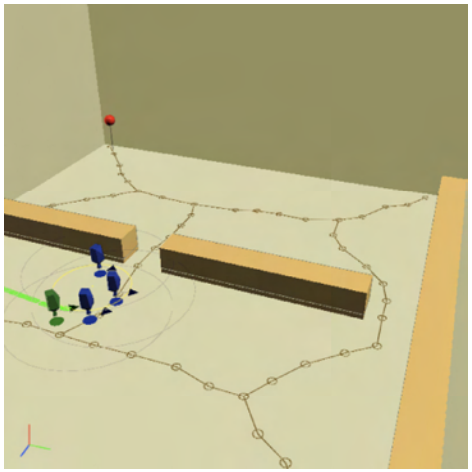


Portrayal of the Meta Graph

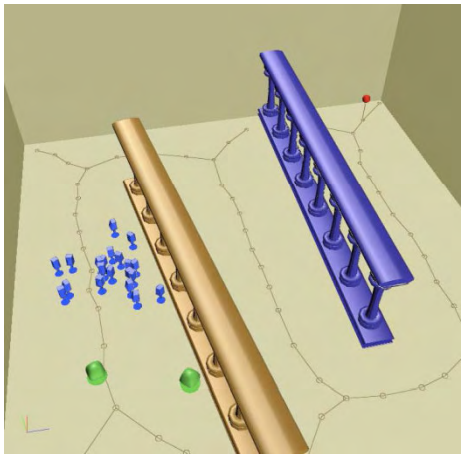


Resulting Path

Experiments and Results

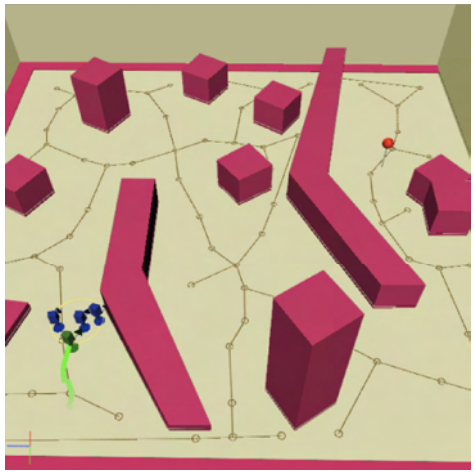


broken t

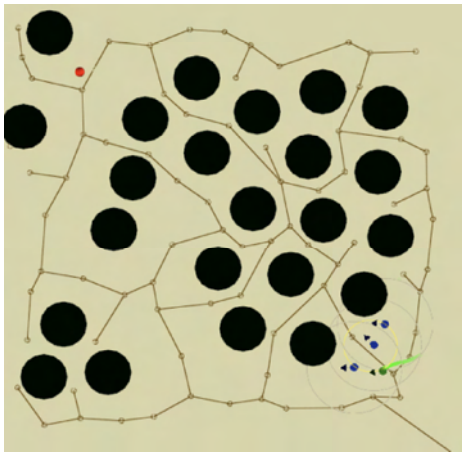


S

spiral



maze



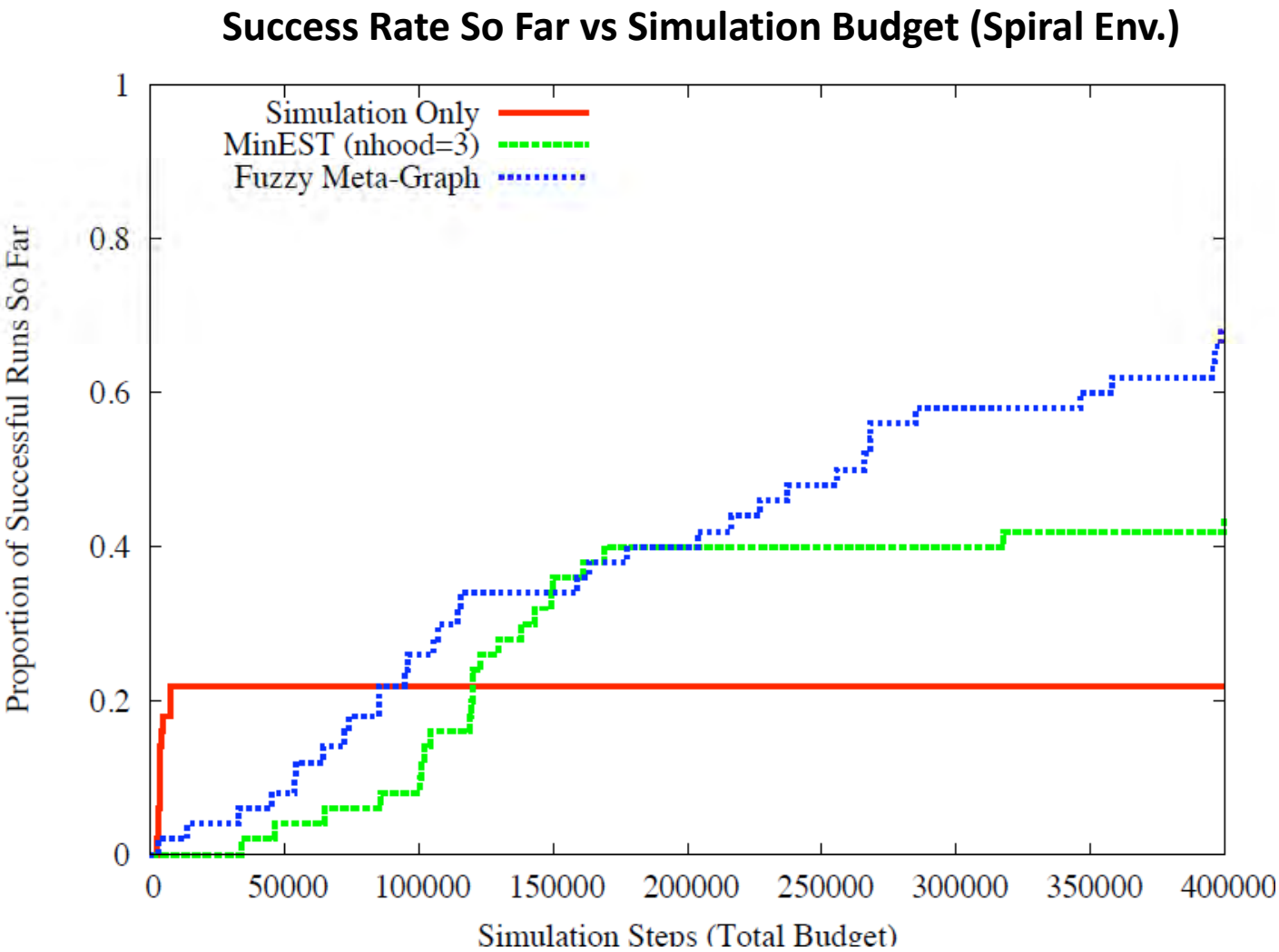
maze 2

Results Table

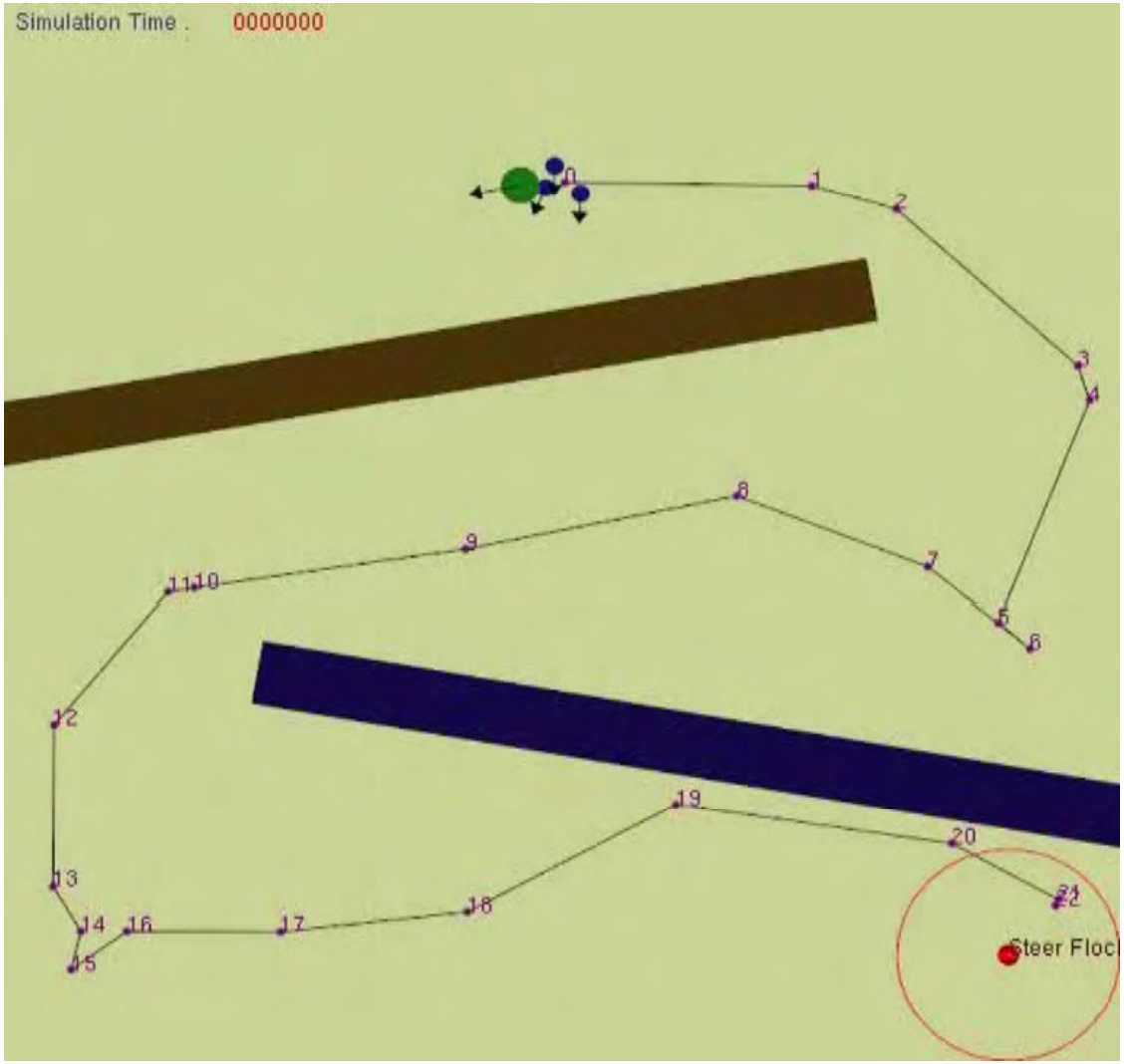
	S	Broken T	Spiral	Maze 1	Maze 2
Simulation Only	0.72	0.58	0.22	0.58	**0.82**
MinEST (nhood=3)	0.44	0.48	0.44	**0.66**	0.68
Fuzzy Meta Graph	**0.96**	0.68	**0.68**	0.1	0.24

- Simulation-only (with medial axis) performs the best on Maze 2, worst on Spiral
- MinEST performs modestly throughout
- Fuzzy Meta Graph performs well on S, Spiral, and Broken T but has problems with Mazes

More Results: Progress



Shepherding Example



Summary of Contributions

- We test motion planning algorithms which combine existing high-level planning algorithms with shepherding behaviors
- We present a meta-graph planning algorithm for group control
- Motion planning helps in some cases to explore the space and make progress when simulation only fails
- However, so far, results are inconsistent.

Future Work

- Use this behavior-based approach for pushing deformable or fragile objects
- Experiment with pushing behaviors for rigid objects
- Experiment with more complex behaviors (human crowd models, fluid models)
- Improve handling of noisy situations