

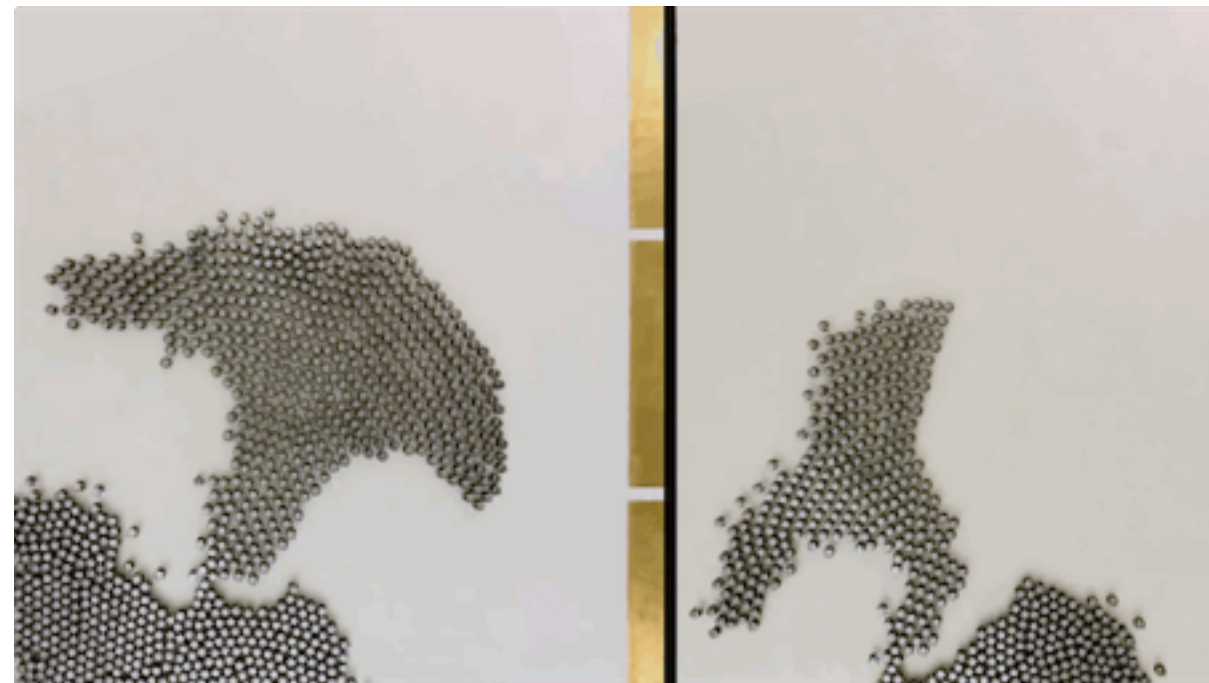
Introduction to Swarm Robotics¹

Samuel Jackson (slj11)

1. Navarro, Iñaki, and Fernando Matía. "An introduction to swarm robotics." *ISRN Robotics* 2013 (2012).

What is Swarm Robotics?

- **Large groups** of robots
(large is relative of course!)
- How can we **coordinate** them?
- Only using **local rules**
- Produce complex **global behaviour**



Kilobot robots developed at Harvard
<https://goo.gl/iGtG9d>

Why Swarm Robotics?

- Performance
- Task enablement
- Distributed
 - Sensing & Actions
- Fault tolerance
- Environments
 - Dangerous & remote

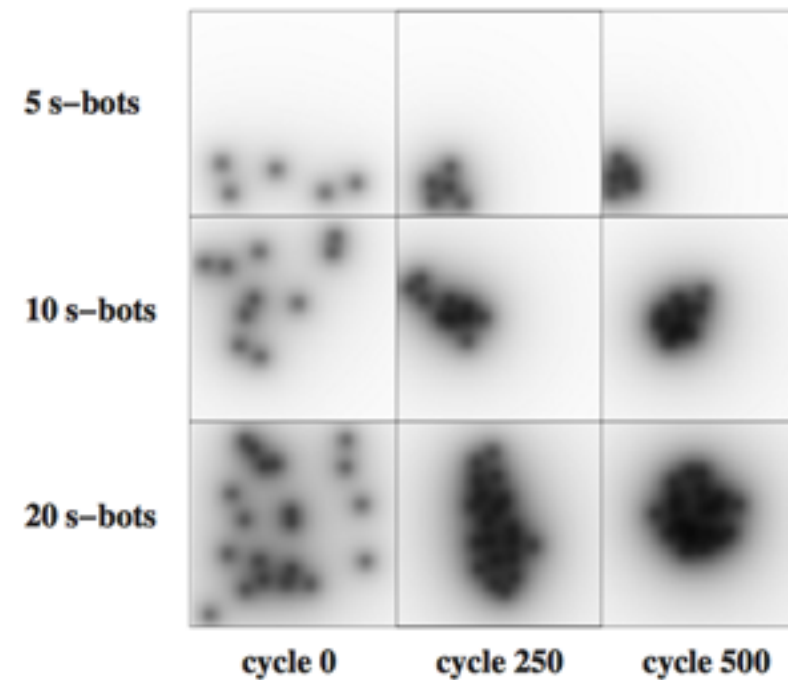


S-Bot performing a climbing task
Image Source: Francesco Mondada and Michael Bonani.
<https://goo.gl/8whVcX>

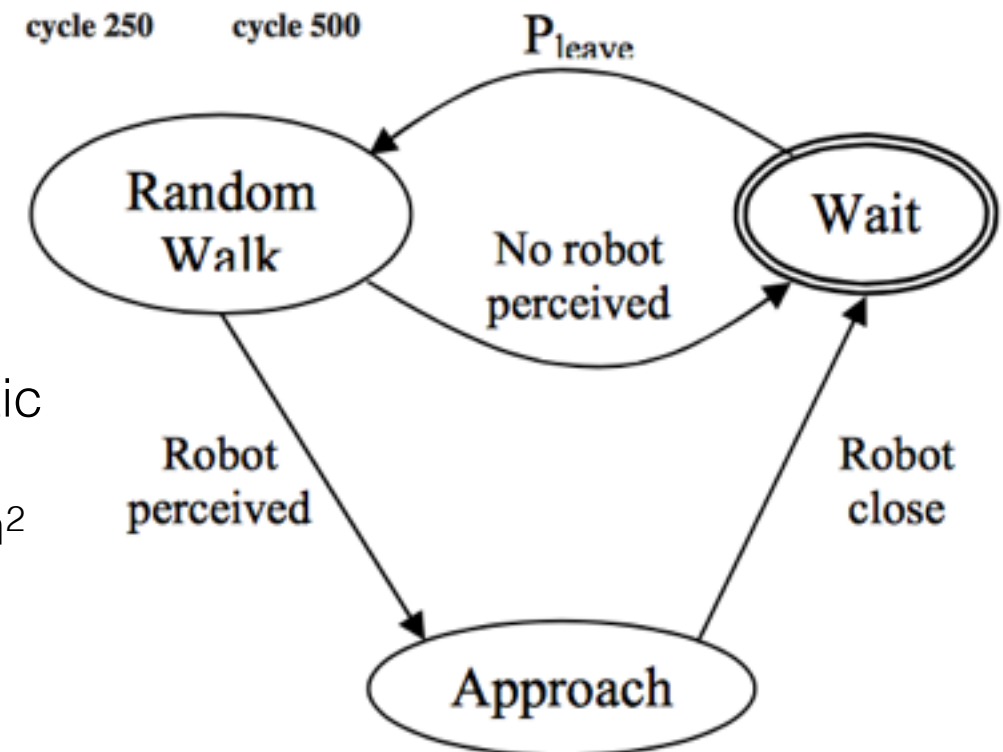
Behaviours

Aggregation

- How do robots find each other?
- Methods
 - Evolutionary Algorithms
 - Potential Functions
 - Probabilistic FSM



(Left) Evolving clusters of robots.
Trianni et al.¹



(Right) Probabilistic
FSM
Soysal and Sahin²

1. Trianni, Vito, et al. "Evolving aggregation behaviors in a swarm of robots." *Advances in artificial life*. Springer Berlin Heidelberg, 2003. 865-874.
2. Soysal, Onur, and Erol Şahin. "A macroscopic model for self-organized aggregation in swarm robotic systems." *Swarm robotics*. Springer Berlin Heidelberg, 2006. 27-42.

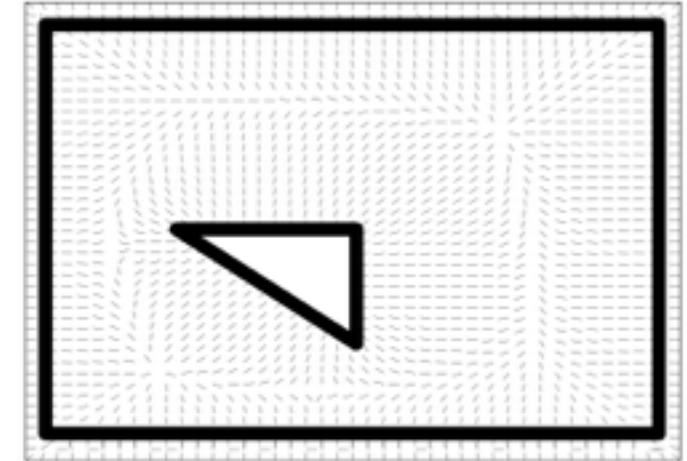
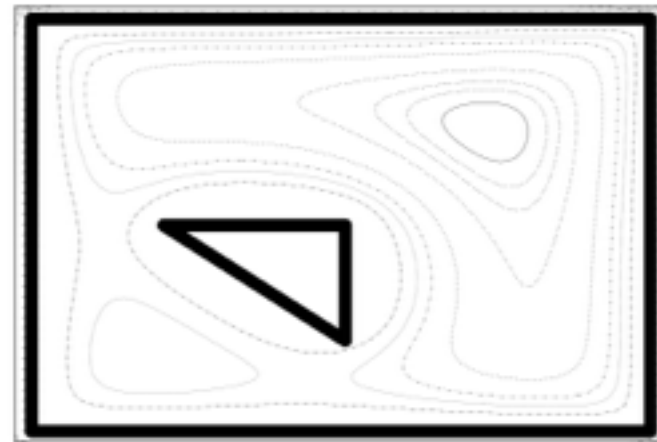
Dispersion

- Efficiently distribute in environment

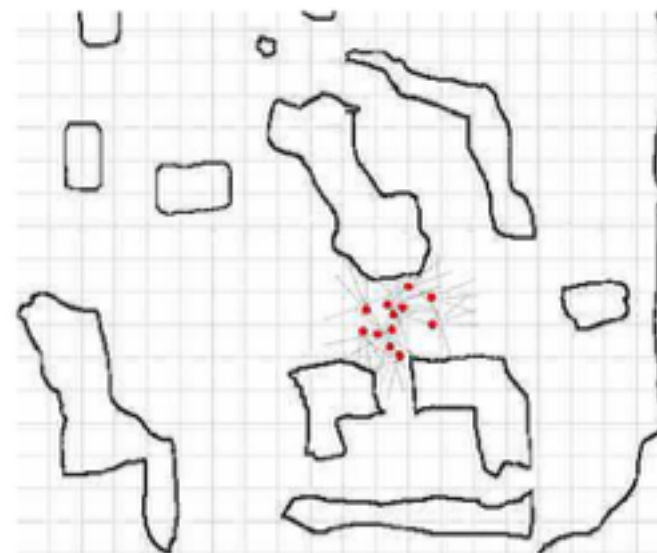
- Methods

- Potential Fields

- Wireless Signal Intensity



Potential fields. Walls exhibit repulsive forces.
Andrew et al.¹



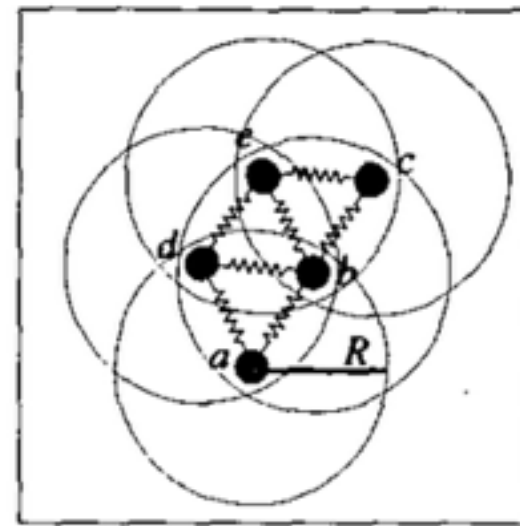
Wireless signals repel according to the inverse square law.
Damer et al.²

1. Howard, Andrew, et al. "Mobile sensor network deployment using potential fields: A distributed, scalable solution to the area coverage problem." 2002.

2. Damer, Steven, et al. "Dispersion and exploration algorithms for robots in unknown environments." 2006.

Pattern Formation

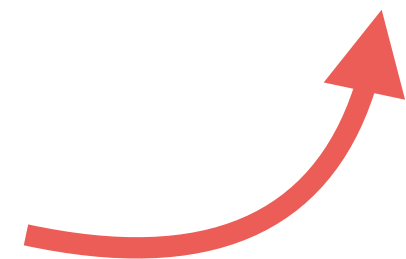
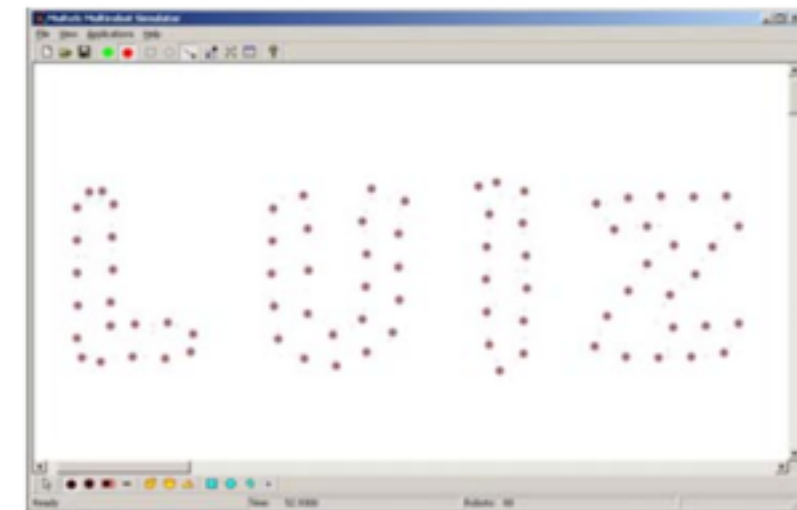
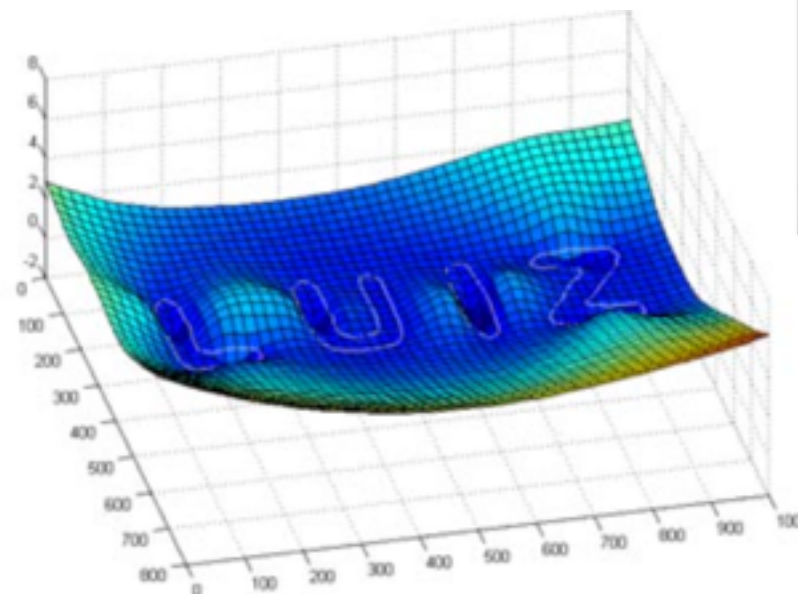
- Creating global shapes by changing the positions of individual robots.



(Right) Virtual springs push and pull robots into position.
Fujibayashi et al.¹

- Methods
 - Virtual Springs
 - Implicit Functions

(Left, Middle) Implicit functions find zero isocontour.
Chaimowicz et al.²



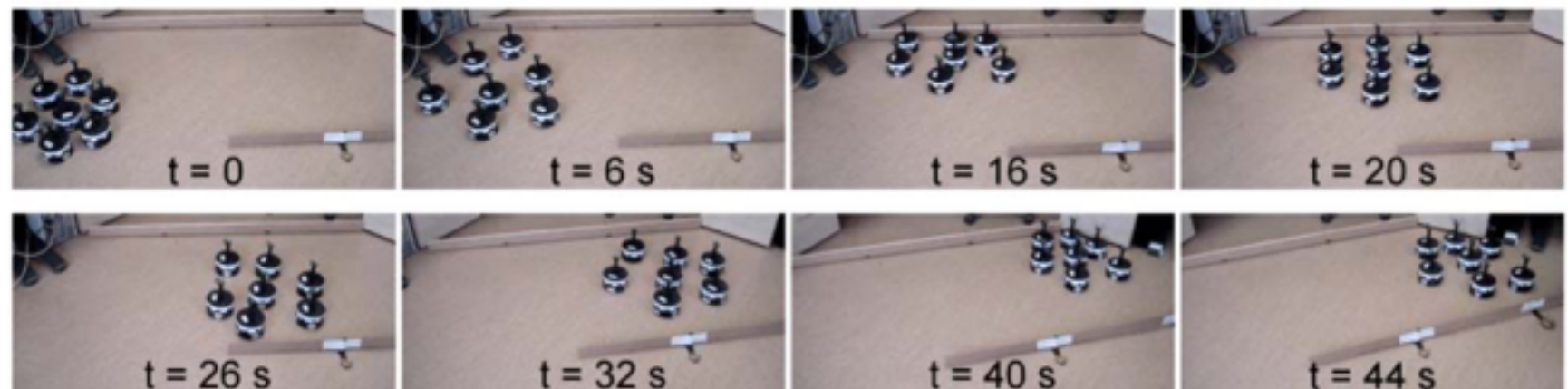
1. Fujibayashi, Kenichi, et al. "Self-organizing formation algorithm for active elements." 2002.
2. Chaimowicz, Luiz, Nathan Michael, and Vijay Kumar. "Controlling swarms of robots using interpolated implicit functions." 2005.

Movement

- How to coordinate robots and move them as a group
- Methods
 - Physicomimetrics
 - Flocking



(Top) In Physicomimetrics robots minimise the potential energy of the system.
Spears et al.¹



(Right) Flocking using order, entropy, and velocity measures. Using Kobot robots.

Turgut et al.¹

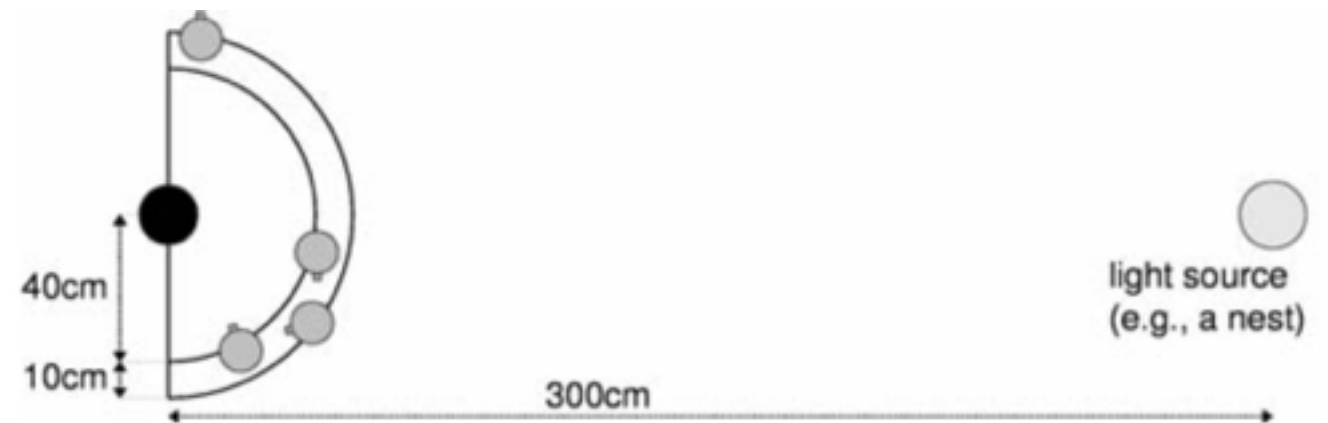
1. Spears, William M., Diana F. Spears, and Rodney Heil. "A formal analysis of potential energy in a multi-agent system." 2004.

2. Turgut, Ali E., et al. "Self-organized flocking in mobile robot swarms." 2008.

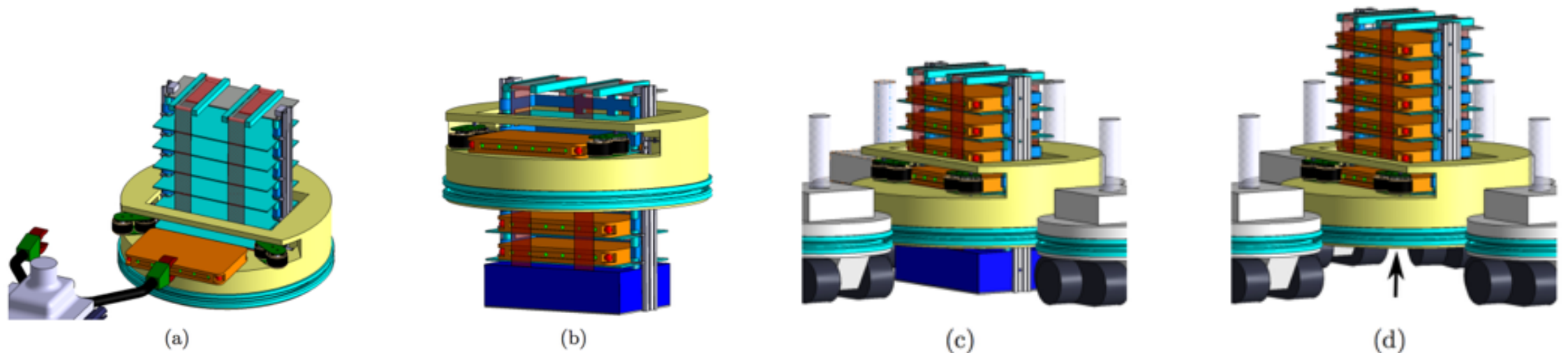
Tasks

Transport

- Moving objects using more than one robot
- Methods
 - Evolutionary Box Pushing
 - Collective transport²



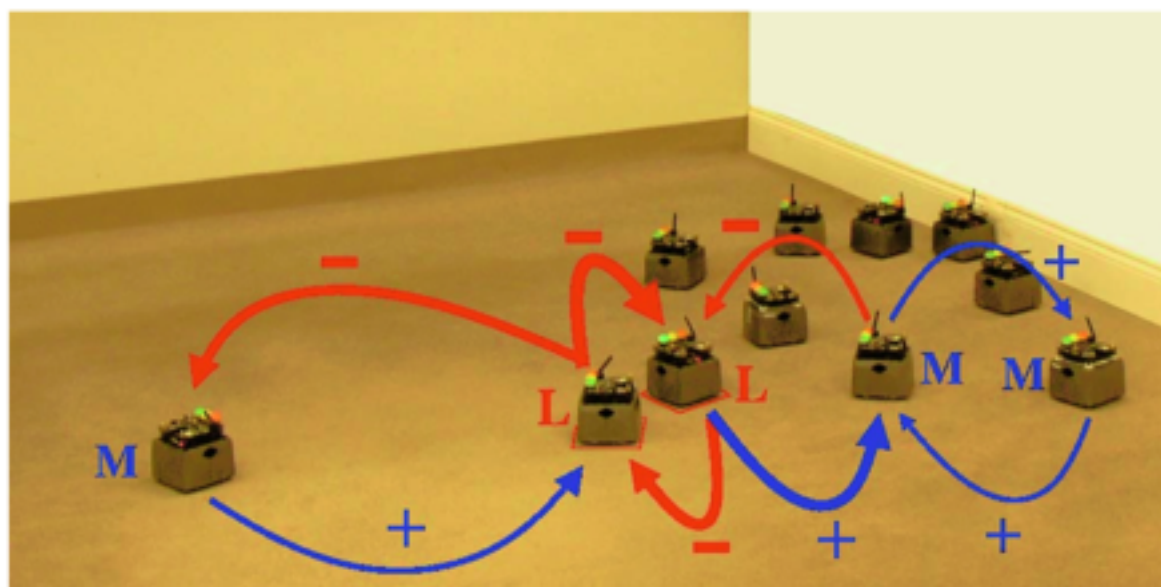
(Top) Evolutionary approach uses a recurrent NN to push an object to a source.
Gross and Dorigo¹



1. Gross, Roderich, and Marco Dorigo. "Towards group transport by swarms of robots." 2009
2. Decugniere, Antoine, et al. "Enhancing the cooperative transport of multiple objects." 2008

Mapping

- Mapping an environment using multiple robots
- Methods
 - SLAM with swarm
 - Landmarks



(Top) Heterogenous groups of Pioneers map an environment and merge maps.

Howard et al.¹

(Left) Swarmlbot “Landmarks” and “movers” compete with one another to map.

Rothermich et al.²

1. Howard, Andrew, Lynne E. Parker, and Gaurav S. Sukhatme. "The SDR experience: Experiments with a large-scale heterogeneous mobile robot team." 2006.

2. Rothermich, Joseph A., M. İhsan Ececi, and Paolo Gaudiano. "Distributed localization and mapping with a robotic swarm." 2004.

Research Challenges

- Algorithm Design & Scalability
- Implementation & Testing Frameworks
- Analysis & Modelling
- Security Concerns



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Final Thoughts

- Not as impressed by this paper
- Slightly skeptical of the publishing company
- Failed to give me a “taste of the methods”
- Some parts were not well written (sec. 4, para 1)
- I had to look elsewhere!

Thank you

Any Questions?