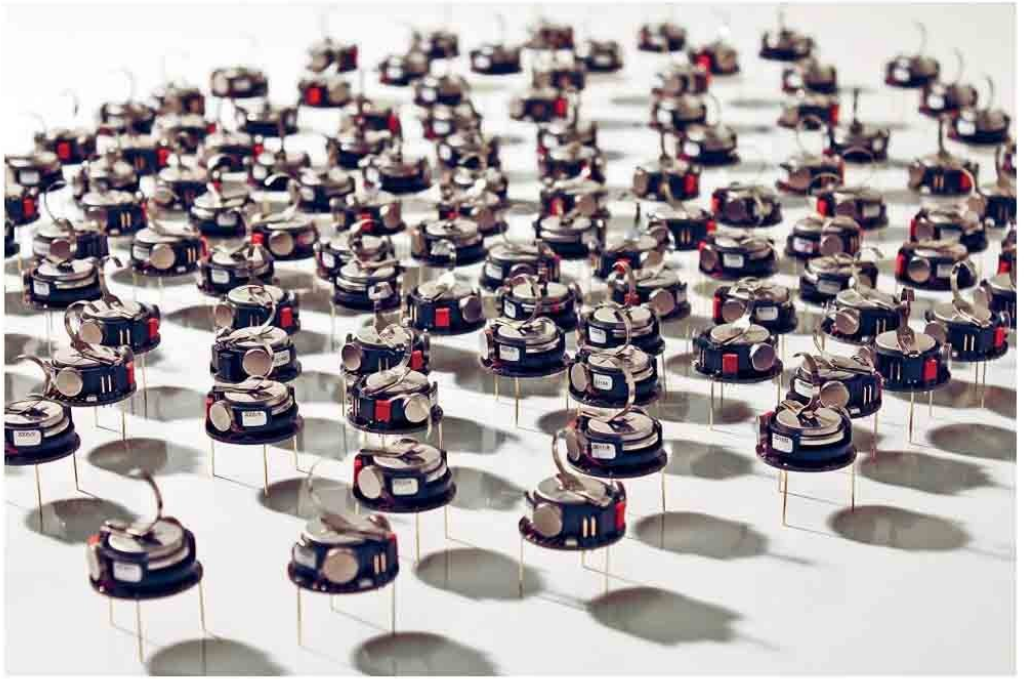


Swarm Robotics

Jan Kubový

29.10.2018

Inspired by Nature

- Bacteria
  - defending
- Fish
  - predator avoidance
- Ants
  - construction, path finding
- Bee
  - search on large area

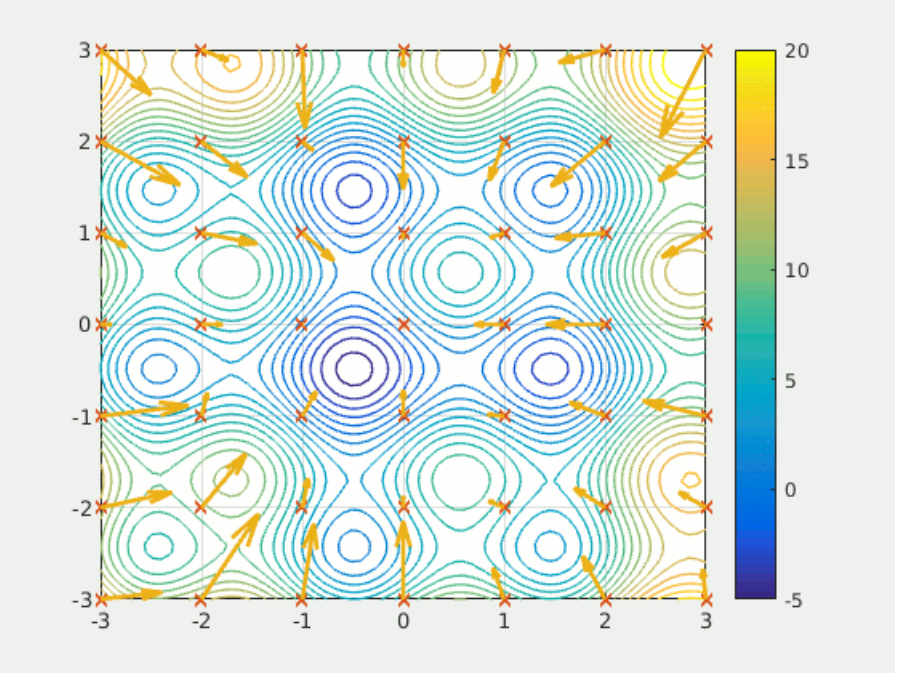
Swarm Intelligence

- Concept from 1980s
- Simple individual x Complex swarm behavior
- Plain set of rules + local interaction
- Simulate nature

Beni G. The concept of cellular robotic system. In: Proceedings of international symposium on intelligent control. (https://doi.org/10.1109/ISIC.1988.65405)

Particle swarm optimization

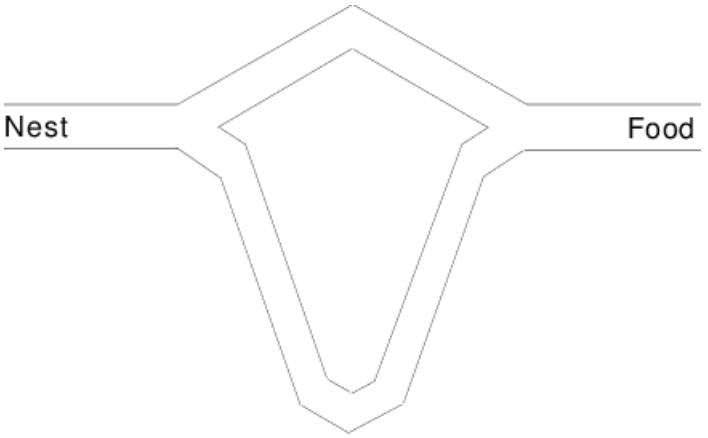
- Moving in search-space
- Simple rules
- Not guarantee best solution



Couceiro MS, Rocha RP, Ferreira NMF. A novel multi-robot exploration approach based on particle swarm optimization algorithms (https://doi.org/10.1109/WSCNIS.2015.7368299)

Ant colony optimization

- Pheromones model
- Path finding
- Obstacles avoidance



Jackson DE, Ratnieks FL. Communication in ants.
(https://doi.org/10.1016/j.cub.2006.07.015)

Swarm robotics

- Local communication
- Autonomous
- Large number of individuals
- Movable
- Simple → cheap
- Robust

Local communication

- Can communicate only to neighbors
- Message can propagate to whole swarm

- Global communication → cost

Types of communication

- Direct communication
- Communication through environment
- Sensing

Dorigo M, Bonabeau E, Theraulaz G. Ant algorithms and stigmergy. (https://doi.org/10.1016/S0167-739X(00)00042-X)
Payton D, Estkowski R, Howard M. Pheromone robotics and the logic of virtual pheromones. (https://doi.org/10.1007/978-3-540-30552-1_5)

Autonomous

- Decentralization
  - Every individual makes own decision
- Cooperation
- Change environment

Mobility

- Some possible movement in environment
- Motioning and local planning
- Better mobility → less rely on communication

Simplicity

- Cheap individual → large number
- Finite state machine
- Local communication

Swarmanoid: Towards Humanoid Robotic Swarms
(http://www.swarmanoid.org/index.php.html)

Robustness

- Dynamically add or remove from swarm
- Replaceable
- Can operate with some robot loss

Locating

- Global vs Local coordinating system
- Ability to distinguish nearby robots
- On-board sensors

Compare to other approaches

Comparison of swarm robotics and other systems.

	Swarm robotics	Multi-robot system	Sensor network	Multi-agent system
Population Size	Variation in great range	Small	Fixed	In a small range
Control	Decentralized and autonomous	Centralized or remote	Centralized or remote	Centralized or hierarchical or network
Homogeneity	Homogeneous	Usually heterogeneous	Homogeneous	Homogeneous or heterogeneous
Flexibility	High	Low	Low	Medium
Scalability	High	Low	Medium	Medium
Environment	Unknown	Known or unknown	Known	Known
Motion	Yes	Yes	No	Rare
Typical applications	Post-disaster relief	Transportation	Surveillance	Net resources management
	Military application	Sensing	Medical care	Distributed control
	Dangerous application	Robot football	Environmental protection	

Research Advance in Swarm Robotics
(https://doi.org/10.1016/j.dt.2013.03.001)

Current obstacles

- No useful local communication protocol
- High price
- Lightweight relative position system

Kilobot

- Low-cost
- For testing purposes
- Communicate up to 7 cm
- Self-assembly formations

Michael R, Christian A, Radhika N. Kilobot: a low cost scalable robot system for collective behaviors.
(https://doi.org/10.1109/ICRA.2012.6224638)
https://www.k-team.com/mobile-robotics-products/kilobot

Seaswarm

- Oil spill removal
- Autonomously navigating
- Local oil “digest”

http://senseable.mit.edu/seaswarm/

Future

- Great potential
  - Farming, Military, SaR (Search and Rescue),
- Quite far from practical application

Stormont DP. Autonomous rescue robot swarms for first responders (http://dx.doi.org/10.1109/CIHSPS.2005.1500631)

Sources

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- http://senseable.mit.edu/seaswarm/
- Slaughterbots (2017) [video] https://www.imdb.com/title/tt7659054/