MEWbot: Toward a Low-Cost and Easy-to-Build Kit for Morphogenetic Swarm Robotics

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Context

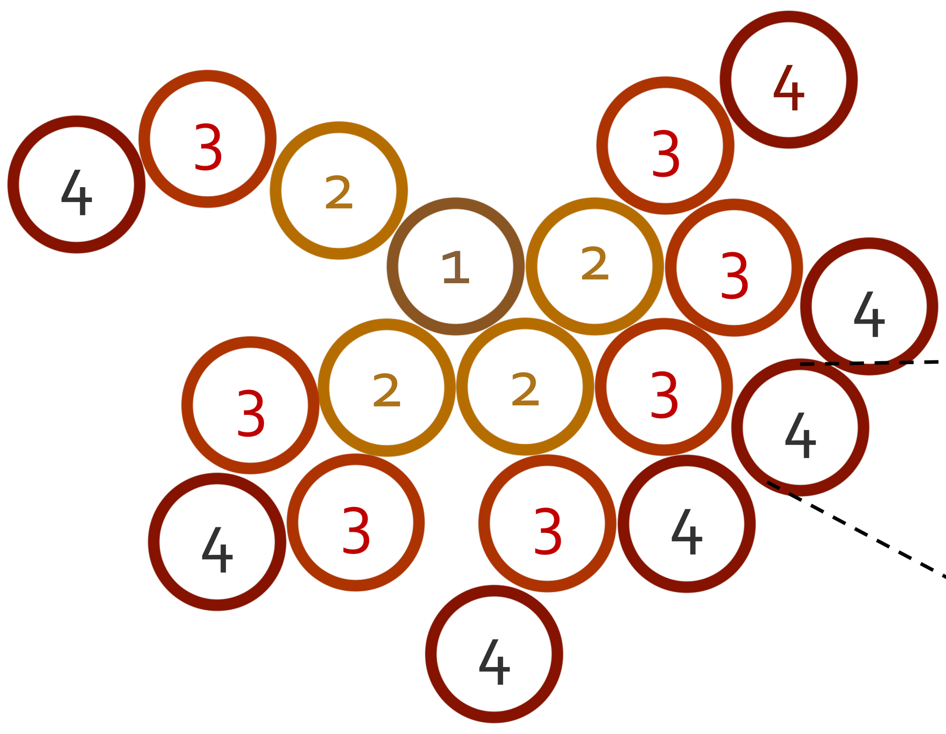
Modular & **collective robotics** promote systems made of a number of *distributed* components:

- In modular or "self-reconfigurable" robotics, interconnected parts rearrange themselves to change the shape of a robot.
- In collective or "swarm" robotics, individual mobile robots get together to form a larger entity by flocking or attaching.

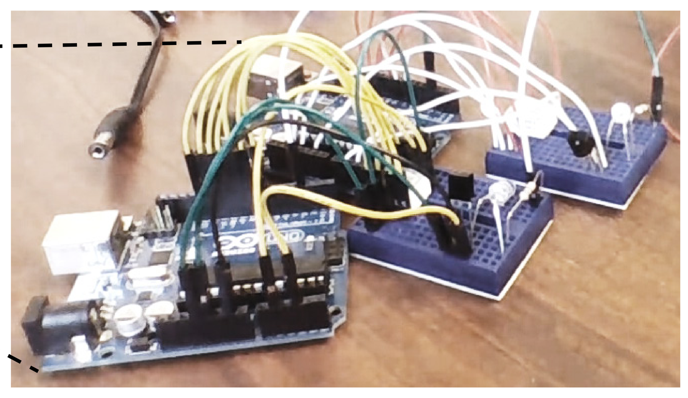
Morphogenetic engineering (Doursat et al. 2012) concerns the design of the *self-organizing* properties of the agents of complex systems toward functional *architectures*, in particular inspired by biological development.

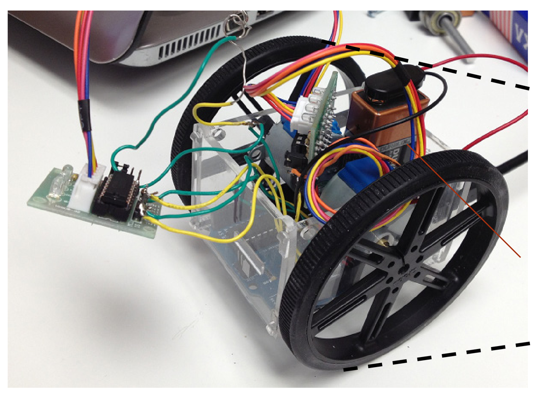
Idea

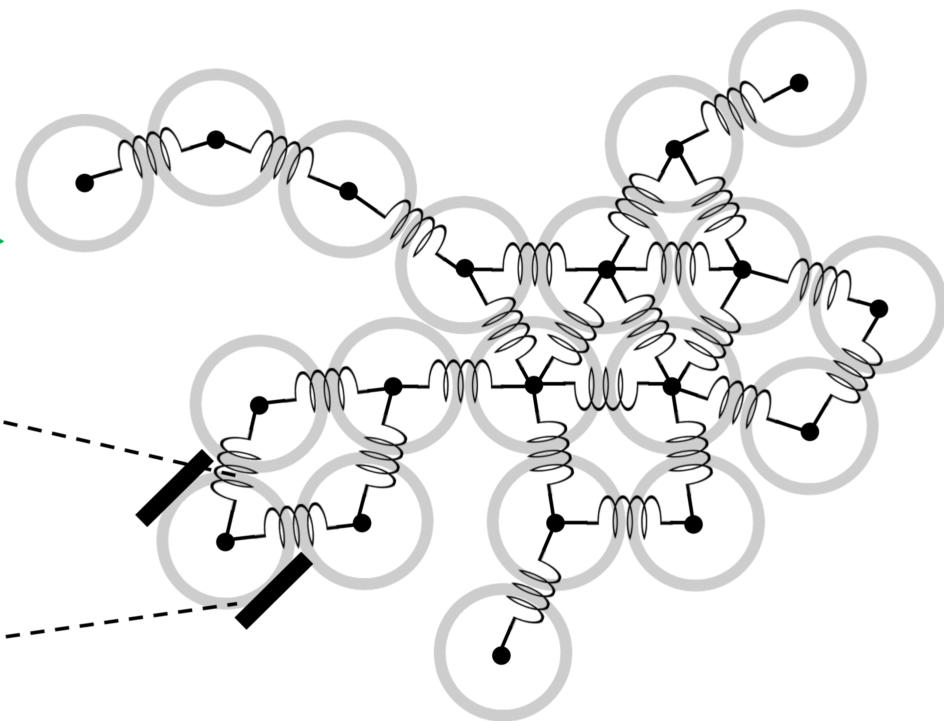
Putting these two concepts together, we propose a hardware kit that is cheap, easy and quick to assemble, toward the "mass production" of small robots capable of creating spatial formations with specific morphologies. Our template unit is called the **MEWbot**, for "Morphogenetic Engineering Work-bot". Each bot makes decisions based on its state and neighborhood, which may contain other bots and environmental cues.



Morphogenesis combines
← chemical **pattern formation (PF)**
and mechanical **self-assembly (SA)** →







PF: Gradient formation & differentiation

- The goal is to establish and display "hop counters" that increase with the distance from a source agent
- **Infrared sensors (IR)** allow bots to exchange small numbers and calculate their degree of separation from the source agent as follows:
  - source agent always displays "0"
  - other agents obey 4 rules ("n" is the agent's number):
    1. Send "n+1" signal to agents nearby
    2. Replace "n" by the smallest number received if it is smaller than current number
    3. if no number is received, reset to NaN value
    4. if value is currently NaN, take the first value received

→ *Our experiments with Arduino boards and LEDs demonstrate that a programmable pattern can be achieved through decentralized computing*

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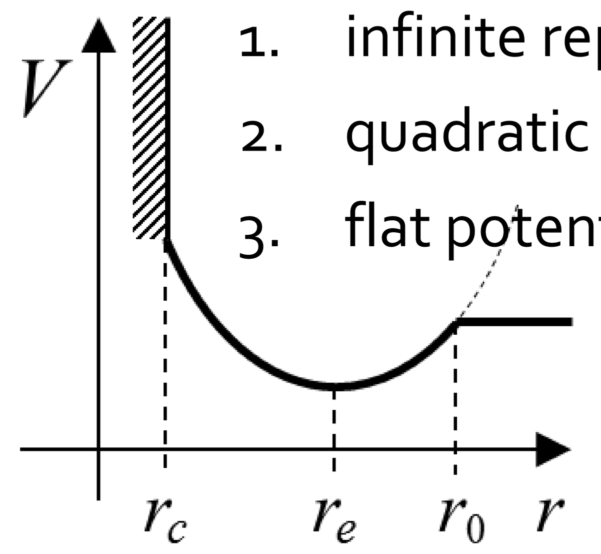
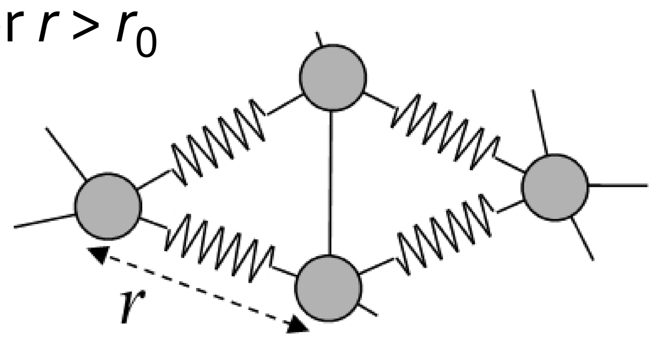
SA: Virtual multi-spring-mass system

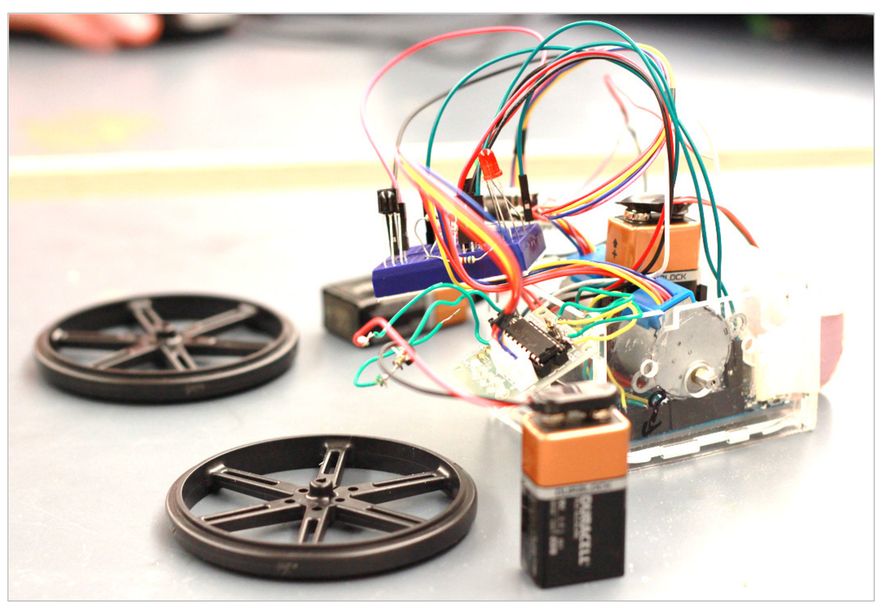
- Mutual adhesion affinities are modeled by a local interaction potential V among pairs of nearest neighbors, based on three parts:

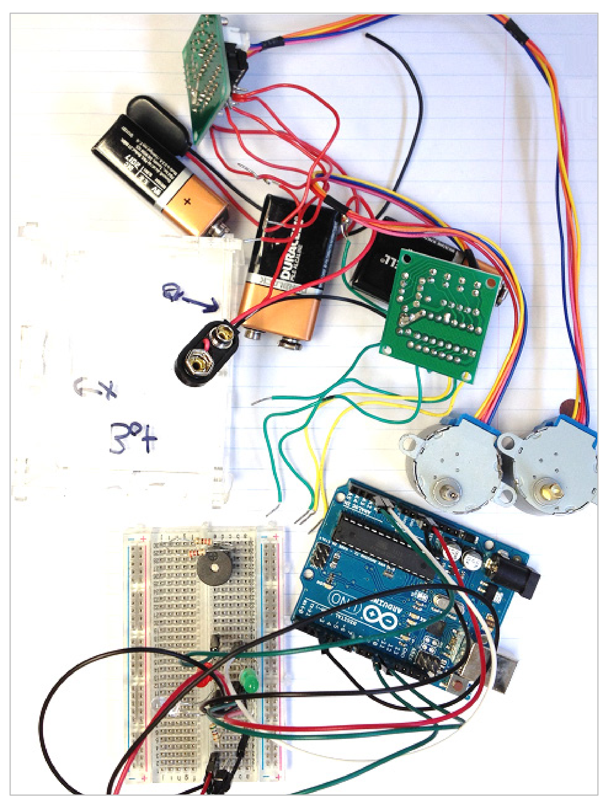


1. infinite repulsion (solid core) for $r < r_c$
2. quadratic (elastic) attraction around r_e
3. flat potential for $r > r_0$



- This can be implemented with **ultrasonic proximity sensors**: robots adjust their position by steering their wheels according to a calculated average force → *Under construction…*





Benefits of swarms

- Swarms of small robots can collect data from a larger area than a single big robot
- Lack of centralized control allows easy replacement of individual agents and avoids single point of failure
- The swarm continues to operate even if a few agents break down or go missing
- Bots communicate only with their neighbors instead of a distant central computer, hence extend their battery life through low-energy local transmission

Material used

- *Arduino* microcontrollers
- Infrared LEDs for communication
- C/C++ programming
- Inexpensive parts: step motors, etc. (≈ $30/bot)

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