BSU Robotics
Swarm Robotics

Admin

- Quiz of course
- Lab?
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Swarm Robotics

- Special Subset of Multi robot systems.
    - Becoming more popular in last decade or so
- Revenge/Refuge of the insect roboticists
    - Generally very much inspired by insect collectives
        - Especially today
    - Ants/bee other social insects.

Swarm Characteristics

- Characteristics
  - Large-ish numbers of robots
    - More recently quite large
  - Fault tolerant
  - Generally small, individually unimpressive robots
  - Usually homogeneous robot collective
  - Usually have some mechanism for physically connecting to others

Example Swarms

- The original swarmbots
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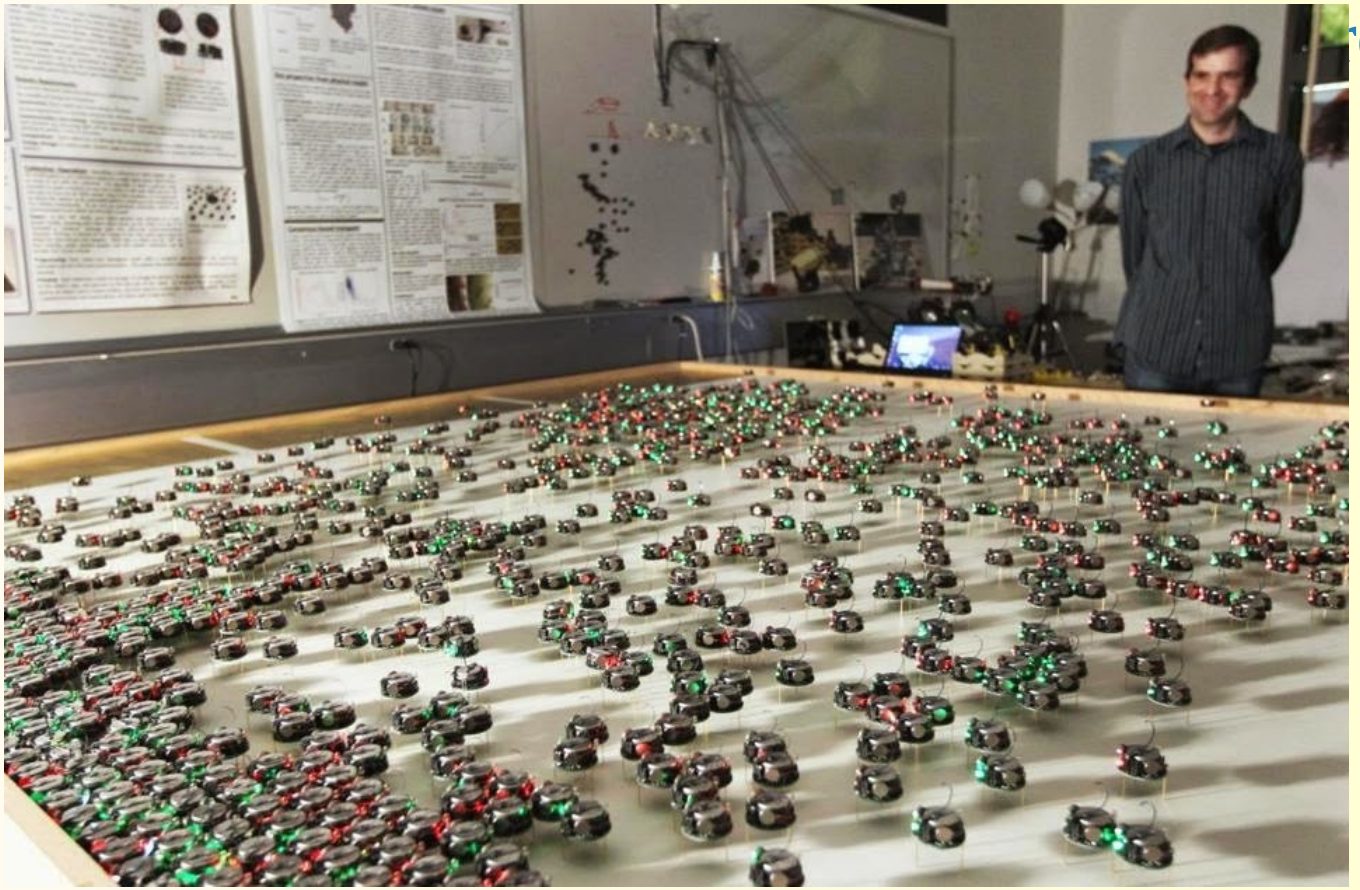
Swarms 2016-17

- Radhika Nagpal (Harvard) Kilobots
  - Rubenstein (grad student) pictured
  - Kilobot project
- 
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Example Swarms II

- Some newer swarms
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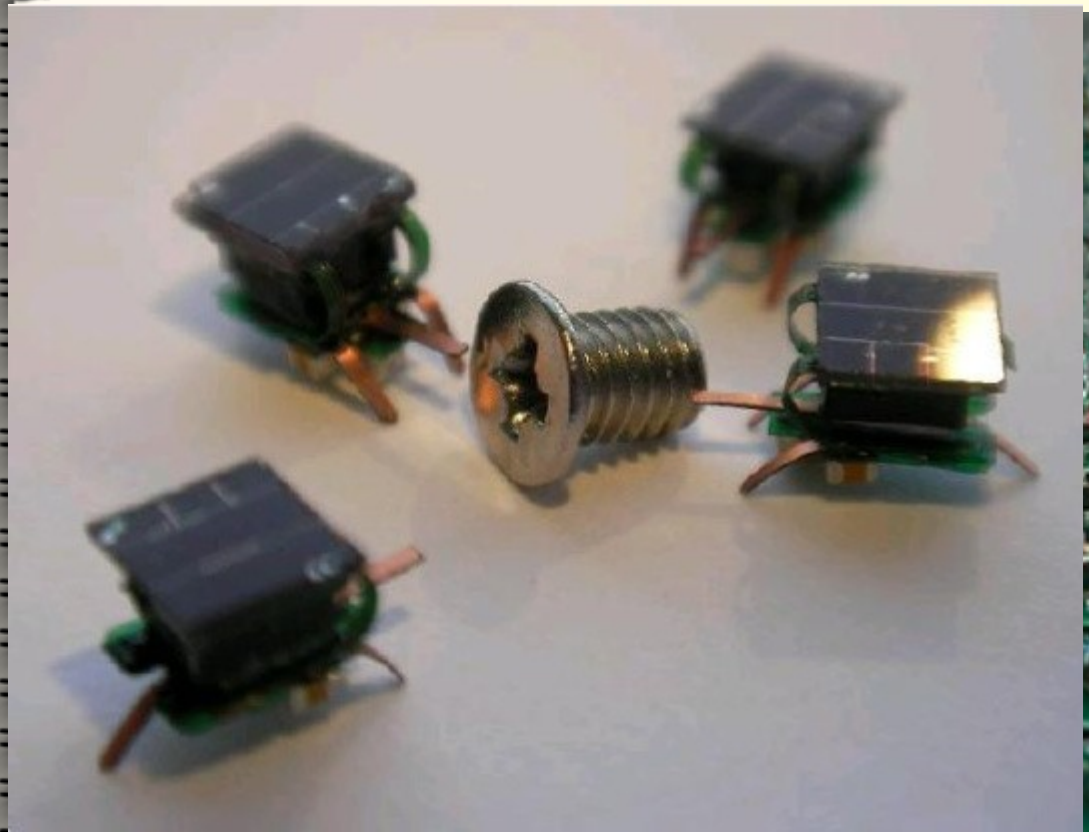

Example Swarms III

- Commercial and cutting edge research
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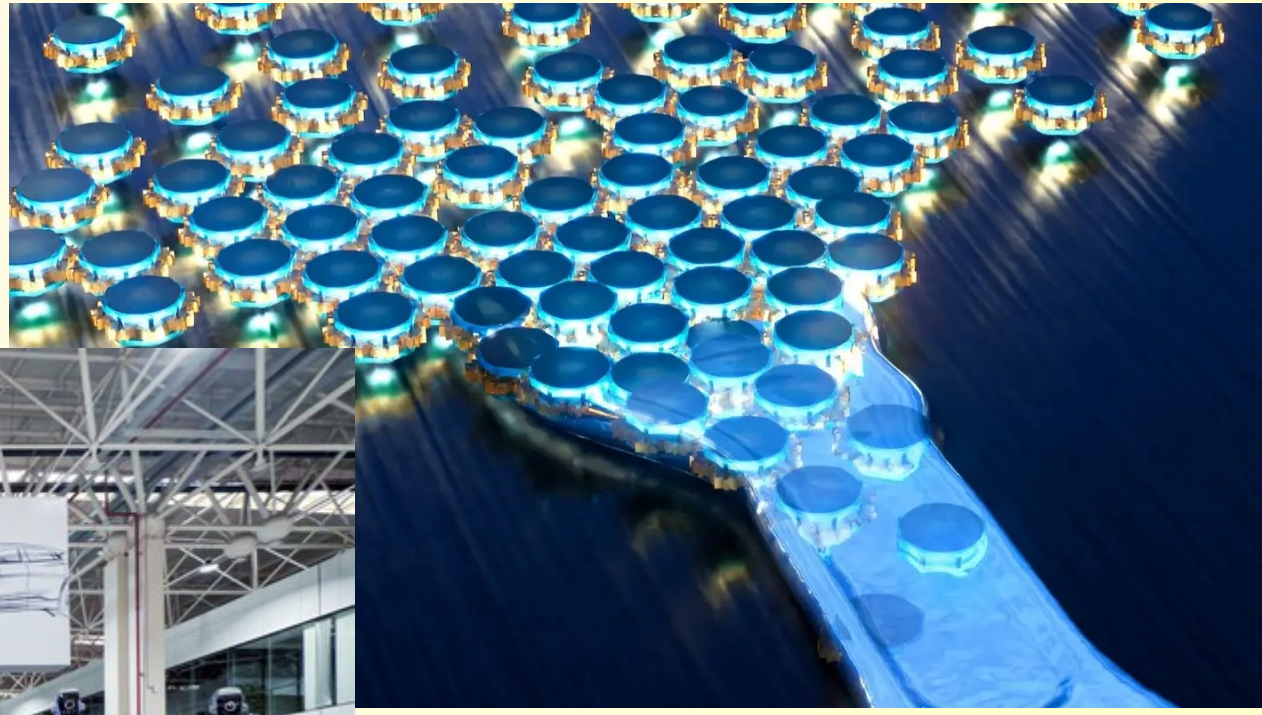

Swarms today

- Pentagon swarm policies
- https://www.politico.com/newsletters/digital-future-daily/2023/02/07/killer-robot-swarms-an-update-00081623
- Swarms in business
- https://www.factmr.com/report/swarm-intelligence-market
- Pictures of swarms in business 2021
- https://www.cnn.com/2021/06/15/asia/swarm-robots-hong-kong-warehouse-hnk-spc-intl/index.html

Not all on land

- Not all of the swarms are land based
  - Though most are
  - aquatic
  - https://www.youtube.com/watch?v=761IxFeaK4w
  - Chinese 'loitering munitions' drone swarms
  - https://www.youtube.com/watch?v=Ma3ya_lqCLM
  - Search and (rescue?)
  - https://www.youtube.com/watch?v=P9ZbipO8vxM
  - And the Brits
  - https://www.youtube.com/watch?v=zq1ud7CBOaU

The original swarms

- Best video of original swarms showing basic behaviors
  - https://www.youtube.com/watch?v=J7xFLrqVRVM
  -

Swarm Algorithms I

- Swarm Robot algorithms
  - Had to throw out nearly everything from AI/ALife swarms
  - Operating in the real world
    - Can't (and usually shouldn't) destructively modify environment by laying down trail

Swarm Algorithms II

- Characteristics of Swarm Algorithms
  - Distributed
  - Tolerant of lost members
  - Scale well
    - Should work with a few – and better with more
    - More robots-> more effective
    - Mythical man month syndrome not allowed
  - Total behavior of the algorithm treats swarm as single entity.
    - Rely on existing ad-hoc communication networks to focus on higher level behaviors.

Swarm Algorithms III

- Characteristics continued
  - Built from simple behaviors
    - Individual behaviors often can be represented with simple finite state machine
  - Decentralized
    - Each robot is autonomous
  - All interactions are local
    - No broadcast messages – just messages to local neighbors.

Common Swarm behaviors

- Robotics, like CS, often has minimum bar to reach to be taken seriously
    - Computer vision example
- Swarms nearly all need to implement
    - Dispersion/exploration
    - Docking/connecting
    - Clumping (like to like)
    - Follow the leader

Dispersion

- Basic algo for indoors
  - Locate C nearest neighbors
  - Use pfields vectors or some equivelent to find vector to maximize distance from all
  - Move robot
  - What should C be?
    - Empirical testing says 2
    - Means what?

Dispersions Friend: Exploration

- Generally Dispersion coupled with frontier exploration
  - Have robots flow to new regions – maximum dispersion and coverage.
  - Trade off each time step – first dispersion, next exploration, repeat
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Exploration

- Algo:
  - Each robot decides
    - Am I at wall (obstacle)
    - Am I on Frontier (open space)
    - Am I interior? (neither – only robots around)
    - Wall nodes and frontier nodes don't move during this step
    - Interior nodes
      - query
      - Messages passed from robot to robot
      - Count number of hops to frontier
      - Find neighbor with shortest hops and move toward it

Distributed mapping

- Basics
  - Take each individual robot's map and superimpose them on one another.
  - Problem?

Distributed mapping

- Basics
  - Take each individual robot's map and superimpose them on one another.
  - Problem:
    - How do we know what part of robot I's map corresponds to the same part of robot J's map?
    - Optometry deteriorates over time

Cheap solution

- Cheap and easy solution
  - Add beacons to the environment to know where robot is in relation to beacon.
  - Except?

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  - Add beacons to the environment to know where robot is in relation to beacon.
  - Except
    - Swarms aren't allowed to modify environment
    - Big no-no with so many

Solution

- Beacon solution
  - Let other robots in swarm be the beacons.
    - Once lead robots are in place,
      - Stop and go into beacon mode till swam passes by, then move on and rejoin

Chain formation

- Often want to group swarm bots up
  - Want to do this in orderly manner
  - Form chains
  - Original implementation on Sbots
    - Four state machine
      - Search, explore, chain, finished
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Chain swarm states

- Search
  - Randomly move around – avoid obstacles, no lit LEDs (s bot communication)
  - If find chain move to explore
- Explore
  - Move along chain following colors
  - Chain always follows pattern