Swarm Robotics

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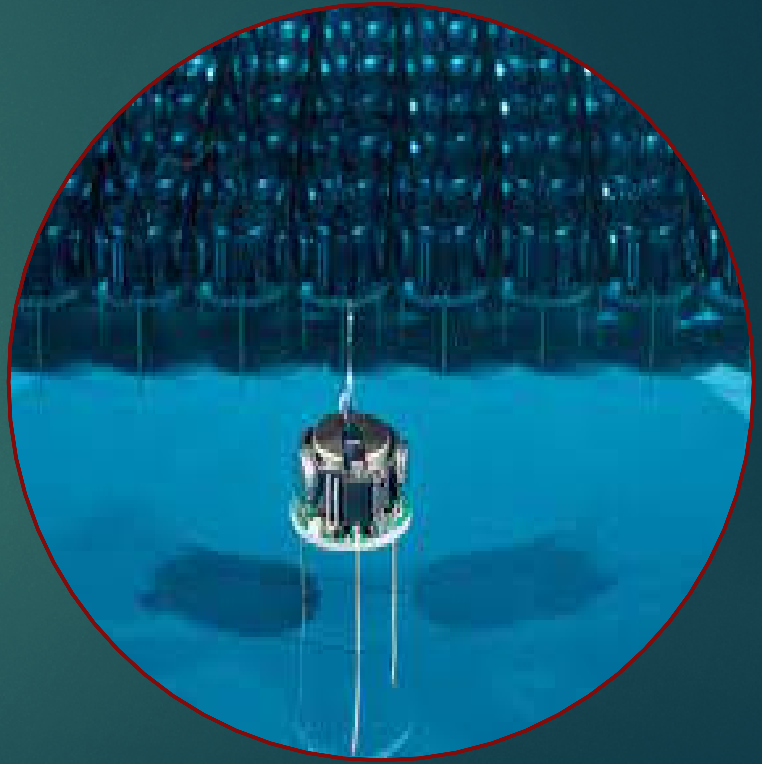
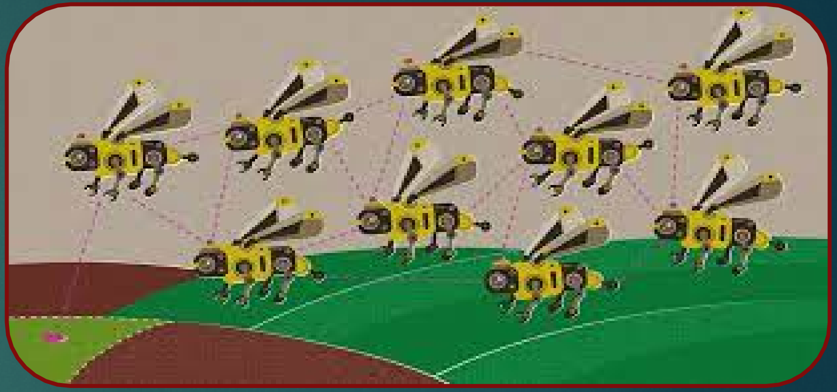


What is Swarm Robotics?

- Multiple Robots completing complex tasks
- Groups of noncomplex robotic systems
- Based off swarms in nature
- Decentralized

Origin of Swarm Robotics



- Term was first used in 1988
- Early Development looked at nature for inspiration
  - One Idea was to use stigmergy, which is commonly used by termites
- Another development suggested that the swarm needs to be simple, identical, self-organized, scalable, local communication

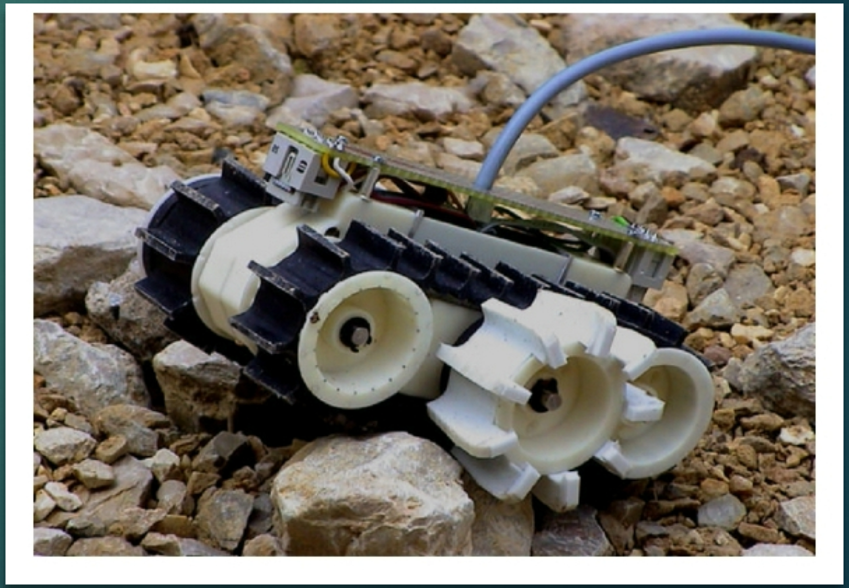
Main Principles of Swarm Robotics

- They must be simple
- Optimized coordination of how they interact with their environment
- They must be homogenous or near Identical
- Local interactions to ensure coordination to be distributed evenly

Hardware

- Depending on the nature of the task at hand will determine the hardware the robots use
- Areial type robots will have different components compared to ground robots and so on

- Hardware consistent with every robot include:
  - Sensors
  - Cameras
  - Controllers
  - Actuators
  - Many more



Algorithms used by Swarm Robotics

- Particle Swarm Optimization (PSO)
- Ant Colony Optimization (ACO)
- Artificial Bee Colony(ABC)
- Stigmergy
- Self-Propelled Particles(SPP)
- Cellular Automata(CA)
- And many more

Algorithms Continued

- Particle Swarm Optimization (PSO)
  - Developed in 1995 by James Kennedy and Russell Eberhart
  - Most commonly used algorithm in Swarm Robotics
  - Based off patterns in bird flocking
  - Main goal is to meet a group objective based off of the groups feedback
- One Equation used in PSO

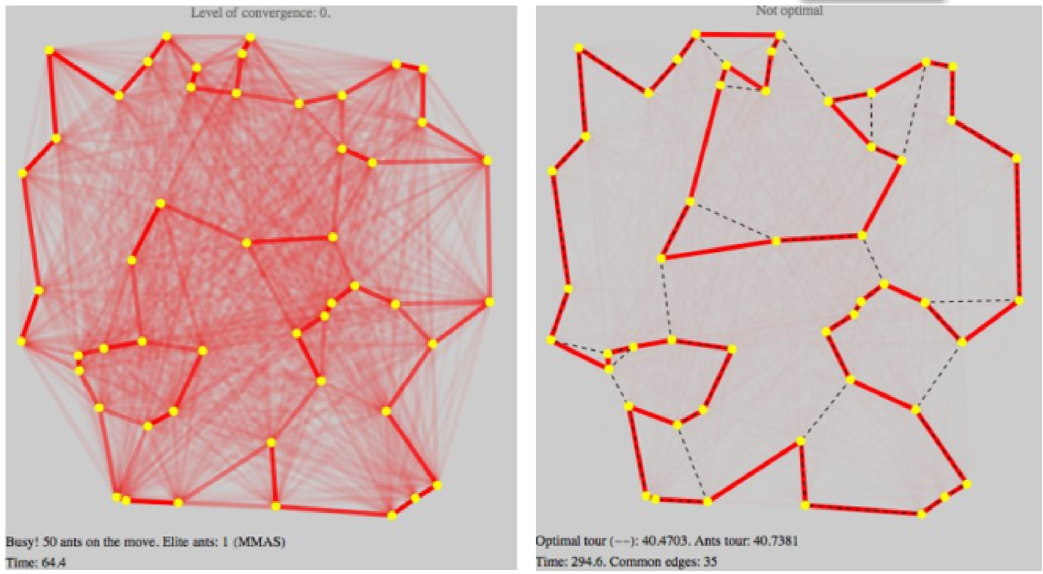
$$v_i^{t+1} = v_i^t + \varphi_1 U_1(0,1) * (p_i - x_i^t) + \varphi_2 U_2(0,1) * (s - x_i^t),$$
$$x_i^{t+1} = x_i^t + v_i^{t+1},$$

Algorithms Continued

- Ant Colony Optimization(ACO)
  - Introduced in 1992 by Marco Dorigo
  - Model real life behavior of ants
  - Main goal is to find the shortest path between two points
  - Ants leave pheromone in the path they walk which cause other ants to follow the same path and reinforce the pheromone as well
- Various variations have been made
  - Elitist Ant System (EAS)
  - Max-Min Ant System (MMAS)
  - Rank-based Ant System(RAS)

Algorithm Continued

- Max-Min Ant System(MMAS)
  - One of many successful ACO applications
  - A piecewise function used in MMAS



$$p_j^k = \begin{cases} \dfrac{\tau_j[\eta_j]^\beta}{\sum_{h \notin S_k} \tau_h[\eta_h]^\beta}, & \text{if } j \notin S_k \\ 0, & \text{otherwise,} \end{cases}$$

Communications

- Direct Communication
  - Robots send/receive signals with information directly between one another
  - Without the need of physical interaction
  - Helps robots coordinate tasks
- Environmental Communication(stigmergy)
  - Robots leave traces of where they have been
  - Other robots can sense the trace without the use of direct communication
  - Robot follows path with higher intensity of trail and discards the path with lower intensity
  - Guides the robots through the environment

Swarm-bots Project (S-bots)

- Project is based out of Université Libre de Bruxelles manged by Marco Dorigo
- Main goal of this project is to test three algorithms
  - Hole avoidance algorithm
  - Cooperative dragging algorithm
  - Chain formation algorithm

Applications of Swarm Robotics

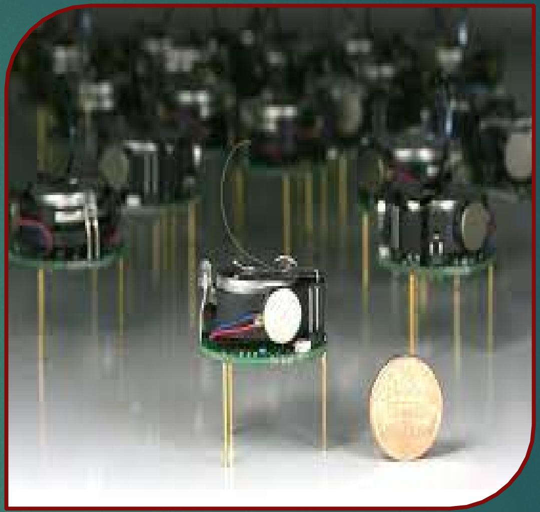
- Implementations of Swarm Robotics are still largely underdeveloped
- Planned use cases for swarm robotics
  - Disaster Recovery
  - Defense
  - Reconnaissance, Inspection, Mapping
  - Farming and Food Management
  - Space Systems

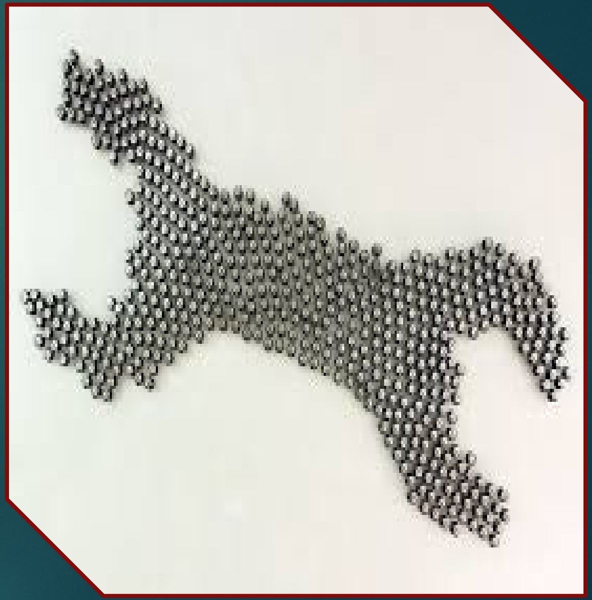
Applications Continued

- Disaster Recovery
  - Use of unmanned aerial systems to search and rescue
  - American Red Cross, Nasa, and many more are considering the use of these systems
- Reconnaissance, Inspection, Mapping
  - Allow for a detailed depiction of a large area
  - Allows for quit scanning of the area
  - Robots use a coordinated effort to map the area

Advantages in Swarm Robotics

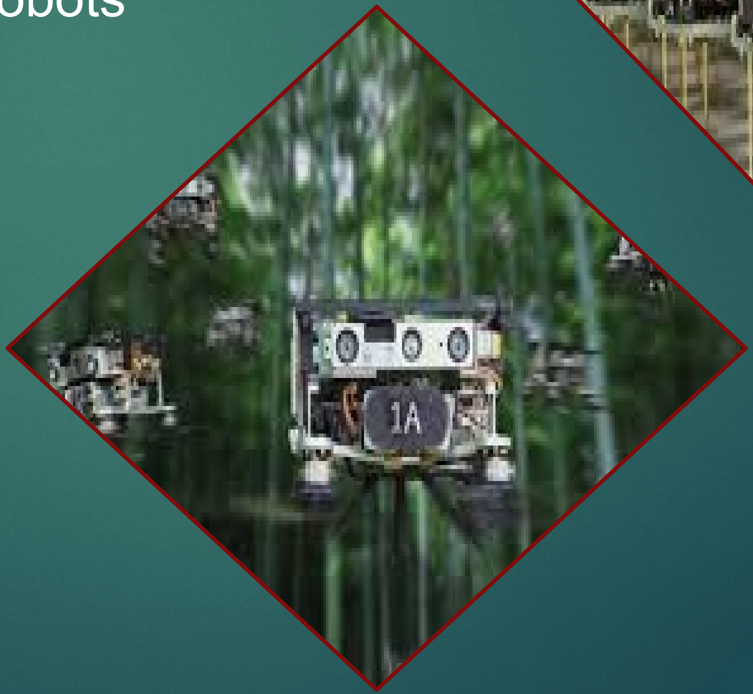
- Used in hostile environments
- Improves safety
- Less expensive
- More capable than individual robots





Challenges in Swarm Robotics

- Problems with Scalability
- Problems with Robustness
- Coordination between individual robots
- Change in environment
- Simple



What's in the future for Swarm Robotics?

- Lots to be developed still
- Expected to be developed with real world applications in the next 15 years
- Sought by defense agencies
- Might be used on space missions
- Entertainment
- Nano-Robotics?

Conclusion

- Swarm Robotics, inspired by natures efficiency, allows us to try and emulate collective behavior in solving complicated tasks
- With many challenges ahead, with scalability, robustness, coordination and many more, ongoing research is getting ever closer to creating solutions to these problems
- Swarm robotics in the future will play a pivotal role in how we solve large scale tasks like disaster recovery missions, large scale mapping and many more

Sources

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