SWARMING ROBOTS

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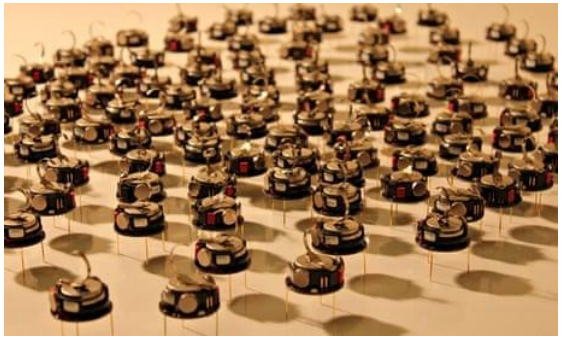
Introduction

Swarm robots are a collection of small, autonomous robots that cooperate to accomplish a shared objective. Swarm robotics attempts to research and build systems that display emergent behavior through the interaction of many basic robots and is inspired by the group behavior of social insects like ants, bees, or termites. Each robot in a swarm normally has limited powers and intelligence on its own, but by collaborating and interacting with other robots in the group, they may collectively do challenging tasks. Self-organization, resilience, scalability, adaptability, and fault tolerance are some traits that swarm robots may display.



History

The development of swarm robots can be traced back to several key milestones in the field of robotics and artificial intelligence. Here's a brief overview of the history of swarm robot development:

- The concept of swarm robotics is inspired by the group behavior seen in social insects like termites, ants, and bees. The cooperative behavior and self-organization displayed by these animals have long captivated scientists and researchers.
- The idea of multi-agent systems rose to popularity in the artificial intelligence community in the 1980s and 1990s. The notion of creating systems made up of several autonomous entities capable of cooperating with one another to accomplish shared objectives has been investigated by researchers.
- Roboticists Gerardo Beni and Jing Wang first used the phrase "swarm robotics" in the latter part of the 1980s. They envisioned a branch of study that focused on creating and managing massive squadrons of basic robots that are able to work together to solve difficult problems.
- In the 1990s, several pioneering experiments were conducted in swarm robotics. For example, Mark Millonas and colleagues demonstrated the synchronization and collective behavior of a group of simple robotic agents known as "Kilobots." These experiments laid the foundation for future developments in swarm robotics.

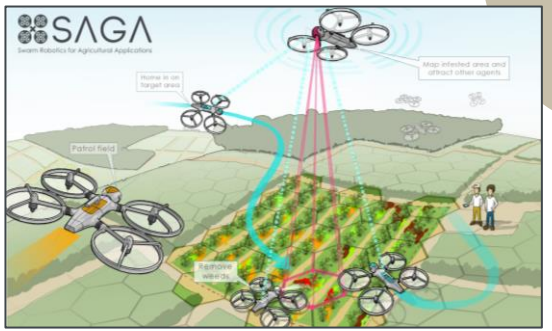
History

- In the early 2000s, the idea of "swarm intelligence" became popular. When a group of people interact, a collective behavior results that is more intelligent than the sum of the acts of its individual members. Swarm robotics research has come to rely heavily on swarm intelligence concepts like distributed decision-making and self-organization.
- Researchers created complex algorithms and communication protocols for swarm robots as computer power and communication technology advanced. These developments centred on making it possible for effective work distribution, coordination, information exchange, and self-organization inside the swarm.
- Swarm robotics has been useful in a number of fields in recent years. Swarm robots, for instance, have been employed in search and rescue missions, environmental monitoring, building projects, farming activities, and exploration. They have benefits including scalability, fault tolerance, and environment adaptation.
- The field of swarm robotics is still actively being researched and developed. New methods for swarm control, behavior modelling, swarm optimization, and human-swarm interaction are being researched by scientists. The field tries to address issues with large-scale swarm systems' scalability, resilience, energy efficiency, and robust decision-making.

Application

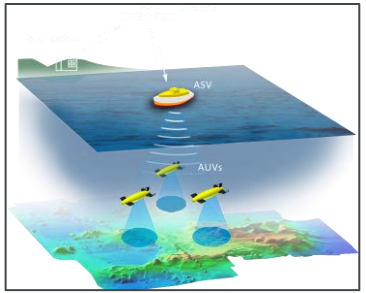
- **Search and Rescue Operations**
  Swarm robots can be employed in search and rescue operations to investigate dangerous or difficult-to-reach settings, such as fallen buildings or disaster-stricken areas. In order to increase the effectiveness and safety of rescue efforts, they might work together to search for survivors, map the area, or supply supplies.

- **Agriculture**
  Swarm robots can help with agricultural activities by keeping an eye on the crops, administering precise treatments, or carrying out pollination. Together, they can improve agricultural productivity, better allocate resources, and lessen the need for human intervention.

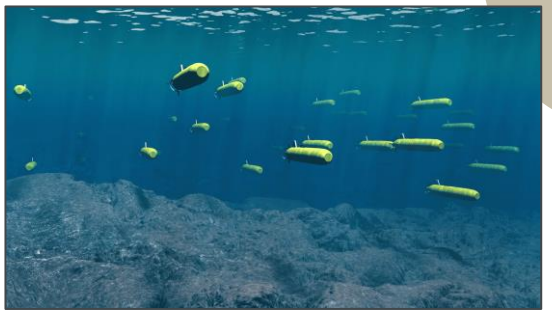


Application

- **Exploration and Mapping**
  Swarm robots may investigate uncharted or dangerous locations, such deep marine settings, subterranean caverns, and space. By working together and exchanging information, they may produce intricate maps, gather samples, and support scientific study.



- **Environmental Monitoring**
  Swarm robots can be used to detect pollution levels, gather information on wildlife habitats, or keep an eye on the condition of ecosystems as part of environmental monitoring projects. Due to their dispersed nature, they can give real-time data for environmental monitoring and decision-making while also covering broad regions.



Main Component (Body Design)

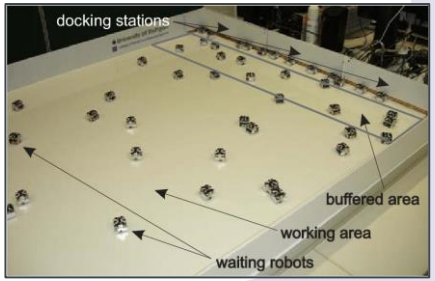
- **Modular Swarm Robots**
  Individual modules make up modular swarm robots, which may be connected and disconnected from one another to create various configurations. Usually, these modules are capable of computation and movement on their own. Swarm robots may change their form and function to fit various activities and situations by merging modules.

- **Hybrid Swarm Robots**
  Hybrid swarm robots combine several modes of propulsion or body construction into a single unit. To maximize their mobility and adapt to various environments or jobs, they may combine wheeled, legged, or winged locomotion methods.

Main Component (Body Design)

- **Swarm Robots with Docking Stations**

  Robots can dock with certain stations or docking ports in some swarm robot systems. Robots may alter their hardware or software configuration at these docking stations, which also act as charging stations, data exchange points, or reconfiguration sites.



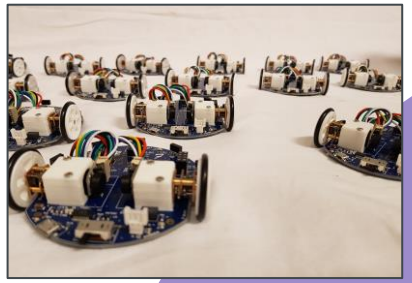
- **Swarm Robots with Aerial Capabilities**

  Swarm robots with flying prowess combine flying with ground-based movement. These robots may be equipped with retractable wings, rotors, or propellers that enable them to fly and land, giving them the ability to access various locations and carry out duties both on the ground and in the air.

Main Component (Locomotion)

- **Wheeled**

  Robots can travel on wheels or rails using this kind of locomotion. This approach offers stability and effective movement and works best on flat surfaces. Wheeled swarm robots can move swiftly and maneuver around organized settings with ease.



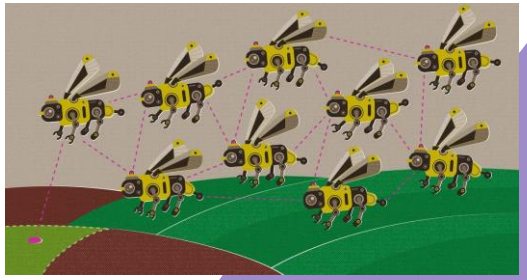
- **Legged**

  Legs or limbs are used in leg locomotion, which imitates the animal walking or crawling action. Swarm robots may now navigate uneven or difficult terrain where wheeled mobility could have trouble. Better flexibility and maneuverability come with leg locomotion, although more complicated control algorithms would be needed.

Main Component (Locomotion)

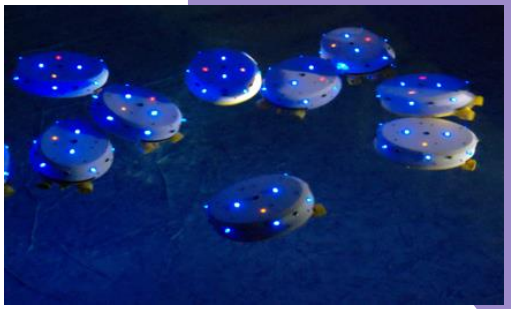
- **Flying**

  Wings or propellers are used in flying locomotion to move in the air. Flying swarm robots can maneuver in the air, allowing them to access hard-to-reach places or go around barriers on the ground. Flying locomotion provides for quick and effective mobility, but it may have restrictions on the amount of cargo it can carry and how much energy it can use.



- **Swimming**

  Swarm robots can move using swimming locomotion in watery situations. These robots can move across water using fins, propellers, or other methods. When doing jobs that require underwater exploration, monitoring, or maintenance, swimming locomotion is helpful. But it poses difficulties like buoyancy control and water resistance.



Behaviour

Behaviour	Description	Example
Collective exploration	Robot swarm exploration of the environment through navigation of the swarm across the environment	Locating items, setting up a communication network, or keeping an eye on the surroundings
Coordinated motion	Moving the swarm of robots in a formation	A line or flocking formation
Collective transport	Allowing a group of robots to transport bulky or heavy things at once	Moving large stuff like furniture
Collective localization	Utilizing a local coordinate system to assist the swarm of robots in determining their location and orientation with respect to one another	Establishing a local coordinate system to track relative locations across the swarm

Data Collection

Swarm robots have a variety of techniques to collect data. An approach that is frequently used is sensor fusion. Sensor fusion creates a more accurate and comprehensive picture of your surroundings by combining data from many sensors. For instance, a swarm of robots equipped with cameras, LiDAR sensors, and ultrasonic sensors may produce a 3D map of their surroundings. Swarm robots may also gather information by cooperating with one another. For instance, robot swarms can be used to scour disaster zones for survivors. Together, robots can split up spaces and communicate their findings. Swarm robots can be used to gather information in dangerous or challenging-to-access locations. For example, swarms of robots could be deployed to explore nuclear reactors or clean up oil spills.

Robots may be sent out in a swarm to gather information about the surroundings in the disaster zone. Cameras, LiDAR sensors, and ultrasonic sensors might be added to robots. Robots can detect survivors, find dangerous objects, and map the environment in three dimensions using these sensors. Robotic data might aid emergency personnel in planning and assessing the situation.

Data Collection

Examples:

- Robots named Khepera and Khepera IV employ optical sensors to gather information about their surroundings. They can recognise things and barriers by detecting and processing light.

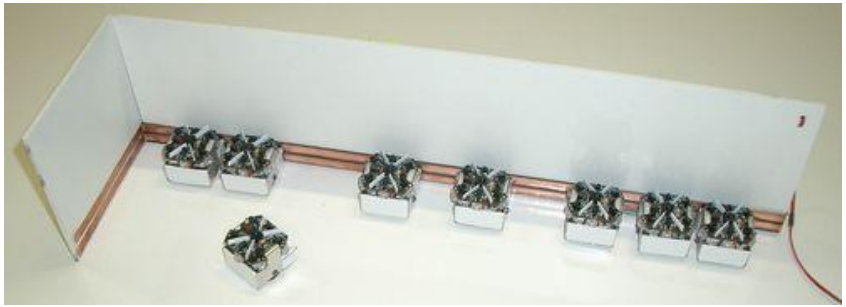
- Robots called Khepera, Khepera IV, E-puck, E-puck 2, and Pheeno employ microphones to gather sound information and pinpoint the origin of sound.

- Robots Colias and S-bot employ cameras to record pictures and films of their surroundings.

- Robots like Alice, Kobot, Jasmine, and Kilobot employ infrared sensors to determine the proximity and existence of things.

Power Management

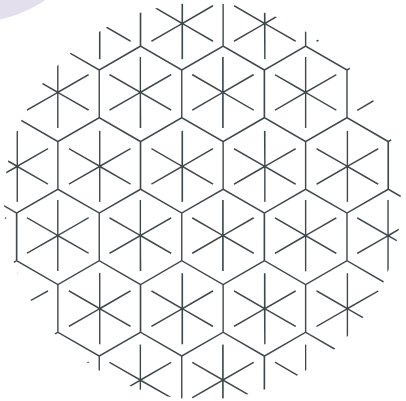
- Charging Station
  A charging station for swarm robots is a centralized location where the robots recharge their batteries. It provides a power source and a connection mechanism for the robots to dock and transfer energy. The station may have communication capabilities for data exchange and safety features to prevent overcharging. It ensures the swarm robots have sufficient energy, prolonging their operational time and optimizing their productivity.



Power Management

- Maintenance Station
  Swarm robots have special locations where they may go for maintenance and repairs, called maintenance stations. It serves as a focal point for all aspects of robot maintenance, such as diagnostics, component swaps, and software upgrades. By ensuring the swarm robots are in top functioning condition, the station increases their longevity and overall performance.

- Charging Robot
  - Portable charging station to support large swarm robots
  - Have several docking stations for easy multiple robot charging
  - Adaptive to various place as it is versatile and easily moved
  - Employ comparable data packets as swarm robots
  - If a mobile robot's battery level falls below a specific threshold and unable to relocate themselves, they will send message for mobile charging robot assistance.



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