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Assignment 4 – Swarming robot

Introduction:

Swarm robots are a class of autonomous robots that work together to complete tasks. They operate on the principle of swarm intelligence inspired by the behavior of social insects such as ants, bees and termites.

Swarm robots are designed to interact with each other using communication and sensing mechanisms, allowing them to work together and coordinate their actions. This will enable them to perform complex tasks such as exploration, mapping, surveillance, search and rescue, and even construction.

Swarm robots can also adapt to changing environments and conditions by reorganizing their behavior and strategies as a group. It is being researched and developed for various applications in fields such as agriculture, mining, disaster relief and transportation.

History:

Date	Event
1988	G.Beni and Fukuda invented the swarm in robotics
1989	-Fukuda explained that swarm describe robots work as a group like human cells -G.Beni and J.Wang introduces the concept of “swarm intelligence”
1993	Gregory Dudek defines swarm robotics based the multiple features of the system Early swarm robotic system investigate swarming behavior in natural species
2004	G.Beni directly explain swarm as a simple, identical and self-organizing robots with scalable system and only local communication

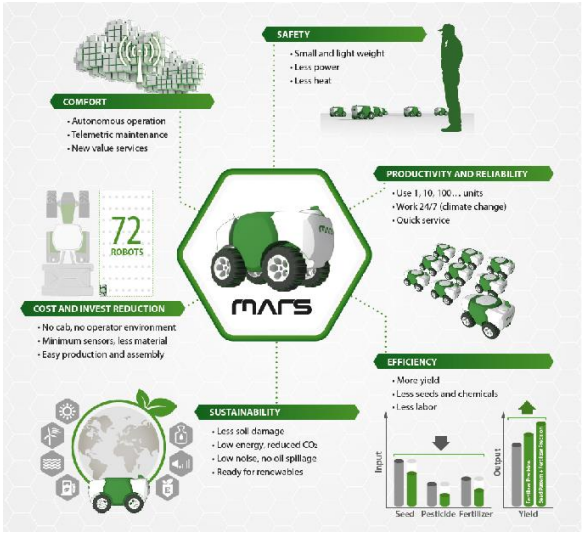
Key Characteristics of Swarm robots:

1. Autonomy: Autonomous robot that can physically interact with the environment.
2. Large Numbers: The system consists of limited homogeneous groups of robots in which each group contains a large number of members.
3. Limited capabilities: Each robot in the system is relatively incapable or inefficient in performing tasks alone, but can be very efficient when working together as a group.
4. Scalability and robustness: The swarm robot system is scalable and robust. Increasing the number of units improves overall performance.
5. Distributed coordination: Coordination between robots is decentralized. Each robot has localized and limited perception and communication abilities.

Application:

Field	Application
Agriculture	Swarm robots used for crop monitoring, pollination, and harvesting
Military	Swarm robots used for surveillance, reconnaissance, and combat support

Entertainment	Swarm robots used for art installations, interactive displays, and public performances
Healthcare	Swarm robots used for medical procedures, drug delivery, and patient monitoring
Industrial Automotion	Swarm robots used for manufacturing, assembly, and quality control



Figures 1: Concept design for agricultural industry

(Mars-Mobile Agriculture Robot Swarms)

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DARPA's Initiative to Train Military Robots Swarm Using Gamers' Brain

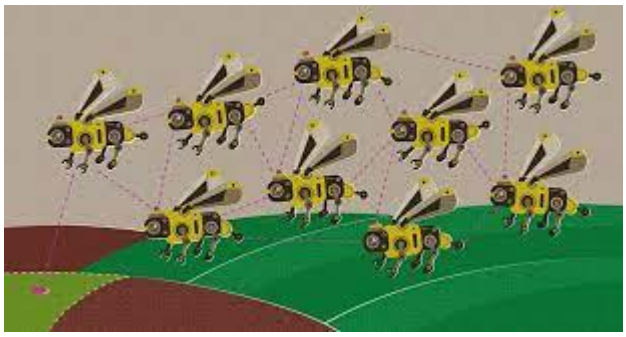
Smriti Srivastava
February 13, 2020 . 2 mins read

Figure 2: Development of swarm robots in military

Main Components of Swarm Robots

1. Body design

The designs are usually small in size, simple and low in cost. Mostly the designs are inspired by insects. Below are some examples of swarm robot:

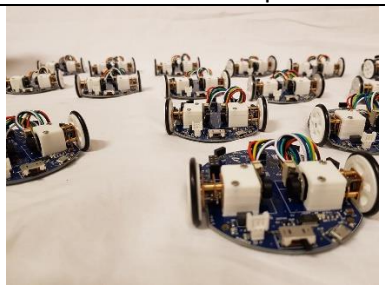
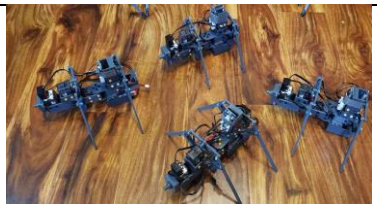
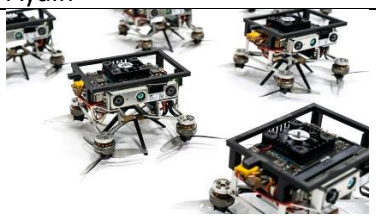


In swarm robotics quantity is more important than quality as more robot you have, more tasks can be done while size is considered by the task.

Types	Description
Wheeled	Most useful on flat surfaces. Depending on the task the design can be simple or complex.
Legged	Most suitable use on rough, mountain terrain. The robot can crawl and walk with more complex design than wheeled for higher mobility
Aerial	Most suitable for surveying large areas or hard-to-reach locations. They can vary in size and complexity, from small quadcopters to larger drones.
Underwater	Most suitable for tasks such as ocean exploration or monitoring water quality. They can be shaped like fish or have propellers for movement.
Hybrid	Combined of multiple function for versatility.

2. Locomotion

There is a total of 6 types of locomotion system of the swarm robot

Types	Locomotion system	Example
Wheeled: Uses wheel to move	The robots uses wheels to generate forward motion using materials that are suitable for flat surfaces. Move in group to complete tasks.	 MONA swarm robot
Legged: Uses leg to move	The robot uses leg to move in coordination with other robot to perform task.	 Swarm robot developed by Prof. Ozkan-Aydin
Arial: Uses wings or rotor to move	The robots flies by using a set of wings or propellers and coordinates with robot in the air, suitable for surveying	 Autonomous swarm drones
Underwater: Uses fins or propeller to move	Underwater robots that designed as aquatic organism or fish	 Bluebot that swims like group of fish

3. Navigation

The sensors used in swarm robot navigation systems vary depending on the specific application. For example, a robot navigating cluttered environments may need a camera and his LiDAR sensor. Robots that move in tight spaces may require ultrasonic sensors.

Sensors are typically used in combination to provide a more comprehensive view of the environment. For example, cameras can be used to identify objects, LiDAR sensors can be used to measure distance, and IMUs can be used to track robot movements. Information from sensors is used to create navigation maps. A navigation map is a representation of the robot's environment. This can be used to plan the path taken by the robot and avoid obstacles.

Swarm robot navigation systems are a complex and challenging research area. But they have the potential to revolutionize the way we interact with the world around us.

Sensor	Description
Camera	A camera can be used to see the environment around the robot. This information can be used to navigate around obstacles and to find targets.
LiDAR	LiDAR is a type of sensor that uses light to measure distance. This information can be used to create a map of the environment around the robot.
IMU	An IMU is a sensor that measures the robot's orientation and velocity. This information can be used to keep the robot stable and to track its movement.
Ultrasonic	An ultrasonic sensor emits sound waves and measures the time it takes for the waves to return. This information can be used to measure the distance to objects in the robot's path.
Radia Transceiver	For communication between robot and controller at station
Accelerometer	To track the acceleration, able of inclination or to detect any collision
Wheel Encoder	Measure the estimation of robot position by wheel rotation

4. Data collection

Swarm robots can collect data in many ways. A common method is to use a technique called sensor fusion. Sensor fusion combines data from multiple sensors to create a more accurate and complete picture of your environment. For example, a swarm of robots can create a 3D map of their environment using a combination of cameras, LiDAR sensors, and ultrasonic sensors.

Another way swarm robots collect data is by working together. For example, swarms of robots can be deployed to search for survivors in disaster areas. Robots can work together to divide areas and share information about what they find.

Swarm robots can also be used to collect data in hazardous or difficult-to-access environments. For example, swarms of robots could be deployed to explore nuclear reactors or clean up oil spills.

Below is an example of how a swarm robot collects data:

A swarm of robots may be deployed to collect data on the environment of the disaster area. Robots could be equipped with cameras, LiDAR sensors, and ultrasonic sensors. Using these sensors, robots can create 3D maps of the environment, identify survivors, and locate hazardous materials. Data collected by robots could help first responders assess the situation and plan rescue operations.

Some others example:

- Platypus (an autonomous swarm boat robot) collect data about water quality which consists of (sanity, oxygen and stratification)
- SAGA (Swarm Robotics for Agriculture Appication) monitoring and mapping farm using swarm of UAVs as part of smart farming

Swarm robots are a promising new technology for collecting data in a variety of demanding environments. As technology advances, we can expect even more innovative and groundbreaking use of swarm robots for data collection.

5. Communication

Most common technology used for communication are Bluetooth, wireless LAN or infrared.

6. Control & Behavior

Control Type	Description
Centralized Control	1 controller is responsible for controlling the entire swarm. This controller has a complete view of the environment and the state of all the robots in the swarm. Centralized control is simple to implement and can be very efficient. However, it is also vulnerable to single point of failure.
Decentralized Control	Each robot in the swarm is responsible for controlling its own behavior. The robots communicate with each other to share information about the environment and their own state. Decentralized control is more robust than centralized control, but it is also more complex to implement.
Hybrid Control	Combination of centralized and decentralized control. In hybrid control, a central controller is responsible for high-level decisions, such as the overall goal of the swarm. The individual robots are responsible for low-level decisions, such as how to move around the environment. Hybrid control is the most complex control architecture, but it also offers the most flexibility and robustness.

Behavior	Description
Flocking	the coordinated movement of a group of robots. This behavior is often observed in nature, such as in flocks of birds or schools of fish. Swarm robots can be used for a variety of tasks such as surveillance, search and rescue, and delivery.
Aggregating	the action of a group of robots gathering in one place on her. This behavior is often observed in nature, such as in ant or bee colonies. Accumulator robots can be used for various tasks such as cleaning, inspection, and agriculture.
Dispersing	the act of dispersing a group of robots over a large area. This behavior is often observed in nature, such as in herds of animals and swarms of insects. Distributed robots can be used for a variety of tasks such as search and rescue, reconnaissance, and surveillance.
Escaping	the action of a group of robots running away from a threat. This behavior is often observed in nature, such as when a flock of birds is startled by a predator. Getaway robots can be used for a variety of missions, including self-defense and disaster relief.
Foraging	the act of a group of robots searching for food and other resources. This behavior is often observed in nature, such as when ants search for food. Foraging robots can be used for a variety of tasks such as search and rescue, exploration, and agriculture.

7. Power management

Swarm robot have huge numbers of robots working hence it will be hard to maintain the power stored without some automated method of charging and reprogramming. There are a few methods by which the swarm could be charged.

- Charging Station
    - Low cost and simple method for charging purpose.
    - Allows robot charge automatically when needed.
    - Provide correct charging voltage
    - Safe as the port has charging regulator that prevent over charging
    - Easily placed in different area
    - 2 contacts to bot (Power and Ground)

- Maintenance Station
    - Serve as charging and reprogramming station
    - Allows the robot to autodock, recharge, reprogram, and communicate with a host.
    - Provides correct voltage regulation for battery charging
    - 4 contacts to bot (Power, Gnd, Clock and Data)
    - Provides I2C communication

    - Microcontroller to handle I2C communications
    - USB or RS-232 communication with the host computer.

- 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.