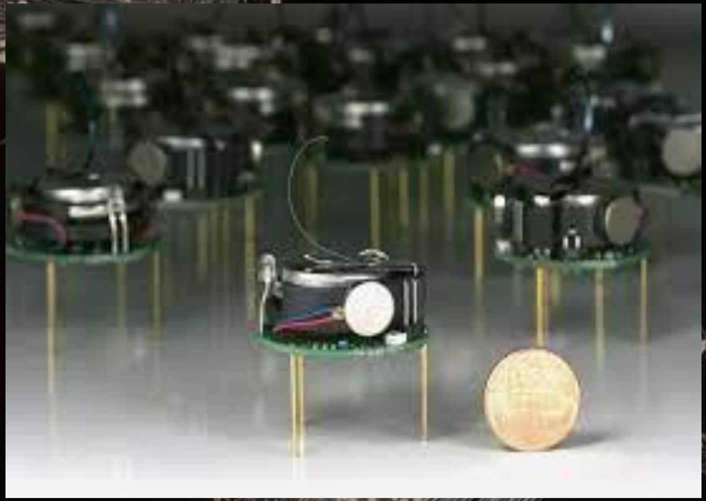


Swarm Robots

IQMAL HAKIMI BIN RAZALI

1912103

Introduction

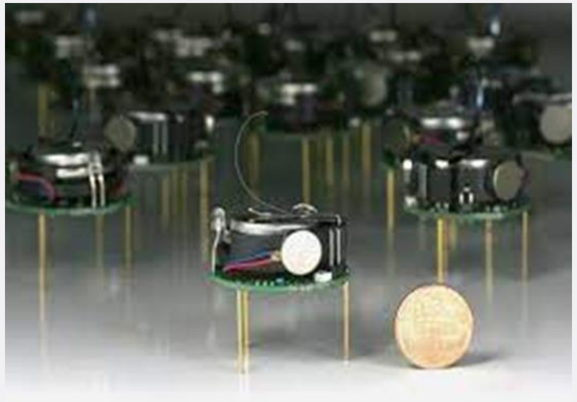
History & Application

Main Components

Content

Introduction

- Swarm robotics is a field of robotics that studies the behavior of large groups of relatively simple robots, called swarm robots, that work together in a coordinated manner to accomplish a task. Swarm robotics draws inspiration from the behavior of social insects, such as ants, bees, and termites, that can achieve complex tasks as a collective without the need for a centralized control.
- In swarm robotics, each individual robot can perform a limited set of actions, and the group's behavior emerges from the interaction of the robots with each other and their environment. The swarm robots typically communicate with each other using wireless protocols and make decisions based on local information and simple rules.
- Swarm robotics has applications in many fields, including search and rescue operations, environmental monitoring, agriculture, and industrial automation. The advantages of swarm robotics include scalability, fault tolerance, and robustness, as well as the ability to perform tasks that are beyond the capabilities of individual robots.
- Research in swarm robotics is ongoing, with a focus on developing new algorithms and control strategies to improve the performance and efficiency of swarm robots, as well as exploring new applications for this emerging technology.



History

- The history of swarm robotics can be traced back to **the early 1980s** when the concept of distributed artificial intelligence (DAI) was introduced. The idea of DAI was to create systems that could solve problems collaboratively using decentralized control, similar to how social insects operate.
- In **the late 1980s and early 1990s**, researchers started exploring the concept of swarm intelligence, which is the collective behavior of decentralized, self-organized systems. The term "swarm intelligence" was first coined by Gerardo Beni and Jing Wang in 1989, and they applied it to the study of robotic systems.
- **The first swarm robotics** experiments were conducted in the **early 1990s** by roboticist **Marco Dorigo**. He developed the concept of ant colony optimization (ACO), a method of solving complex optimization problems based on the behavior of ant colonies. ACO was the first algorithm that used swarm intelligence principles to solve real-world problems.
- In **the late 1990s and early 2000s**, the field of swarm robotics grew rapidly, with researchers developing new algorithms and control strategies to improve the performance of swarm robots. **The first international conference on swarm robotics was held in 2004**, which helped to establish the field as a distinct area of research.
- Since then, swarm robotics has continued to evolve, with researchers exploring new applications and developing new algorithms and control strategies. Some of the current research areas in swarm robotics include cooperative transportation, collective decision-making, and swarm behavior analysis.

Applications

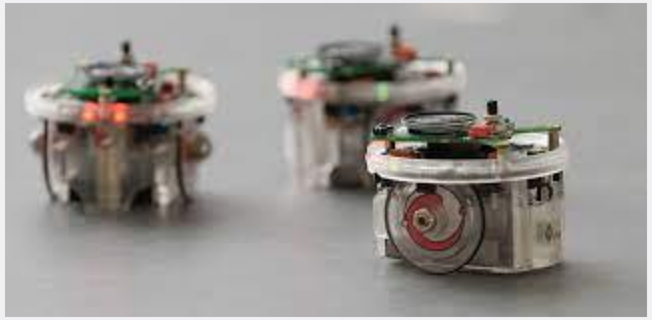
- **Search and Rescue:** Swarm robots can be used in search and rescue operations to quickly and efficiently search large areas for survivors in the aftermath of natural disasters or accidents.
- **Environmental Monitoring:** Swarm robots can be used to monitor environmental conditions, such as water quality, air pollution, or climate change, over large areas. They can be equipped with sensors to collect data and transmit it back to a central location.
- **Agriculture:** Swarm robots can be used in precision agriculture to automate tasks such as planting, harvesting, and crop monitoring. They can also be used to map soil and crop conditions, optimize irrigation, and identify pests or diseases.
- **Industrial Automation:** Swarm robots can be used in manufacturing and logistics to perform tasks such as inventory management, product assembly, and material handling.
- **Surveillance and Security:** Swarm robots can be used for surveillance and security purposes, such as monitoring public spaces, tracking suspicious activities, or inspecting infrastructure.
- **Space Exploration:** Swarm robots can be used in space exploration to explore other planets and moons, conduct scientific experiments, and gather data.
- **Medical Applications:** Swarm robots can be used in medical applications such as minimally invasive surgery, drug delivery, and targeted therapy.

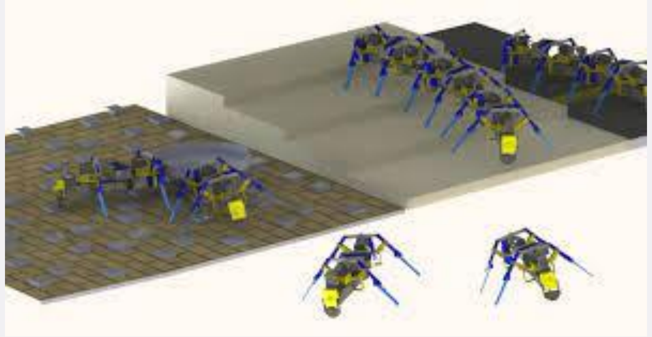
Main Components

- Design
- Propulsion System
- Navigation System & Control
- Data Collection
- Data Transmission
- Power Management

Design

- Typically inexpensive, basic, and modest in size. The design of the body was influenced by insects.





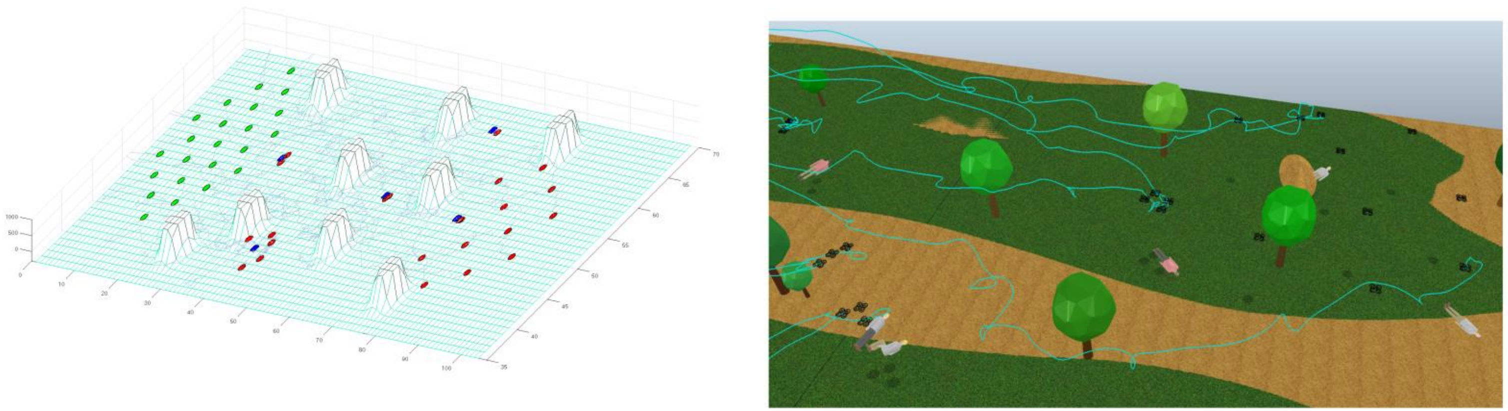
Propulsion System

- **Wheeled robots**: Wheeled robots typically use electric motors to power their wheels. The motors can be controlled using a variety of techniques such as pulse-width modulation (PWM) or digital signal processing (DSP).
- **Legged robots**: Legged robots often use hydraulic or pneumatic actuators to control the movement of their legs. These actuators can be controlled using valves and pumps that are powered by an electric motor or other power source.
- **Flying robots**: Flying robots use electric motors to power their propellers or wings. The motors can be controlled using PWM or DSP techniques. Some flying robots use flapping wings that are actuated using piezoelectric materials or other mechanisms.
- **Swimming robots**: Swimming robots can use a variety of propulsion systems such as thrusters, paddles, or fins. The propulsion system can be powered by electric motors or other power sources.
- **Rolling robots**: Rolling robots typically use a mechanism such as a ball or a cylinder to propel themselves. The mechanism can be actuated using electric motors or other power sources.
- **Crawling robots**: Crawling robots can use a variety of propulsion systems such as legs, wheels, or tracks. The propulsion system can be actuated using electric motors or other power sources.

Navigation System

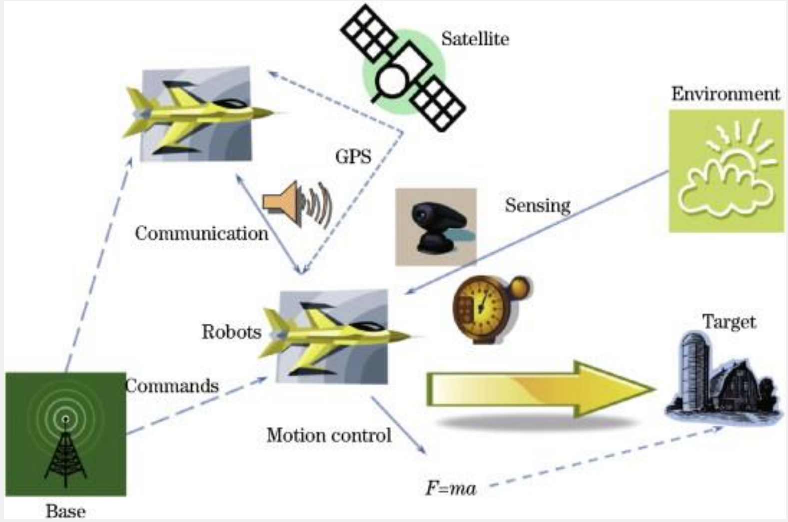
- **Global Positioning System (GPS):** GPS is a satellite-based navigation system that provides location and time information. This system can be used for outdoor applications where the robots need to navigate over long distances and where GPS signals are available.
- **Inertial Navigation System (INS):** INS is a navigation system that uses sensors such as accelerometers and gyroscopes to determine the robot's position, velocity, and orientation. This system can be used for applications where GPS signals are not available, such as indoor environments.
- **Visual Navigation System:** Visual navigation systems use cameras or other visual sensors to navigate in the environment. This system can be used for applications such as object tracking or obstacle avoidance.
- **Swarm Intelligence Navigation:** Swarm intelligence navigation involves using the collective behavior of the swarm to navigate in the environment. This can be used for applications such as area exploration or object clustering.
- **Hybrid Navigation System:** Hybrid navigation systems involve combining different navigation systems to achieve a specific set of capabilities. For example, a robot may use GPS for global positioning and INS for local positioning.

Navigation System



(**a**) Navigation and victim localization in Matlab.

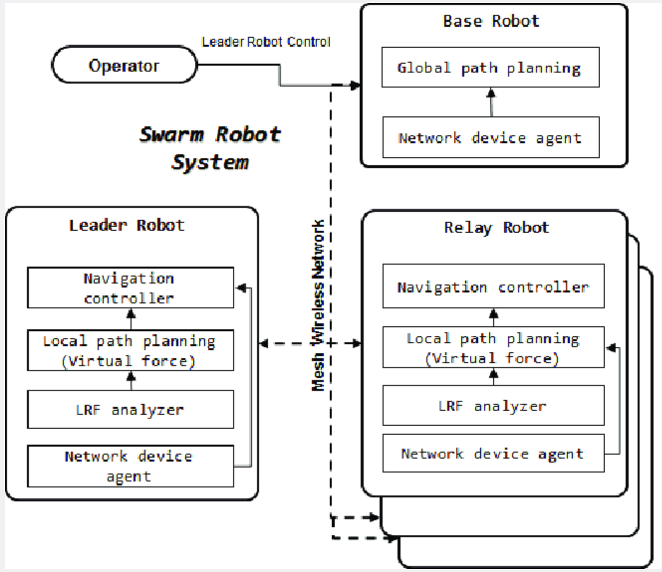
(**b**) Navigation and victim localization in a virtual environment.

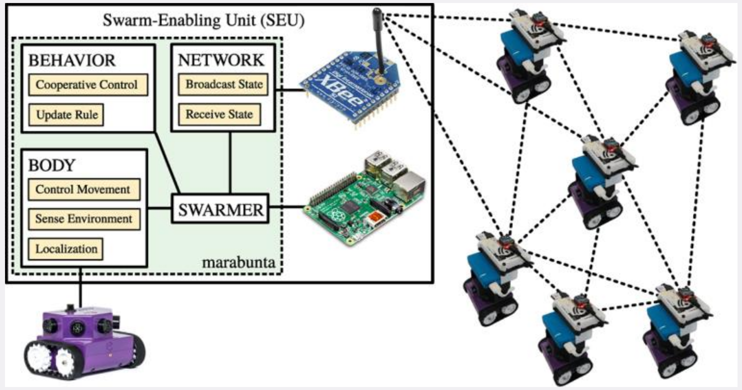


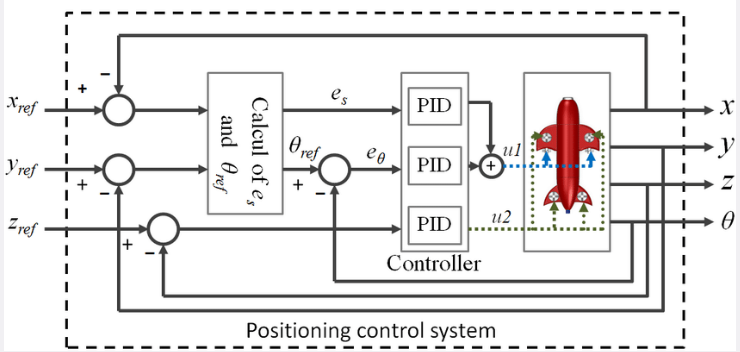
Control System

- Centralized Control: In a centralized control system, there is a central controller that coordinates the behavior of the swarm. This controller receives information from the robots and sends commands to them based on a predetermined set of rules or algorithms.
- Distributed Control: In a distributed control system, each robot in the swarm has its own decision-making capabilities and communicates with its neighbors to make decisions collectively. This allows for greater flexibility and adaptability in the behavior of the swarm.
- Emergent Control: Emergent control involves the emergence of complex behavior from the interactions between individual robots in the swarm. This behavior is not predetermined by a central controller but rather emerges spontaneously from the interactions between the robots.
- Hybrid Control: Hybrid control systems combine different control systems to achieve a specific set of capabilities. For example, a swarm may use centralized control for initial coordination and then switch to distributed control for more flexible and adaptive behavior.

Control System







Data Collection

- Sensors: Sensors are used to gather data from the environment, such as temperature, humidity, light, sound, and proximity. Examples of sensors used in swarm robotics include infrared sensors, ultrasonic sensors, and camera sensors.
- Communication Devices: Communication devices are used to transmit data between robots and between robots and a central controller. Examples of communication devices used in swarm robotics include radio frequency (RF) transceivers and Wi-Fi modules.
- On-board Processing Units: On-board processing units are used to process data collected from the environment and make decisions based on that data. These units may include microprocessors or microcontrollers that are designed to handle the specific requirements of the swarm.
- GPS and Inertial Navigation Systems: GPS and inertial navigation systems are used to collect data about the swarm's location and orientation. This data is used to make decisions about how to navigate and interact with the environment.
- Data Storage Devices: Data storage devices are used to store the data collected by the swarm. Examples of data storage devices used in swarm robotics include flash memory chips and microSD cards.

Data Collection (Components)

Infrared Sensor

Ultrasonic Sensor

Camera Sensor

RF Transceiver

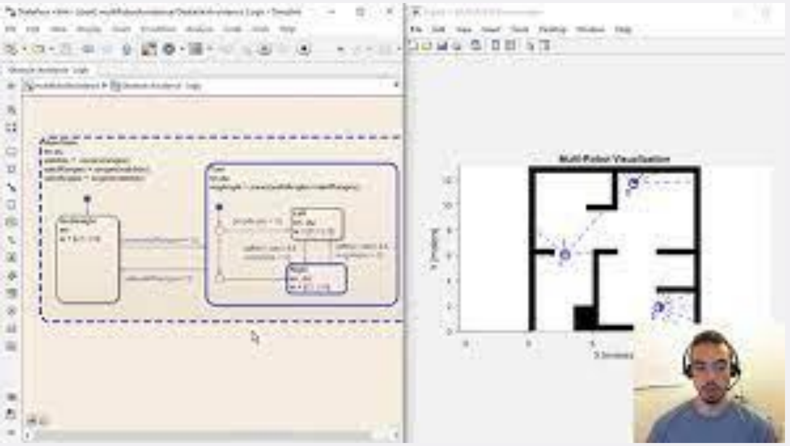
GPS Module

MicroSD card for memory

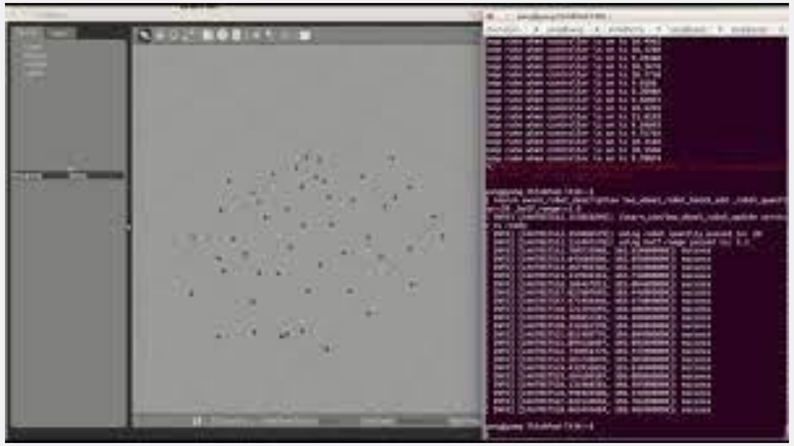
Data Collection

- **Robot Operating System (ROS):** ROS is a popular open-source middleware framework that is widely used in robotics, including swarm robotics. It provides a set of tools and libraries that enable robots to communicate with each other and with other devices, as well as to process and analyze data collected from sensors.
- **MATLAB:** MATLAB is a high-level programming language that is widely used for scientific computing and data analysis. It provides a set of tools for processing and analyzing data collected from sensors, as well as for developing algorithms for controlling the behavior of the swarm.
- **Python:** Python is a high-level programming language that is widely used in scientific computing and data analysis. It provides a set of tools for processing and analyzing data collected from sensors, as well as for developing algorithms for controlling the behavior of the swarm.
- **Java:** Java is a popular programming language that is widely used in software development for a wide range of applications, including swarm robotics. It provides a set of tools for developing software that can run on different platforms, as well as for processing and analyzing data collected from sensors.
- **C/C++:** C and C++ are programming languages widely used in robotics and embedded systems. They provide a set of tools for developing software that can run on different hardware platforms, as well as for processing and analyzing data collected from sensors.

Data Collection (Software)



MATLAB



ROS

Data Transmission

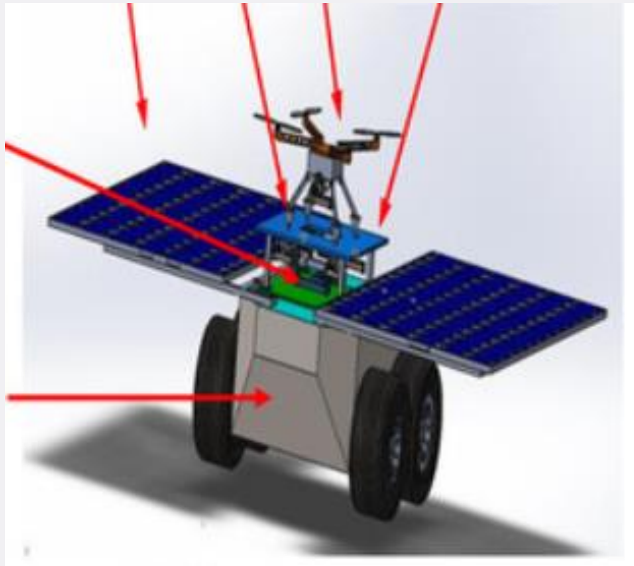
- **Wireless Communication**: Wireless communication is a common way to transmit data in swarm robotics. This can be achieved using various wireless protocols such as Wi-Fi, Bluetooth, ZigBee, or radio frequency (RF) communication. These protocols can allow for fast and efficient data transmission over a short range, which is useful in many swarm robotics applications.
- **Wired Communication**: In some cases, wired communication may be necessary for reliable data transmission in swarm robotics. This can be achieved using cables or other physical connections to transfer data between robots or between a central controller and the swarm.
- **Infrared Communication**: Infrared communication can be used for short-range data transmission in swarm robotics. Infrared communication requires a direct line of sight between the transmitter and receiver, but it can be a useful option for applications that require low power consumption or that are sensitive to electromagnetic interference.
- **Acoustic Communication**: Acoustic communication involves using sound waves to transmit data between robots in a swarm. This can be useful in underwater or other environments where radio frequency communication is not possible.
- **Visual Communication**: Visual communication can be achieved using cameras or other visual sensors to transmit data between robots in a swarm. This can be useful in applications that require object recognition or tracking, or that require robots to navigate based on visual cues.

Power Management

- Batteries: Batteries are one of the most common power sources used in swarm robotics. They are easy to use, compact, and can provide a high amount of energy. Batteries can be recharged, making them ideal for applications where the robots need to operate for extended periods.
- Solar Panels: Solar panels are another common power source used in swarm robotics. They convert sunlight into electrical energy, which can be used to power the robots. Solar panels are lightweight, environmentally friendly, and can operate for long periods without needing maintenance.
- Fuel Cells: Fuel cells are a type of electrochemical cell that converts chemical energy into electrical energy. They are highly efficient and can provide a high amount of energy in a small package. Fuel cells can be refueled, making them ideal for applications where the robots need to operate for extended periods without requiring frequent recharging.
- Kinetic Energy: Some swarm robots can generate power from kinetic energy. This may involve using piezoelectric materials that generate electrical energy when subjected to mechanical stress or harvesting energy from the robot's movement or vibration.
- Other Sources: Other sources of power that may be used in swarm robotics include wind turbines, thermoelectric generators, and electromagnetic induction.

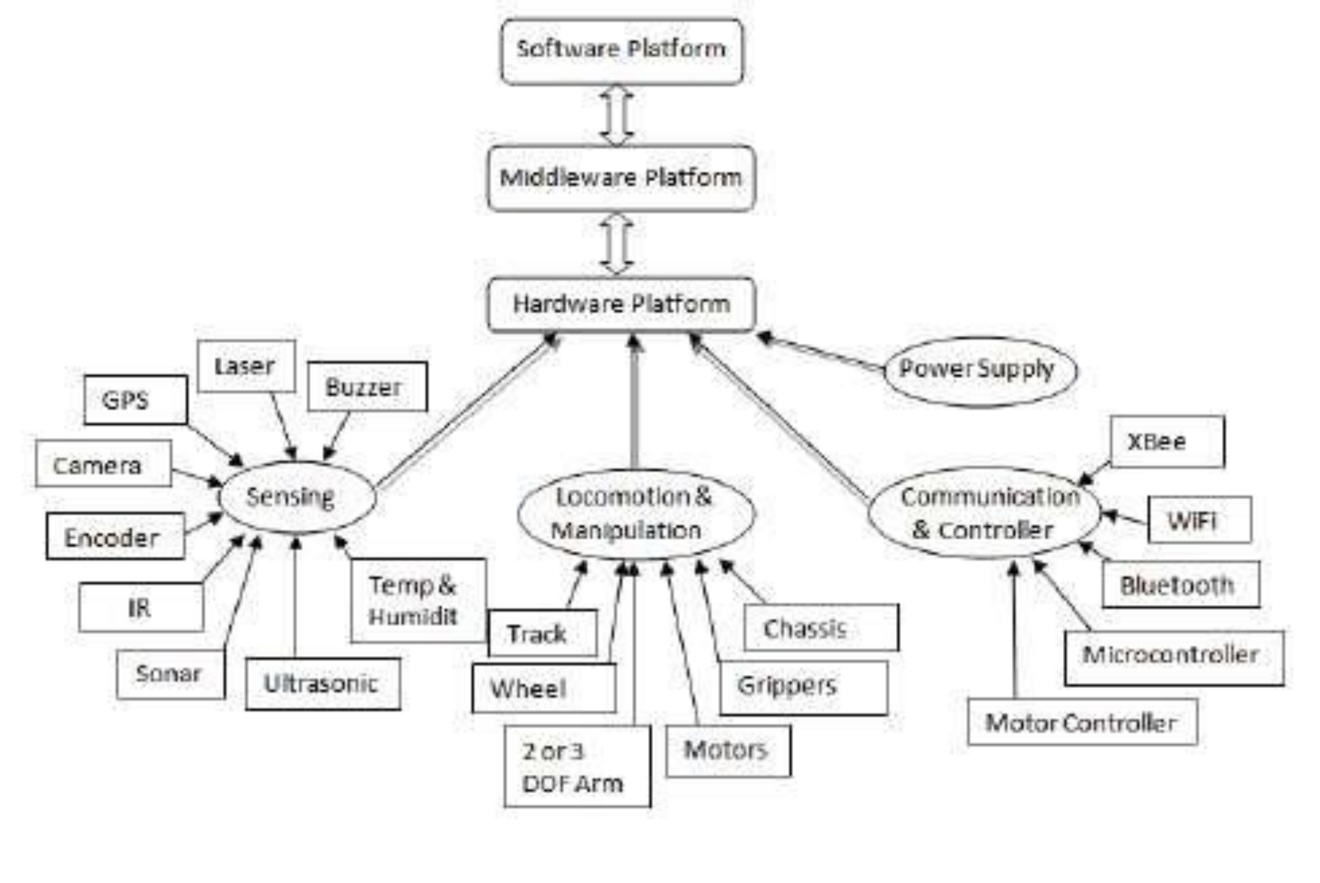
Power Management

Batteries



Solar Panel

Conclusion



Software Platform
Middleware Platform
Hardware Platform
Power Supply
Laser
GPS
Buzzer
Camera
Sensing
Encoder
IR
Sonar
Ultrasonic
Temp &
Humidit
Locomotion &
Manipulation
Track
Wheel
2 or 3
DOF Arm
Motors
Grippers
Chassis
Communication
& Controller
XBee
WiFi
Bluetooth
Microcontroller
Motor Controller