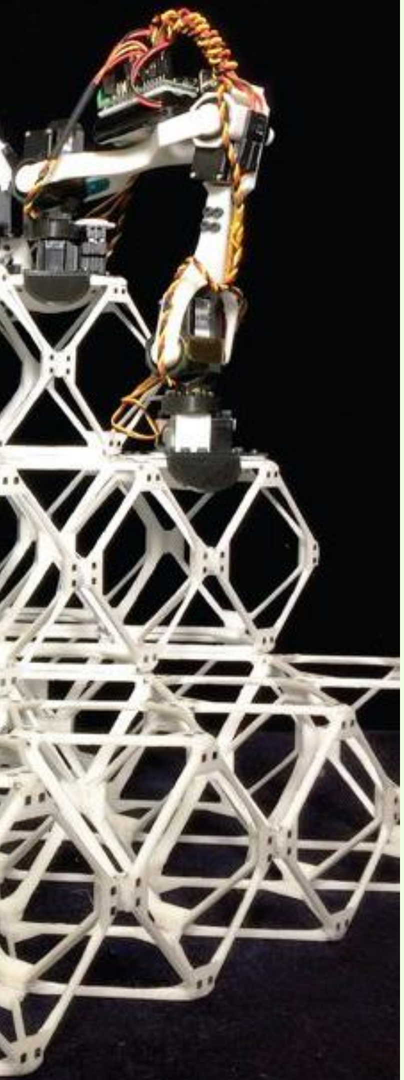

SWARM ROBOT

MCTE 4362
(ROBOTIC HARDWARE SYSTEM)

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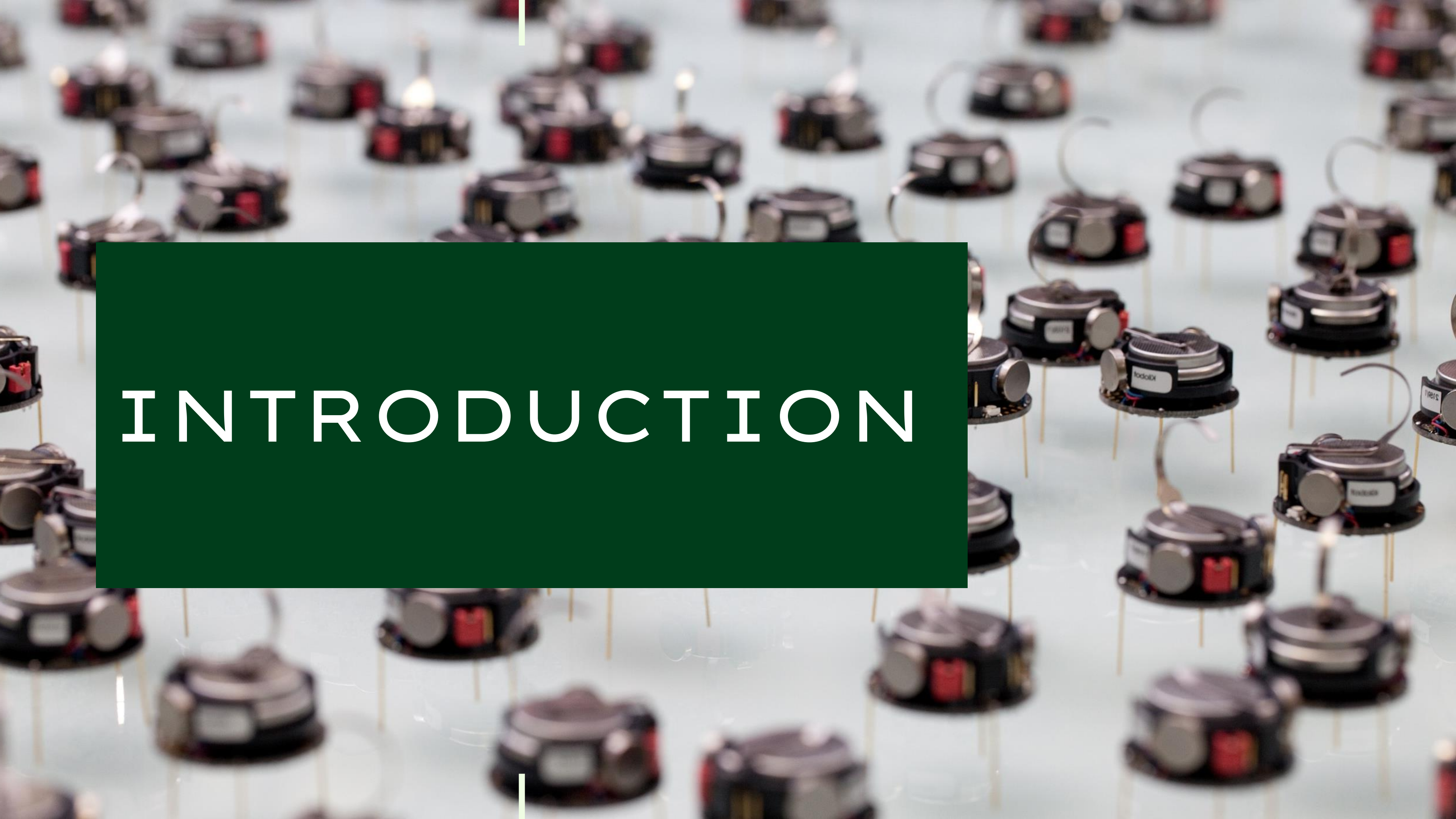


INTRODUCTION

INTRODUCTION

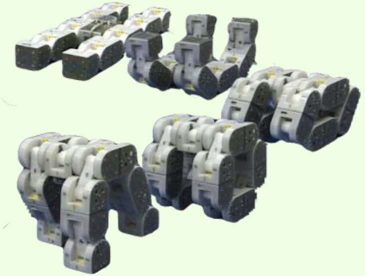
Birds flocking

A fish shoal

Swarming honeybees

- Natural swarms, such as ants, bees, and fishes, exhibit collective behavior that has inspired humans to develop robotic swarms that can act similarly.
- Natural swarms can coordinate simple behaviors to achieve complex tasks that individual members cannot perform alone, such as building bridges or mounds.
- Swarm robotics aims to create systems with groups of robots that can interact and work together towards common goals, like natural swarms.
- Understanding the definition of a swarm is important in developing swarm robotics systems.
- The goal of swarm robotics is to realize natural swarming behavior in robotic systems, enabling them to achieve common tasks like natural swarms.

TYPES OF SWARM ROBOT



MODULAR ROBOTS

M-BLOCKS

BILL-E

TRIBOTS

PARTICLE

SMARTICLE

KILOBOT

SWARM ROBOTIC PROJECTS

Projects	Objectives	Basic Properties
SWARM-BOT	To form simple, reliable, flexible, scalable, self organized and self assembling micro-robotic systems	Robots show robustness, flexibility and are able to solve complex problems via self organisation
Swarmanoid	The main goal is to design a heterogeneous distributed swarm robotic system that operates in 3-dimensional human environments	In addition to s-bots, Swarmanoid consists of hand- and eye-bots that can climb objects and fly, respectively
I-SWARM	The goal of the I-SWARM project is to build the largest robotic swarm that consists of up to 1000 mini robots of size 3*3*3 mm and a single robot looks and moves like an insect. But it consists of various modules that enables it to perform significant tasks. These modules include, power, electronics, locomotion and communication module	[78], [79]
SensorFly	To build an aerial mobile sensor network of robots that can perform monitoring in indoor emergency situations	The aerial robots are low-cost, autonomous, and are capable of 3D sensing, obstacle detection, path identification and adapting to network disruptions
Marsbee	Exploring Mars	Consists of a colony of small flying robotic bees that can sense their environments via sensors. There is a charge station where the marsbees can recharge themselves
Kilobot	It is a low-cost swarm of small robots designed to study collective swarm behavior	Each kilobot has a programmable controller, is capable for locomotion, local communication and can sense its environment
Kobot	A circular shaped, cheap, small, and expendable robot. These features make it very suitable for various swarm robotic applications	Has IR-based short-range sensors, supports wireless and parallel robot programming and has a battery that can last up to 10 hours.

AN OVERVIEW OF SOME SWARM ROBOTIC PROJECTS

HISTORY & APPLICATIONS

THE TIMELINE HISTORY

1988

Introduced by G. Beni and Fukuda. Beni defined cellular robotics as a system of autonomous robots that operate in an n-dimensional cellular space without a central entity, while Fukuda described swarm as a group of robots that can work together like the cells of a human body to achieve complex goals.

1993

Kube and Zohng created a multi-robot system inspired by natural swarm behaviors. Early research on swarm robotics focused on exploring natural swarm behaviors in different species like ants, birds, and fish and finding ways to implement them in robotic systems.

2004

G. Beni provided a more detailed description of swarm robotics. He defined swarm robots as simple, identical, and self-organizing, with scalability and local communication between them.

Recent

Swarm robotics is a fast-growing field of research and development that has potential applications in several industries, including search and rescue, environmental monitoring, agriculture, and manufacturing.

APPLICATIONS

AGRICULTURE

Used to revolutionize farming and decreasing the workload of farmers. All farming tasks like harvest, sowing of seeds and so on can easily be done via robots.

INDUSTRIAL

Use of activities like the dealing with chemicals. Robots can be used instead of human beings in order to reduce any damage or harm to human workers.

MILITARY

Can be used to detect and defuse bombs. This would exclude the need of human bomb diffusers. An army of robots can also be created to perform military tasks.

APPLICATIONS

MEDICAL

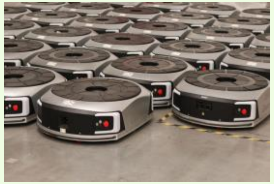
Nanorobots can move into the veins and arteries to detect and cure various diseases like cancer cells.

ASTRONOMY

Robots can be used to detect the effects of dark energy

HAZARD ZONES

Can be used to monitor dangerous areas to look for specific items like chemicals and toxins or survivors after a natural disaster.



HOUSEHOLD

Swarms of simple and small robots can be used for all day tasks, like cleaning.

ADVANTAGES AND DISADVANTAGES

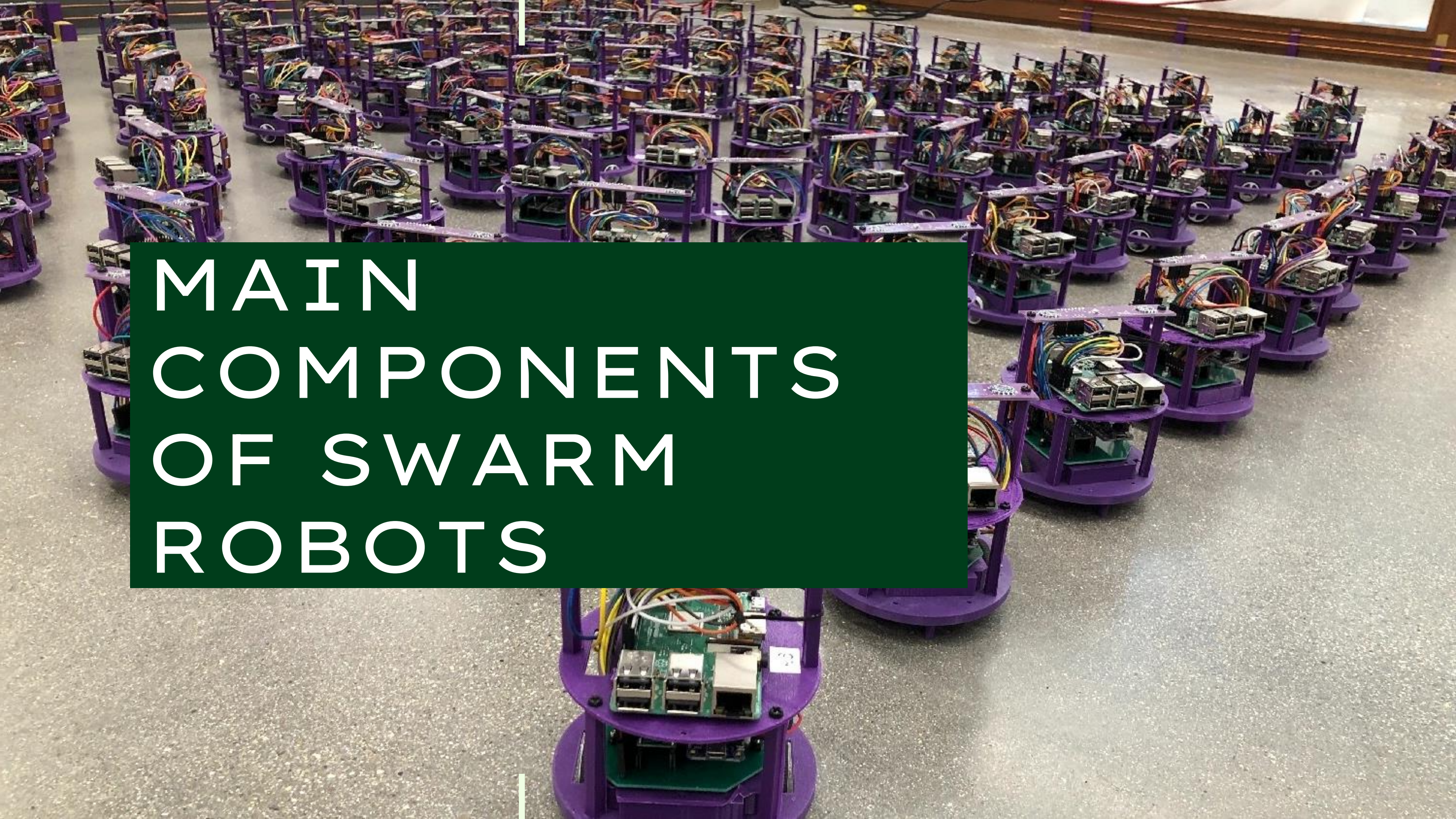
ADVANTAGES ☺
✓ Robots are autonomous that can cope with their environmental changes.
✓ Robots can combine their powers and abilities to form complex structures and offer unlimited features.
✓ The systems are flexible. That means they can be applied in different fields and for a verity of tasks.
✓ The systems are scalable, that means all robots can manage to obtain its goals no matter how big or small the swarm is.
✓ Parallelism makes the systems work more faster. Parallelism means tasks can be divided into sub tasks that can be allocated to different robots.
✓ Robots are designed very simply, that means they are cost effective.

DISADVANTAGES ☹
X The decentralized nature of swarm robotic systems make them a not so optimal choice for many applications.
X Due to their autonomy they will act to the changes in their surroundings individually and spontaneously. Even if the goal is to obtain tasks in a collective manner, the decentralization can result in single robots acting differently than the rest of the group.
X The simple design and implementation of robots also makes it tough to design systems for real life applications in such a way that they achieve goals with a hundred percent guarantee.
X For many real-life applications, global knowledge must be provided to robots.

Robotic Systems	Swarm Robotic Systems	Multi-Robotic systems	Multi-Agent Systems	Sensor Networks
Number of members	Large (as compared to other robotic systems)	Small (as compared to swarm robotic systems)	Small (as compared to swarm robotic systems)	Large (as compared to MAS and MRS)
Design and implementation of robots	Very simple. Single robots are unable to do anything significant	Single robots can perform significant parts of a task	Single robots are able to perform significant parts of a task	Nodes can be designed simple or complex
Self-organisation	Yes	Yes	Yes	Yes
System Control (centralized or decentralized)	decentralised	Both	Both	Both
Homogeneity or heterogeneity	Mostly homogeneous	Mostly heterogeneous	Both	Homogeneous
Autonomy	Yes	No	No	Yes
Environment	unstructured (unknown)	structured and unstructured (known and unknown)	structured (known)	structured (known)
Movement	Yes	Yes	Mostly not	No
Robustness	yes (high)	Yes	Yes	Yes
Scalability	yes (high)	Yes (low)	Yes	Yes
Flexibility	yes (high)	Yes (low)	Yes	Yes
Cost	Low	Medium	Medium	High

Differences And Similarities Between Swarm Robotic Systems And Other Robotic Systems

MAIN COMPONENTS OF SWARM ROBOTS

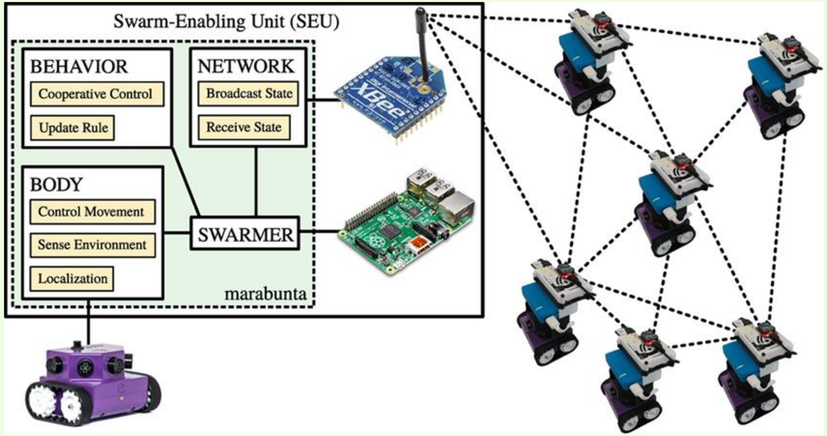


01

BODY DESIGN

BASIC SYSTEM ARCHITECTURE

- SEU (Swarm Execution Unit) acts as a bridge between a specific robot and the swarm.
- SEU consists of a communication module and a processing unit running code using the marabunta module.
- Each agent or swarmer consists of three elements: body, network, and behavior.
- The body controls robot movement and gathers information from its state and environmental data.
- The network interacts with the communication module to broadcast agent state and gather information from other agents' states.
- The behavior contains the cooperative control strategy, implemented by an update rule defining robot movement based on the current state and data gathered from body and network.



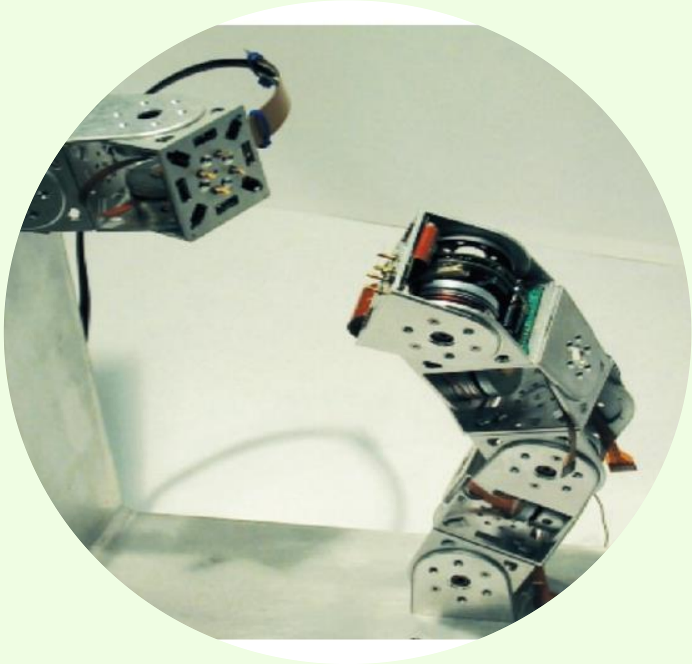
1. LATTICE-BASED ROBOT ARCHITECTURE

ATRON MODULES

- Lattice architectures involve arranging mobile robot units in regular three-dimensional patterns, allowing for simpler reconfiguration and control
- Examples include the "molecube" and ATRON systems, which demonstrate self-reconfigurability and self-replication, respectively
- Fracta and Metamorphic are 2-D lattice-based robots, while other systems like 3-D SRS, I-Cube, and Proteo are homogeneous but have complicated hardware implementation due to the required geometric symmetry for actuation and more DOFs.

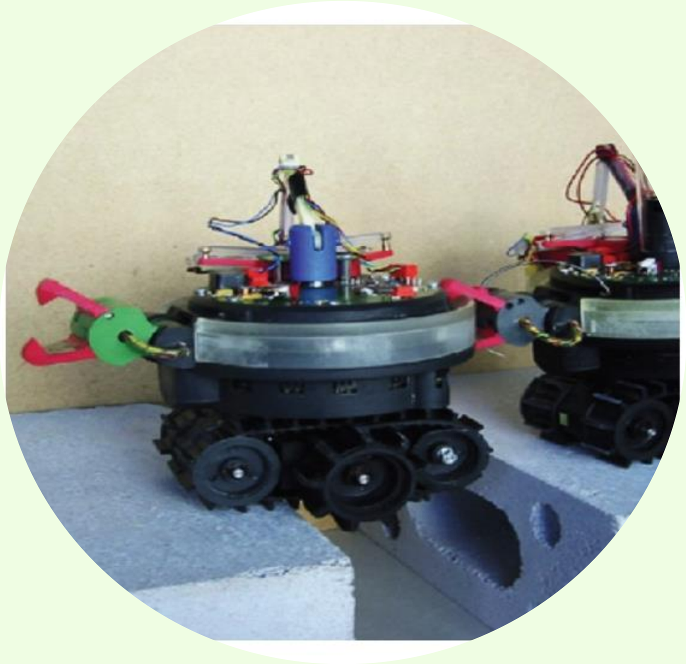
2. CHAIN-BASED ROBOT ARCHITECTURE

- Chain-based architectures have units connected in a string or tree topology, which can fold up physically to fit in arbitrary spaces.
- They are versatile but computationally challenging to control.
- PolyBot, CONRO, and M-TRAIN are examples of modular chain robots that can self-reconfigure, self-reassemble, and change configuration by changing positions and connections with other modules.



POLYBOT ROBOT

3. MOBILE-BASED ARCHITECTURE



SWARM BOT

- Mobile architectures have units that use the environment to maneuver and can form chains, lattices, or coordinated swarms
- Examples of such architectures include CEBOT, CYBOT, AUTOBOT, S-BOT, Swarm Bots, and IROBOT
- These platforms have varying capabilities and features such as heterogeneous modules, low cost, obstacle detection, wireless communication, and coordinated motion
- Swarm Bots are particularly adaptable and require minimal human interaction, while IROBOT is a homogeneous platform with 25 mobile robots equipped with IR transceivers and a 32-bit microprocessor as a controller.

02

PROPULSION SYSTEM

(ACTUATORS/LOCOMOTION)

PROPULSION SYSTEM

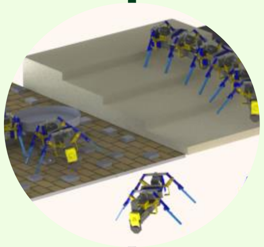
WHEELED SWARM ROBOT

- Use two-wheel, three-wheel, or four-wheel platforms with gear assembly attached to a DC motor
- Eg: E puck, Alice, Sumobot, SamBot, and the Tri-Star
- Energy efficient but have the drawback of being unable to run over obstacles and changing speed with changes in surface roughness and inclination.

TRACKED SWARM ROBOT

- Use crawl units or tracks suitable for difficult terrain
- Eg: Nanokhod (fig above) is a miniaturized tracked robot developed based on Russian technology. It has four internal drive units with stepper motors and planetary gears
- Have better traction capability on loose soil
- Can handle large hinder and small holes, but are inefficient due to friction of tracks "scrubbing" along surfaces while turning.

PROPULSION SYSTEM



LEG-BASED ROBOT

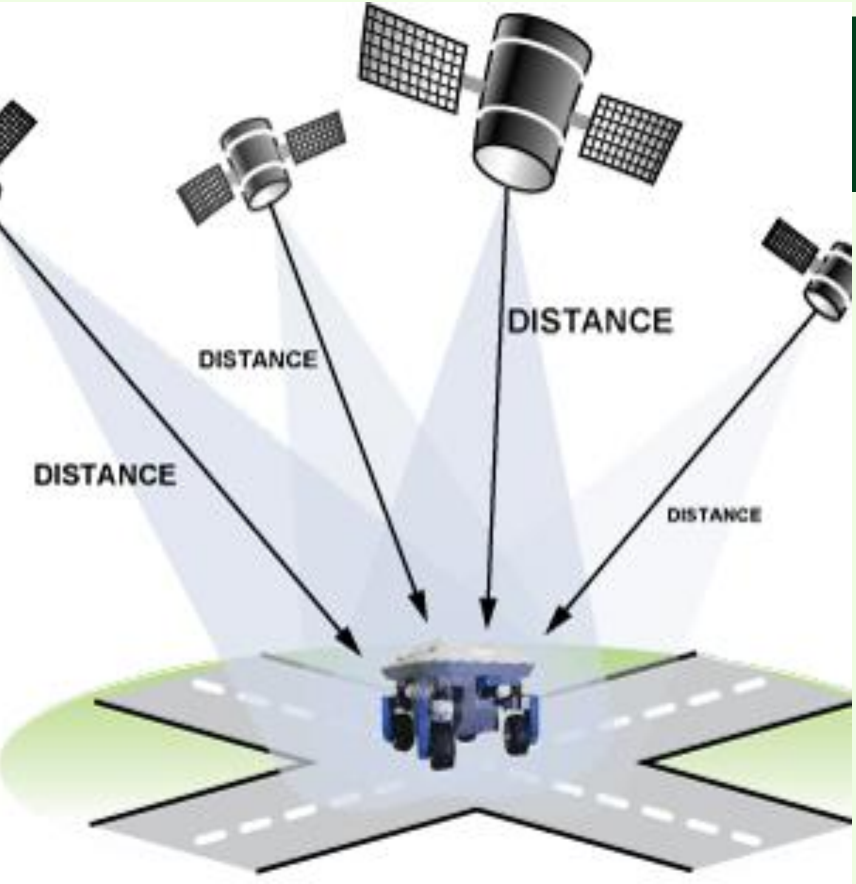
- Use legs for locomotion
- Very complex to build and controlling the legs is also complicated
- Tend to be very slow and create an impact with each step.

HYBRID ROBOT

- Combines two mechanisms for better performance
- Eg: AutoBot and S-Bot (fig above)
- S-Bot uses Treels, a combination of track and wheel platforms, with independent motors for each Treel. It allows S-Bot to move over moderately rough terrain with complex obstacles and rotate easily on the spot.
- AutoBot uses a differential drive with caster wheels and pulse width modulation for DC motor control

03

NAVIGATION SYSTEM & CONTROL

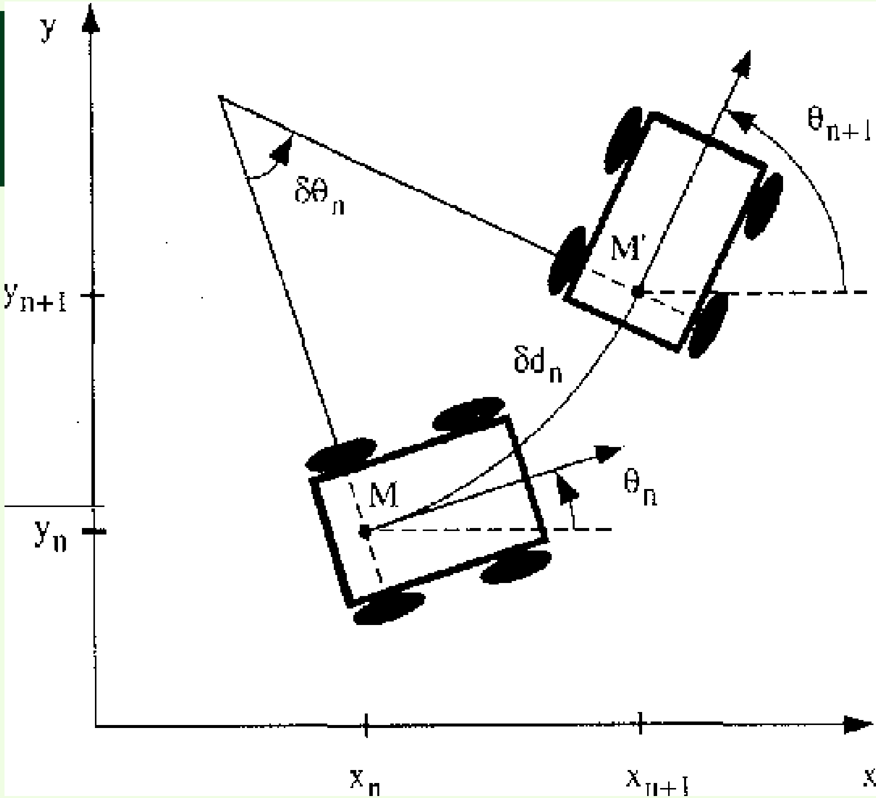


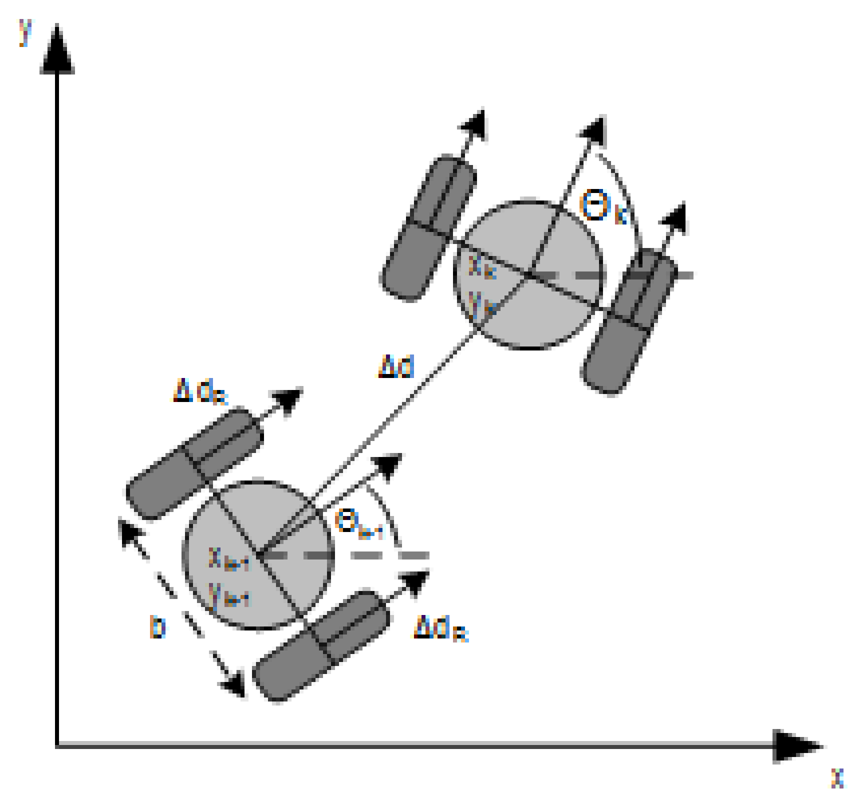
1. GLOBAL POSITIONING SYSTEM (GPS)

- GPS is a commonly used localization method for swarm robots that provides global positioning information.
- Swarm robots using GPS typically have GPS receivers that receive signals from GPS satellites to determine their position.
- GPS signals can be weak or unavailable in some environments.
- Alternative localization methods such as dead reckoning or visual odometry may be used in such cases.
- Techniques such as differential GPS (DGPS) and real-time kinematic (RTK) GPS can be used to improve the accuracy of GPS-based localization for swarm robots.

2. DEAD RECKONING

- Dead reckoning is a technique used by swarm robots to estimate their position based on distance and direction of movement
- It's useful when GPS signals are weak or unavailable
- Sensors like wheel encoders and IMUs are used to measure robot movement
- Errors can accumulate over time, causing drift in the estimated position
- Additional sensors or algorithms, like Kalman or particle filters, can improve dead reckoning accuracy.





3. VISUAL ODOMETRY

- Visual odometry estimates position by analyzing visual features in the environment.
- Used when GPS signals are weak or unavailable.
- Robots use cameras to capture images and identify visual features.
- Errors can occur due to lighting, motion blur, and occlusions.
- Additional sensors or algorithms may be used to improve accuracy.
- Requires careful calibration and error correction.

04

DATA COLLECTION

SENSORS USED IN ROBOTS

LASER RANGE FINDER (LRF) SENSOR

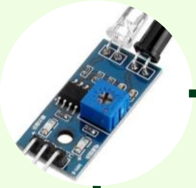
Has higher speed, accuracy, and resolution than LED-based IR sensors, but is limited due to its high expense.

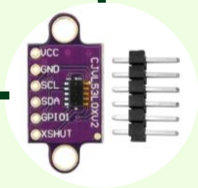
CAMERAS

S-Bot uses an omnidirectional camera for visual communication and target sensing.

SONAR TIME-OF-FLIGHT DISTANCE SENSOR

Work over a longer range than infrared sensors but can be easily affected by the hardness of objects





IR PROXIMITY SENSOR

Works by emitting infrared light which propagates through the air, and once the emitted light hits or is blocked by an object, it reflects back to the sensor.

ULTRASONIC SENSOR

To detect the distances and angles of surrounding robots in relation to each other

ODOMETRY SENSOR

Used to explore positions of swarm modules in the environment

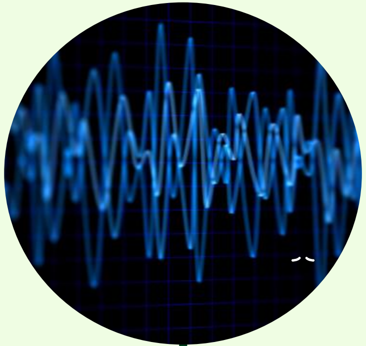
05

DATA TRANSMISSION

DATA TRANSMISSION

BLUETOOTH

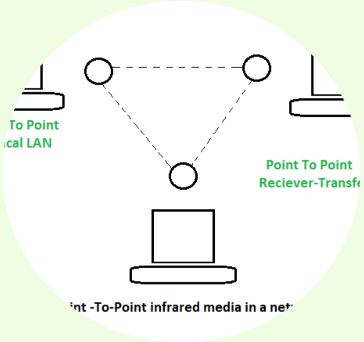
- Allows transmission of data such as sensor readings or control commands
- Can help in forming ad-hoc networks between the swarm robots, thereby enabling cooperative behaviors and improving overall system performance
- Research from Villanova University used LEGO NXT mobile robots with Bluetooth communication via NXT bricks.



RADIO FREQUENCY

- Allows swarm robots to transmit and receive data between each other or with a central controller. It can form ad-hoc networks, enabling cooperative behaviors and improving system performance
- AUTOBOT uses 2.4 GHz 1 Mbps GFSK radio-based local communication.
- Cleveland State University used MaxStream 9Xtend RF transmitter/receiver and PIC18F4520 microcontroller for communication between square robot swarms and base station.

DATA TRANSMISSION



INFRARED (IR)

- Allows them to communicate with each other or a central controller, share data, and collaborate on tasks
- Suitable in situations where radio frequency communication is not feasible, but requires a clear line of sight between the communicating devices.
- CORNO and M-TRAIN use IR transmitters and receivers for local communication.

WIFI

- Offers high data transfer rates and a longer range compared to other wireless communication technologies
- Can improve overall system performance but may require more power and complex hardware and software configurations.
- KOBOT uses IEEE 802.15.4/ZigBee compliant XBee wireless module, PIC 18F4620A microcontroller, and a PC (supervisor).

06

POWER MANAGEMENT

LITHIUM-POLYMER BATTERIES (LI-PO)

- Most swarm robots work on 5 to 25 V DC power supplied by rechargeable lithium batteries.
- Lithium-Polymer batteries (Li-Po) are commonly used in swarm robots due to their high energy density, thin size, and operational safety.
- The ATRON swarm robot module uses two 3.6 V 980 mAh ion-lithium-polymer cells, providing 7.2 volts at an ampacity of 980 mAh for each module.
- S-Bot uses two Lithium-ION batteries with a power storage capacity of 10 Wh, with a power consumption of 3-5 W for continuous operation for at least two hours.
- AutoBot is powered by an 11.1v Li-Po battery with 500 mAh ampacity.
- CYBOTS, which are smaller in size, around 25 cm in length, use a pair of Li-Po rechargeable batteries as a power source.

CONCLUSION

CONCLUSION

1. Swarm robots are a type of robotics system that involves a large number of small, mobile robots that work together to accomplish a task.

2. Wireless communication technologies such as Bluetooth, RF, IR, and WiFi can be used to enable communication and coordination between swarm robots.

3. Power supply for swarm robots is an important consideration, with rechargeable lithium batteries being a popular choice due to their high energy density, small size, and safety.

4. Swarm robots have a wide range of potential applications, including environmental monitoring, search and rescue missions, and industrial automation.

5. Research in swarm robotics is ongoing, with advances in sensing, communication, and control systems continuing to improve the capabilities and performance of swarm robots.

THANK YOU