Formation Control in a Low-Cost Robot Colony

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THE ROBOTICS CLUB

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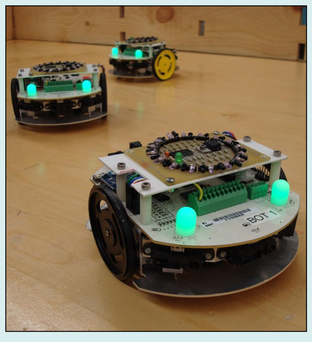
Abstract

Formation control, as it applies to the field of mobile robotics, is the challenge of maintaining a certain distance and orientation between robots as they move as a group throughout an environment. This can be a simple and effective method of coordinating the movements of multi-robot systems with applications such as robotic patrols or resource protection. Through this research, the Colony Project has investigated how the principles of formation control apply to a colony of low-cost robots. In developing a flexible research platform for formation behaviors, we have explored how formation control can enhance the movement and sensory capabilities of our robot colony. This work is a continuation of previous Colony Project research and will serve as a foundation for future research within the Robotics Club.

Robot Platform

At the core of each Colony robot is the Dragonfly microcontroller board.

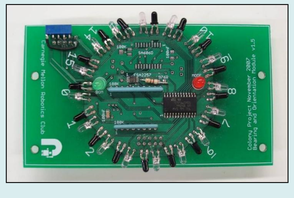


Features:

- ATMega128 µcontroller
- XBee wireless module
- USB interface
- Differential drive
- 5 Sharp IR rangefinders
- Magnetic encoders
- 2 Tri-color LEDs

BOM Sensor

Colony robots use the Bearing and Orientation Module (BOM) to locate other robots.



- Coplanar ring of infrared LEDs and detectors
- Provides orientation data used for relative localization between robots

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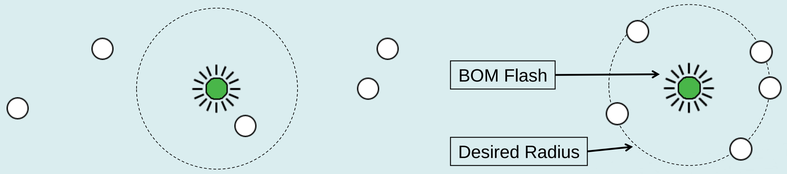
1 Circle Up

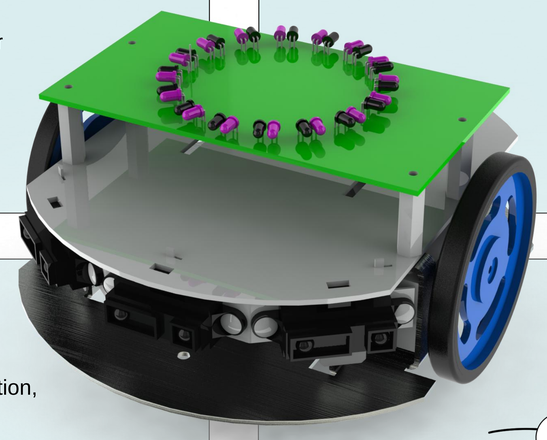
Objective: Scattered robots group up so that all bots are equidistant from a designated center robot.

How it works:

- Robots begin in a "waiting state": they scan for wireless messages.
- Upon pressing a button on one robot, it becomes the center robot.
  - It broadcasts a message to all other robots to let them know.
- The center robot sends a message requesting a count of robots. Each other robot sends a message containing its robot ID until it is acknowledged. After a timeout, the center forms a list of all the robots in its group.
- The center robot turns on its BOM, and the other robots turn to face the BOM.



- The other robots move forward or backward based on their rangefinder reading, keeping their BOM oriented correctly.
- When a robot reaches the right spot, it sends a message to alert the center bot.
  - The center robot knows it is done when all robots in its group have sent this message.

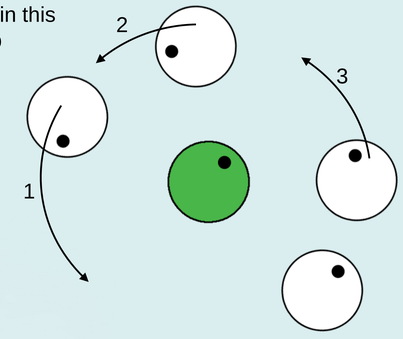


2 Equal Spacing

Objective: Equally distribute robots around a circle, starting with all the robots on the same radius but randomly placed.

How it works:

- The center robot identifies surrounding robots using its XBee and maps their angular location using its BOM.
- The center allows the edge robots to move around the circle one by one.
- During the displacement:
  - The edge robot is responsible for maintaining its radius.
  - The center is responsible for stopping the edge at the correct position.
- A simple algorithm prevents the edge robots from colliding with each other.
  - Edge robots always move in one direction.
  - Move the robot that has the greatest angular gap from its neighbor in this direction, until the angular gap is 360°/(number of edges).
  - Repeat until they are all equally spaced.

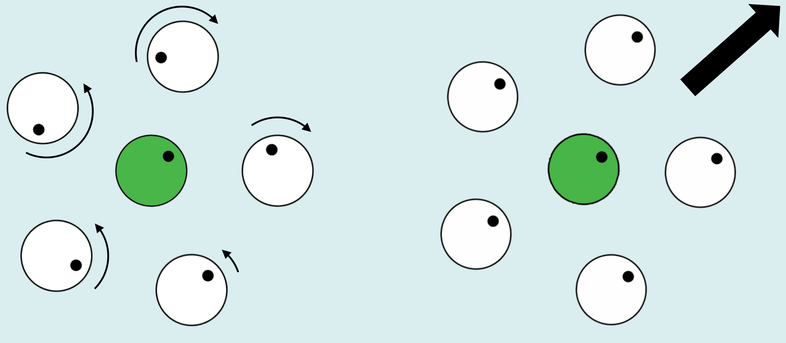


3 Group Driving

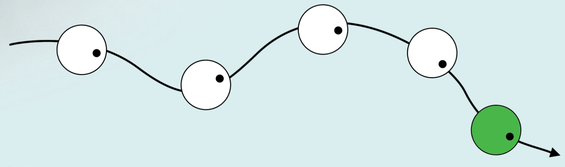
Objective: After forming a circle, all robots face the same direction, drive a certain distance, and then circle up again.

How it works:

- The center robot sends a packet to each robot in its group, one at a time.
- That robot turns on its BOM, and the center robot reads that BOM direction.
  - After doing this for all robots, the results are stored in a table.
- The center robot turns on its own BOM and sends each robot its own reading.
- The edge robots turn to the direction opposite of the center robot's reading.
- All robots drive forward at the same speed for the same distance using their encoders to stay in formation.
  - The center robot specifies both the speed and distance.



Follow the Leader 4



Objective: All robots follow a designated lead robot in a line.

How it works:

- The lead robot turns on its BOM and begins driving, either in a given pattern or with obstacle avoidance.
- The trailing robots turn on the back half of their BOMs, while reading from the front half.
- The trailing robots follow using a proportional control law based on the direction of the strongest signal, which should be the direction of the robot directly in front of it.
- Error detection:
  - Errors can come from to sources: missing readings and bad readings.
  - Isolated missing or bad readings have no significant.
  - Multiple bad readings, due to external interference, cause the robots to lose the chain.
  - Once the robot recognizes it is lost, it begins to rotate and search for the rest of the chain, and rejoin