SWARM ROBOTICS IN AND OUT OF THE CLASSROOMS

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Abstract

In swarm robotics, multiple robots work together to complete a task. Small and inexpensive Kilobots [1] enable large-scale experiments that mimic real world scenarios to help better understand the associated phenomenon or problems.

The design of Kilobots was revised at WCU in 2016 [2,3] to help world-wide researchers and educators build these themselves. See more resources at https://kilobot.wcu.edu/

The capstone team has examined several functionalities of the Kilobots and accomplished various tasks, which will be the essential building blocks to perform more complicated tasks, such as going towards light (mimicking a target or the location of an emergency such as fire) while maintaining the coverage of a big area instead of swarming towards the single point of interest.

The demonstrations will be useful educational tools in classrooms to illustrate the moving, sensing, and communication principles, and draw interests in open houses and outreach activities.

Research Questions

- How should the Kilobots be calibrated for both its distance measurements and motor strengths?
- How does the infrared communication, distance measurement, ambient light sensing, analog to digital conversion work on Kilobots?
- How can a swarm of Kilobots be charged efficiently?
- How can the Kilobots be programmed with a common code but each robot's movement is determined by its situation so that the swarm as a whole perform a task collectively?

Calibration and Checking Kilobot Functionality

The two slip-stick legs of a Kilobot are driven by two motors separately. One on-board infrared (IR) transceiver measures relative distance to others. Distance calibration, motor calibration, and sensor testing, on all Kilobot units, are essential for uniform performance among different units.

Distance Calibration- Pair-wise distance measurements are averaged to account for variations in both transmitter and receiver.

Motor Calibration- Three movements (turning left, turning right, and going straight) are optimized for each Kilobot with its own "best speed" of both motors to allow quick and accurate movement.

Light Sensor- On-board phototransistor measures ambient light intensity. It is converted to a 10-bit integer and can be displayed in the serial monitor in Kilogui for testing.

LED Color and Intensity- On-board tricolor LED works as a status indicator (such as battery voltage level or position in a group). The set_color function in the kilolib library can set each color at three intensities. All combinations of colors are tested.

Receiving and Storing Messages- Whether robots can work as a swarm relies on their ability to communicate. In testing, one Kilobot is connected to the overhead controller to be the receiver, and all other Kilobots are transmitters to be moved by hand into the range of the receiver one by one. Serial monitor is used to display the unique ID (kilo_uid) received from another Kilobot. Messages are sent in bytes but kilo_uid needs two bytes. Therefore, the ID must be separated into two bytes, sent, stored, and reassembled. Other messages need to be similarly pre- and post-processed.

Accomplished Tasks

Moving Towards or Away from Light (Phototaxis and Anti-phototaxis)- Once a Kilobot gets an initial measurement of light intensity, it rotates or moves to get another measurement. If the value increases then the robot knows that it is moving toward the light, otherwise it is moving away from the light. Based on this decision, the Kilobot moves towards the desired direction. This movement is a building block for many more complicated tasks such as shape assembly/disassembly, where a single light source guides the Kilobots that are not in the shape to move away from the shape.

Orbiting- One Kilobot is stationary like a sun, and other Kilobot constantly measures its distance to the stationary Kilobot and attempts to maintain that distance, so that it orbits the sun like a satellite.

Dispersing- Dispersing is the inverse process of orbiting where all the Kilobots try to increase their distances to other Kilobots until they are out of their communication range.

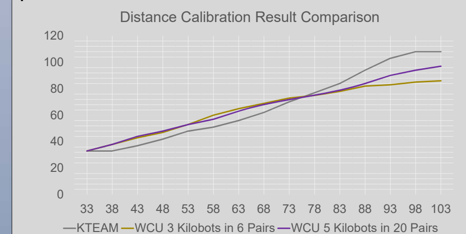
Edge Following- Edge Following is an extension of orbiting to orbit a group of Kilobots. Given the required communication between multiple Kilobots, Kilobots are programmed to store the incoming messages in a ring buffer and to only act on the information being received from the closest Kilobot. The ring buffer holds kilo_uid and the distance from that Kilobot, and operates in a first-in-first-out fashion, greatly helping the orbiting Kilobot not to be confused by multiple incoming messages.

Adaptive Gradient Represented by Colors- Gradient here means the number of communication hops a message needs to reach a Kilobot. A seed Kilobot, or the starting point, needs to be specified. The tri-color LED mixes red, green, blue, using the set_color function, to get nine visually distinctive colors to indicate how many hops it takes from the seed to reach another Kilobot.

Hop # (cycled)	1	2	3	4	5	6	7	8	9
Gradient Color	red	orange	yellow	yellow-green	green	cyan	blue	purple	bright white
RGB mixture	2,0,0	3,1,0	2,2,0	1,2,0	0,2,0	0,1,1	0,0,1	1,0,1	3,3,3

Results

The distance calibration using more pairs of Kilobots is significantly more accurate than the commercial K-team calibrated ones or fewer pairs of Kilobots.



In the accomplished tasks, the distance measurements between Kilobots and/or the ambient light intensity help determine the desired movements for each Kilobot collectively using the common code.

References

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2. N. Thomas, Y. Yan, H. Jack. "Maker: A Kilobot Swarm". ASEE's 123rd Annual Conference and Exposition. New Orleans, LA. June 26-29, 2016.
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