Study the Collective Behavior of Swarm Robotics Using Kilobots

Western Carolina University

Objectives

The objectives of this capstone project are to

- Examine the functionalities of the Kilobots;
- Accomplish various tasks, such as photoaxis and anti-photoaxis movements, orbiting, dispersing, edge-following, and gradient coloring;
- Design a case-charger;
- Modularize the coding as building blocks to accomplish more complicated tasks in the future.

The demonstrations obtained from this capstone project can be also used as educational tools for

- In-classroom illustrations on moving, sensing, and communication principles;
- Drawing interests in open houses and outreach activities.

Requirements

Req #	Requirement	Description	Test	Requirement Type	Affected Requirement
1	Avg. Comm. Distance	Average communication distance of 7cm	Demonstration	Performance	8, 9, 10
2	One-hour Battery Life	Minimum battery life of at least one hour	Demonstration	Functional	5, 6
3	Windows OS Compatible	Must be able to be programmed from a computer using a Windows OS	Demonstration	Interface	4
4	Kilogui	Firmware must be compatible with Kilogui programmer	Demonstration	Interface	3
5	Charge Multiple Kilobots	Must be able to charge at least 5-10 Kilobots at a time	Measurement	Functional	2, 6
6	Attachable Battery Charging clip	Must be able to be attached to the top of the battery on the Kilobot	Inspection	Functional	2, 5
7	Ambient Light Sensor	Must have a fully operational ambient light sensor (Can read ADC values between 0-1023)	Demonstration	Functional	
8	Clear Bot-to-Bot communication	Transmit and receive signals clearly from other Kilobots that are within range	Demonstration	Performance	1, 9, 10
9	Accurate Distance Measurements	Able to read and approximate its current distance from another Kilobot up to 7cm	Demonstration	Performance	1, 8, 10
10	Ease of Calibration	Design or formulate an easier method to calibrate the Kilobots under different amounts of lighting	Analysis/Inspection	Functional/ Interface	1, 8, 9

Concepts

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

Problem Statement

In swarms, each individual agent is very simple and interacts only with its neighbors, but as a group, they make intelligent decisions. Dr. Yan and Mr. Nathan Thomas have redesigned the Kilobots to be easy to build and reliable to work, with resources posted at https://kilobot.wcu.edu/.

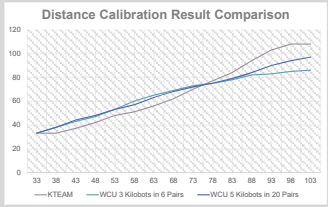
- A very special **thanks to Mr. Thomas** for building all the Kilobots, overhead-controllers, and a stand-alone charger.

To control Kilobots as a group using the same and simple command is a challenging but fun task. This project is to use Kilobots to develop and accomplish tasks that mimic practical scenarios, which include but are not limited to

- Light-following, mimicking the response of a fleet of rescue crew to an emergency;
- Pattern forming using the LED lights on the Kilobots, mimicking the cellular differentiation in biology;
- Pair-interaction such as orbiting, parallel following, herding, dispersing, mimicking the interactions between cells;
- Arithmetic operation showing the calculation steps, with a fixed set-up of Kilobots, each representing certain bit, as an educational tool for young kids.

Accomplished Tasks

Distance Calibration- Pair-wise distance measurements are averaged to account for variations in both transmitter and receiver. Then the common distance table is transmitted to all Kilobots.



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.

Kilobotics-Labs Tasks- Orbiting, dispersing, etc, using source code from https://www.kilobotics.com/labs provided by Harvard.

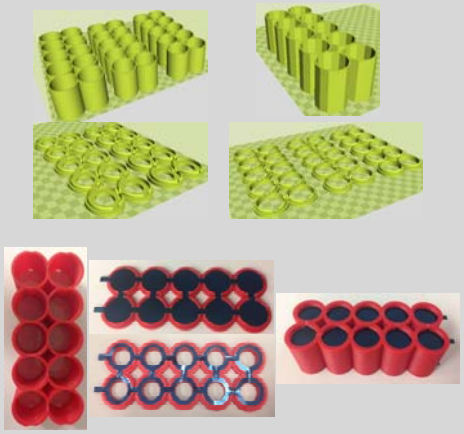
Moving Towards or Away from Light (Phototaxis and Anti-phototaxis)- Once a Kilobot gets an initial measurement of light intensity, it rotates or moves to get another measurement. If the value increases then the robot knows that it is moving toward the light, otherwise it is moving away from the light. 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.

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 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

Design and Prototype of a Case Charger



Team & Acknowledgements

- William Honeycutt (left in the photo), Electrical and Computer Engineering Technology
- Jason LaQuerre (right in the photo), Electrical and Computer Engineering Technology
- Brandon Alexander Letchworth (center in the photo), Electrical Engineering

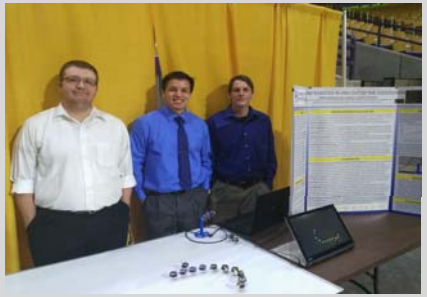


Photo was taken on Mar 29, 2017, at WCU Undergraduate Research Expo

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