Dr. Yanjun Yan
Swarm Robotics

Self-Disassembly for Shape Formation Using Kilobots

Western Carolina University

Objectives

- Create code to accomplish the shape formation task using self-disassembly
- Evaluate the mission accomplishment by both accuracy and speed metrics
- Improve shape accuracy and shorten the time to accomplish a shape through innovative research
- Document all steps and procedures to allow for easy repetition of the missions by other users

Requirements

Requirement #	Requirement	Description	Test	Requirement type	Affected Requirements
1	Functional code	The code being developed needs to be debugged for all errors and commented	Demo.	Interface	2,3,4,5
2	Backing up all the programs	Each time the program is tested and altered there should be a backup with comments	Analysis	Interface	1,3,4,5
3	Three modularized functions	These functions are written to complete shape formation	Demo.	Functional	1,2,4,5
4	Post-processing program	This program can be written in Matlab to evaluate and assess the performance to help determine if revisions need to be made	Demo.	Analysis	1,2,3,5
5	Developing shape formation	Automated shape formation	Demo.	Functional	1,2,3,4,5

Concepts

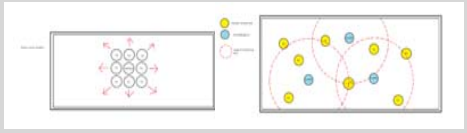

Figure 1: Dis-assembly and Localization Concept

- Localization is commonly used in Global Positioning Systems (GPS). Trilateration is used to locate an unknown position using 3 or more known locations and the ranges measured from the unknown location to the known locations.
- After localization for all Kilobots to figure out their locations from three seed Kilobots that know their locations, dis-assembly is carried out by directing the Kilobots inside the desired shape to stay put while directing the Kilobots outside of the shape to move away based on anti-photoaxis movement.

Problem Statement

- Last year in the 2016-2017 capstone project, "Study the Collective Behavior of Swarm Robotics Using Kilobots", several tasks have been accomplished using Kilobots, such as distance and motor calibration, photoaxis and anti-photoaxis movement, edge following, and adaptive gradient representation by colors. These movements are the building blocks for other complex movements in swarm robotics. This year in the 2017-2018 capstone project, "Self-Disassembly for Shape Formation Using Kilobots", shape formation is studied using a group of Kilobots.
- Traditionally, shape formation is done by self-assembly where additive movement is employed to cluster swarm robots together into a proper shape. Recently, shape formation is attempted by self-disassembly where subtractive movement is employed to move the non-shape robots away from the initial block of swarm robots, which yields a much faster implementation than self-assembly.
- In nature, groups of thousands to millions of units can morph into complex structures, purely through local interactions, in cellular formation, colony construction, and swarming patterns. Many collective and modular robotic research efforts take inspiration from such natural phenomena, and this capstone project will advance the understanding and implementation of shape formation in swarm robotics. The challenges in this capstone project include localization of each swarm robot, an effective global control algorithm for the robots to move, and the creation and debugging of control programs.

Final Design/Results

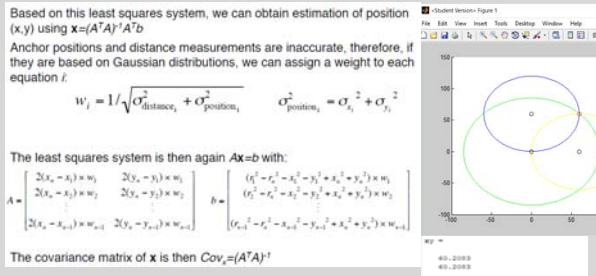

Figure 2: Matlab prototyping localization results

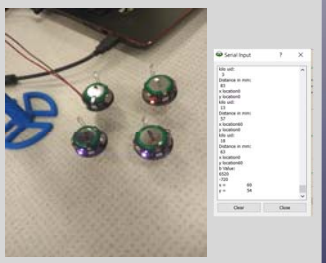

Figure 3: Kilobots' true location (left) and calculated location (right)

Figure 4: Code to do anti-photoaxis movement

- The code above guides the Kilobots outside of the desired shape to move away from light and reach the area that is not illuminated, leaving only the Kilobots that are inside the desired shape.
- It requires a light source in the middle of the shape.

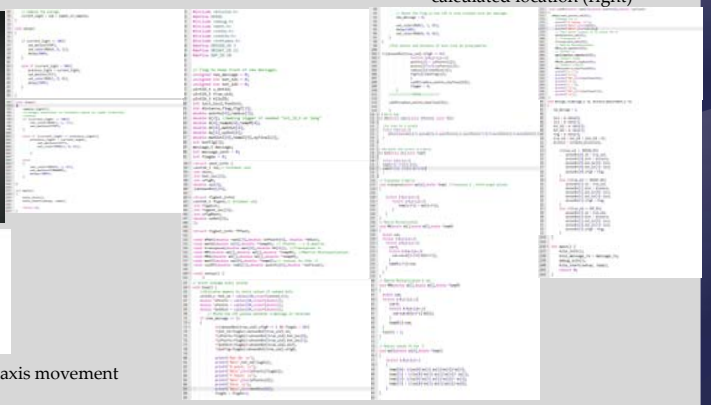

Figure 5: Code to do localization

- The concept of localization in C using dynamic arrays and functions to store and evaluate data was used in order to complete dis-assembly.

Conclusion

- Early in the year the team faced challenges with complier issues and communications with the Kilobots as the server of the Harvard Kilobotics was in maintenance due to the update of Dropbox 2.0. The team was able to accomplish dis-assembly through simulation prototyping in Matlab, and then in C implementation for Kilobots.
- Using dynamic arrays manipulations, matrix multiplication, and photo-axis algorithms the team completed dis-assembly.
- The assembly of Kilobots using edging movements was initially planned but not yet complete, in the future, it will be beneficial to consider both assembly and dis-assembly to complement both approaches' pros and cons.
- The experiment so far is at a small scale where noise or message crashes might not be significant. In the future, a large scale testing will be interesting and crucial to expand this project's application.

Team & Acknowledgements

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