Development of in vivo Programmable Robotic Swarms

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Introduction:

- **Swarm robotics** is the coordination of multiple robots in a group collaborating and working together to complete a task
- **Key Applications:**
  - Search and Rescue [2]
  - Self-assembly [1]
  - Item transportation [3]
- **Popular Examples:**
  - Harvard Kilobots
  - Georgia Tech Robotarium
  - Festo BionicANTS
- **Scalability:**
  - The ability to increase the number of robots in a swarm
  - **Key factors**: cost of robot, assembly time, communication
- **Research Objective:** To build a scalable and easy to use swarm of robots to further research on swarm algorithms

Fig. 1. Kilobots forming a shape [1]

Hardware Design:

The main components that allow us to have a high bandwidth of communication at a low price are an Arduino Uno microcontroller paired with an ESP8266 for wireless communication over Wi-Fi between the individual robots and the web server on the computer

Core Components:

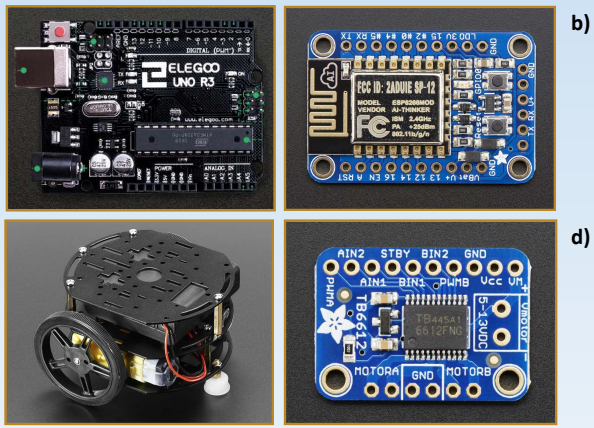

Fig. 2. a) Arduino Uno Microcontroller **b)** Wi-Fi Chip (ESP8266) **c)** Two wheel frame **d)** Motor Controller (TB6612)

Scalability:

- Around $50 for each robot
- Can be assembled in under an hour and a half
- Made from off-the-shelf parts that are easily purchased
- Wi-Fi communication with large range and bandwidth

Ease of use:

- All components have breakout boards to be easily connected
- Open-source components with a lot of online support and documentation
- We sacrifice compactness for ease of use

Robot Design:

Component connections:

- These components require less specialized tools and skills to be put together and connected to other components
- All the components are connected by breadboard, allowing the robot to be reconfigured and modified to add functionality

Power Supplies:

- One 9 Volt battery provides power to the two motors
- A second 9 volt battery is regulated down to 5 volts to power the Arduino, ESP8266 Wi-Fi chip, and the motor controller
- 2 switches allow for the robot to be powered on and off

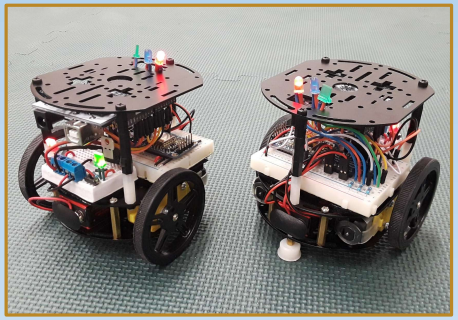

Fig. 3. Final version of robots, rear and front

Indicator Lights:

- 2 LED lights in the rear warn the user when each of the power sources for the motor and other components are switched on
- 3 LED lights on the top indicate the robot's Wi-Fi connection status and blink depending on the signals the robot receives

System Design:

VICON Motion Capture

- A system of overhead cameras tracks each robot in its field
- This system constantly records the position coordinates of each robot

MATLAB Web Server:

- Streams position data from VICON cameras
- Waits for a robot to request a connection and sends the robot its position data

Robot Client:

- Robot coded in Arduino receives its own position data from the web server
- The robot then interprets this data depending on the algorithm that is coded, and controls the motors to move itself

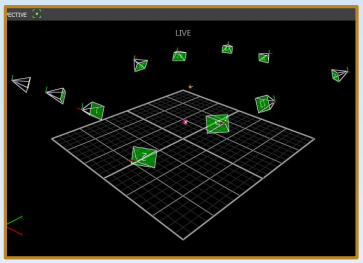

Fig. 4. Motion Capture Screen

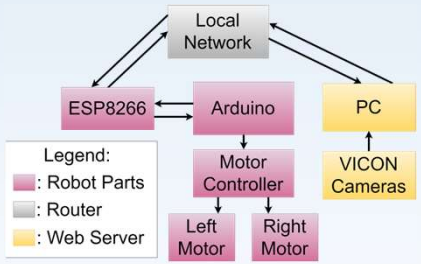

Fig. 5. System Diagram

Coverage Control Algorithm:

To demonstrate the functionality of this research platform, we are currently implementing the execution of an algorithm where the robots disperse themselves evenly across a known area in simulation of a search and rescue situation. We will implement this algorithm with two and four robots and assume the robots are initially placed as a square

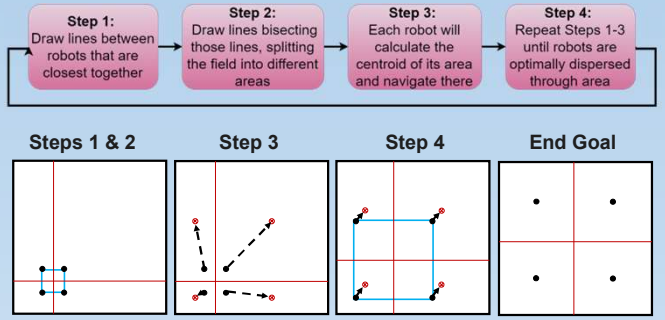

Fig. 6. Basic Steps of Coverage Control Algorithm with black dots representing robots

Discussion/Conclusion

Design Challenges:

- Initial wireless chip NodeMCU firmware was difficult to program and couldn't communicate with the Arduino
- The motor controller requires the connection of many cables, making it easy to accidentally connect the cables to the wrong spot. We used a color coded ribbon wire to prevent this
- Three iterations of the robot design were created in the process of making the platform more compact and organized

Future Objectives:

- Implementing the coverage control algorithm with two and then four robots. Then testing the algorithm to analyze the accuracy of each run
- Incorporate additional robots to the swarm to test the capabilities and difficulties of controlling a larger swarm
- Add sensors to the robots to collect more information about their environment and not have to depend on the overhead camera system

References:

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3. G. Zhou, F. Bastani, W. Zhu and I. L. Yen, "A Self-Stabilizing Algorithm for the Foraging Problem in Swarm Robotic Systems," 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Daejeon, 2016, pp. 2907-2912.

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