Self-Assembling Network of Devices

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INTRODUCTION

- Self-assembly has the potential to be an incredible tool for various robotic systems.
- Self-assembly on the small scale has yet to be developed
- Applications include rapid prototyping for mechanical objects and accessing small spaces in search missions.
- Goal is to create both a small scale self-assembling robot and a system of programming that will allow those bots to assemble in a given environment
- This involves threes main topics: structure/housing, electronics, and programming.
- The structure of the robot needs to be small enough to reach sub-millimeter, but large enough to house the PCB, voltage supply, and electropermanent magnets (EPMs).
- The EPMs will be wired directly to the PCB and switched on and off by the microcontroller.
- This research would fill gaps in literature regarding full robot development and self-assembly.

RESEARCH QUESTIONS

Can we create a system of small-scale robots that self-assemble?

Can we create a small scale communication system for the robots?

Can we design a method of actuation that can also sustain long-term latching?

BACKGROUND

- Self-assembly utilizes bots that communicate with each other to adjust their positions and form a desired shape in a defined environment

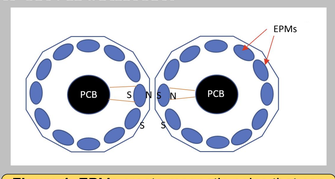

Figure 1. EPMs create magnetic poles that can switch

- Electropermanent magnets can modulate magnet field via electric pulses
- Pathfinding algorithm and movement functionality considers current state of all bots after each movement

BOT STRUCTURE

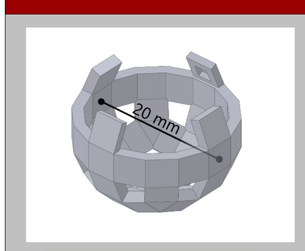

Figure 2a. Bottom half of bot structure

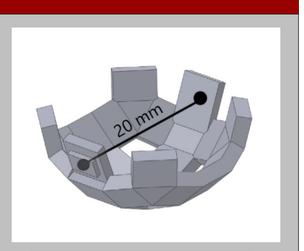

Figure 2b. Top half of bot structure

- Bots are a quasi-sphere
  - Mostly spherical to make it easier to roll
  - Flat faces to create better contact surfaces for latching
- Needs to fit the hardware
  - Dimensions chosen to match hardware specification requirements
  - PCB with ESP32 microcontroller, battery
  - Electropermanent magnets

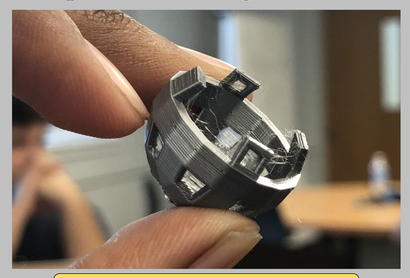

Figure 3. 3D-printed bottom half of bot

ELECTRONICS

PCB Design

- To test our circuit designs, we plan to use the Voltera V-One PCB desktop printer
  - Allows us to print PCB designs in a matter of hours
- Using ESP32-C3-MINI microcontroller
- PCBs will be multi-layered given the small space constraints
- Coin batteries on PCBs to provide power

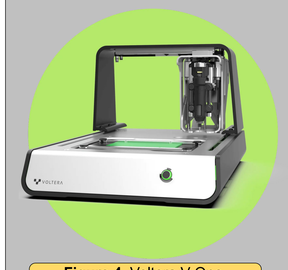

Figure 4. Voltera V-One. Adopted from [52].

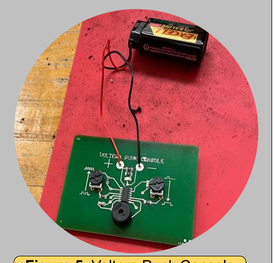

Figure 5. Voltera Punk Console Tutorial

Electropermanent Magnets (EPMs)

	Coercivity	Residual Induction
Grade N40 NIB	1000 kA/m	1.28 T
Sintered Alnico 5	48 kA/m	1.26 T

Table 3.1: Magnetic properties of NIB and Alnico. From [72], [77]

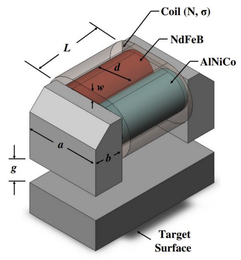

Figure 3-1: Switchable electropermanent magnet construction.

Figure 6. Diagram of EPM. Adopted from [53].

- EPMs can remain on for extended periods of time without power
- Constructed from two ferromagnetic caps, a magnet with high coercivity, a magnet with low coercivity, and enamel wire to complete a magnetic circuit (refer to figure 6)
- Current induces a magnetic flux which causes the poles in the magnet with low coercivity to flip, turning the EPM on or off

PROGRAMMING

- Currently, we have the framework of a self-assembly algorithm with many constraints
- Given the development stage of the physical robots, the accuracy of the algorithm in application is unknown
- Bots receive instructions from central computer via WiFi
- There are many hardware questions to answer:
  - How many directions will the bots be able to move?
  - How accurately will the bots move in those directions, and how do we compensate for error?
- In theory, the on-bot movement code works, pending details about bot hardware

FUTURE STEPS

- Refine CAD model to fit updated parts
- Design and print a PCB to control the bots
- Build and implement EPMs for movement and latching
- For programming:
  - How do we adapt this to a 3D shapes?
  - Is there a better way to do this? Bot-to-bot communication only?

ACKNOWLEDGMENTS

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Scan for references