Exploration and Mapping with a Particle Swarm Controlled by Uniform Inputs on a Magnetic Setup

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***Abstract*— This research deals with mapping a workspace using a swarm of non-intelligent robots. Much work has been done in single robot mapping, but there is a gap where multiple robots explore an enviornment using the same input commands, also known as global control. In our previous work[1], we developed a ClosestFrontier algorithm, with frontiers being unknown boundary cells, that maps a discrete 2D workspace using global control. Here we expand its scope to 3D environments and implement a physical hardware setup using four orthogonal magnetic coils.**

This new setup allows more dynamic interactions that can be introduced as well as continuous boundaries. The unknown workspace to explore is now a laser-cut acrylic maze with the particles suspended in water. With this new setup come challenges like wall friction, surface tension, and hydrophobic interactions of the particles themselves. These physical properties prove hardest to combat in small branched maps because of the high meniscus and local minimum of water that the particles will move towards. To address this problem, we design our workspaces with optimized channel width and curved edges to avoid local minima.

Expanding the previous 2D simulation was as simple as increasing the matrix dimensions and the nodes required to search with the ClosestFrontier algorithm, but it didn't scale proportionally with the moves required to explore holding the number of particles and number of free spaces constant. More simply, there is no tradeoff between dimensions and completeness of the explored workspace. Only the complexity of the map matters, which means that for the same number of free spaces on a 2D and 3D map, the map with the more complex shape will require more total moves to map with the ClosestFrontier algorithm from previous work. Complex shapes are highly branched and take many turns and loops which makes mapping more time and process consuming.

This research allows for precise control over weaker paramagnetic particles as well as a theoretical understanding of algorithmic efficiency in real world workspaces. Ultimately, medicinal applications in active targeted drug delivery and mapping vasculature as an alternative to traditional contrast agents are fields that can benefit from this research as well as pave path for more studies on non-invasive particle treatments as well.

References

[1] A. Mahadev and A. B. D. Krupke, S. P. Fekete, "Mapping, foraging, and coverage with a particle swarm controlled by uniform inputs," *International Conference on Intelligent Robots and Systems*, 2017.

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*This work was supported by the National Science Foundation under Grant No. [IIS-1553063] and [IIS-1619278].

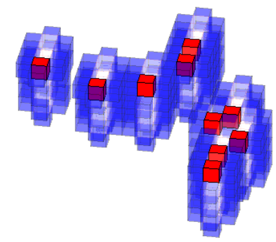

Fig. 1. The 3D simulation is shown above with red blocks being the particles, blue being the frontier cells, and white being free explored cells.

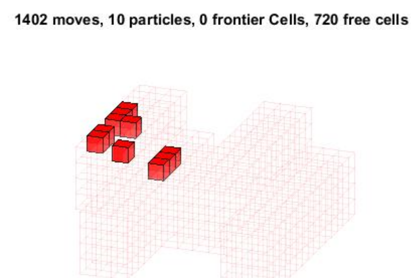

Fig. 2. Here are 10 particles that have completed explored the same workspace shown in Fig. 1. As shown, the workspace is four rectangular boxes alternately added together.

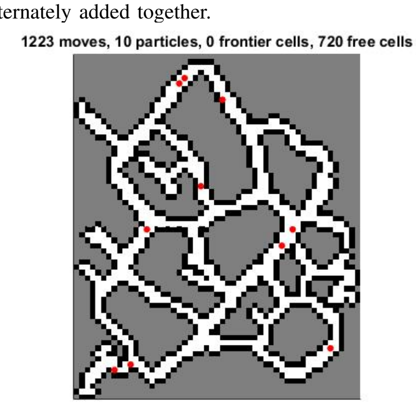

Fig. 3. For an equivalent 720 free cells in 2D, more moves were required by the ClosestFrontier Algorithm due to the increased complexity of this vascular system based off of a leaf tissue sample.