Dynamic Intra-Swarm Module Relocation using the Brazil Nut Effect

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Abstract In most works related to swarm robots, the swarm performs tasks as a whole, and the locations of individual modules within the swarm are ignored. In this paper, we propose a method of dynamic relocation of circular variable-radius modules within a 2D vertical swarm using the Brazil Nut Effect. This was achieved by placing a variable-direction light source or "flashlight" on the module being controlled, and allowing it to dictate the size of certain modules in its immidiate vicinity based on the modules on which the "light" was shone. By controlling the direction of the light, and by subjecting the swarm to vibrations, we moved the module equipped with the "flashlight" in a predictable direction to a desired position.

1 Introduction

A lot of research exists for the control of module swarms [1] [2]. For heterogeneous swarms, it is sometimes necessary to segregate modules by module functionality, or intra-swarm-migration of particular modules in order to perform tasks in certain parts of the swarm. Existing works in the field which attempt to solve this segregation problem for heterogeneous swarms [3]. Most of these works however, rely on the concept of different artificial potential between modules of different groups for segregation effects. While these models are certainly effective for segregation of heterogeneous swarms, they require inter-module communication throughout the swarm in order to be replicated in the real world.

We propose to replace these algorithms with local inter-module communication and physical module interactions to achieve intra-swarm module migration for a swarm of circular modules the radius of which can be dynamically controlled. Our model is inspired by flashlights, and also makes use of the Brazil Nut Effect [4]. Examples of the simulation environment can be seen in Figure.1. The module the position of which we wish to control (pictured in blue) is equipped with a "flashlight", or a rotating light source. In the current model, the module points the light towards a pre-determined goal position (pictured with a magenta circle near the bottom of the container). Also, the module being controlled maintains a large radius throughout the simulation to ensure it remains at the top of the swarm due to the Brazil Nut Effect. The modules "illuminated" by the light (pictured in red) change to a small radius. Due to their small radius, they tend to move underneath the large module more easily than the mid-sized un-illuminated modules (pictured in green) when the swarm is subjected to vertical vibrations. As a result, the module being controlled tends to move in the direction in which the "flashlight" points.

2 Simulation

We conducted simulations to determine the efficacy of the flashlight model described above. For these experiments, the objective was to investigate the effects of difference between module initial positon and goal position on the response rate of the position of the module being considered.

2.1 Method

For this experiment, the simulation was run several times, each time with a different number of goal positions. The first goal position was at the bottom left of the container and the final goal position at the bottom right for all the simulations. The goals were equally spaced along the bottom of the container. The position of the goal was changed

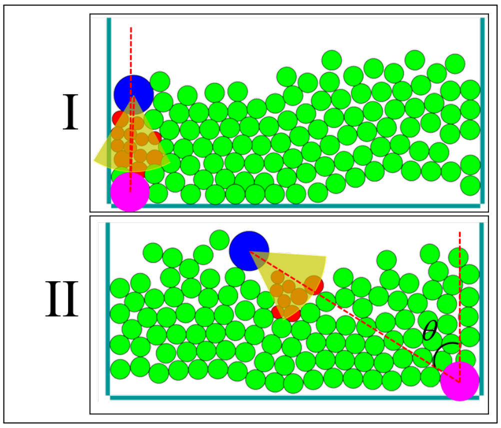

Figure 1: Examples of simulations in progress. The module being considered is shown in blue. The light from the "flashlight" is shown in yellow. The modules being "illuminated" by the flashlight are shown in red. The unillimunated modules are shown in green. The goal position is depicted with a magenta circle at the bottom of the container. Screenshots for the positions of the goal at the left side (top) and right side (bottom) of the container are pictured

every 1500 steps.

2.2 Results

The graph of the absolute value of the error in the angle inscribed between the vertical and the line drawn between the center of the module being considered and the goal position was plotted. This angle is descripted in Figure 1 by θ. In Figure 2, the graph of the absolute value of the angle θ versus time is shown.

In the graph, the angle error is seen to jump to a high value when the position of the goal is changed, approach zero with time, and then oscillate in the neighborhod of zero error. The error during these oscillations is seen to be small compared to the initial error at the time of the shift of the goal position. The "oscillating" error for the goal positions on the extreme ends of the container was seen to be small compared to the error for a central goal position. Similar simulations were conducted for a goal positions closer together, and similar results were seen (graphs not pictured), and the rate of approach to zero error was found to be faster for a smaller distance between goal positions.

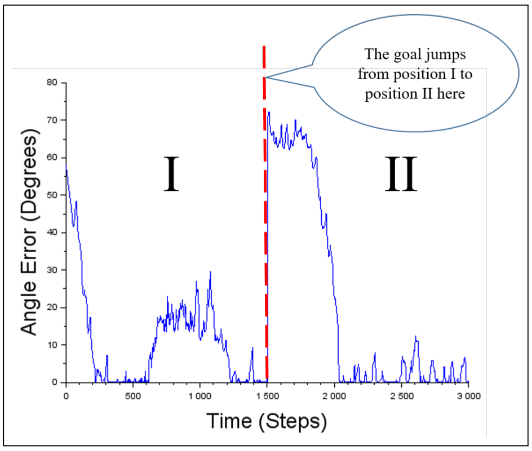

Figure 2: The graph of the absolute value of the error in the angle inscribed between the vertical and the line drawn between the center of the module being considered and the goal position.

3 Conclusion and Future work

In this paper, we proposed a "flashlight" model to allow for dynamically controlling the position of a module on top of a vertical swarm of variable-radius modules. The effects of difference between module initial positon and goal position on the response rate of the module position were investigated. The module was found to respond to a change of goal position faster for a smaller change in goal position.

In future, we hope to expand this model to allow for intra-swarm migration of the module through the swarm, and not just on its surface.

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