Experimental study of self-assembly with Lily robots: control and modeling

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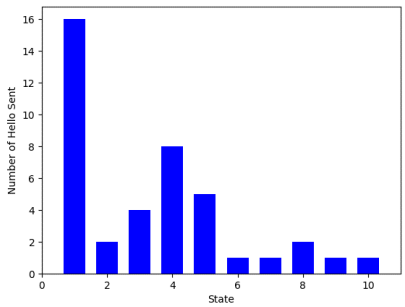
A Lily robot is a miniature floating robotic platform for programmable stochastic self assembly. The single Lily robots float in a water tank, where they are directed by a generated flow, and can form desired pre-specified target structures governed only by a simple rule-set embedded in their micro-controller. The connection between Lilies is done using Electro-Permanent Magnets (EPMs). In this project, we will focus on two main aspects: simulation and real experiments. In the simulation part, a solution to the Webots issues observed and identified during the semester project SP106 is investigated. In addition, a parallel implementation of the PSO algorithm was realized. In the experiment part, the task was to automatize as much as possible the complete setup formed of the tracking system, the lilies check tests, and programming the lilies. Furthermore, a new population-based method was employed to calibrate the simulation to the real system. Finally, some real experiments were done investigating the possibility of target formation even when the default state of the EPMs was off.

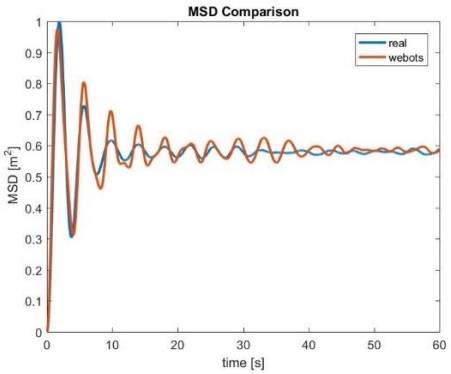
First, all the timing issues in Webots were successfully solved.
Second, two main automated check tests were implemented: the radio test and the EPM communication test. These tests are crucial to verify the reliability of these communications.



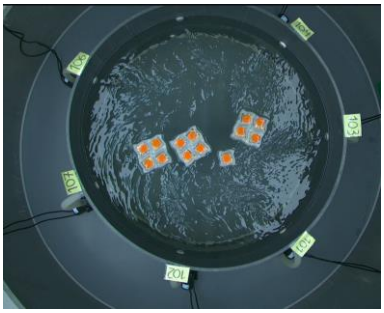
Example of the result of the communication test

Finally, a new calibration method was investigated. In the previous calibration approach only one single blob is considered and the interaction of many modules is not taken into consideration. The suggested new method is a population based method that considers many blobs in the arena and therefore considers the different interaction between them. The new metric is matching the mean square displacement (MSD) curves between simulation and real experiment. After modeling the physics of the system and applying an optimization on the free parameters, a matching MSD was obtained.

At the end, real experiments were conducted. The idea of having the EPM default state as off was found feasible since the lilies were coming into contact due to the capillary forces in the system.



Matching MSD between real and simulated experiments



Formation of Square targets with default EPM off