Optimization of Ruleset Controllers for Programmable Self-Assembly of Lily Robots

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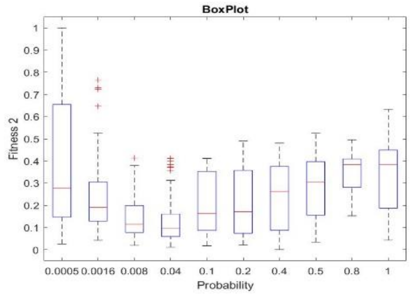
Self-Assembly(SA) is the process where many individual building blocks autonomously assemble themselves into a bigger, more complex structure without any external control. In nature, self-assembly is abundant and present at different scales and domains. Self-assembly has also found its way in the field of Robotics and technology. In this project we will focus on the self assembly of Lily robots: a miniature floating robotic platform for programmable stochastic self assembly. The single Lily robots floats 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. In order not to get trapped in a deadlock, each of the rules has a corresponding reverse rule to which a probability is associated. We wish to find the optimal values for these probabilities. Two aspects are considered for the optimization problem. We wish to have:

- maximum convergence rate: reaching the target as fast as possible
- maximum final yield : forming as many copies of the target as possible

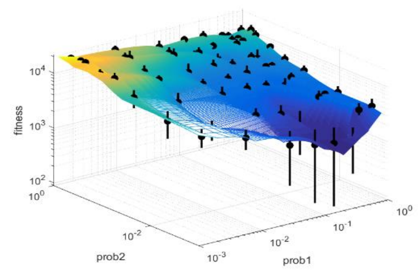
First, modeling of the robotic swarm was studied on three abstraction levels:

- A submicroscopic level (Webots) where the robot is regarded as a physical entity which is affected by the physical environment and forces applied.
- A microscopic level where the physical details are not therefore taken into consideration.
- A macroscopic level where we only care about the average number of robots in a certain state and the transition rate.

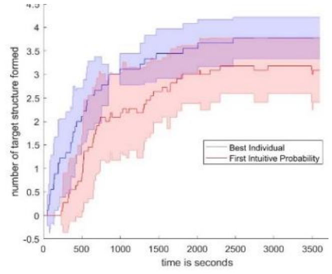
We decided to use the Webots Simulation Framework for the optimization process since physical interactions highly affect the Self-Assembly evolution.
Then, the optimization of three targets was studied: a chain of 3, 4 and 6. A brute force optimization was first used for the chain of 3 (1 reverse probability of the dissociation of a dimer) and 4 (2 reverse probabilities that of the dissociation of a dimer and of a trimer). However, for the chain of 6 (4 reverse probabilities), Particle Swarm Optimization (PSO) was implemented.
Furthermore, solutions were investigated for synthesizing rules for compact structure targets extending the possible final targets choice which was limited to only acyclic structures in the existing framework.



Optimization Results for the Chain of 3



Optimization Results for the chain of 4



Chain of 6: Optimal probabilities from PSO vs first intuitive probabilities