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Self-assembly of soft-robots in simulation inspired by army ant bridge behavior

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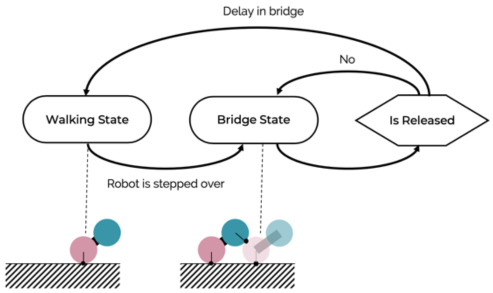
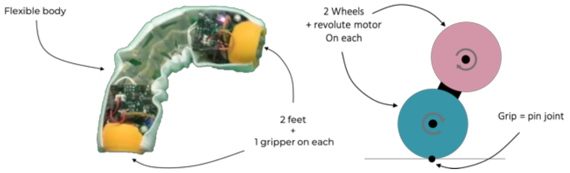
The application of self-assembly principles to robotics such as the ones found in social insect colonies could be highly beneficial to the field. Smaller, cheaper, and simpler robots could collaborate in order to overcome difficult tasks or navigate on rough terrains. In an effort to do so, the team at the Self-Organizing Systems Research Group at Harvard (SSR) is working on designing a self-assembling robot swarm that would be able to reproduce the behavior of army ants, focusing on bridge formation. A first version of the robot has been developed previously and in order to quickly develop algorithms or local rules that would lead to mechanically stable amorphous structures, a simulator is required. For this purpose, I designed a simulator for the newly created soft robot. It is used to verify that simple rules allowing the robot to switch from walking to bridge state can indeed lead to a self-formation and dissolution of a stable structure and to study how some parameters can influence the bridge formation.



State diagram of the simulated robots

The first step was to create a model to obtain a general and abstract representation of the robot but also a simple and computationally efficient simulator.



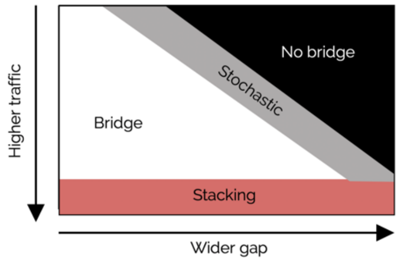
Real robot (left) and model of the robot (right)

The simulated robots are interacting in a terrain with a V-shaped gap to allow a comparison of the results with prior literature on experiments with real ants.

Unfortunately, in part due to the specific flipping movement of the robot, the search space is almost intractable. Both the parameters describing the geometry (angle of the gap, depth) and the robot traffic (initial position, distance/delay between robots, phase shift) are influencing the results. In order to reduce the search space, only the variation of the delay and the V-gap angle have been further studied.

The experiments are composed of two steps: the bridge formation and the dissolution -when the traffic is stopped-.

The overall results show that stable bridges are observable only for a smaller angle of the V and a higher value of the traffic.



Schematic representation of the bridge formation results for the pair of parameters

They also highlight a tendency of the bridge to form where the width of the gap matches 2 body length. However, the bridge height can be influenced by controlling the proportion of stacking robots introduced into the system.

Even if the dissolution process almost always starts, it is sometimes not total due to some geometric constraints, up-grab or double-grab of the robots. Some improvements are proposed but their utility can be discussed as the dissolution failures are mainly due to 2D constraints.

The analysis of the results highlighted several ways to study further the bridge formation if the objective becomes to act on the final bridge height. Nonetheless, implementation on a small group of real robots appears necessary to obtain physical feedback and validate the simulation as it might lead to reconsider some design choices.