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# SELFSYS

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# **Real-time Control of Self-Assembling Systems**

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## **Research Question**

Can we automatically model and control self-assembling systems?



#### **2 cm**

## Lily's passive robots

- » Typical size: 3 centimeters
- » Swarm size: a few units
- » Latching: permanent magnets
- » Fluidic locomotion/disaggregation
- » No sensing, computation, communication

# **8 cm**

SwisTrak real-time tracking of Lily assemblies

metric

ommon

#### Lily's fluidic arena

» Tankdiameter: 30 cm » Controllable fluidic stirring » Real-time visual tracking of robots through overhead camera and SwisTrak  $\gg M^3$  computational framework in the loop

#### **Modeling & Control**

» **Challenge:** capturing the richness of features of self-assembling systems into a single, consistent modeling framework using common metrics.

approach, whole population

#### **Results & Perspective**



» **Solution**: *multi-level* modeling methodology

stochastic simulations



 $X_s + X_s \stackrel{e_s}{\rightharpoonup} X_2$  $X_s + X_i \stackrel{e_i}{\rightharpoonup} X_{i+1}$ 



Microscopic 1: Monte Carlo model, 1 building block = 1 agent, nonspatial

Macroscopic 1: rate equations, mean field

Macroscopic 2: Chemical Reaction Network,



Microscopic 2: Agent-Based model, 1 building block = 1 agent, spatial

environment (e.g., drag, surface tension)





Physical reality: real experiments probed using high speed cameras and microscope

Realistic: faithful representation of thebuilding





#### Example of bang-bang controlled assembly run of 4 Lily's





Software deployment around the M<sup>3</sup> framework All assemblies formed out of 4 Lily's and the 14 associated reactions

ï **Random Optimized** Mode 0 Mode 1 Impact of control on assembly performance **Challenges** ahead » System's partial observability » Parameters mapping and calibration » Automatic phase space exploration » Scaling of swarm and block size

#### **Publications**

[1] Mermoud *et al.,* "Real-Time Automated Modeling and Control of Self-Assembling Systems", IEEE Int. Conf. on Robotics and Automation 2012. [2] Mermoud *et al.,* "Automated Modeling of Self-Assembling Robotic Systems: The M<sup>3</sup> Framework", submitted. Full list available at http://disal.epfl.ch.