Self-Assembly

Self-Assembly is a term used to describe processes in which a disordered system of pre-existing components spontaneously forms an organized structure or pattern as a consequence of specific, local interactions among the components themselves, without external direction.

The kinetic rate model

The kinetic rate model, known from chemical reactions, allows us to model the stochastic time evolution of our system with a large amount of models. The transition of the state vector \( x = (x_1, \ldots, x_6) \), in which \( x_k \) denotes the number of clusters consisting of \( k \) modules, obeys the following difference equation if \( x \) is large enough:

\[
x(t+1) = F(x(t)) + \sum (\text{stochiometric number}) \cdot \text{bonding prob.} \cdot \text{collision prob.}
\]

The degree of parallelism (DOP) \( H \) is a function of the local clustering degree \( c_i \) and is used to quantify the aggregation paths:

\[
H = - \sum c_i \ln c_i
\]

The higher the DOP-value of a particular state is, the less probable it is for the system to converge into a complete final state. By setting the bonding probability relative to the size of the cluster we can make the system aggregate along a path that has intermediate states with a low \( H \).

Conclusion

The yield rate problem is a fundamental problem in stochastic modular robotics. We propose two approaches to address this.

- **Disassembly:** As suggested by comparing the time evolution of the system with and without disassembly we introduce disassembly. Especially for the clusters \( X_4 \) and \( X_5 \) since they can lock the system into a final state with incomplete clusters. Disassembling these clusters effectively puts the system in a state with lower DOP-value.

- **Assembly:** By increasing the bonding probability for larger clusters we can force the system to aggregate along a less parallel pathway already from the onset of reactions.

In conclusion we propose that the morphology of the clusters should be considered as a control mechanism for stochastic self-assembly robot systems.

References
