Universal Shape Formation for Programmable Matter

(Thim Strothmann)

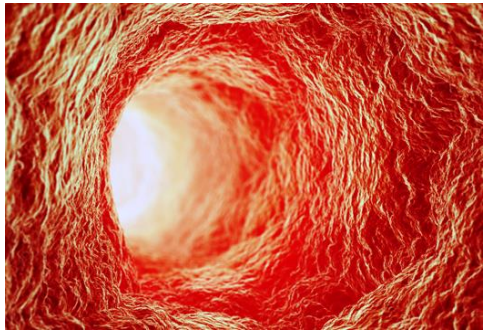
Joint work with



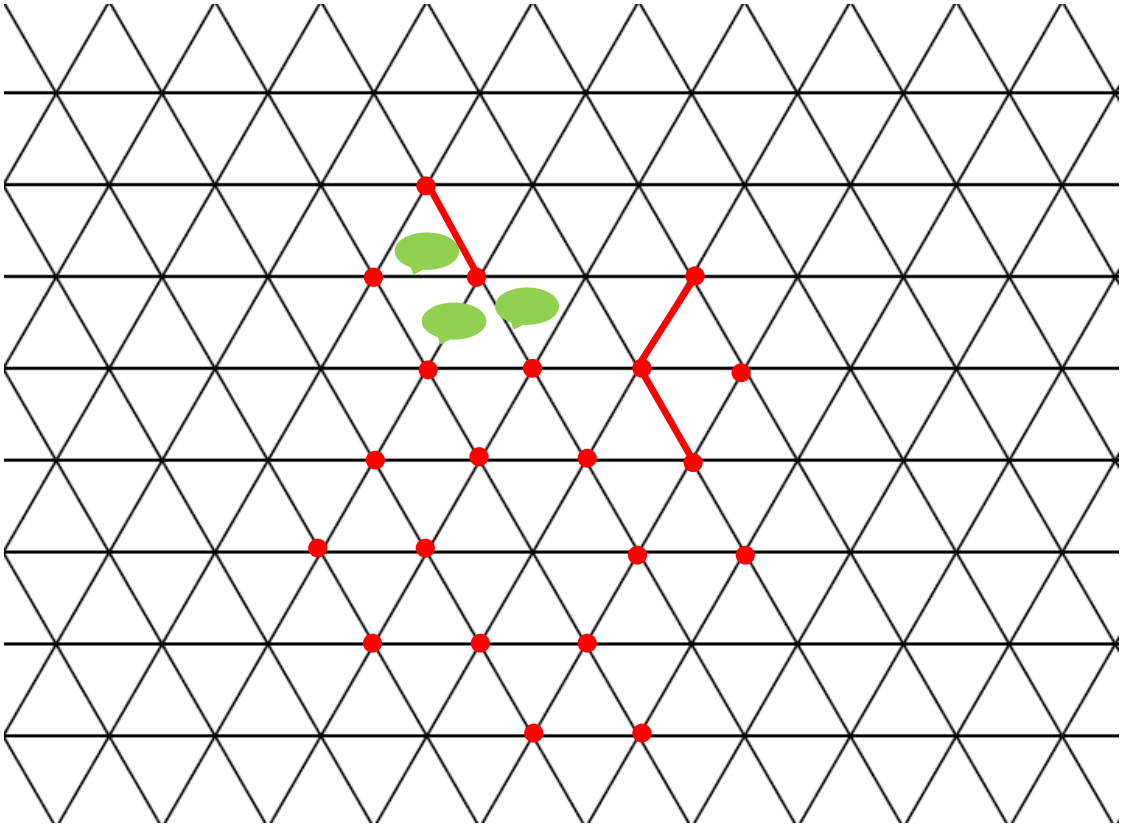

Inspiration

Video on this slide was deleted to decrease file size.
For inspiration Video (scene from Big Hero six) visit https://www.youtube.com/watch?v=fF1rDKEC0TI.

Motivation - Applications



The amoebot Model



Overarching Constraint: Maintain Connectivity

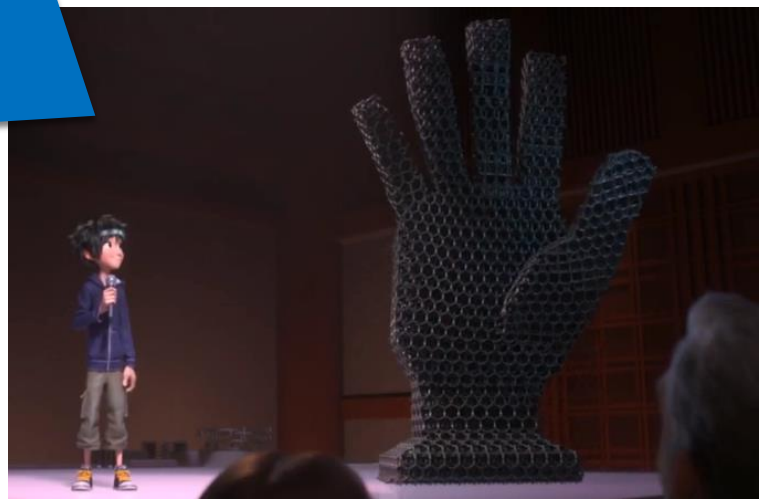
The amoebot Model

- "Standard" asynchronous computation model
  - Only one particle is activated in each time step
  - Once activated a particle can compute, communicate and perform one move
  - an adversary activates particles

- Round: every particle is activated at least once

Shape Formation Problem

Shape Formation

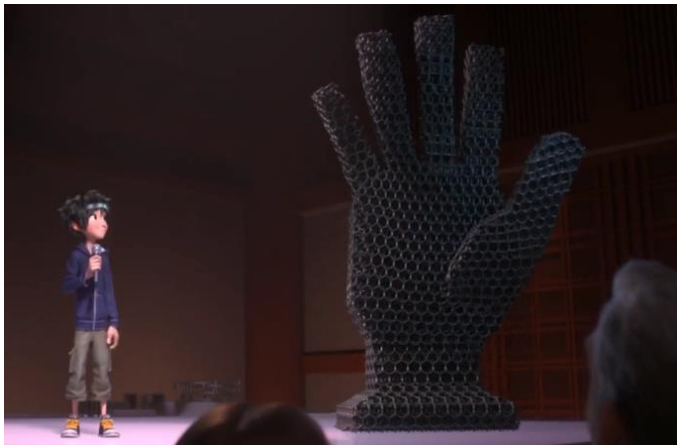


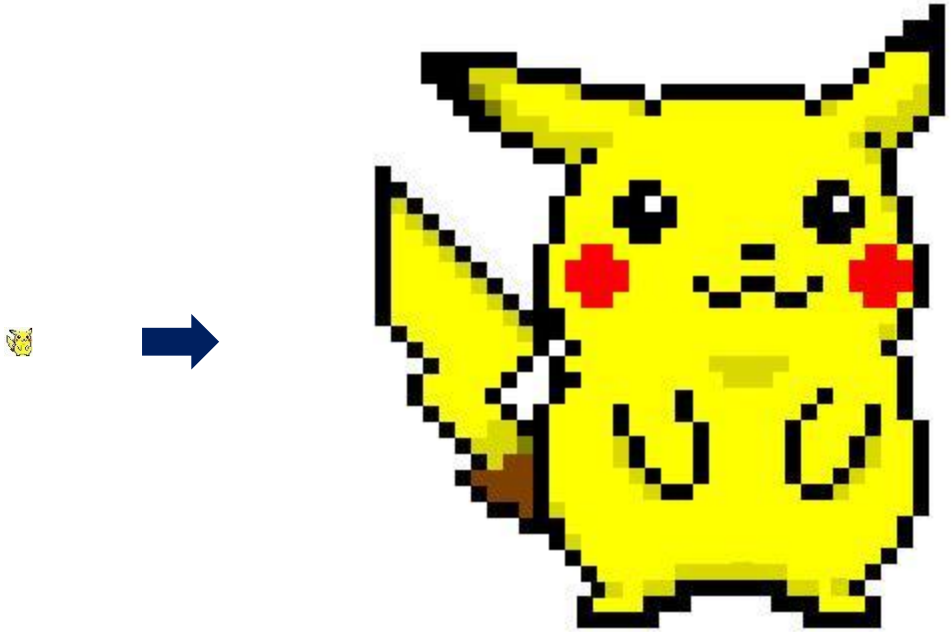
Naive Shape Formation Problem

Video on this slide was deleted to decrease file size.
For naïve Shape Formation algorithms (Hexagon & Triangle) visit http://sops.cs.upb.de/ .

Universal Shape Formation Problem

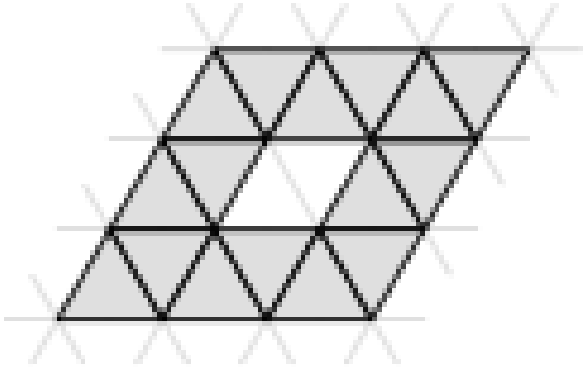
In general not possible, i.e.,





Universal Shape Formation Problem

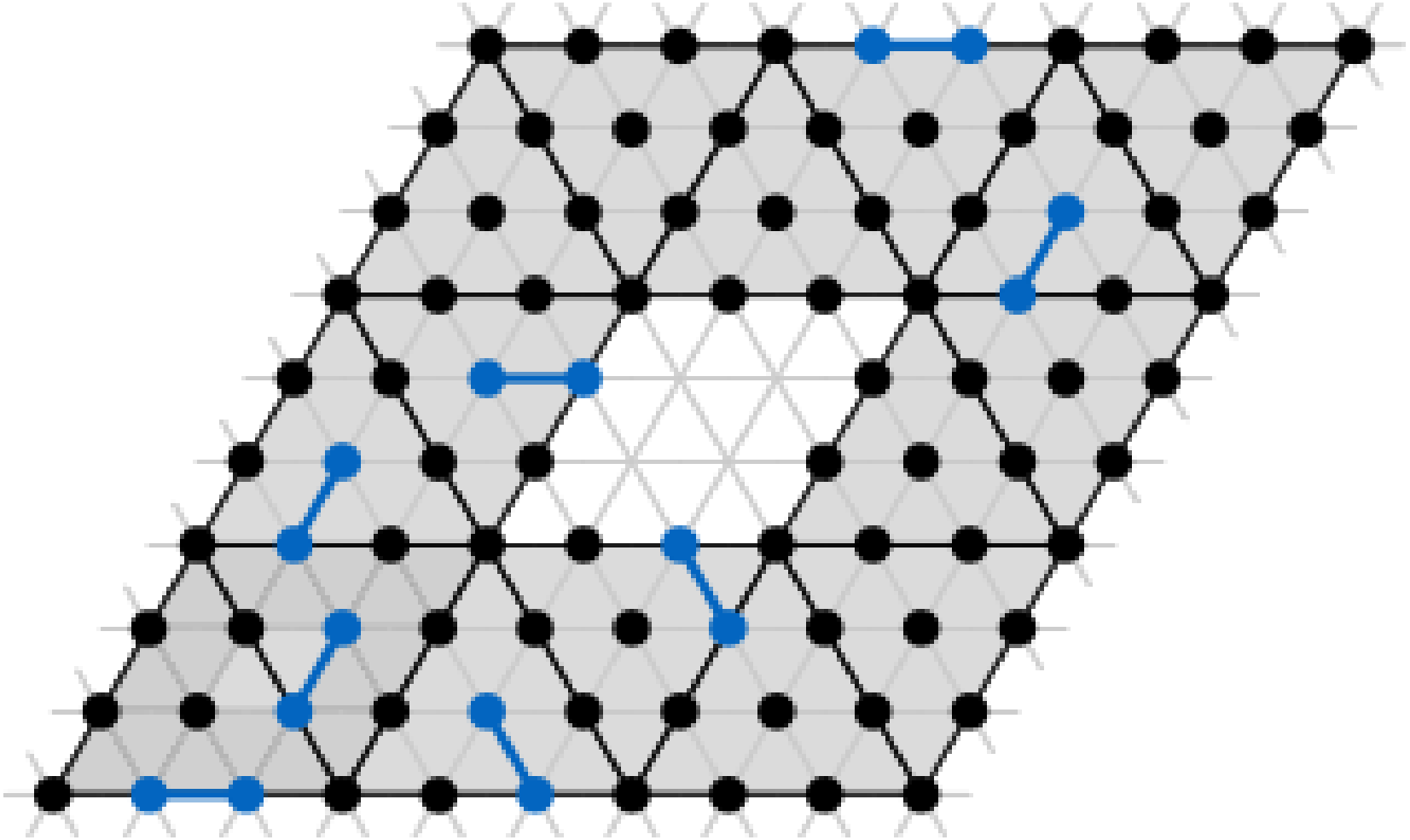
Input: constant size set of faces



Goal:

- build shape given by faces (scaled-up and possibly rotated)
- scale to include all particles
  (no leftover particles)

Universal Shape Formation Problem



Universal Shape Formation Problem

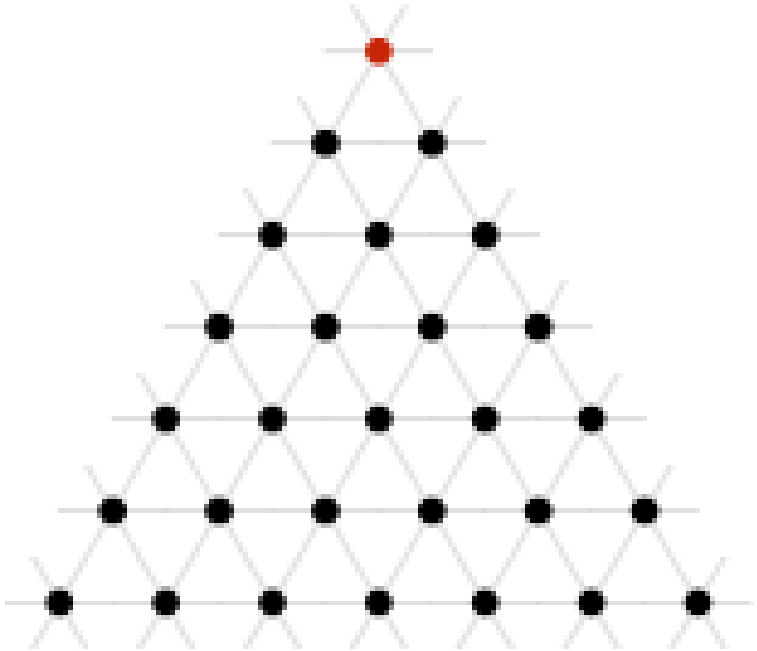
Our Result:

Given any shape described by a constant number of faces, our algorithm builds that shape using all particles in the system in $O(\sqrt{n})$ rounds.

Universal Shape Formation Problem

Note: $O(\sqrt{n})$ rounds is not possible if we start in an arbitrary initial configuration.

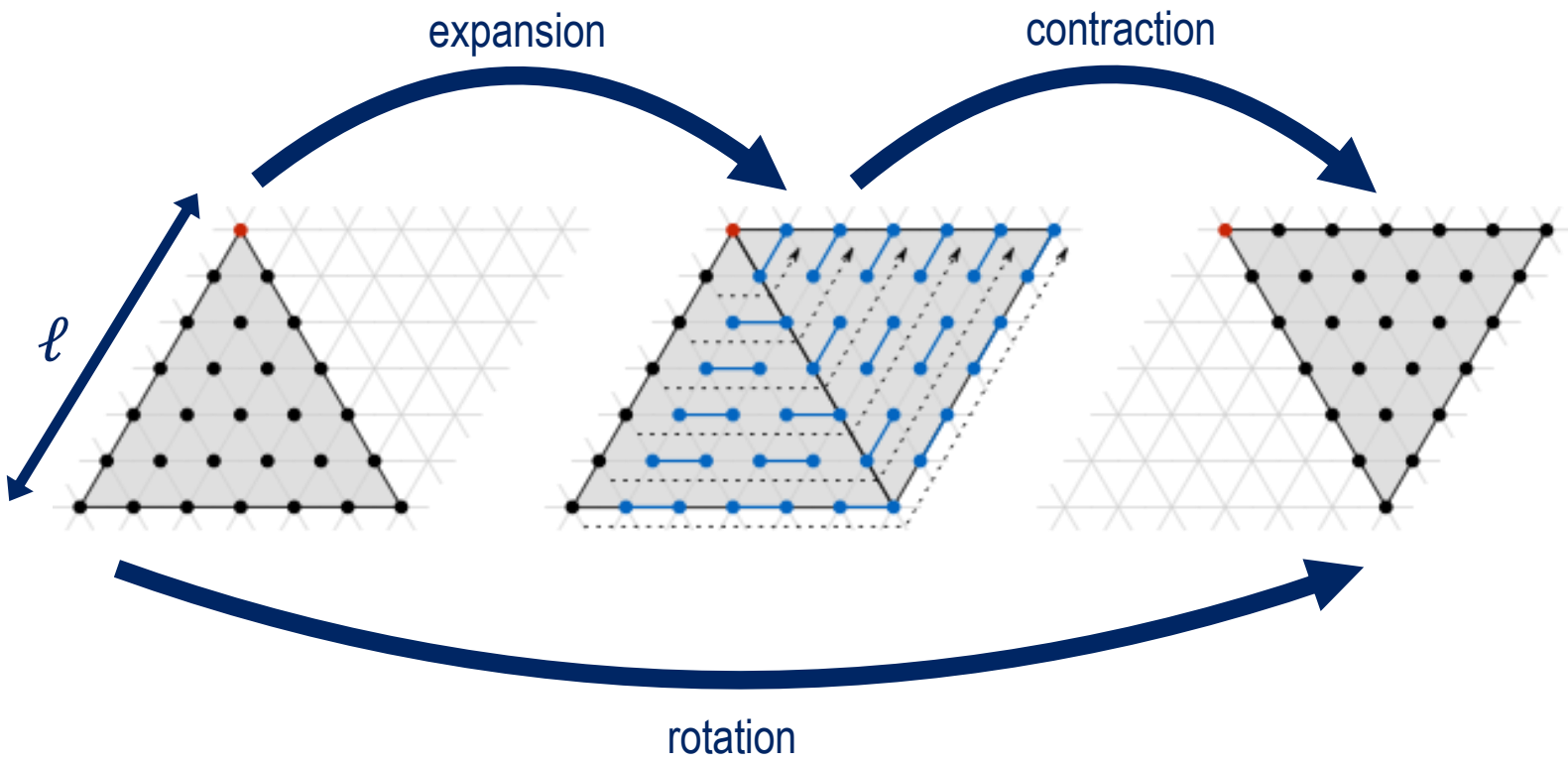
Solution:



Universal Shape Formation Algorithm

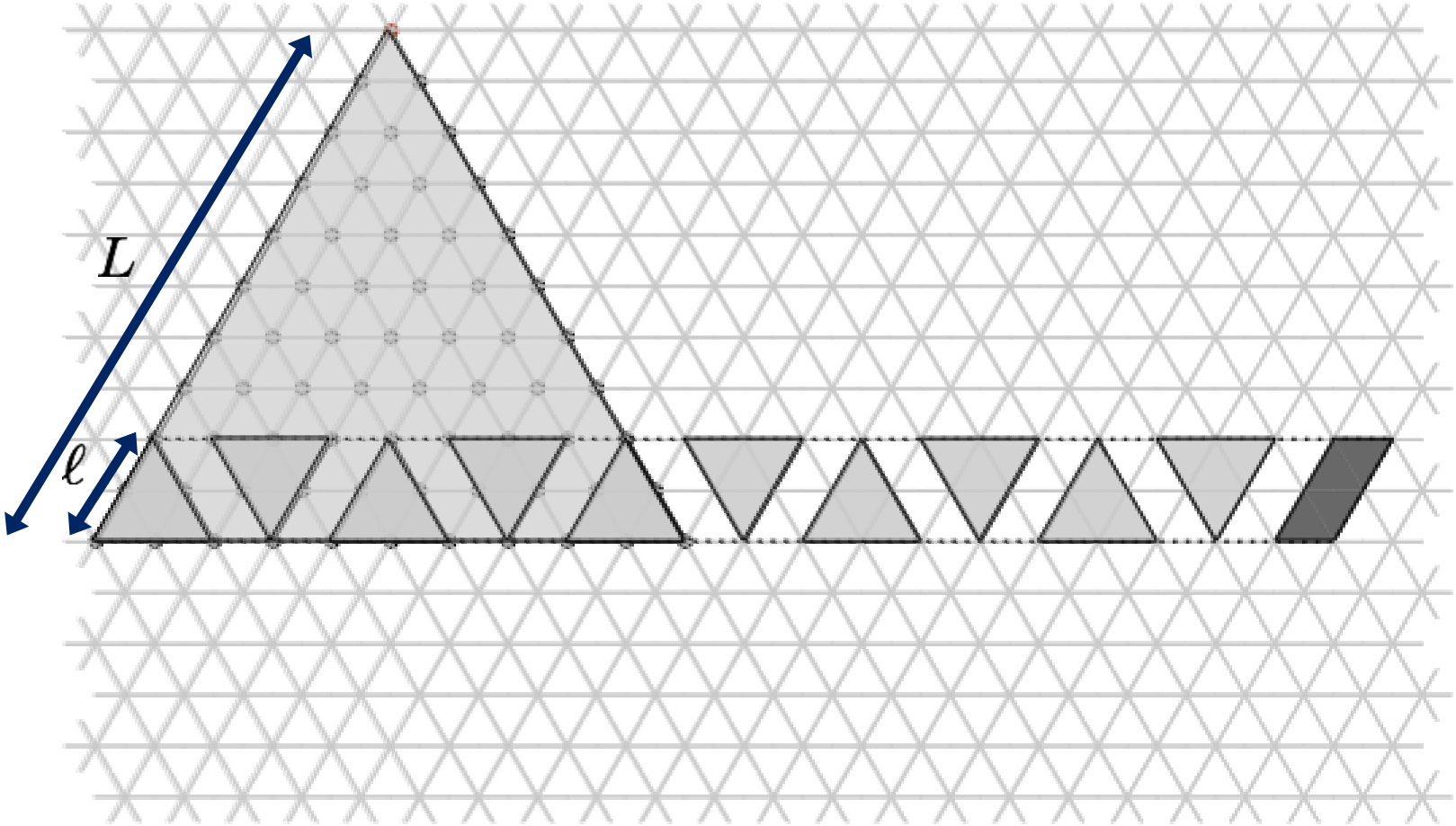
Movement Primitives:

2) Triangle expansion/ contraction/ rotation ($O(\ell)$ rounds)



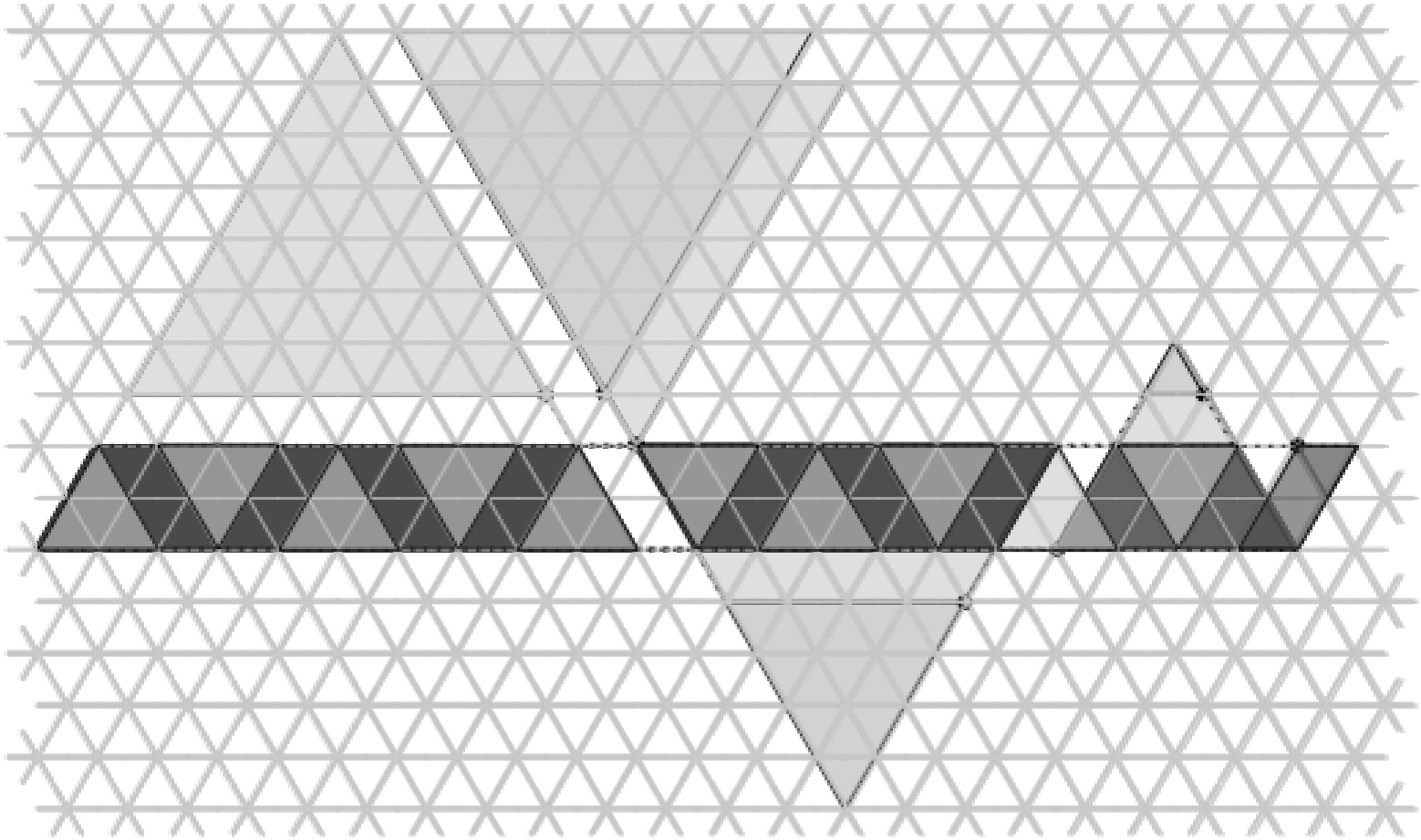
Universal Shape Formation Algorithm

Intermediate Structure



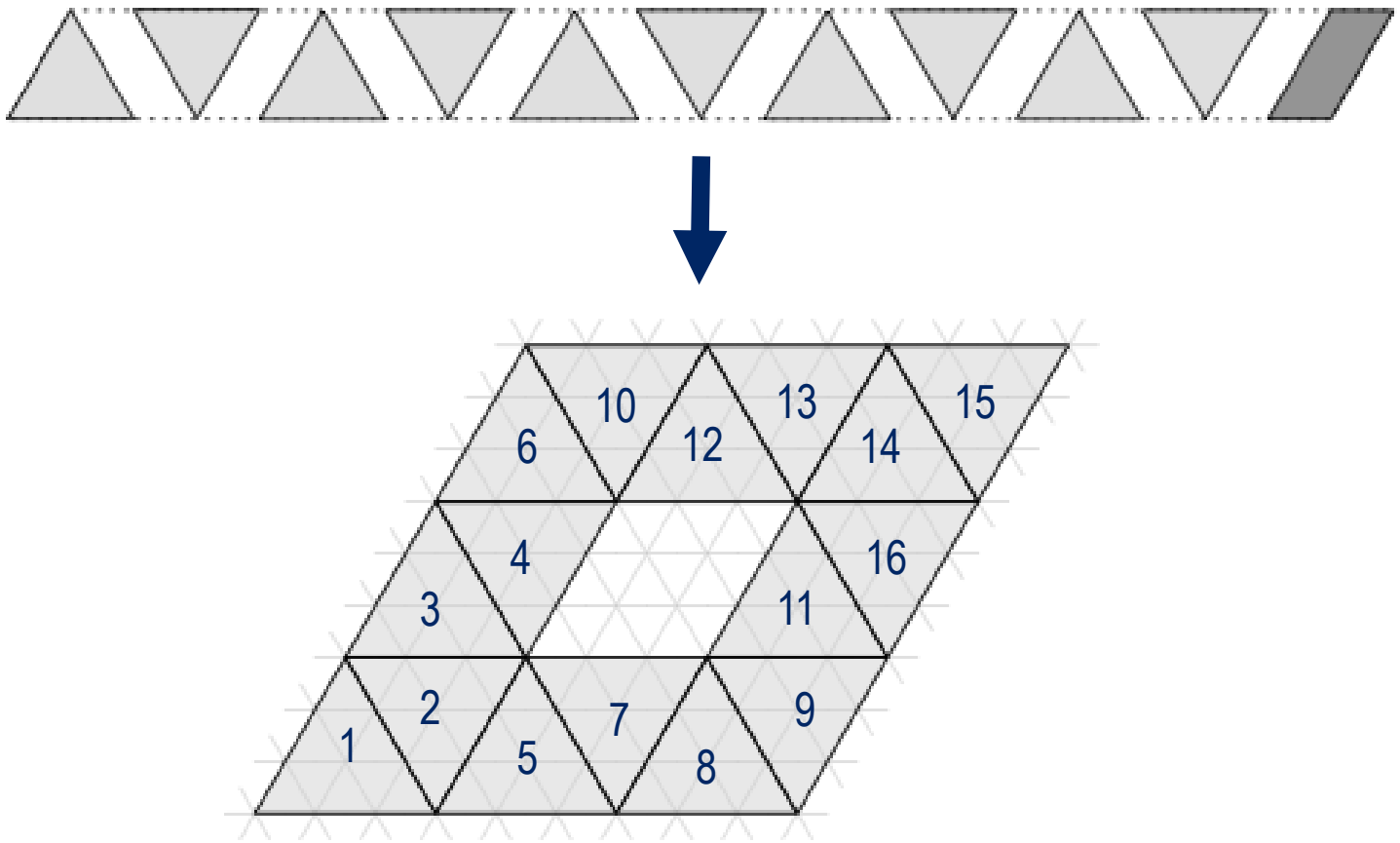
Universal Shape Formation Algorithm

Intermediate Structure



Universal Shape Formation Algorithm

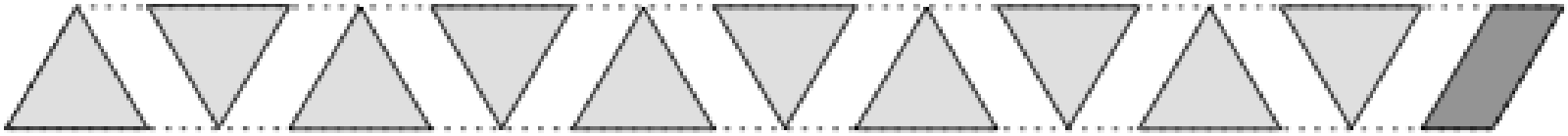
Building the final shape:



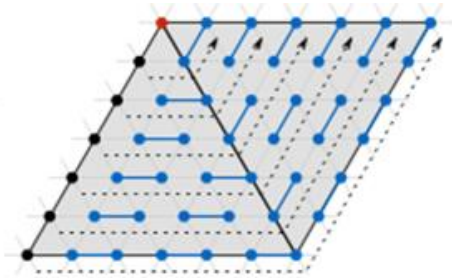
Universal Shape Formation Algorithm

The devil is in the details:

- Take care of the imperfection of the intermediate structure without moving it.



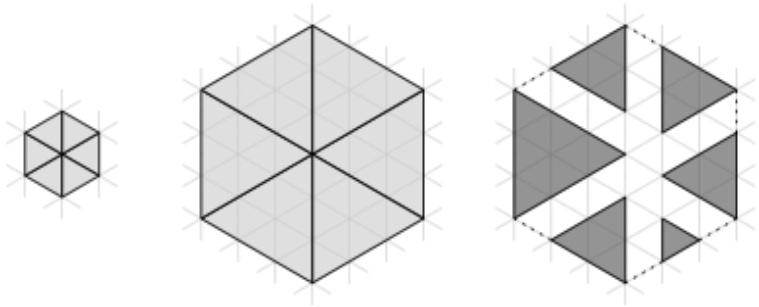
- Make up for the estimation errors of ℓ.



Universal Shape Formation Algorithm

The devil is in the details:

- Triangles have to be cut to different sizes (+ incorporate waste).



- The intermediate structure might block the final building process

Summary & Future Work

Result: Given any shape described by a constant number of faces, our algorithm builds that shape using all particles in the system in $O(\sqrt{n})$ rounds.

Interesting Challenges:

- arbitrary configuration of low diameter
- non-constant size shapes
- 3D
- Failures

References

Corresponding Publication:

Zahra Derakhshandeh, Robert Gmyr, Andréa W. Richa, Christian Scheideler, Thim Strothmann: Universal Shape Formation for Programmable Matter. SPAA 2016: 289-299 (http://doi.acm.org/10.1145/2935764.2935784)

For videos of some of our algorithms and a (slightly outdated) publication history in the topic visit:

http://sops.cs.upb.de/