

6.849

Class 1

Sept. 6, 2012

6.849: Geometric Folding Algorithms  
Prof. Erik Demaine TA: Jayson Lynch  
<http://courses.csail.mit.edu/6.849/fall12/>

### NOTE: VIDEO RECORDING

Inverted lectures: (new this semester)

- online video lectures + notes + slides (from last offering)
- DEMO: slide sync & jump, playback speed, required feedback form
- class time for interactivity
  - answering questions
  - additional detail/material of interest
  - activities folding
  - solving problems
- + optional open problem session (if interest)

### Discuss

## Please:

- ask questions
- request topics for detail/coverage
- send links to cool folding on web ←
- any other ideas

## Requirements:

- short survey of your background
- watch video lecture by noon on Mon./Wed.  
e.g. watch Tues. & Thurs. night OR weekend
- fill out form with questions DEMO
- attend classes (email me about exceptions)
  - interactive content generally not videoed
- problem sets  $\approx$  weekly
  - we drop lowest problem  $\Rightarrow$  can skip
- project & presentation
  - build/design physical structure
  - implement algorithm/illustration/tool
  - pose open problem
  - survey subfield
  - Wikipedia (write/improve several articles)
  - try to solve open problem
- textbook: Demaine & O'Rourke. CUP 2007

# Geometric folding algorithms:

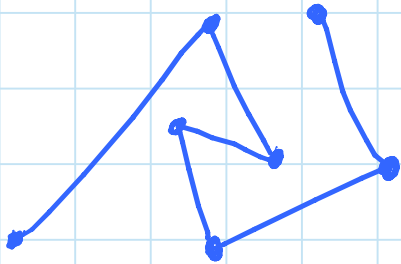
In general: Mathematics & algorithms behind (un)folding of geometric objects

Applications/connections to:

- robotics → arms, Transformers, programmable matter, ...
- graphics → morphing, animation, ...
- mechanics → steam engines, ...
- manufacturing → sheet-metal & tube bending, nanomanufacturing, optics, ...
- medical → stents, drug delivery, ...
- aerospace → telescope deployment, ...
- biology → protein folding & design, ...
- sculpture → origami, interactive sculpture, ...
- architecture → dynamic architecture, deployable/collapsible structures, ...

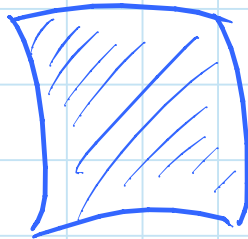
# Geometric objects & rules for folding:

① linkage



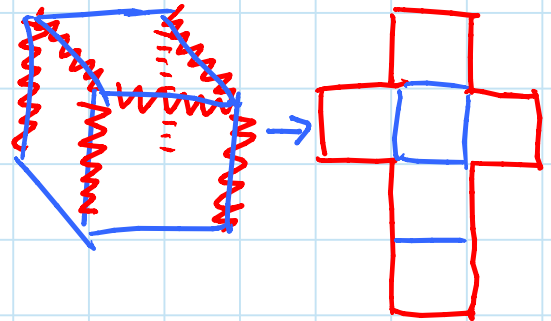
- ↳ rigid bars
- ↳ [don't cross]

② paper



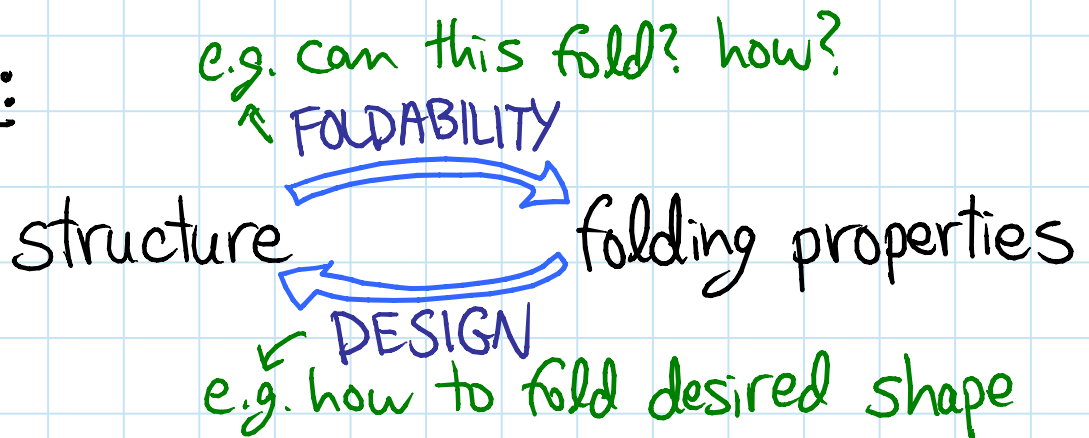
- ↳ don't stretch
- ↳ don't tear
- ↳ don't cross

③ polyhedron



- ↳ cut surface
- ↳ one piece
- ↳ no overlap

## Problem types:

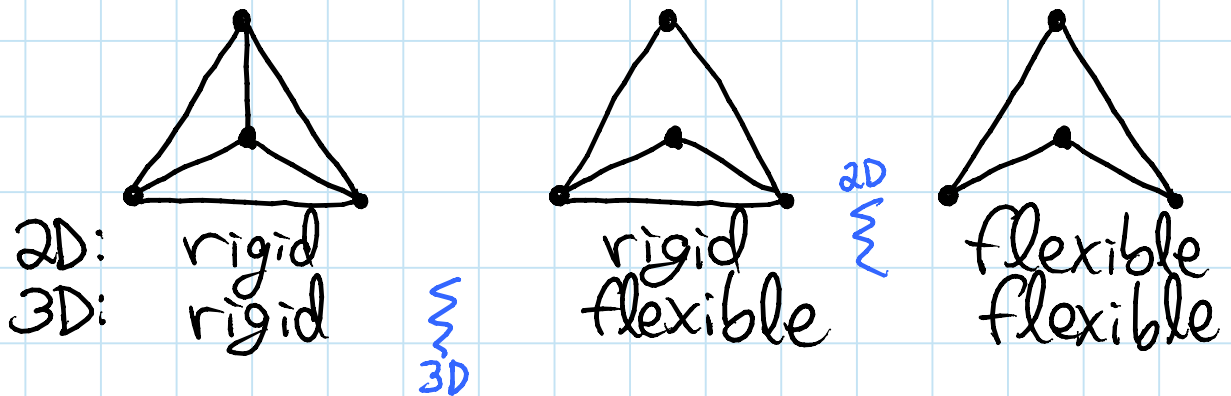


## Result types:

- UNIVERSALITY: Everything is foldable!  
(& here's an algorithm to do it)
- DECISION: Efficient algorithm to decide foldability
- HARDNESS: Computationally intractable to decide foldability

# I LINKAGES:

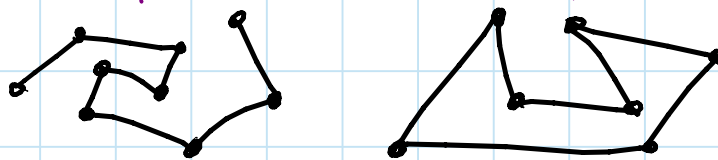
Rigidity: which linkages fold at all?



- efficient characterization in 2D
- **OPEN**: 3D

Universality: which linkages can fold into all possible configurations?

- 2D chains/polygons: **UNIVERSAL**  
[Connelly, Demaine, Rote 2000; Streinu 2000;  
Cantarella, Demaine, Iben, O'Brien 2004]



- 3D chains: **CAN LOCK** (related to protein folding)  
[Cantarella & Johnston 1998]



- 4D<sup>+</sup> chains: **UNIVERSAL**  
[Cocan & O'Rourke 2001]

## II PAPER:

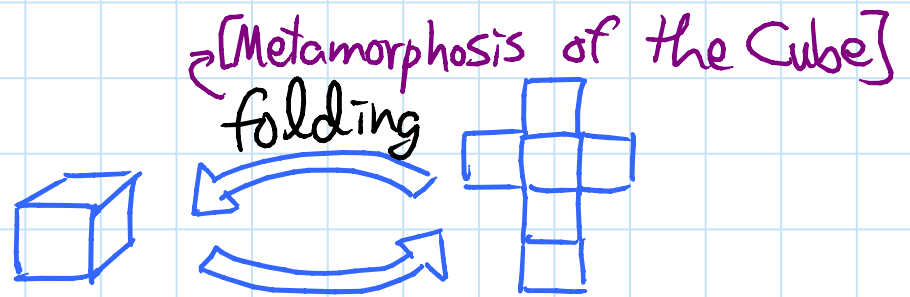
Foldability: which crease patterns fold flat?

- NP-hard [Bern & Hayes 1996]  
( $\Rightarrow$  likely no efficient algorithm)

Design: what shapes can be folded?

- universal: any 2D polygon, 3D polyhedron, 2-color pattern (inefficiently)  
[Demaine, Demaine, Mitchell 2001]
- Origamizer: practical [Tachi 2006; Demaine & Tachi]
- maze folding: fold extruded orthogonal graph with scale factor 3 (independent of maze)  
[Demaine, Demaine, Ku 2010]
- fold & cut: any set of line segments can be aligned by flat folding [Demaine, Demaine, Lubiw 1998; Bern, Demaine, Eppstein, Hayes 1998]

### III POLYHEDRA:



polyhedron  
convex  
general

edge  
OPEN  
NO

general  
YES  
OPEN

### IV HINGED DISSECTIONS:

- any finite set of polygons of same area can be folded from one chain of polygons (without collision)

[Abbott, Abel, Charlton, Demaine, Demaine, Kommer 2008]

MIT OpenCourseWare  
<http://ocw.mit.edu>

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Fall 2012

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