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 ≈ weekly
  - we drop lowest problem ⇒ 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:

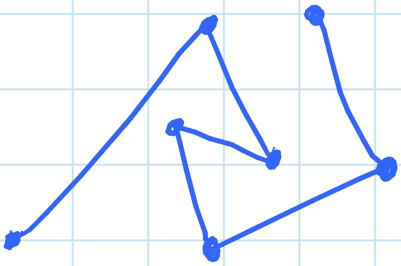
In general: Mathematics & algorithms behind (un)folding of geometric objects

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, ...

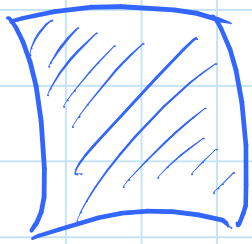
Geometric objects & rules for folding:

① linkage



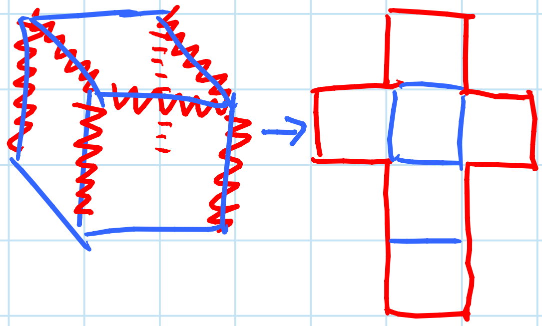
↳ rigid bars
↳ [don't cross]

② paper



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

③ polyhedron



↳ cut surface
↳ one piece
↳ no overlap

Problem types:

e.g. can this fold? how?
↑ FOLDABILITY

structure → folding properties
structure ← folding properties

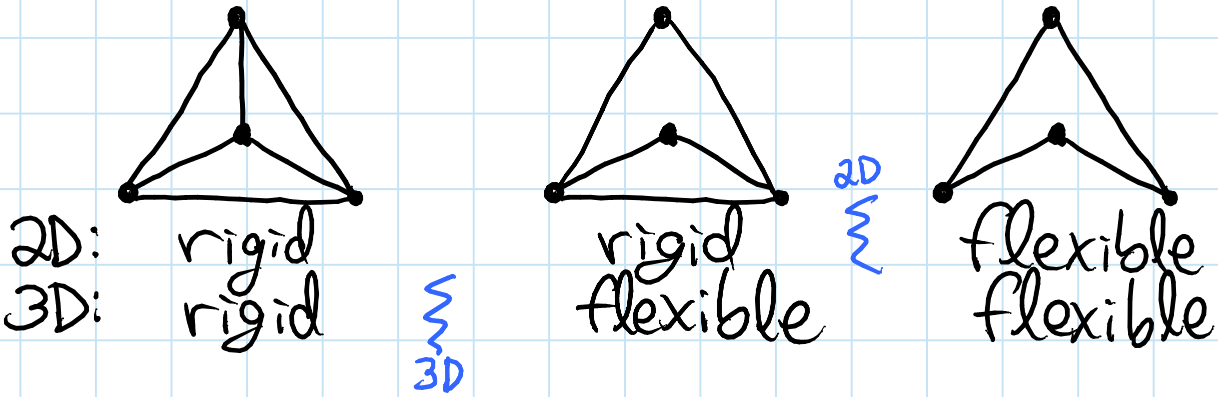
DESIGN
↙ e.g. how to fold desired shape

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:

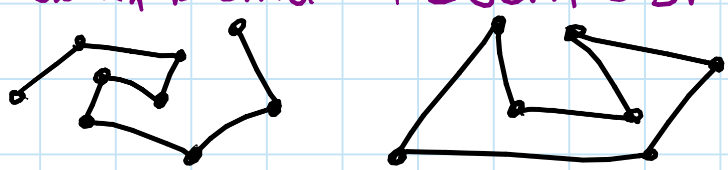
Rigidity: which linkages fold at all?



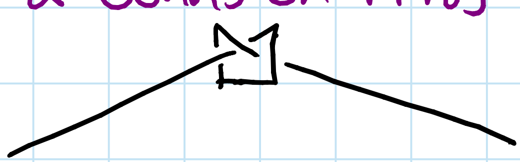
- efficient characterization in 2D
- OPEN: 3D

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+ chains: UNIVERSAL
  [Cocan & O'Rourke 2001]

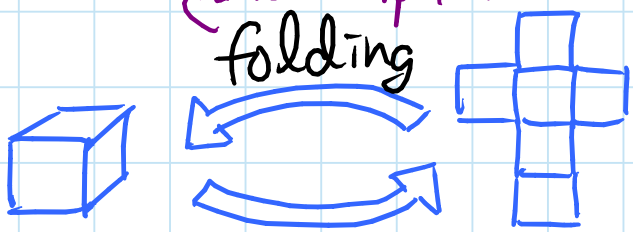
(II) PAPER:

Foldability: which crease patterns fold flat?
- NP-hard [Bern & Hayes 1996]
  (⇒ 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:

[Metamorphosis of the Cube]



polyhedron	edge unfolding	general unfolding
convex	OPEN	YES
general	NO	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, Kominers 2008]