MIT 6.849
Geometric Folding Algorithms
Prof. Erik Demaine

Lecture 6:
Origami Art and Design

Guest Lecturer:
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Jason Ku
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Mechanical Engineering Bachelor's, MIT ’09
PhD student in Mechanical Engineering working in folding on the micro and nano scales
Origami Art

- Akira Yoshizawa [http://www.origami.vancouver.bc.ca/]
- Hideo Komatsu [http://www.origami.gr.jp/~komatsu/]
- Takashi Hojyo [http://origami.gr.jp/~hojyo]
- David Brill [http://www.brilliantorigami.com/]
- Michael LaFosse [http://www.origamido.com]
- Eric Joisel [http://www.ericjoisel.com]
- Brian Chan [http://chosetec.darkclan.net/origami/]
- Satoshi Kamiya [http://www.folders.jp/]
- Jason Ku [http://scripts.mit.edu/~jasonku/]

Websites where photos in presentation come from

Origami Art comparison with Music

Representational origami = traditionally represent living things
Akira Yoshizawa (1911–2005) – father of modern origami
One of first to start creating many new models
Origami a process of breathing life into paper
Pioneer of wet-folding
Wet-folding = weakening the paper fibers and letting them dry
Traditional Style

Characterized by straight, well defined polygons
Little shaping need from base
Hideo Komatsu - Japanese
Design process through trial and error process trying to form specific polygonal shapes in final form
Non-unaxial bases
Small but distinguished repertoire
Takashi Hojyo - Japanese
Box-pleating - characterized by only multiple of 45 deg creases
22.5 deg folding - characterized by 22.5 deg creases
Non-uniaxial but space constraint still must be valid
Non-Traditional Style

Characterized by curved shaping (usually wet-folding)
Much shaping from structural base
David Brill
Curved wetfolding, heavy paper
Michael LaFosse

Also makes his own paper
More control over the medium
Eric Joisel

Influenced by Yoshizawa

Former clay sculptor turned paper folder

Use of texture (non-uniaxial)
Curved lines become 3D and structural
Joisel an expert in human form origami
M.C. Esher–like ‘Self Made Man’
Use of texture
Lots of planning (Tree Theory included)
Box-pleating
Again, breathing life into paper
Modern Realism

The spectrum between the styles with increased complexity
Robert Lang

A pioneer of algorithmic origami design
Caltech laser physicist turned origami artist
Author of TreeMaker, Reference Finder

http://www.langorigami.com/
Bug wars
Paper needs to be thin thus often uses custom paper from Michael LaFosse
Geometrics
Tessellations
Klein Bottle
Brian Chan - Cambridge, MA
MIT BS, MS, PhD ’09 in Mechanical Engineering
Pioneer in pushing the limits of complex folding
Single sheet rose with color change
Anime girl with color change
Nekobus
Attack of the Kraken
Origami Design Challenges = Sailing Ship
MIT Seal, ‘Mens et Manus’
Satoshi Kamiya

Widely recognized as a pioneer in super-complex origami

Texture

Unique balance between Traditional and Non-traditional styles
Crisp, clean folding with well planned 3D shaping structure
Use of texture and completeness of composition
Widely regarded as most complex single work in origami
Took Kamiya over the course of a year to fold
We will analyze structure later
Origami Art

More info on origami art, see this movie!
Featured = Erik & Marty Demaine, Robert Lang, and many more!

http://www.greenfusefilms.com/
Now onto making these works of art
If serious about origami design, ODS is the first major book on methods for origami design
Get now!
Review of Tree Theory thought process
1) Start with object
2) Draw tree
3) Change tree into uniaxial base
4) Shape uniaxial base
Uniaxial Bases

1. in $z \geq 0$ half plane
2. intersection with $z=0$ plane = projection onto the plane
3. partition of faces into flaps, each projecting to a line segment
4. hinge crease shared by two flaps project to a point
5. graph of flap projections as edges is a tree
6. only one point of paper folds to each leaf

Previous definition of uniaxial bases (6) not necessary but convenient

Why would it be useful to have the end of a leaf node map to more than one point on paper? Ans: flap thickness at end

What does this really mean?
Uniaxial Bases

1. flaps lie along or straddle a single line (the axis)
2. flaps hinge perpendicular to the axis
3. can thin to stick figure (tree)

Informal definition are bases that can be trivially modified to become unaxial
Flaps

Modeling a flap
Idea of ‘elevation’ on a flap/tree edge
Rivers separate two parts of a tree with strip of constant width
Circle limiting case of river separating single point from rest
Splitting a leaf edge into a leaf and brach creates a redundant node
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Splitting a leaf edge into a leaf and brach creates a redundant node
Circle/River Packing (CRP) as a space allocation
Uniquely defines a tree
Tree edges can be oriented anyway we like because if uniaxial base is infinitely thinned, base is actually stick figure
Space between circles is wasted paper and maps to a single tree node
Circle/River Packing (CRP) as a space allocation
Uniquely defines a tree
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Which trees represent the given CRP?
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Which trees represent the given CRP?
Which CRP correspond to the given tree?
CRP 1, 2, and 5 have similar trees, but different space allocation
(CRP => Tree) = unique
(Tree => CRP) = non-unique
Which CRP correspond to the given tree?

CRP 1, 2, and 5 have similar trees, but different space allocation

(CRP => Tree) = unique
(Tree => CRP) = non-unique
In reality, CRP is an idealization
By definition, locus of all possible hinge creases represents something topologically similar to a CRP
Can read off tree as before
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By definition, locus of all possible hinge creases represents something topologically similar to a CRP
Can read off tree as before
Analyze structure
Square paper?
Actually fairly simple yet ingenious concept behind space allocation
Box-pleating
Textures
Using thickness at end of flap to make fingers/toes
Actually fairly simple yet ingenious concept behind space allocation
Box-pleating
Textures
Using thickness at end of flap to make fingers/toes
Modeling a crab
First draw tree (blackboard)
Symmetry (book/diagonal)
Identifying/fixing unconstrained nodes with local strain
Triangulation of creasepattern (need three degrees of freedom)
View Settings
Useful Features in TreeMaker

Conditions

- axis of symmetry conditions
- force paths to be active or at specific angles
- force nodes to edge/corner/specific locations

Tree manipulation

- adding local strain (Menu/Action/Scale Selection/)
- triangulation (Menu/Edit/Stub/Triangulate Tree/)

Views

- Menu/View/Show View Settings/ very useful
- Can view just locus of hinge creases by turning off all but (Creases/Minor Creases) and (Creases/Lines)

Symmetry (book/diagonal)
Identifying/fixing unconstrained nodes with local strain
Triangulation of creasepattern (need three degrees of freedom)
View Settings
Possible Problems in Optimization

Problem: A polygon bounded by active paths is concave
Solution: add extra leaf node in interior & expand
(split polygon into multiple convex polygons)

Problem: A polygon bounded by active paths contains an unconstrained node
Solution: add local strain to interior node to create additional active paths

Problem: Optimizer can not find a solution due to trying to optimize under too many constraints
Solution: decrease the number of additional constraints
Example Files

http://jasonku.scripts.mit.edu/misc/treemaker_examples.zip

- crab_book.tmd5 = crab with book symmetry
- crab_diag.tmd5 = crab with diagonal symmetry
- crab_book_tri.tmd5 = triangulated version of book
- crab_diag_tri.tmd5 = triangulated version of diagonal
Non-TreeMaker Example

22.5 degree folding
Constrained under back geometry
Taking thickness into account
Non-uniaxial in ultimate folded form
Texture
Non-TreeMaker Example

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Constrained under back geometry
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Non-TreeMaker Example

Proof of concept
Origami Forum

http://www.thekhans.me.uk/forum/

For more information on all things origami...
MIT's Origami Club

Weekly Meetings
Sundays 2-4pm
Student Center

http://origamit.scripts.mit.edu

Shameless promotion