# MIT 6.849

## Geometric Folding Algorithms

Prof. Erik Demaine

Lecture 6:
Origami Art and Design

Guest Lecturer:
Jason Ku
origami-info@mit.edu

September 27, 2010



Jason Ku
President of OrigaMIT
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
- Robert Lang http://www.langorigami.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



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

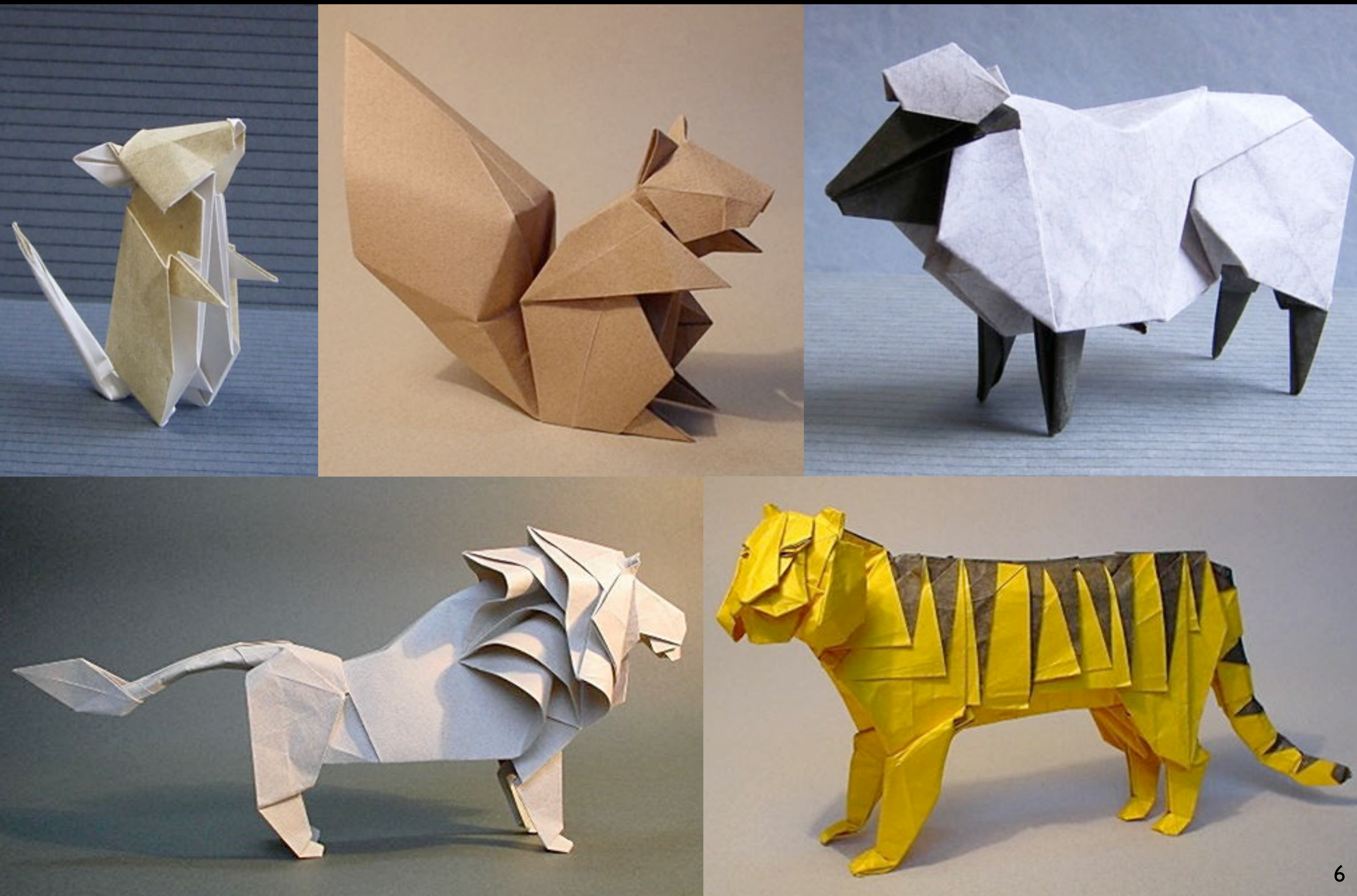
# Traditional Style



Characterized by straight, well defined polygons
Little shaping need from base

# Hideo Komatsu

http://www.origami.gr.jp/~komatsu/





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

http://www.origami.gr.jp/~hojyo/



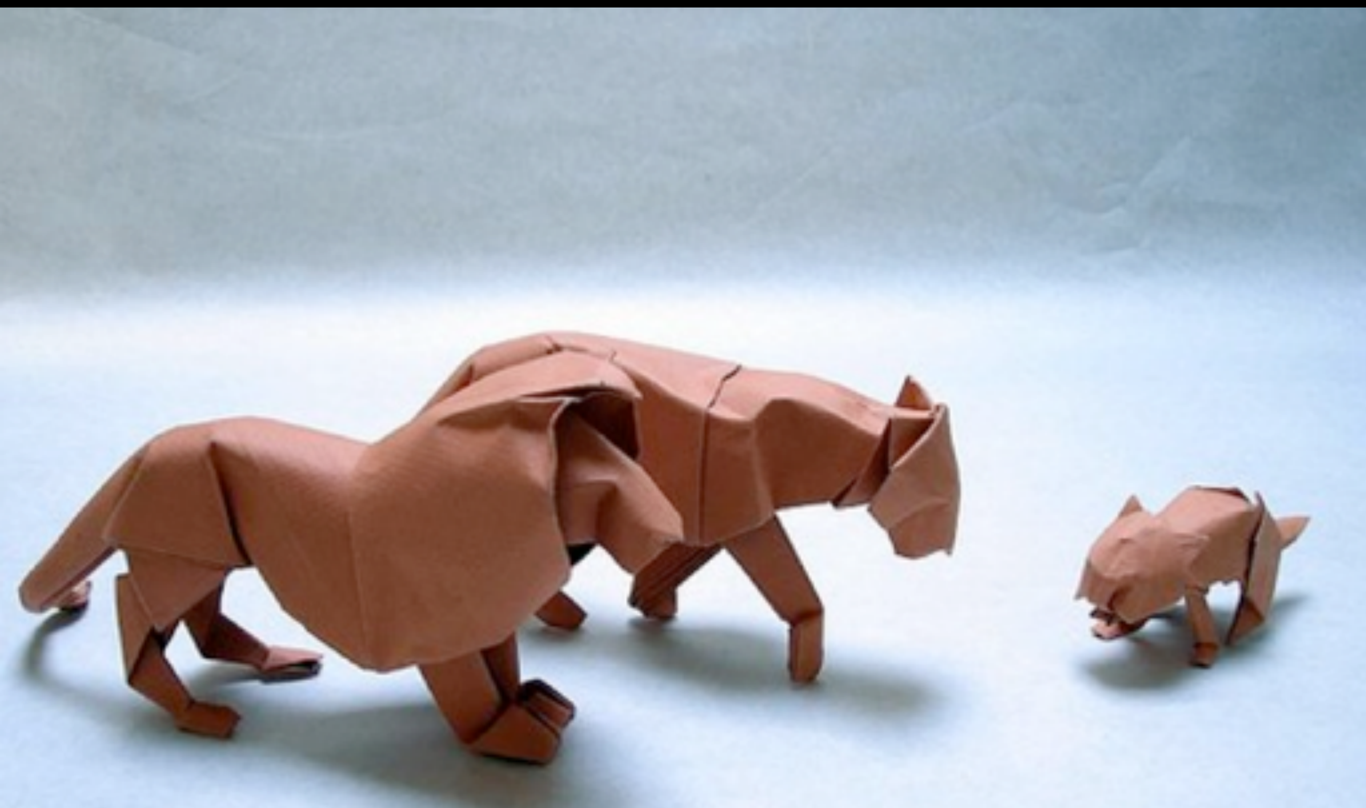
Takashi Hojyo - Japanese
Box-pleating - characterized by only multiple of 45 deg creases
22.5 deg folding - characterized by 22.5 deg creases
Non-uniaxial but space constraint still must be valid

# Non-Traditional Style



Characterized by curved shaping (usually wet-folding)
Much shaping from structural base

# David Brill http://www.brilliantorigami.com/





David Brill – British
Curved wetfolding, heavy paper

# Michael LaFosse

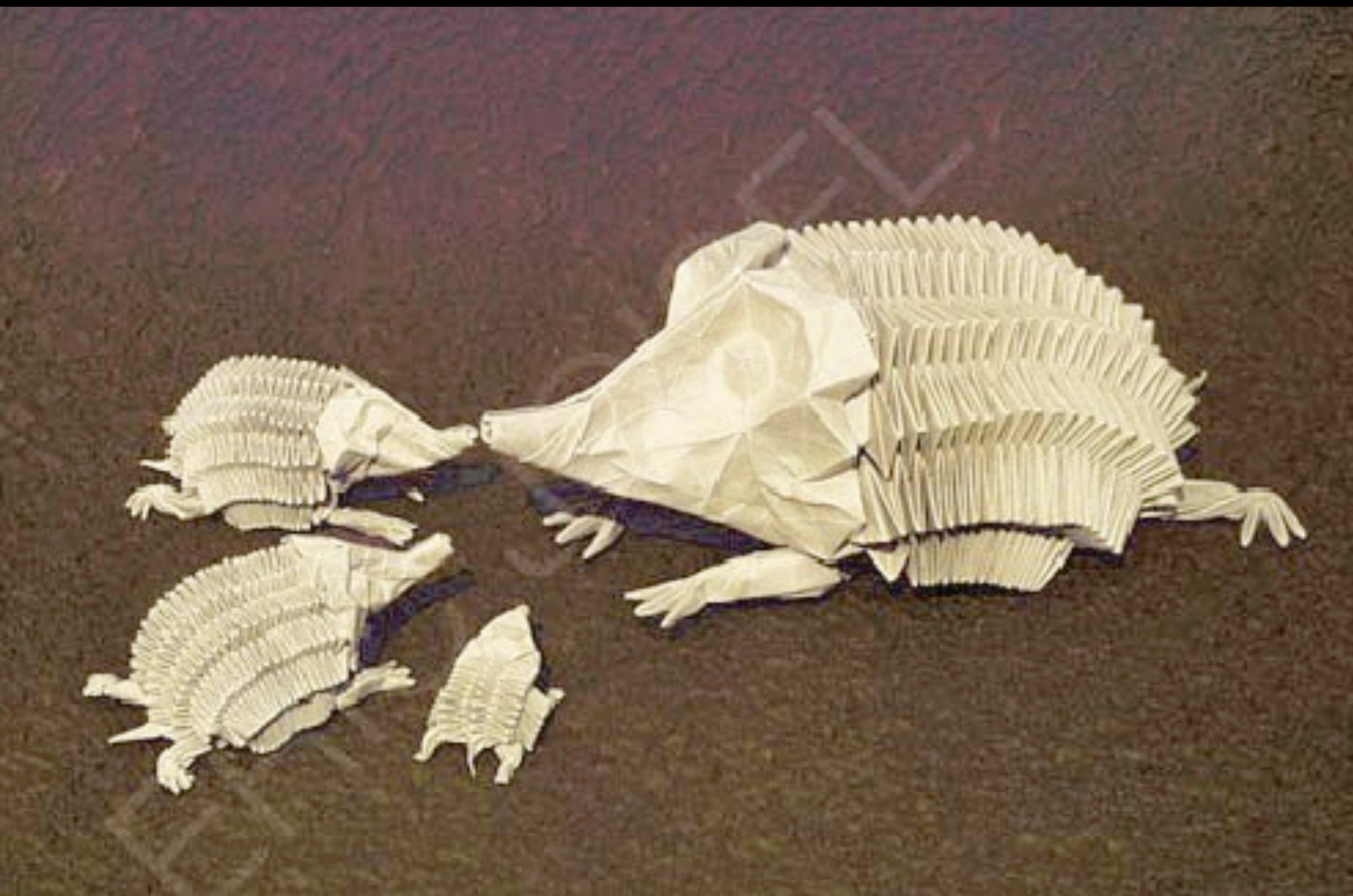
http://www.origamido.com/




Michael LaFosse – Haverhill, MA
Also makes his own paper
More control over the medium

# Eric Joisel

http://www.ericjoisel.com/





Eric Joisel
Influenced by Yoshizawa
Former clay sculptor turned paper folder
Use of texture (non-uniaxial)

# Eric Joisel

http://www.ericjoisel.com/



Curved lines become 3D and structural
Joisel an expert in human form origami

# Eric Joisel

http://www.ericjoisel.com/



M.C. Esher-like ‘Self Made Man”

## Eric Joisel

http://www.ericjoisel.com/



Use of texture
Lots of planning (Tree Theory included)
Box-pleating

# Eric Joisel

http://www.ericjoisel.com/



Again, breathing life into paper

# Modern Realism



The spectrum between the styles with increased complexity

# Robert Lang

http://www.langorigami.com/

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

# Robert Lang

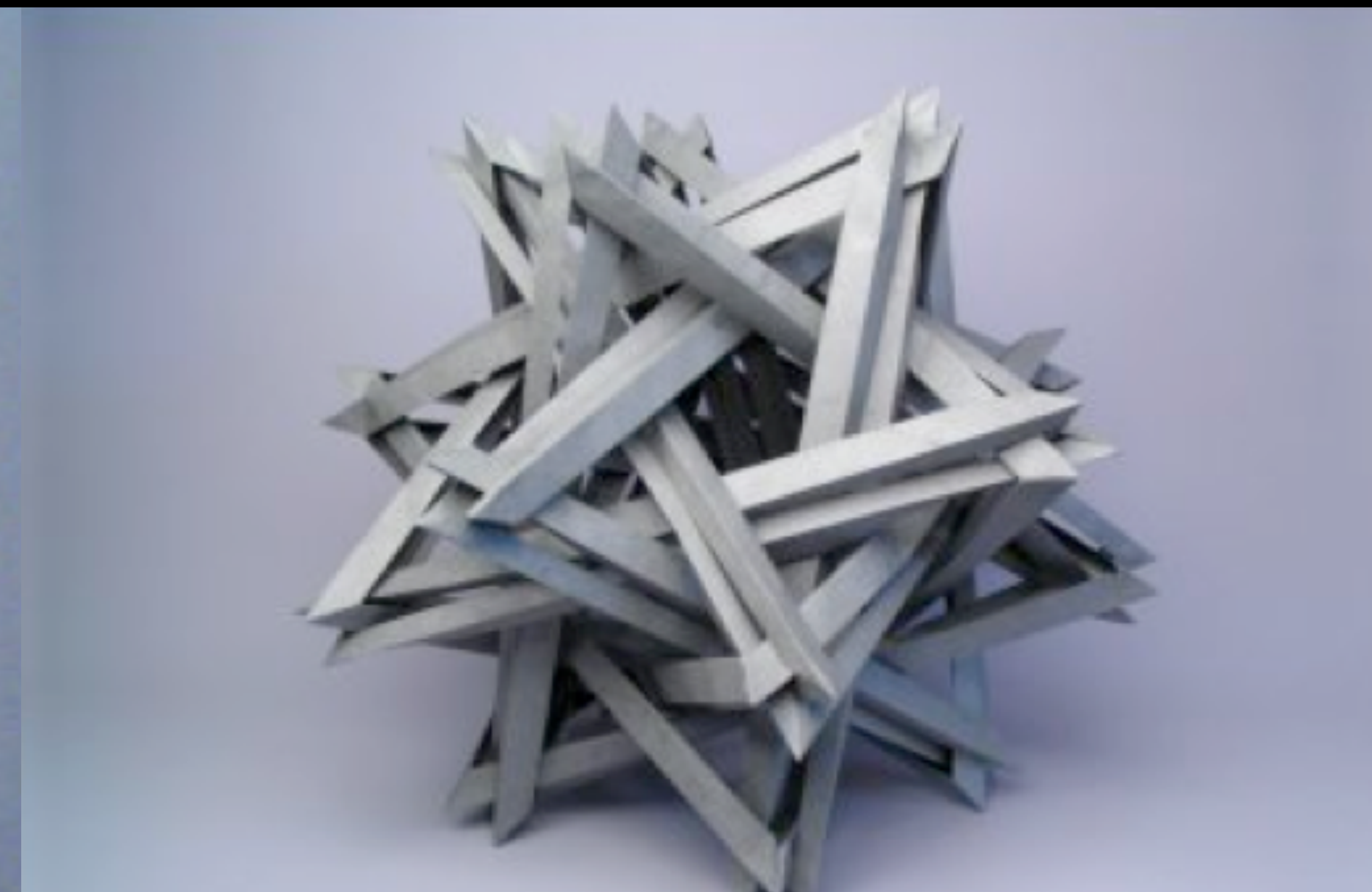
http://www.langorigami.com/



Bug wars
Paper needs to be thin thus often uses custom paper from Michael LaFosse

## Robert Lang

http://www.langorigami.com/





Geometrics
Tessellations
Klein Bottle

# Brian Chan

http://chosetec.darkclan.net/origami/



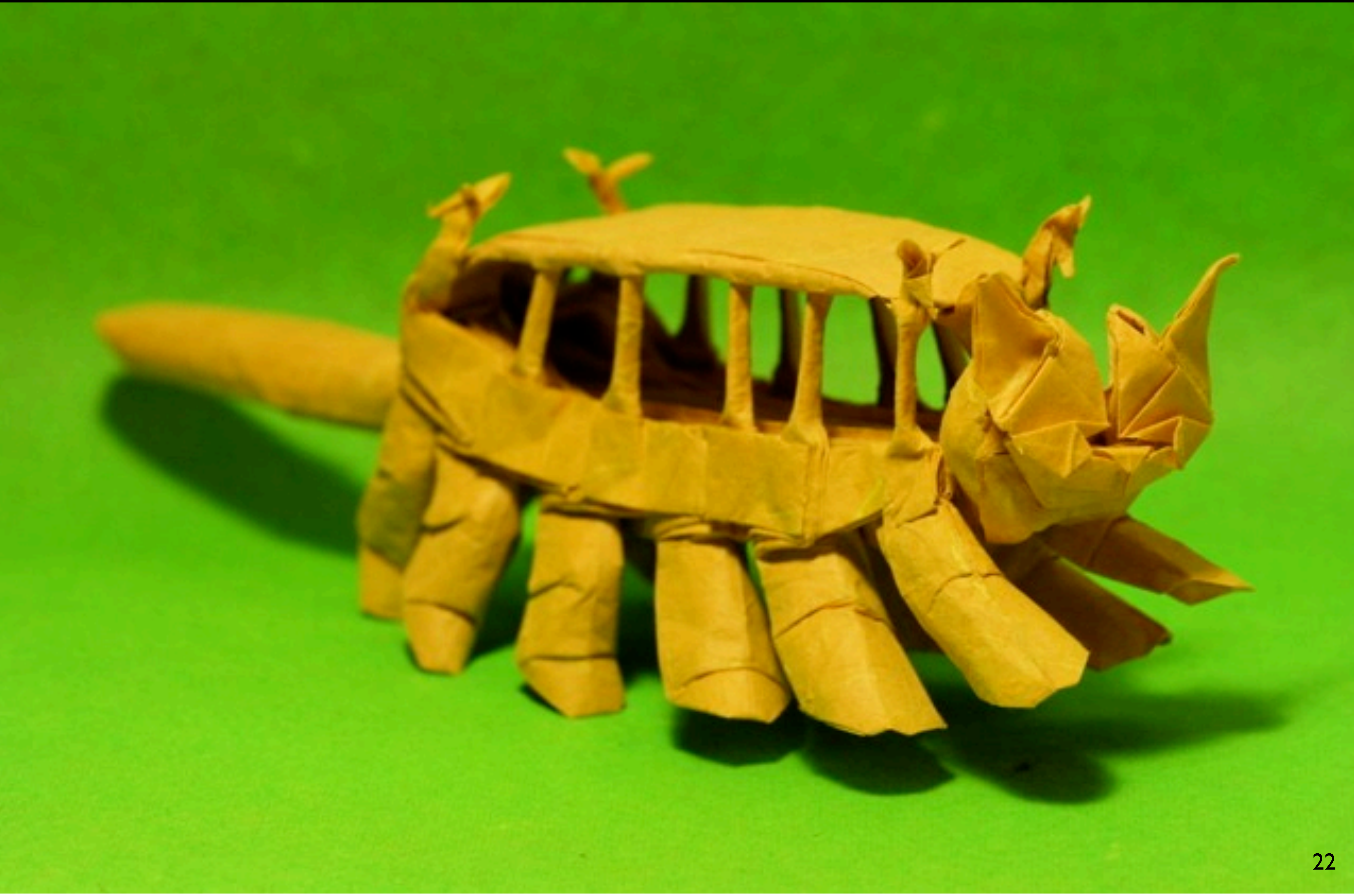
Brian Chan – Cambridge, MA
MIT BS, MS, PhD ’09 in Mechanical Engineering
Pioneer in pushing the limits of complex folding

# Brian Chan

http://chosetec.darkclan.net/origami/


Single sheet rose with color change
Anime girl with color change

**Brian Chan** http://chosetec.darkclan.net/origami/





Nekobus

# Brian Chan

http://chosetec.darkclan.net/origami/



Attack of the Kraken
Origami Design Challenges = Sailing Ship

# Brian Chan

http://chosetec.darkclan.net/origami/



MIT Seal, 'Mens et Manus'

# Satoshi Kamiya

http://www.folders.jp/



Satoshi Kamiya - Japanese
Widely recognized as a pioneer in super-complex origami
Texture
Unique balence between Traditional and Non-traditional styles

# Satoshi Kamiya

http://www.folders.jp/

Crisp, clean folding with well planned 3D shaping structure

# Satoshi Kamiya

http://www.folders.jp/



Use of texture and completeness of composition

# Satoshi Kamiya

http://www.folders.jp/



Widely regarded as most complex single work in origami
Took Kamiya over the course of a year to fold
We will analyze structure later

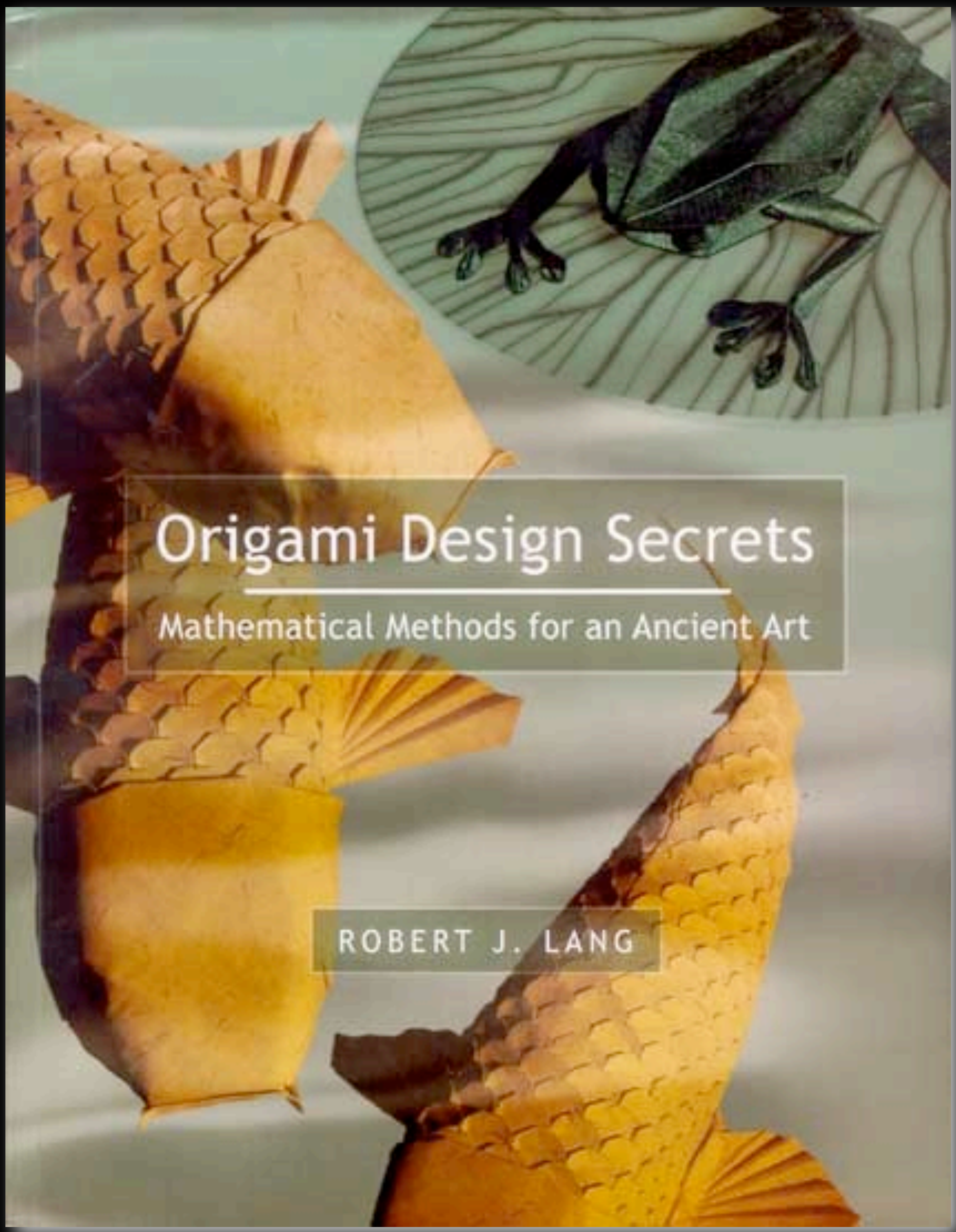
# Origami Art


http://www.greenfusefilms.com/



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

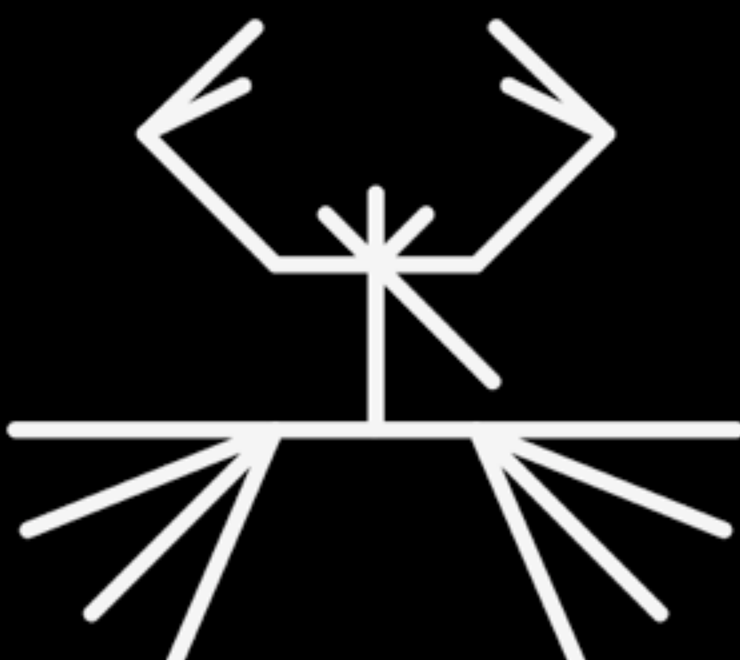
# Origami Design

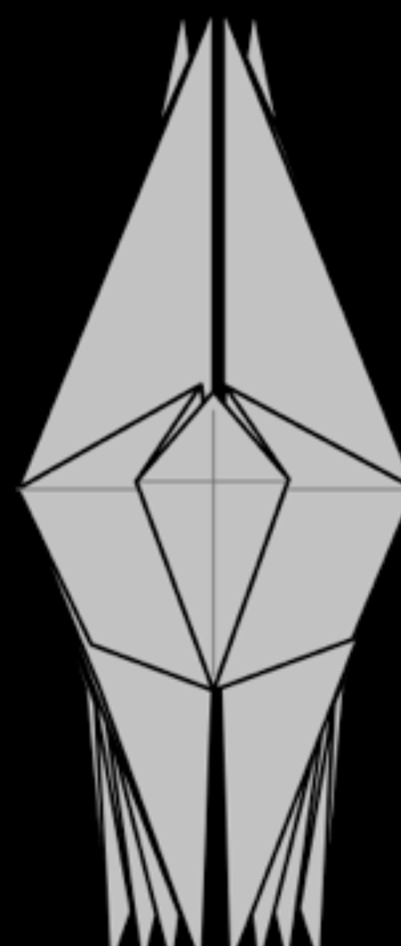


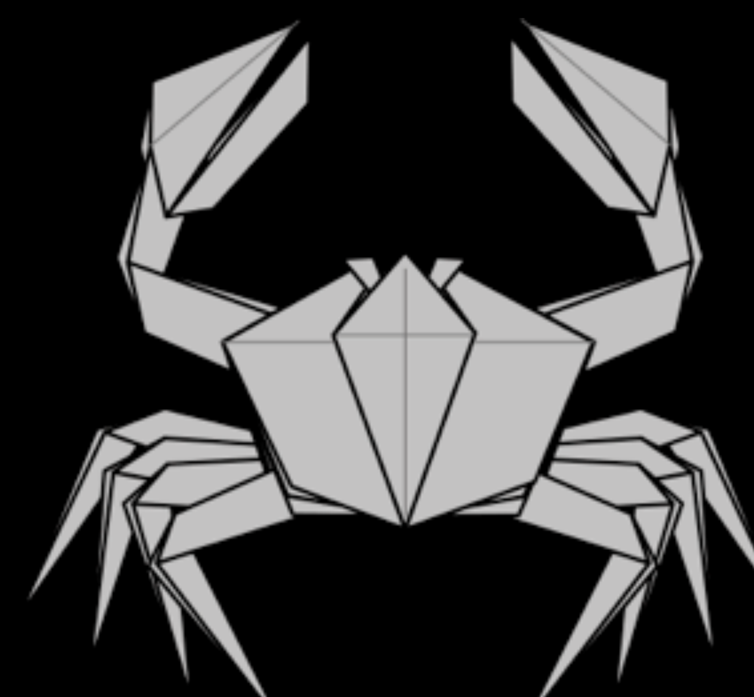



Now onto making these works of art
If serious about origami design, ODS is the first major book on methods for origami design
Get now!

# Tree Theory Review

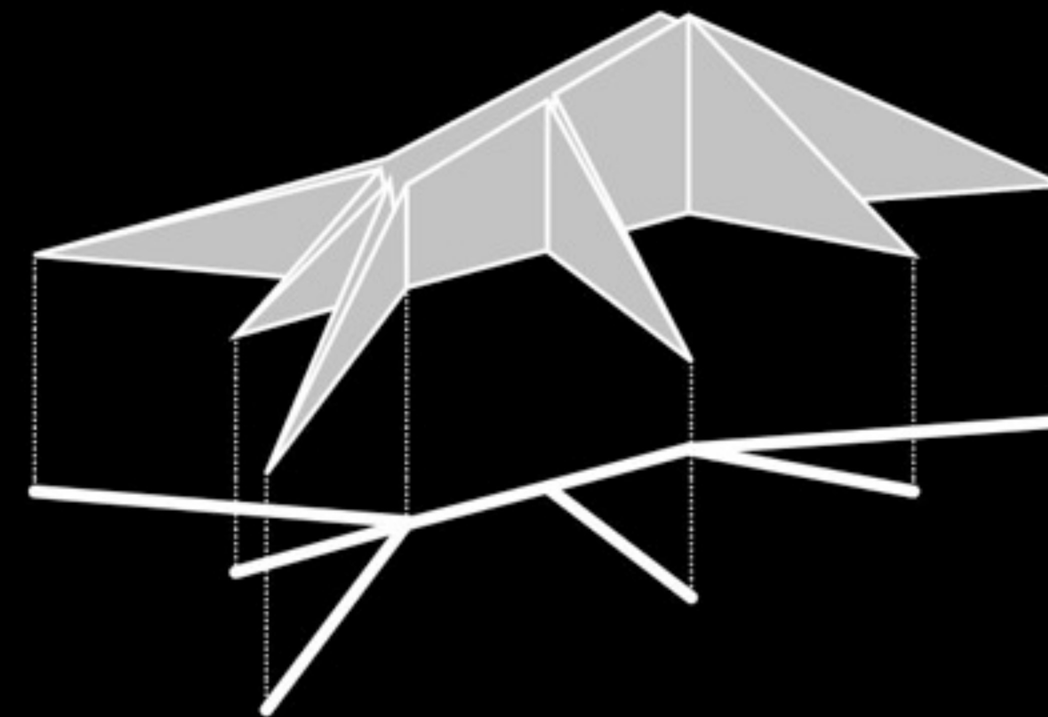






Review of Tree Theory thought process
1) Start with object
2) Draw tree
3) Change tree into uniaxial base
4) Shape uniaxial base

# Uniaxial Bases

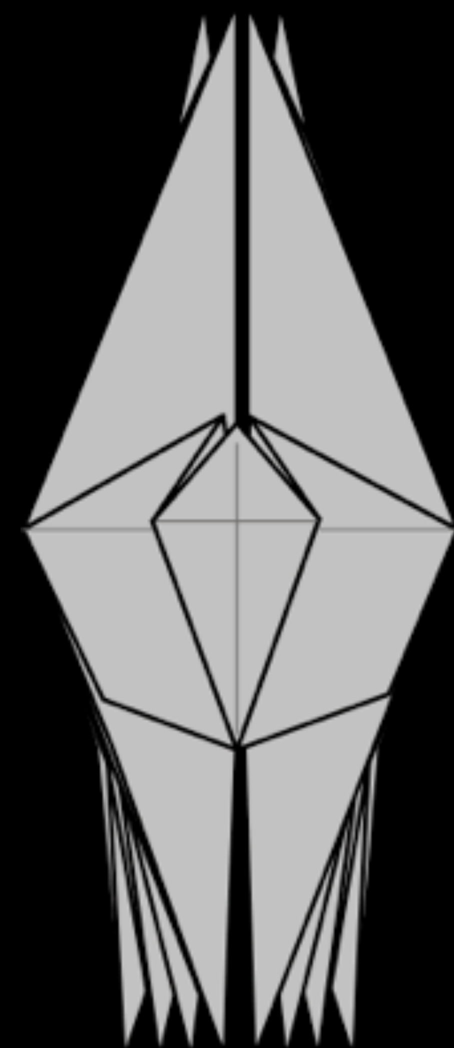


1. in $z \geq 0$ half plane
2. intersection with $z=0$ plane = projection onto the plane
3. partition of faces into flaps, each projecting to a line segment
4. hinge crease shared by two flaps project to a point
5. graph of flap projections as edges is a tree
6. only one point of paper folds to each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

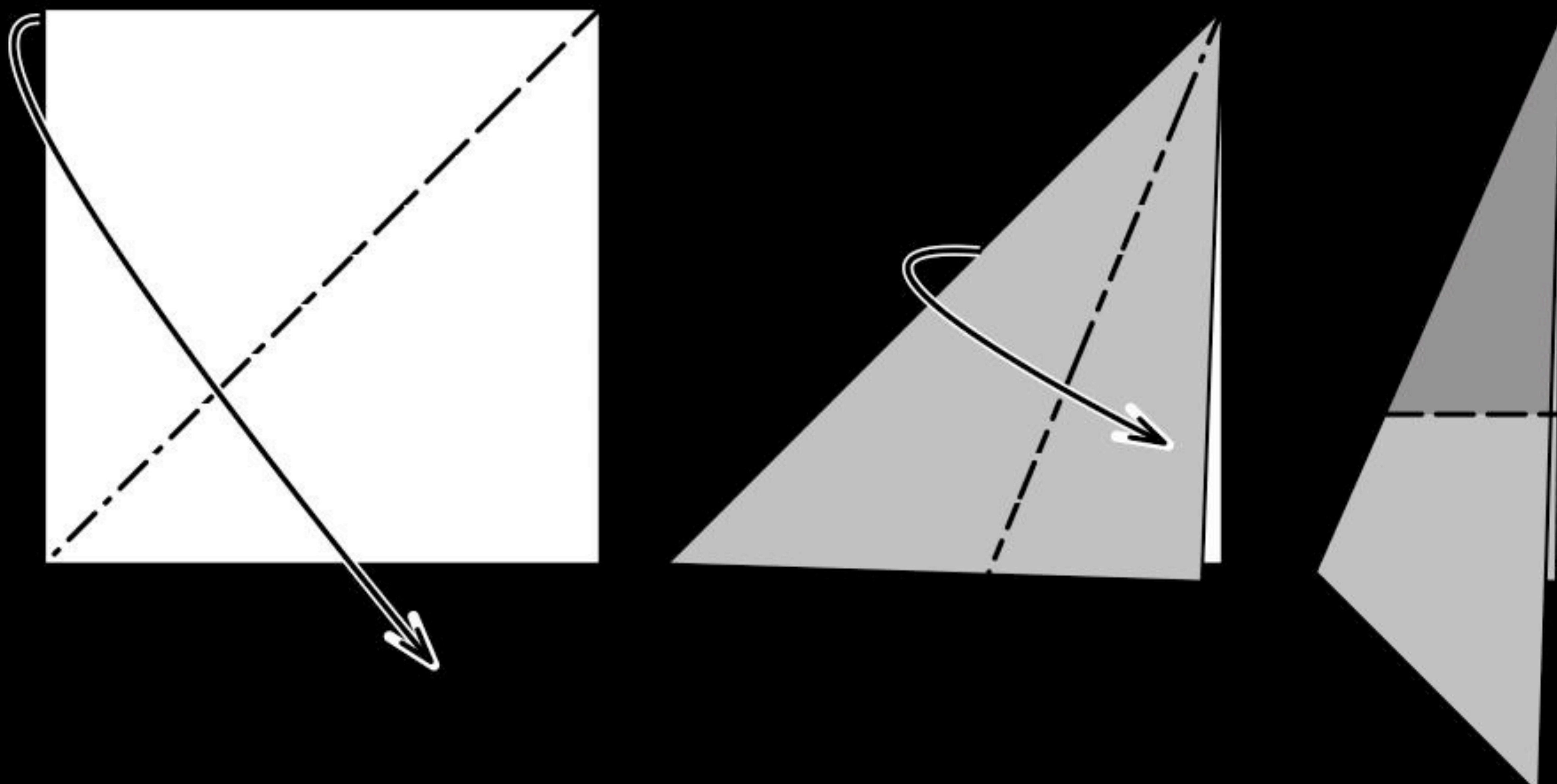


1. flaps lie along or straddle a single line (the axis)
2. flaps hinge perpendicular to the axis
3. can thin to stick figure (tree)



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

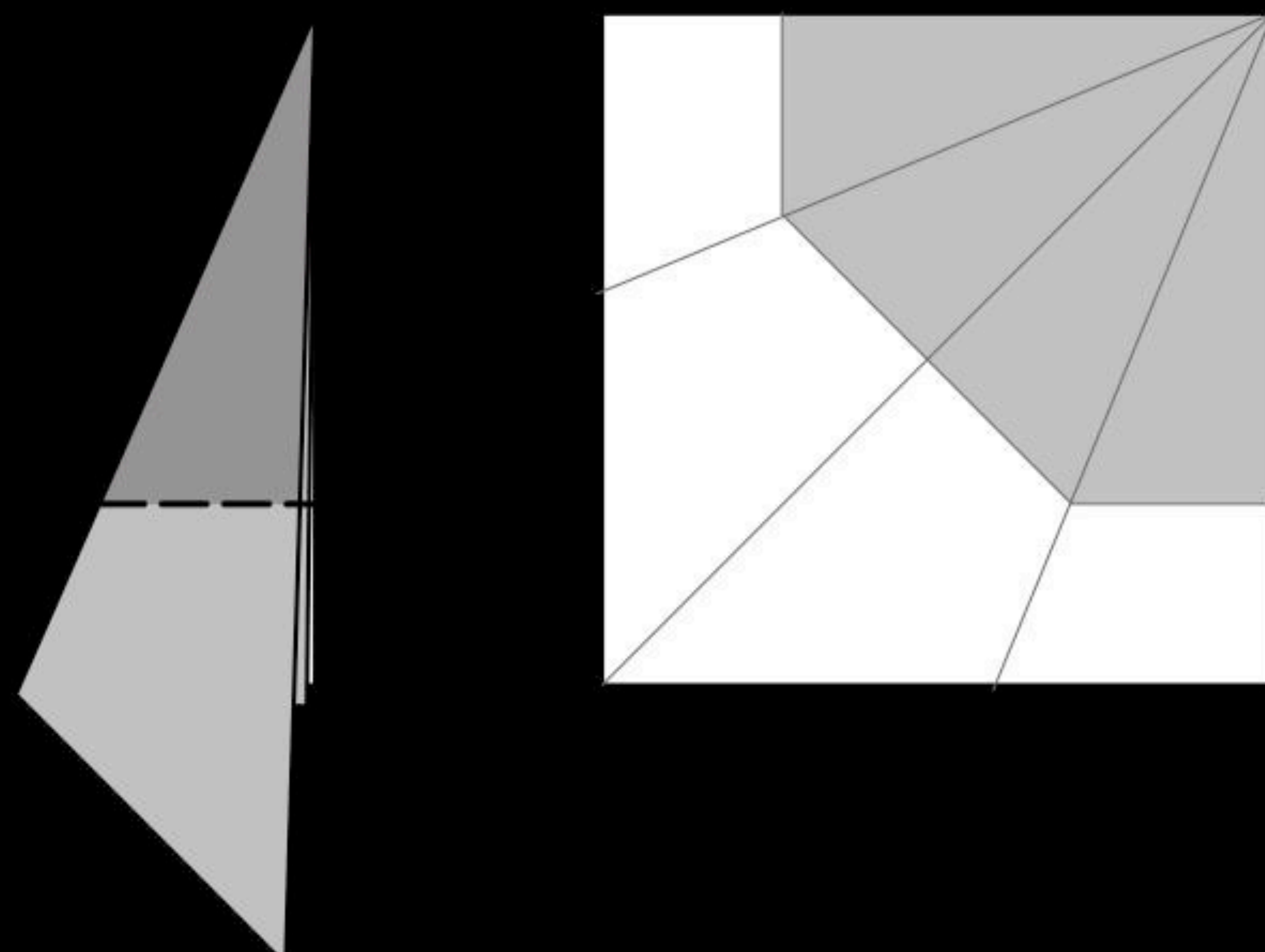
# Flaps





Modeling a flap

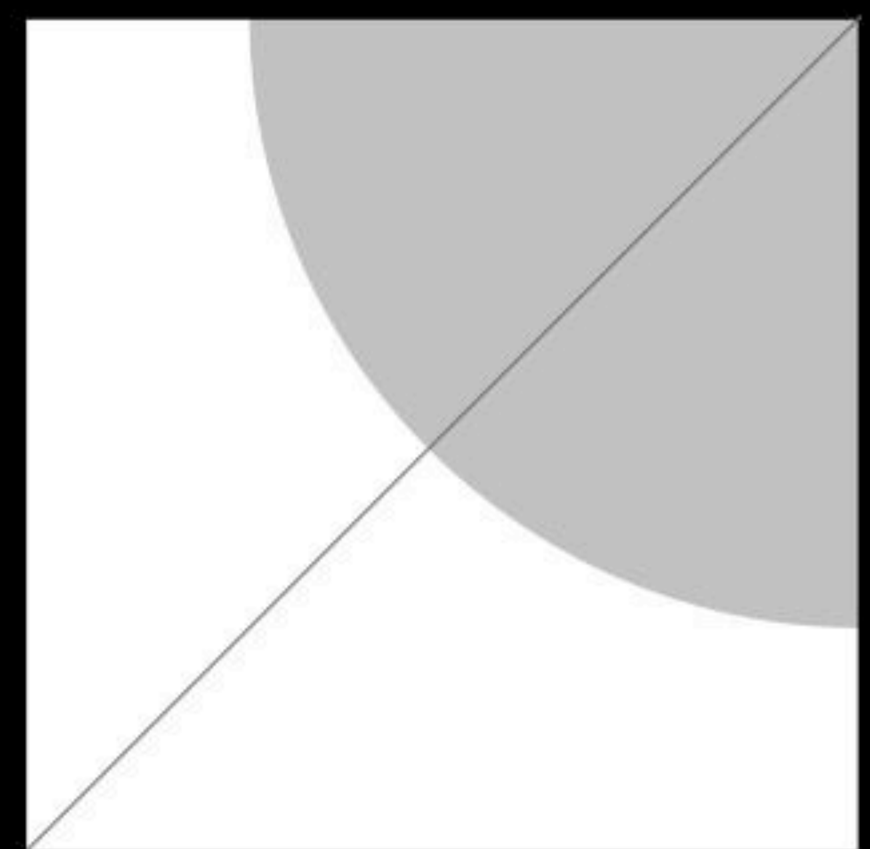
# Flaps





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

# Flaps





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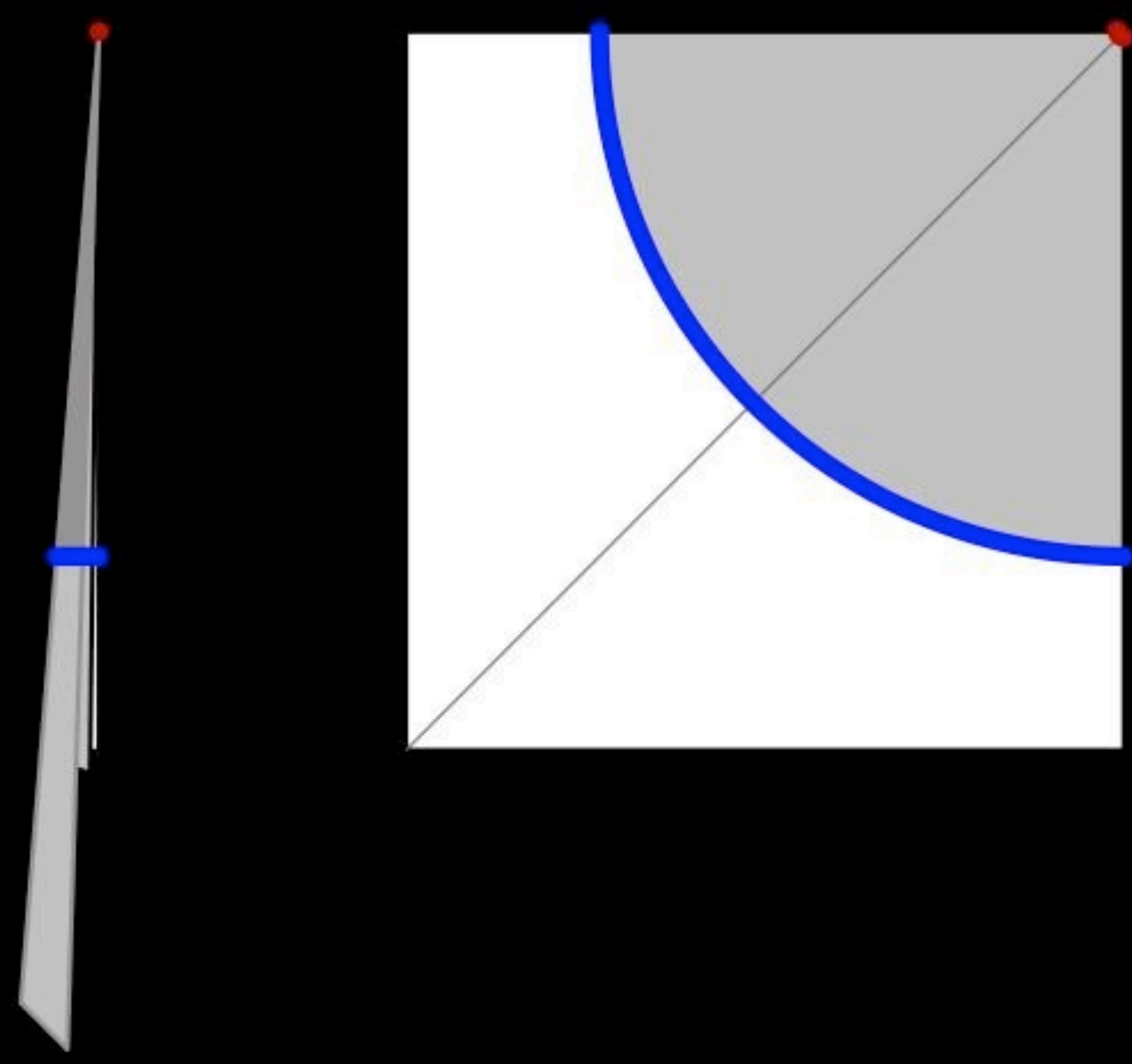



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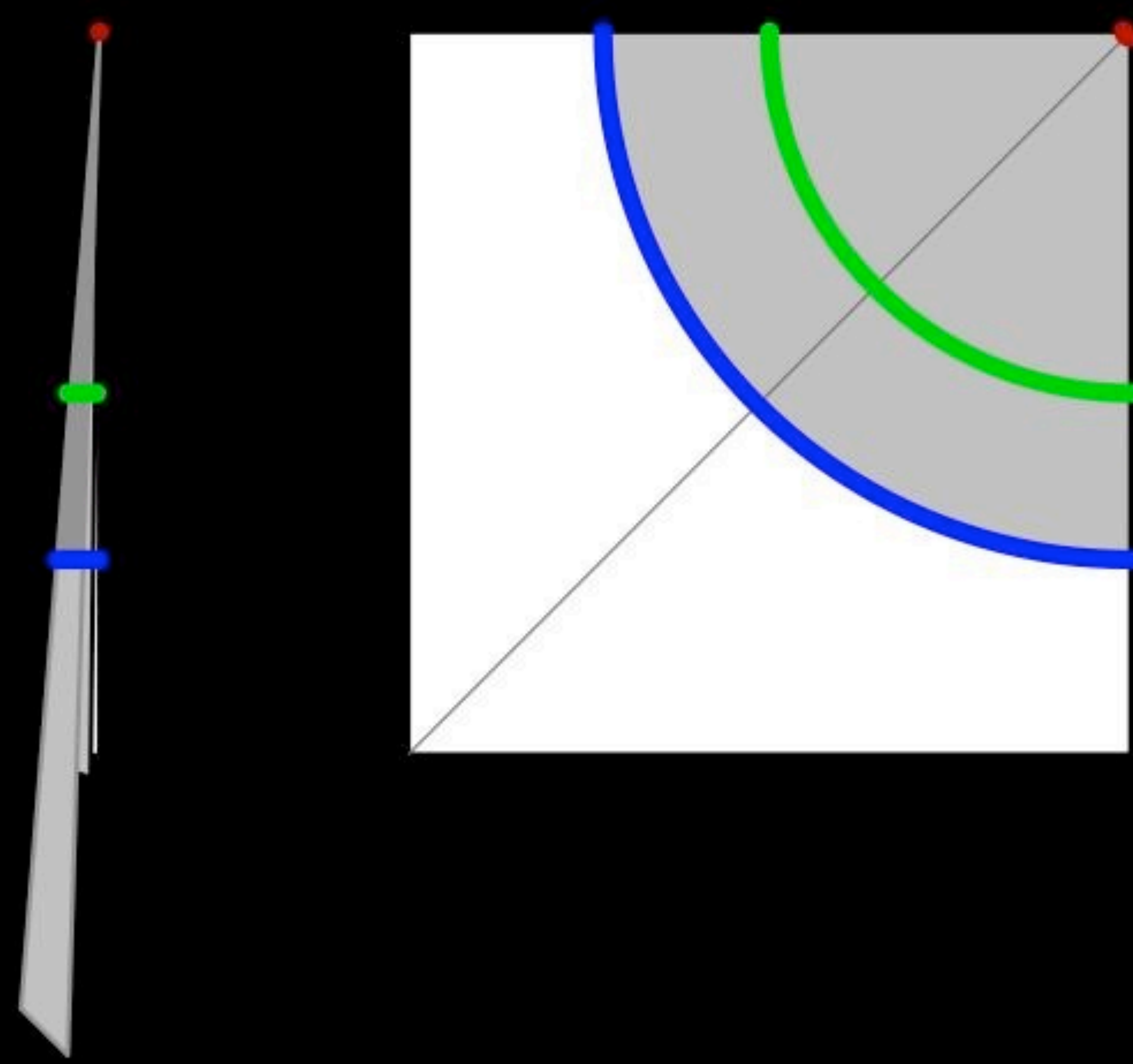

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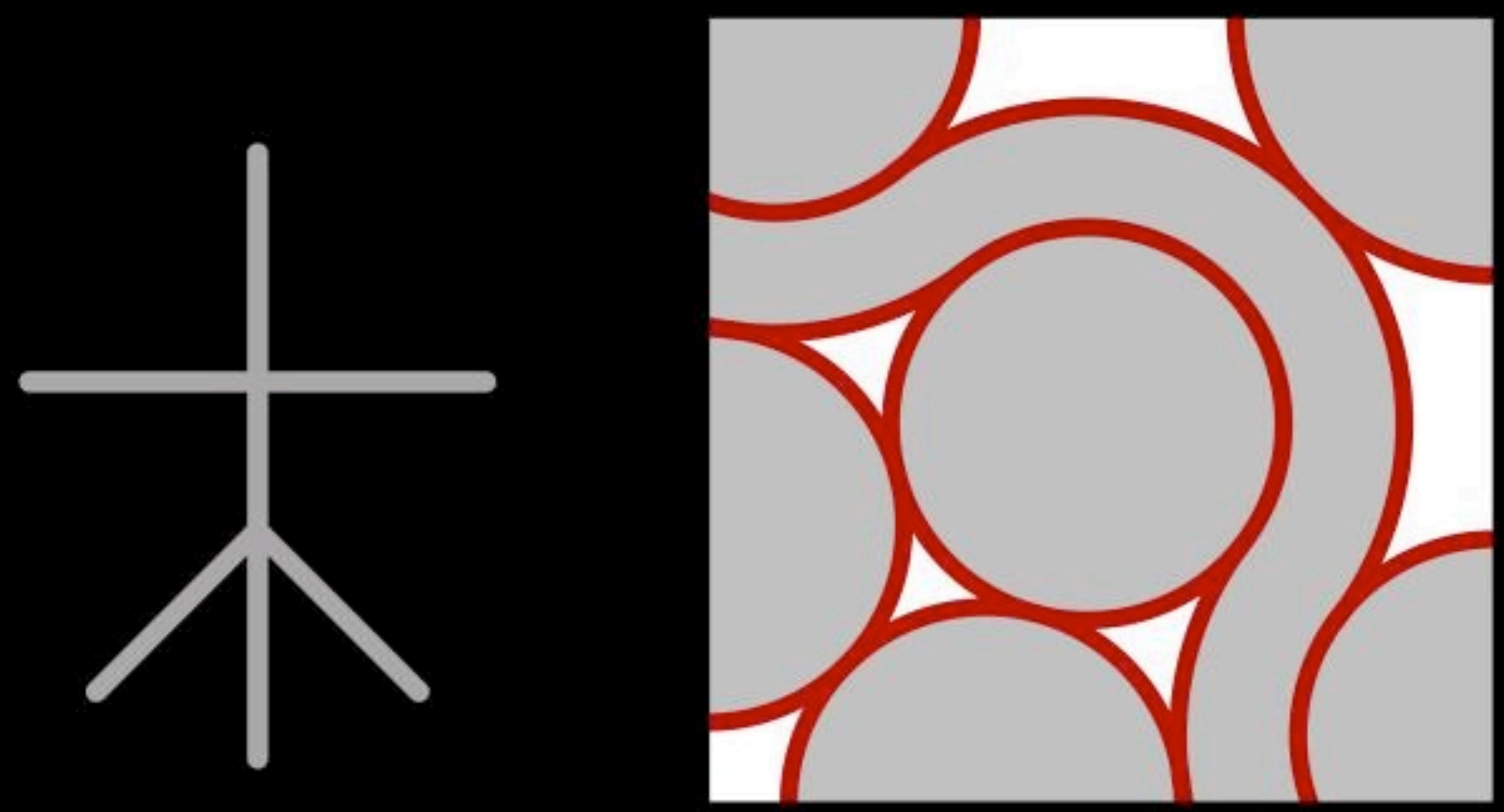

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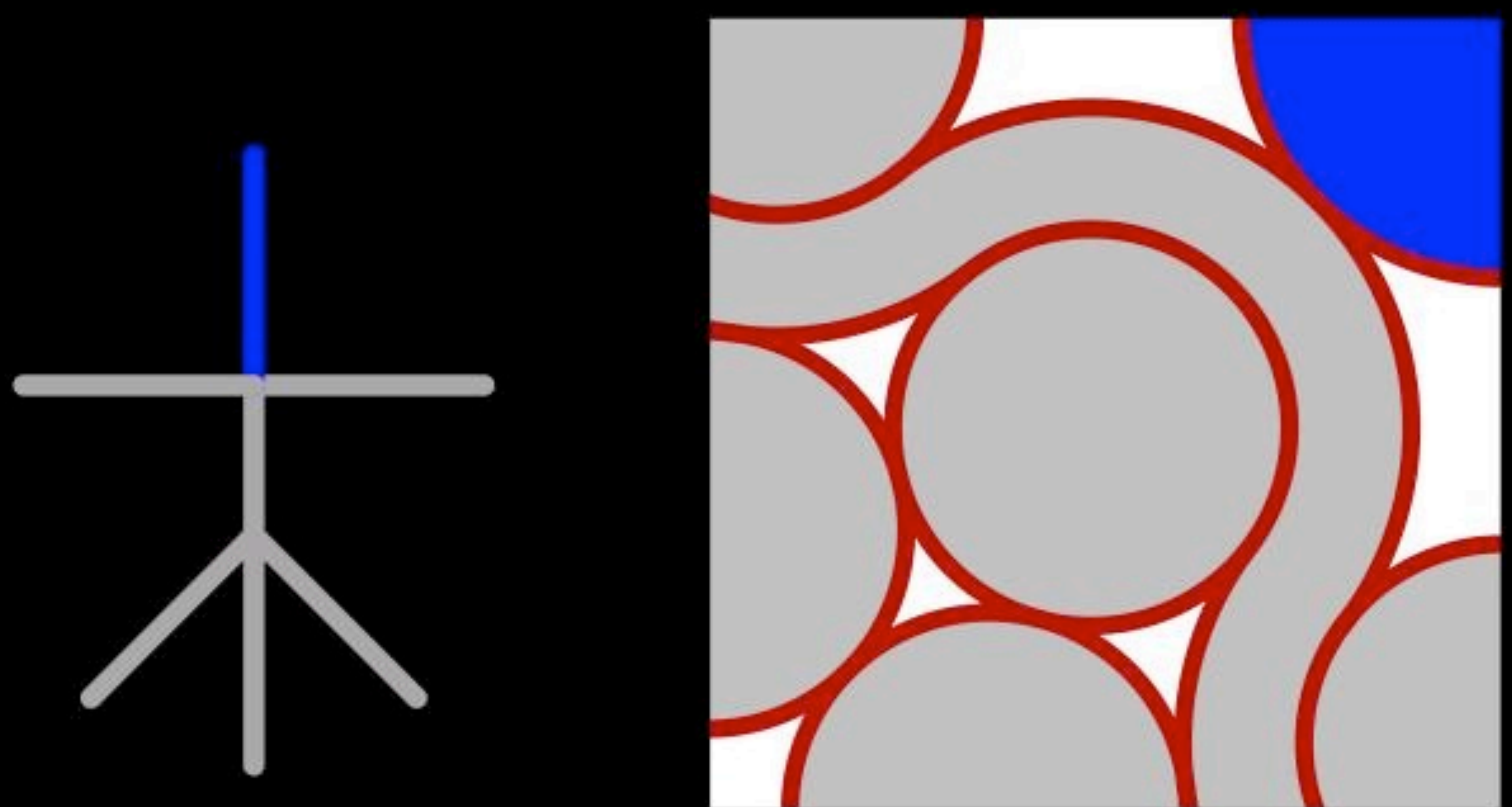
Circle/River Packing (CRP) as a space allocation
Uniquely defines a tree
Tree edges can be oriented anyway we like because if uniaxial base is infinitely thinned, base is actually stick figure
Space between circles is wasted paper and maps to a single tree node

# Flaps





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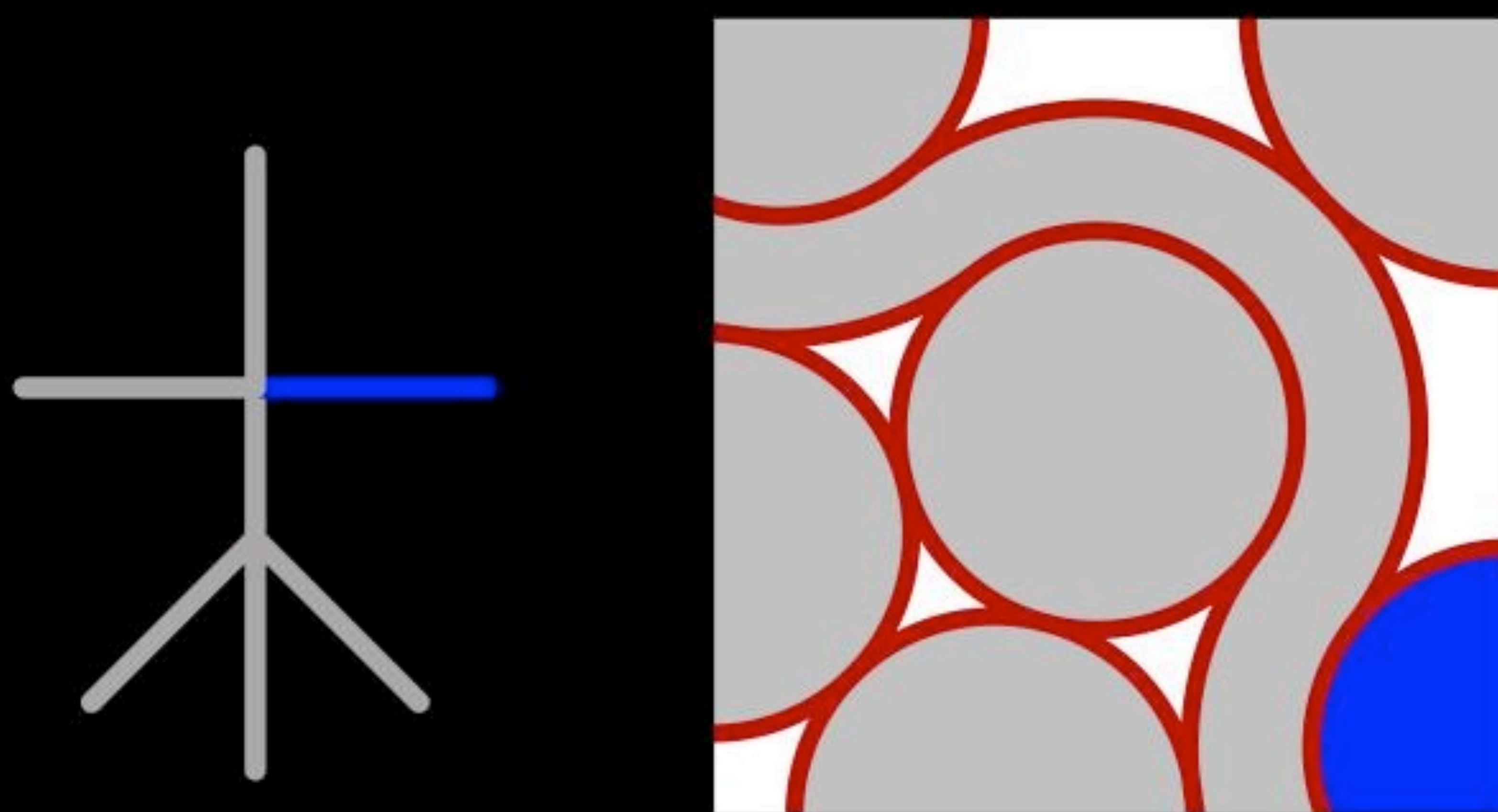



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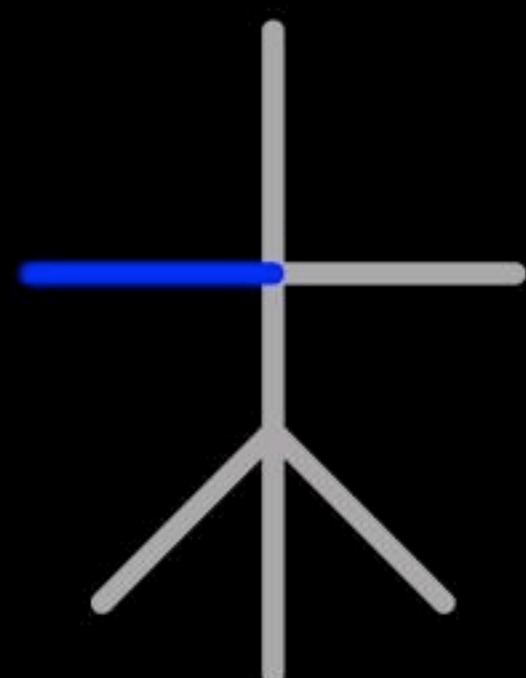

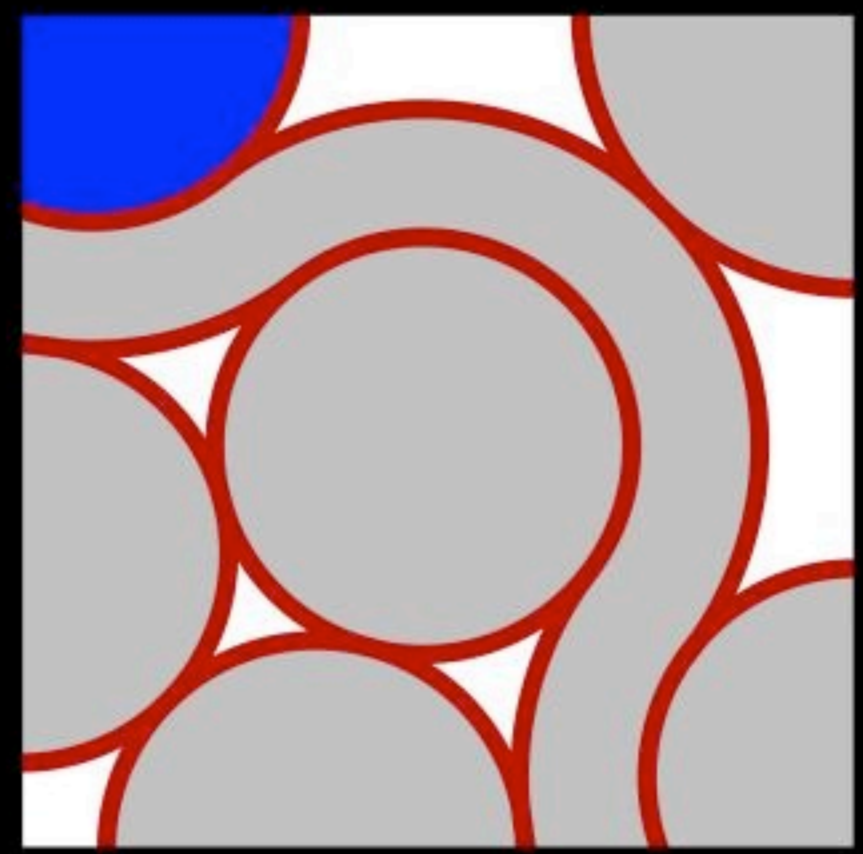



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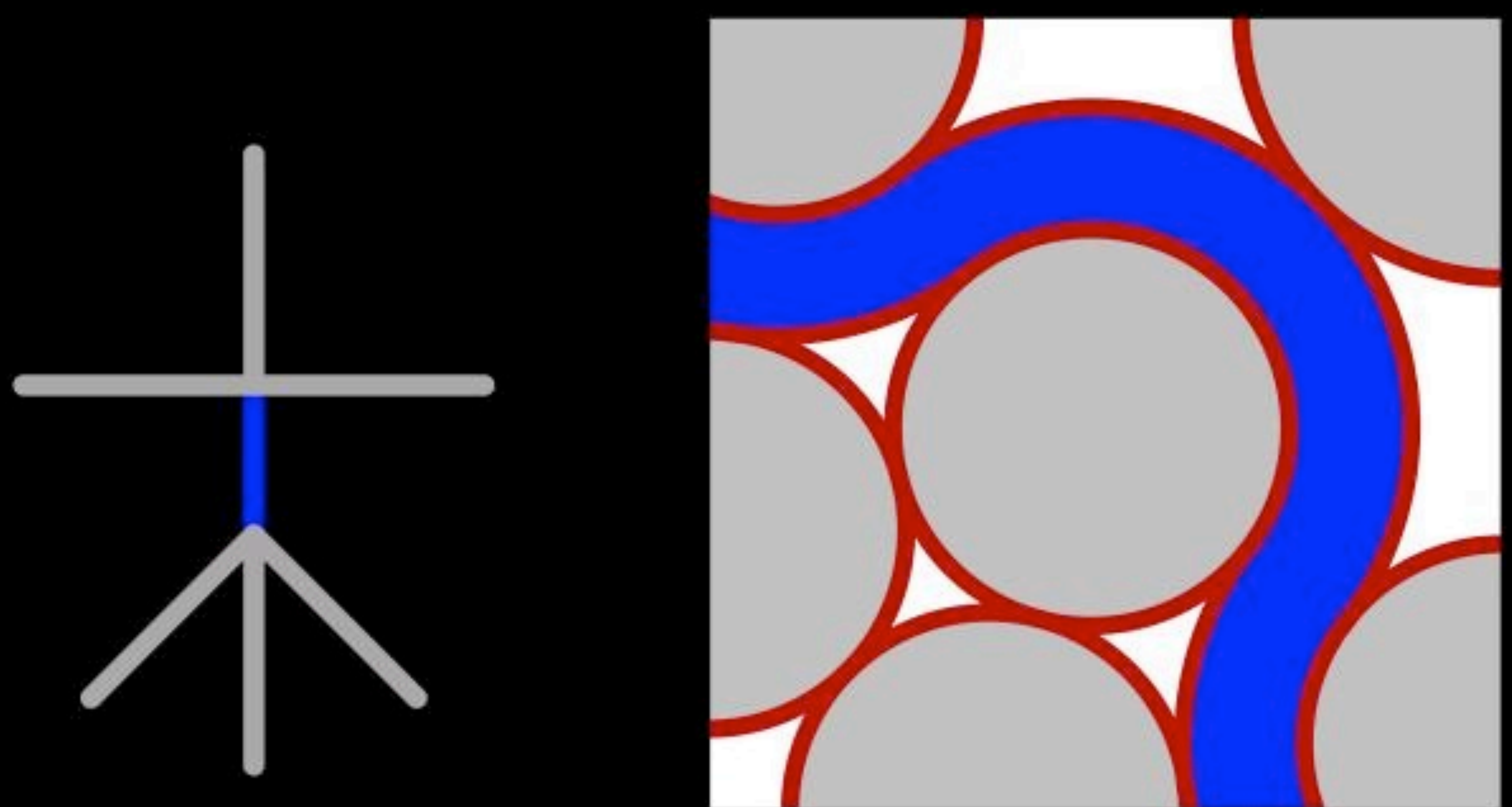



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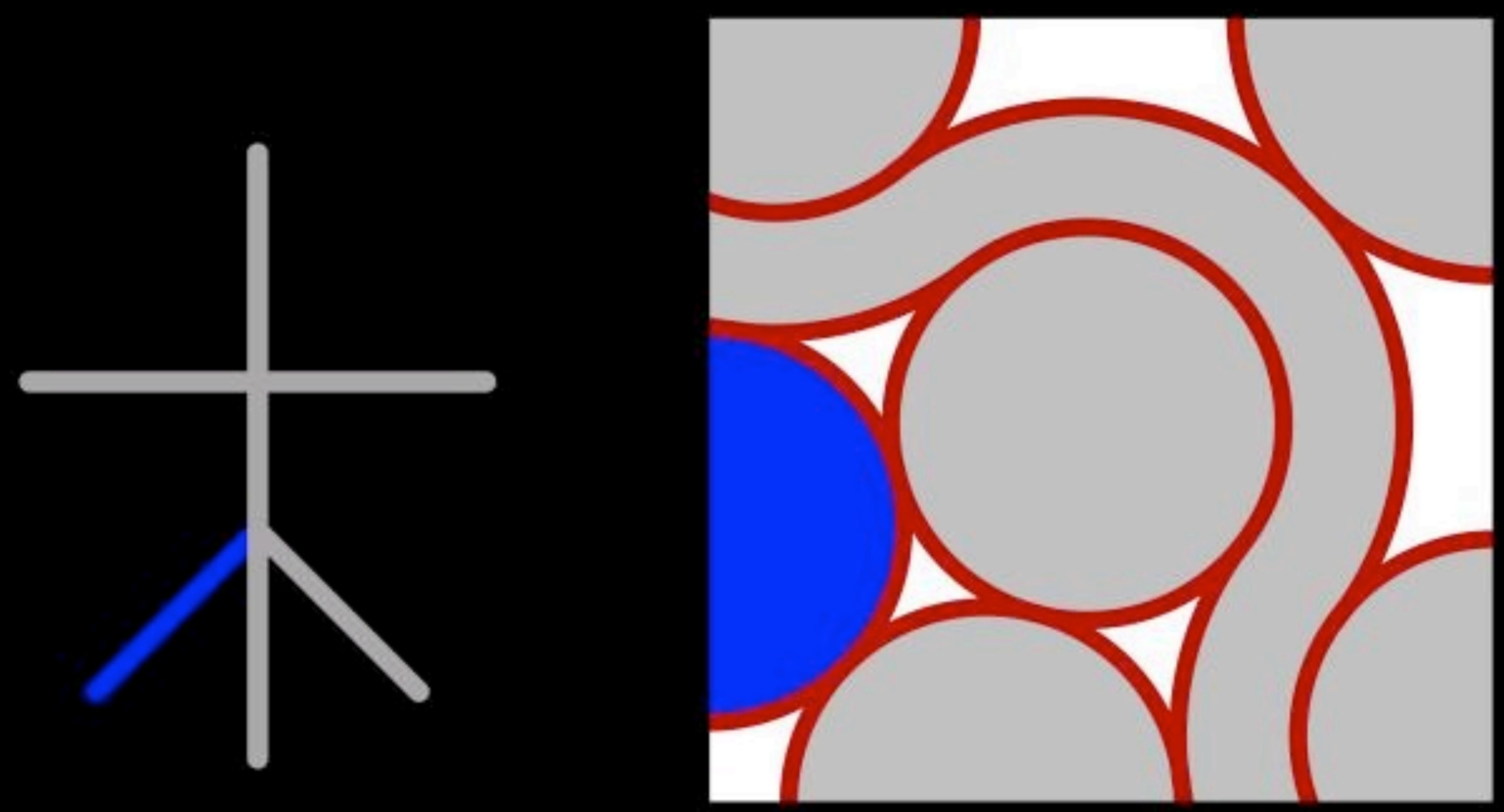



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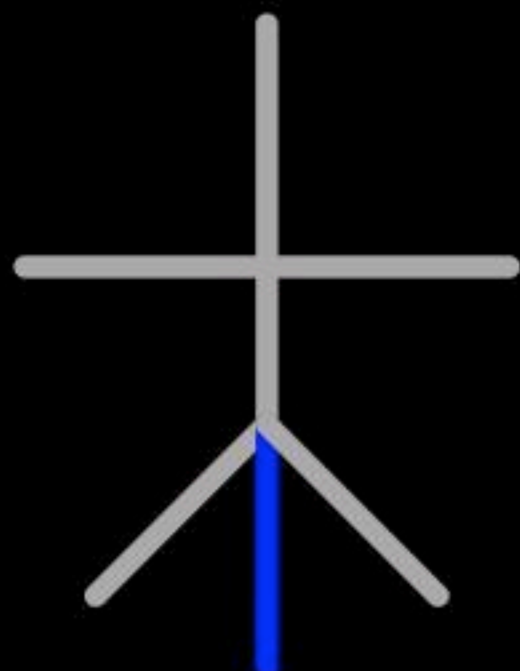

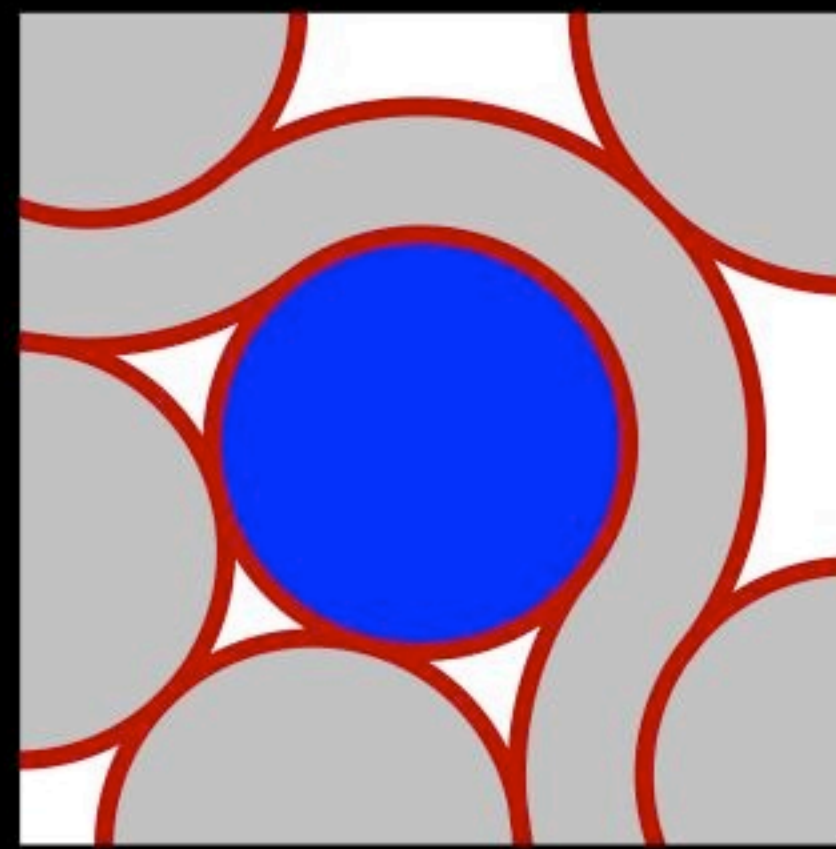

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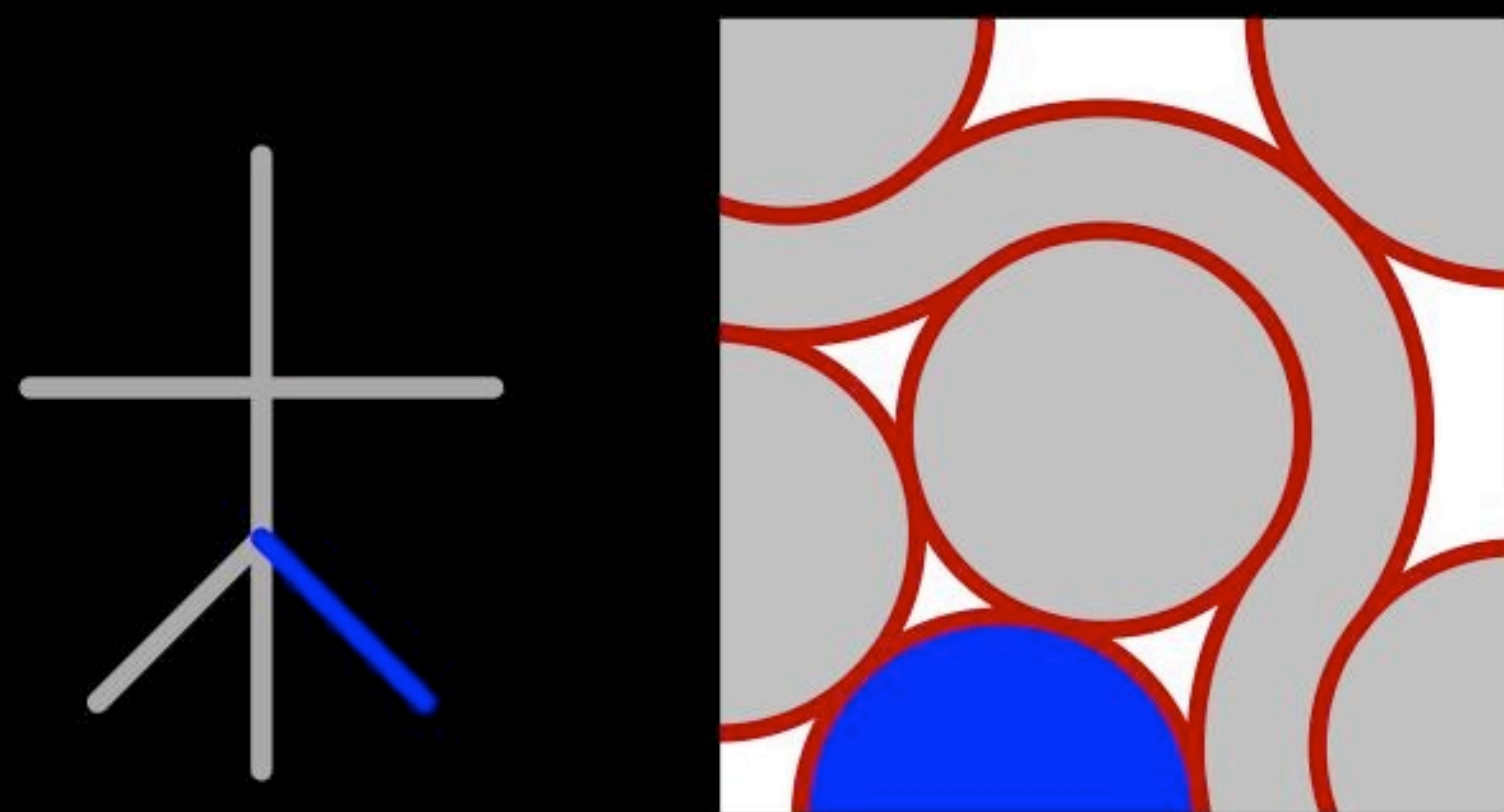



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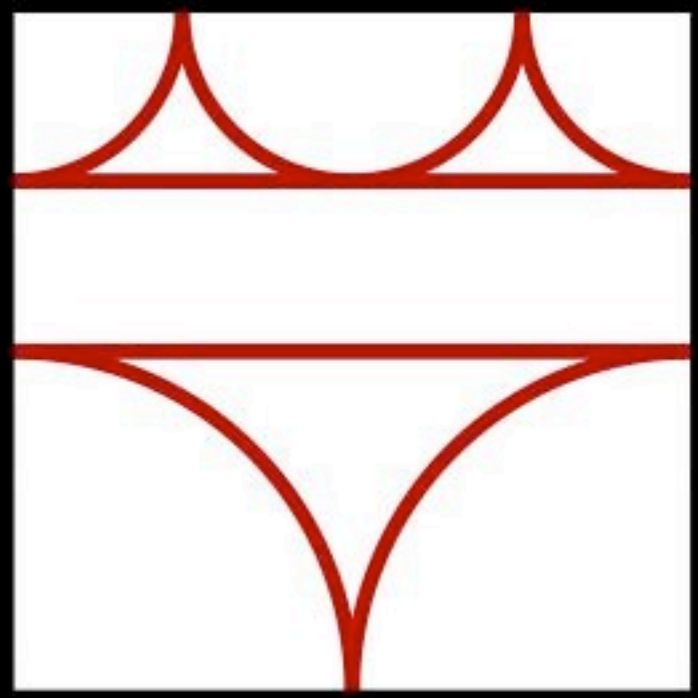
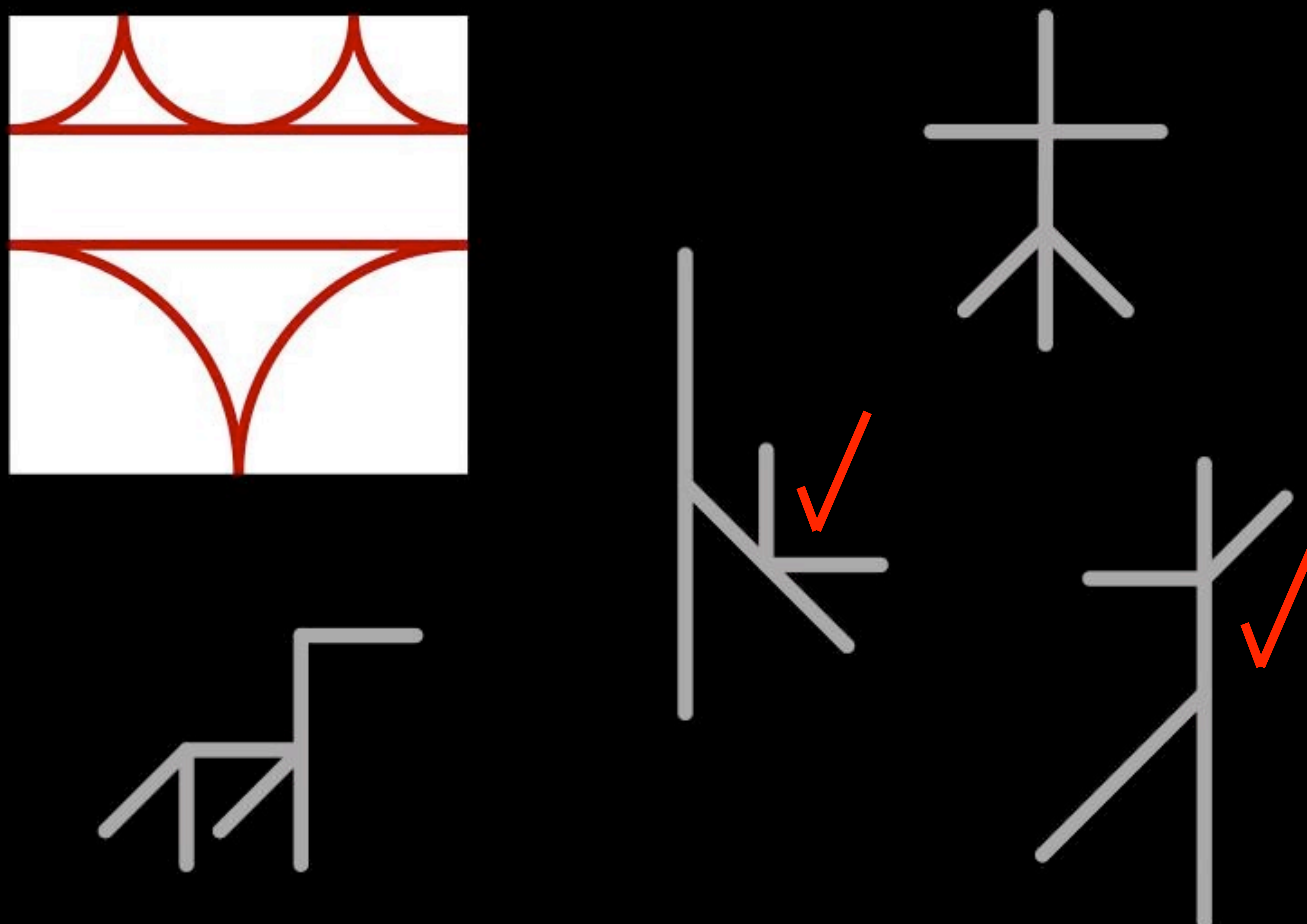
# Practice!





Which trees represent the given CRP?

# Practice!





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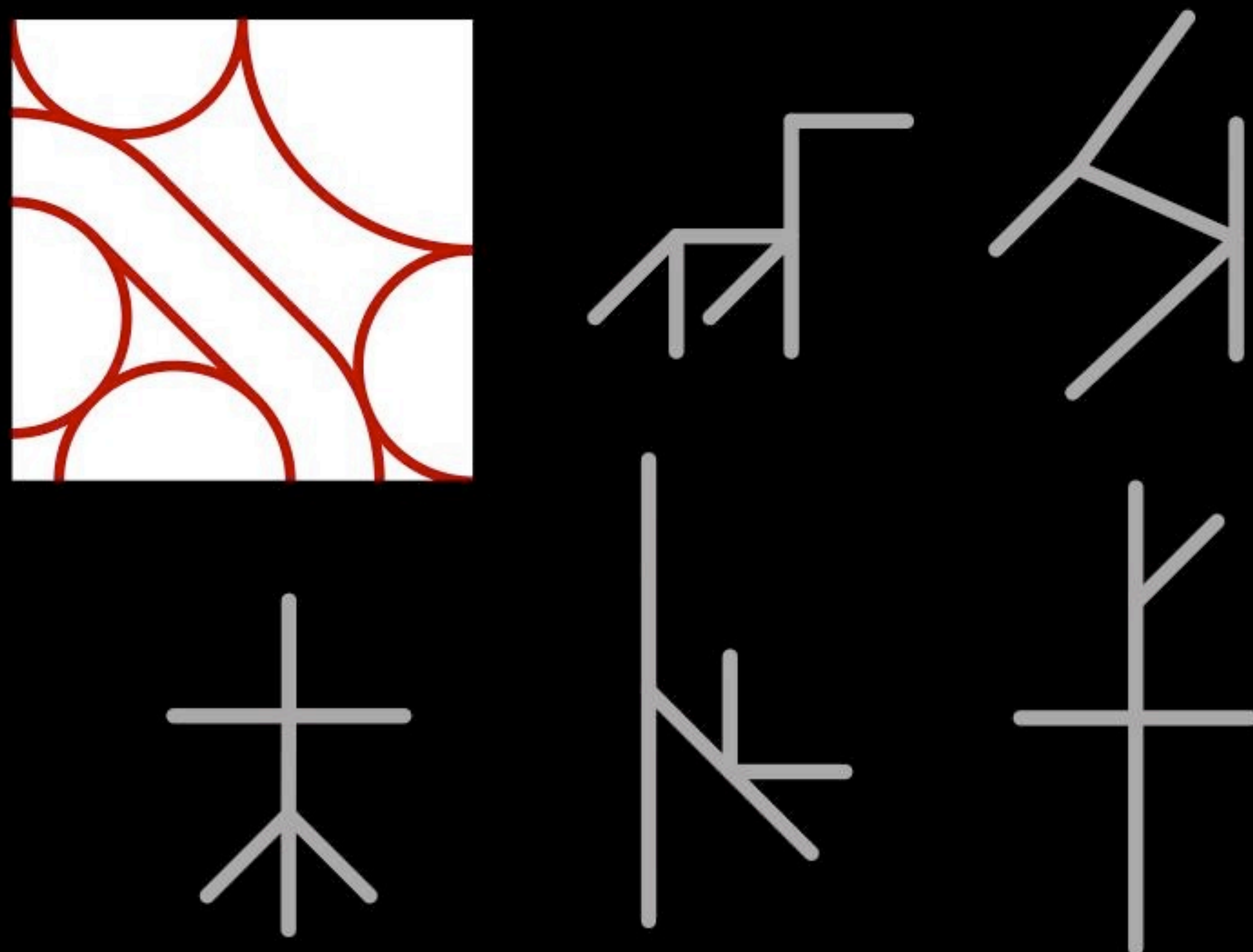



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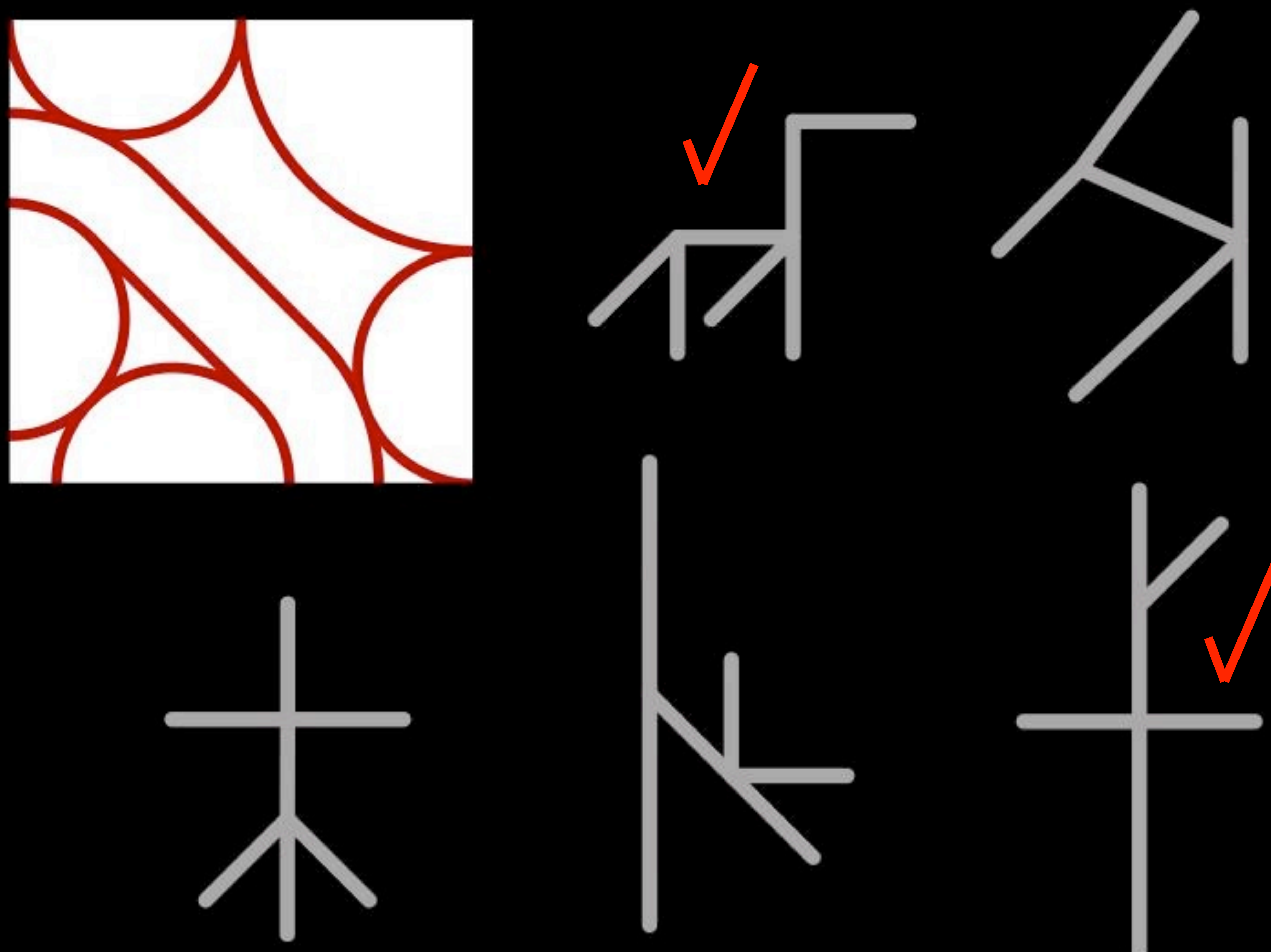



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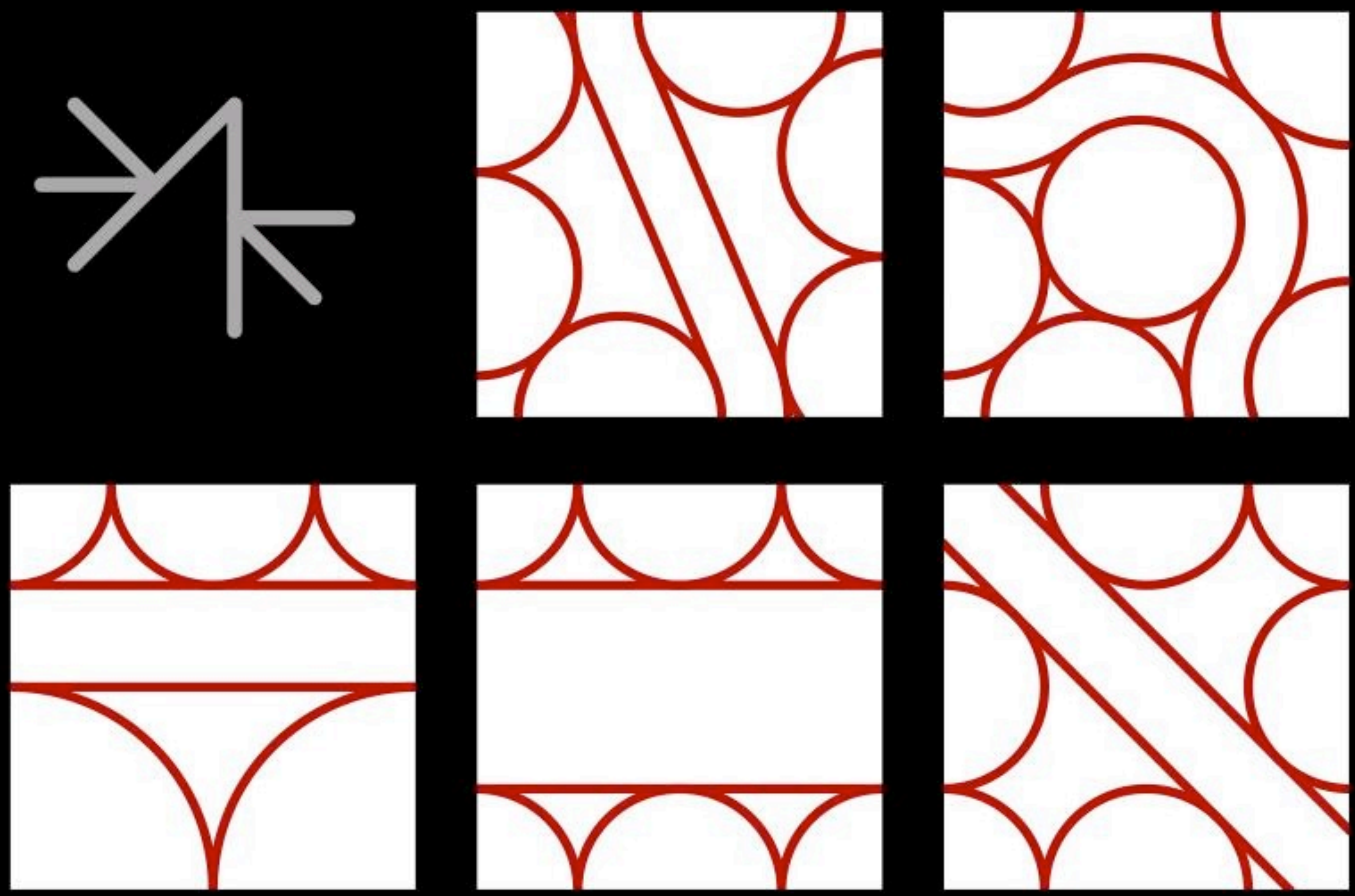
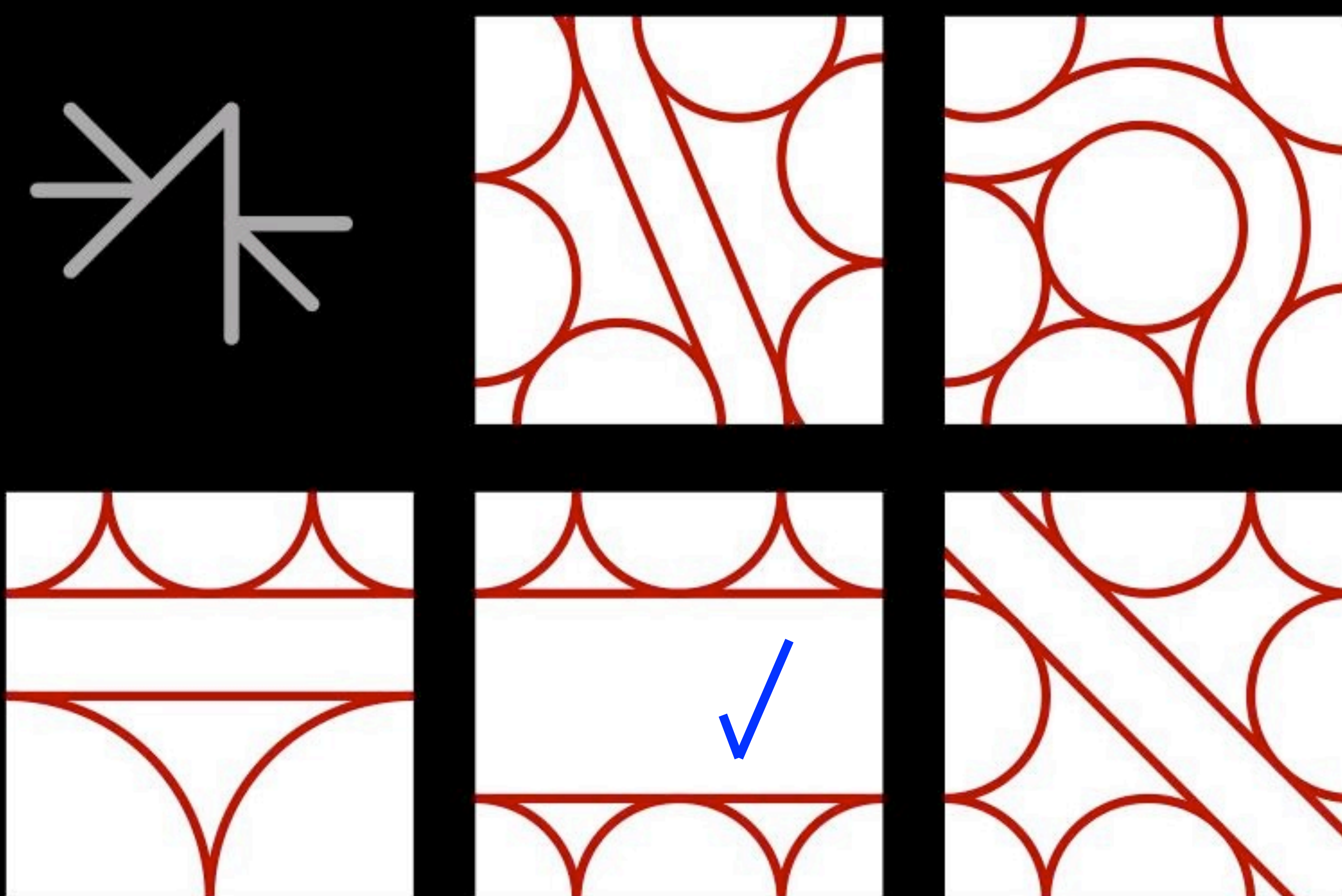




Which CRP correspond to the given tree?
CRP 1, 2, and 5 have similar trees, but different space allocation
(CRP => Tree) = unique
(Tree => CRP) = non-unique

# Practice!





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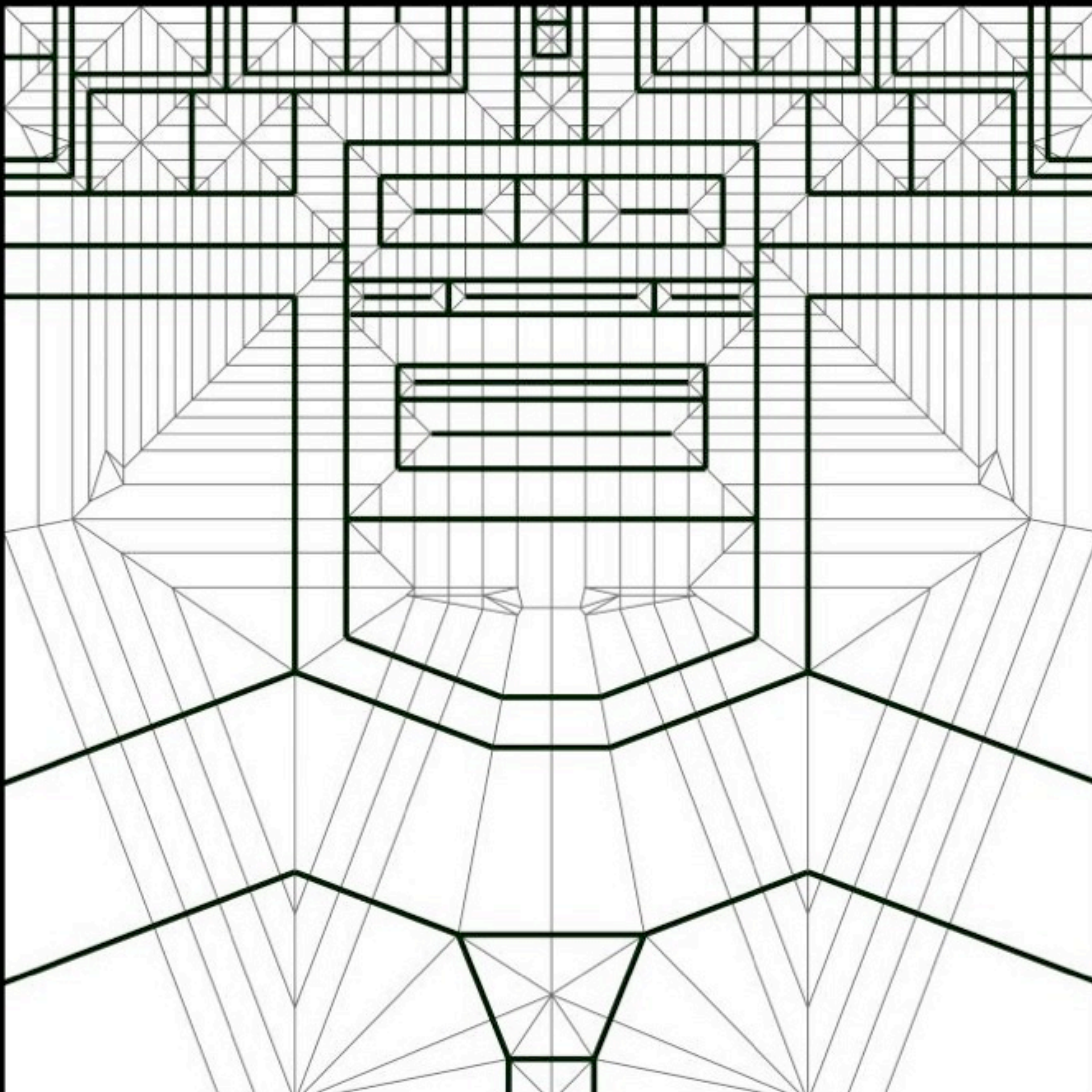
# Model vs. Reality





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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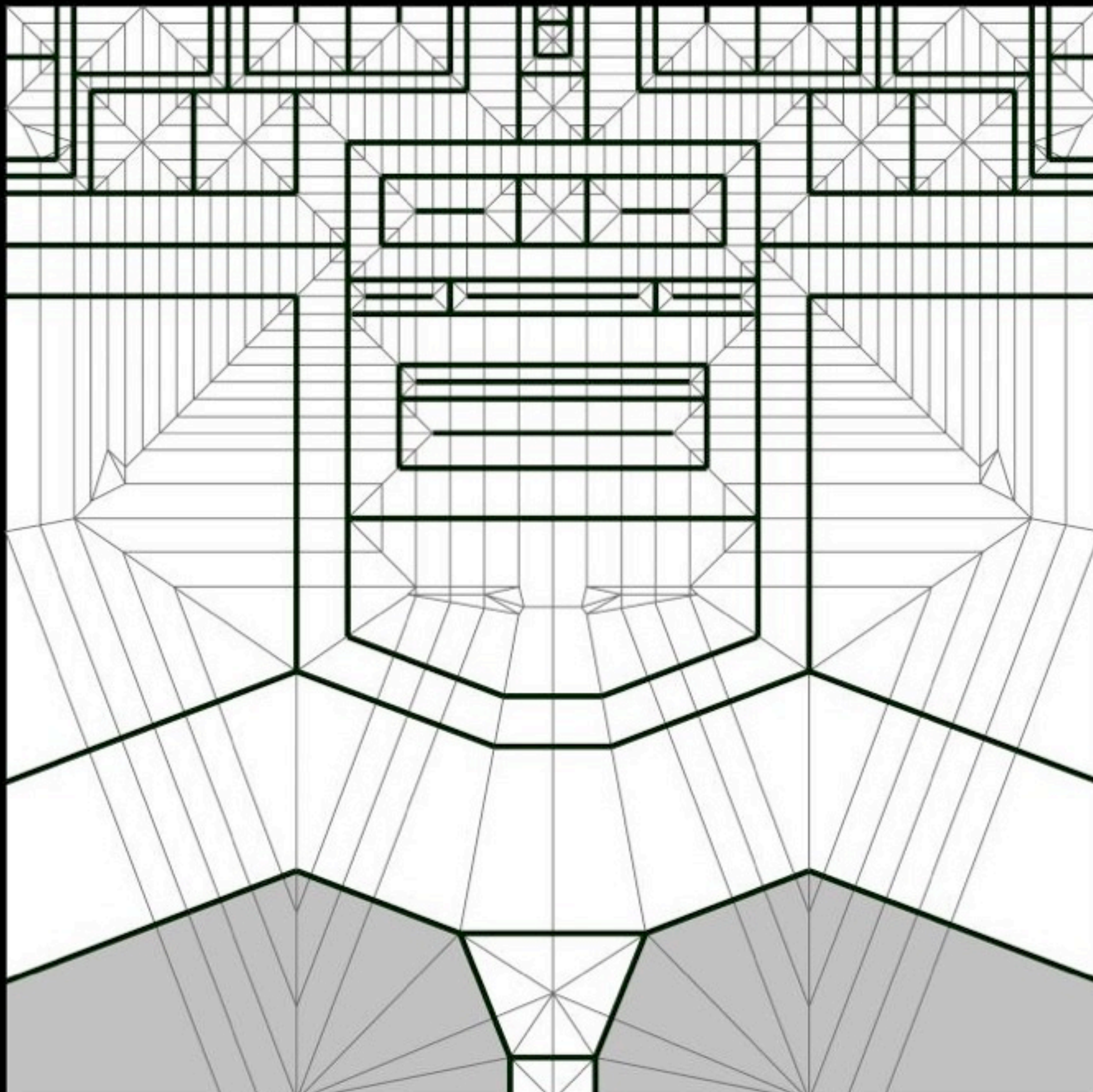



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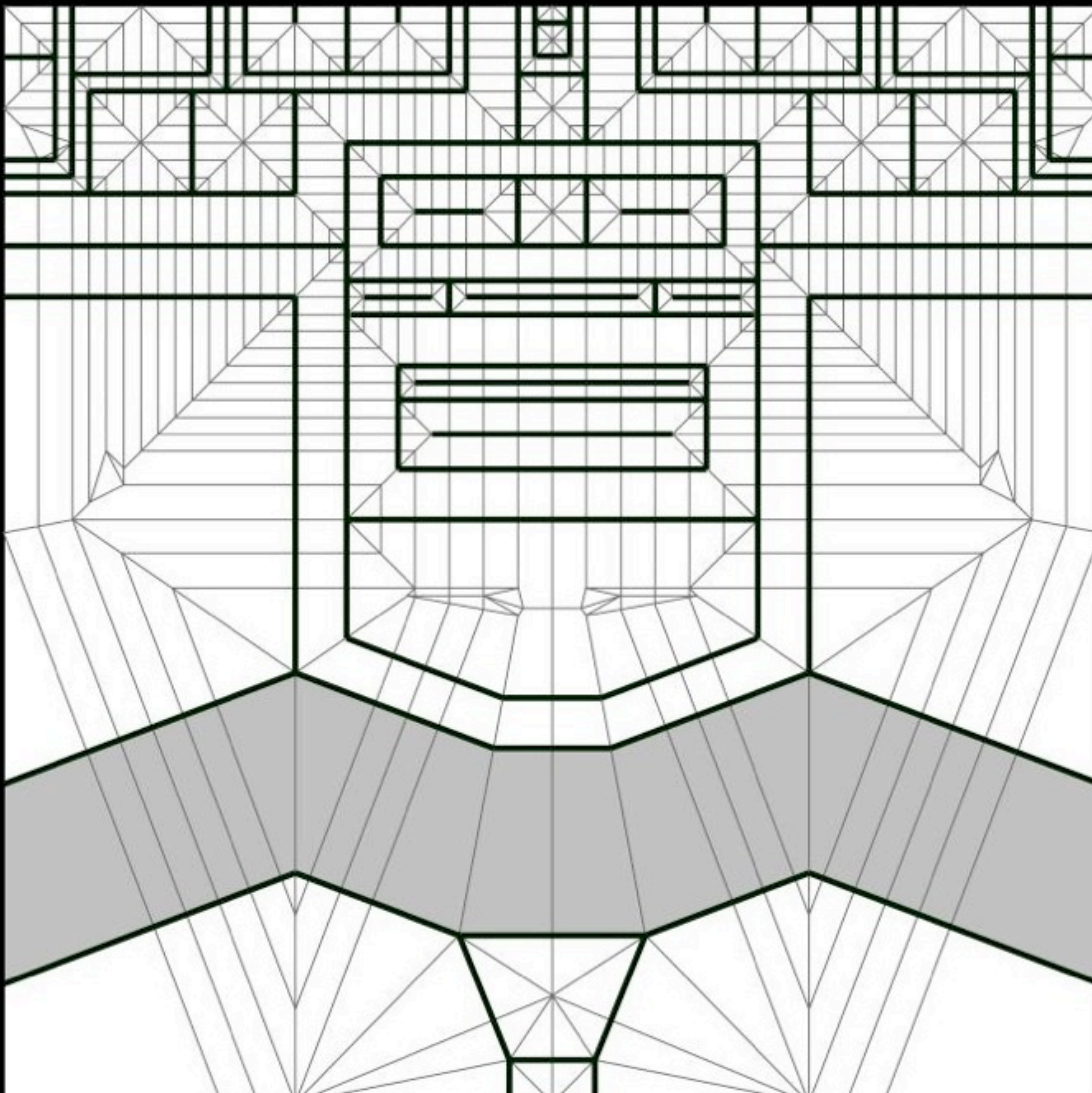

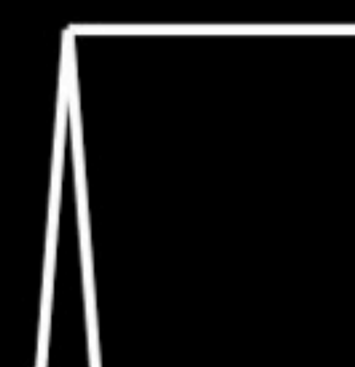



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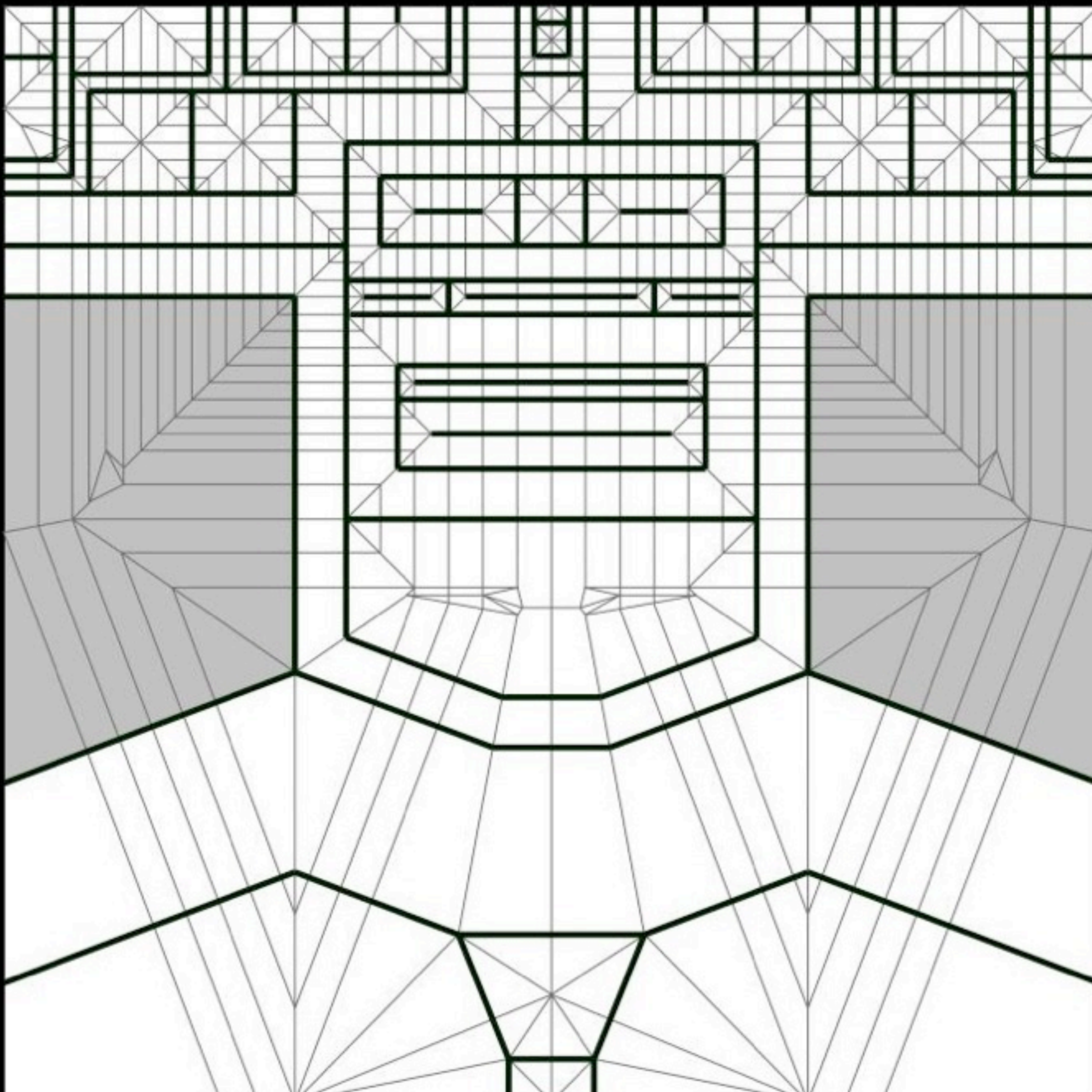

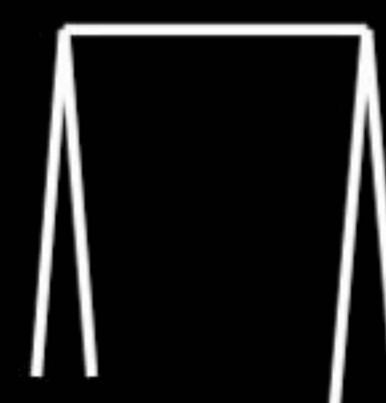

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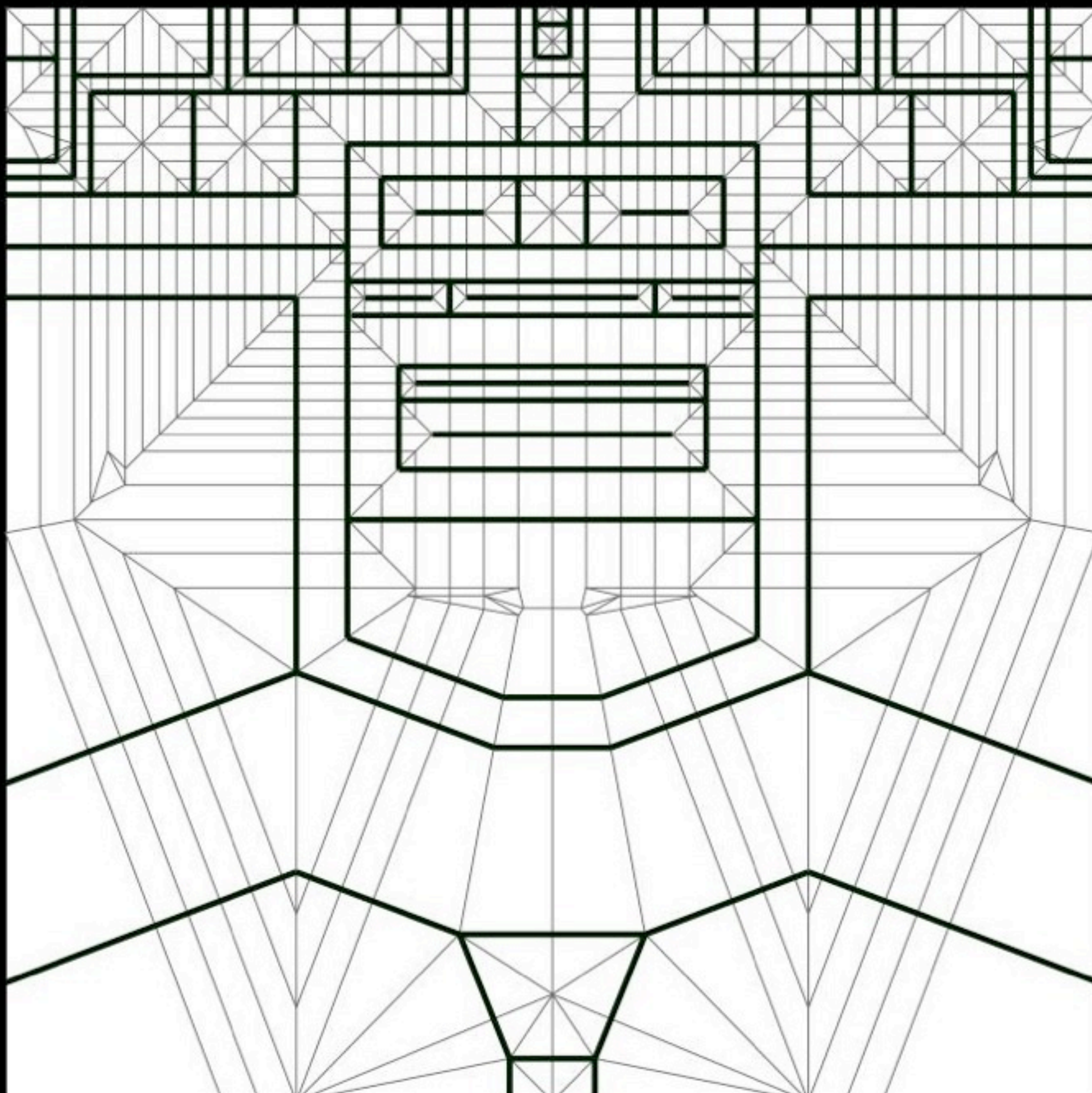

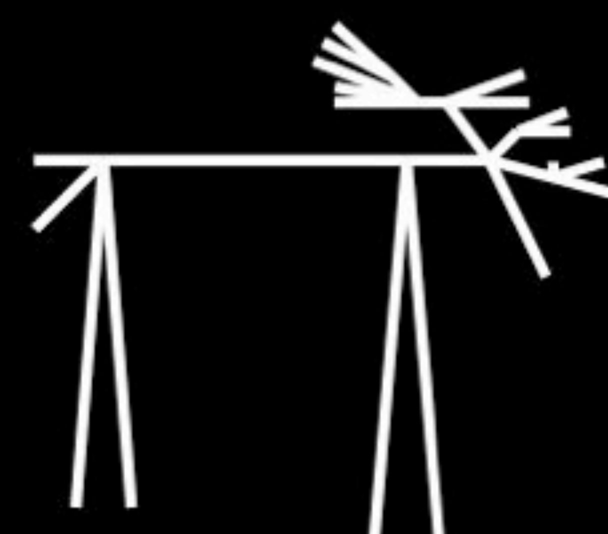



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Can read off tree as before



Jason Ku - 2008

## Satoshi Kamiya

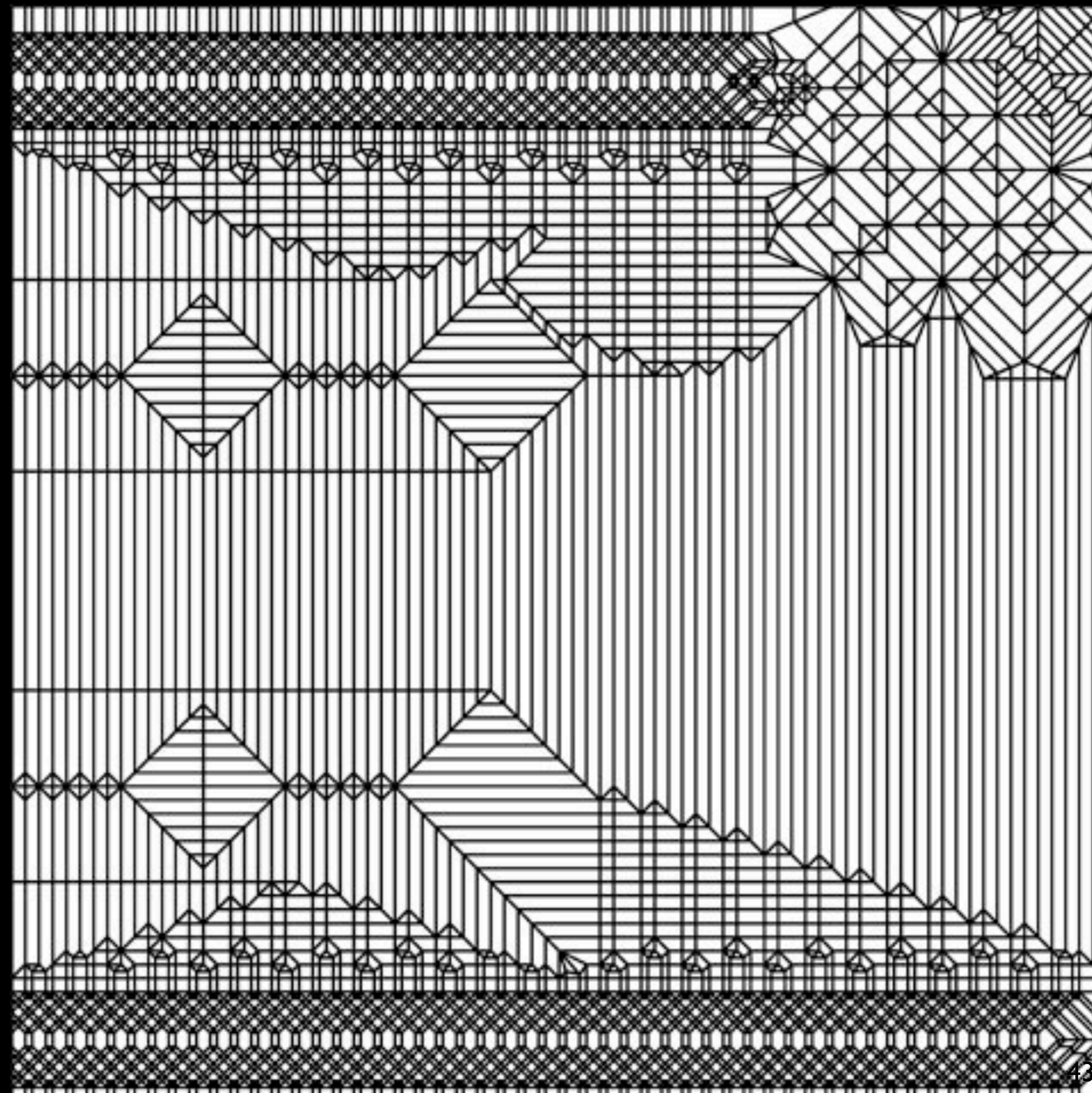
http://www.folders.jp/



Analyze structure
Square paper?

# Satoshi Kamiya

http://www.folders.jp/





Actually fairly simple yet ingenious concept behind space allocation
Box-pleating
Textures
Using thickness at end of flap to make fingers/toes

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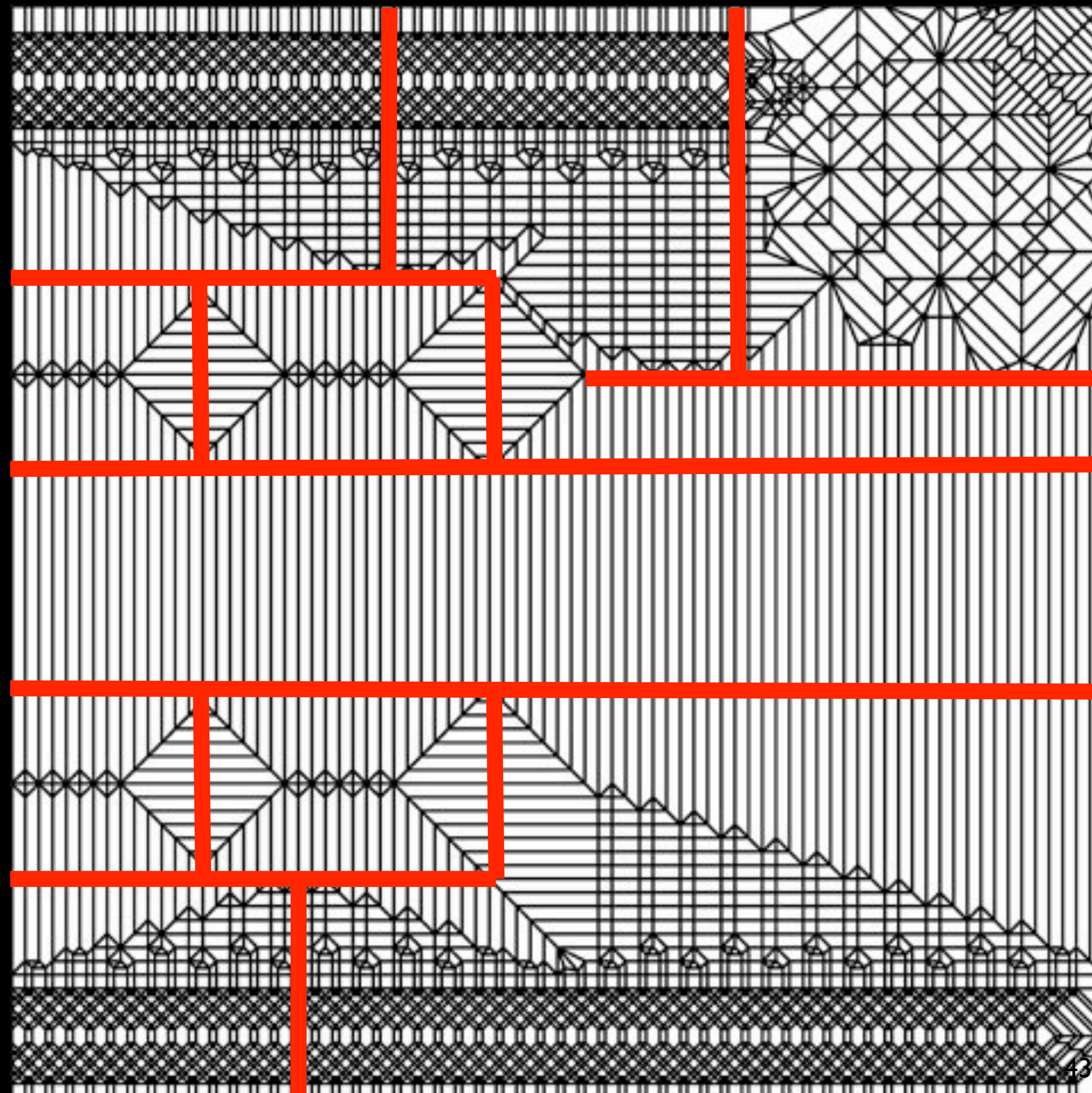


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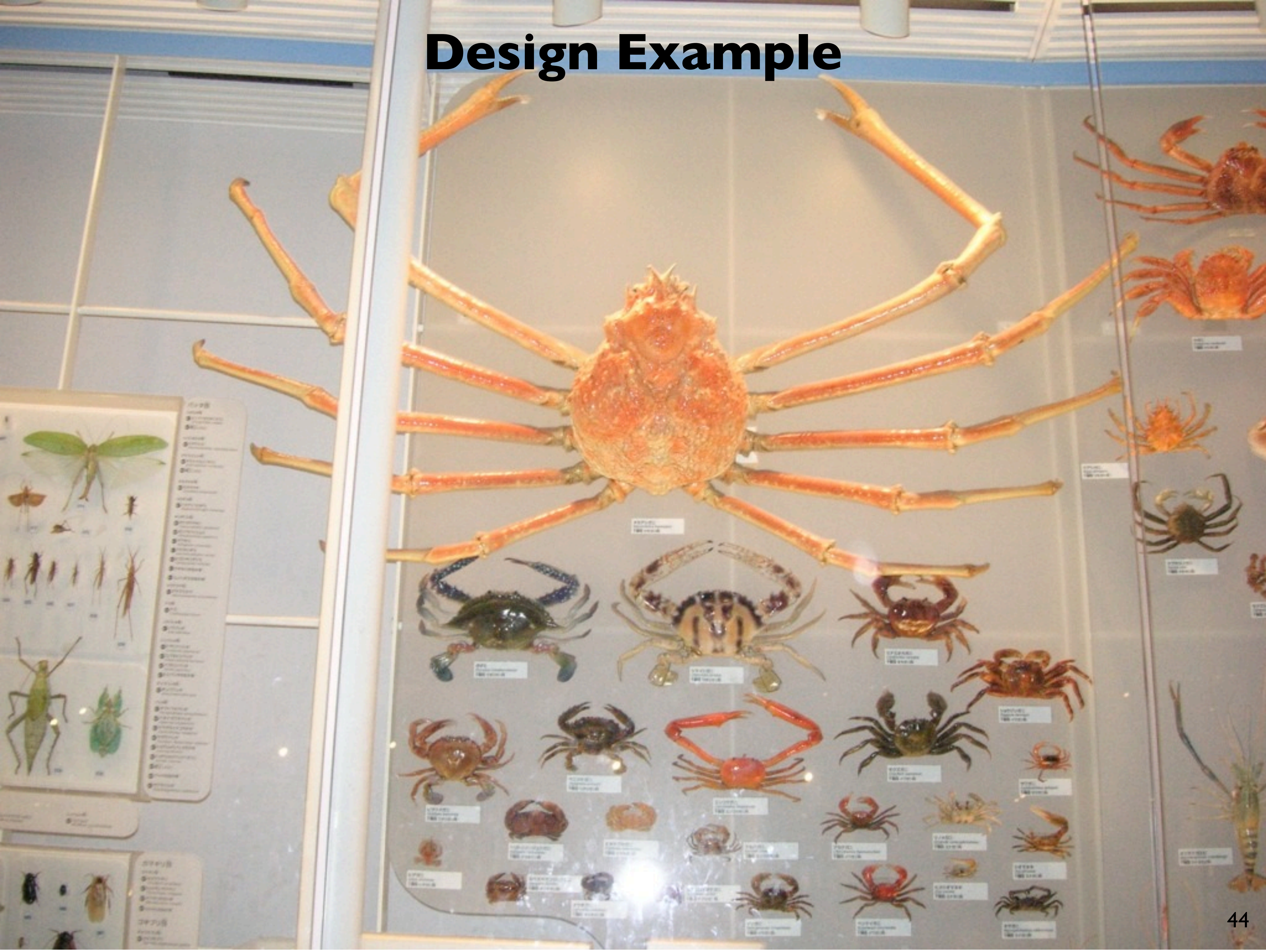
# Design Example





Modeling a crab
First draw tree (blackboard)

# TreeMaker Example



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)

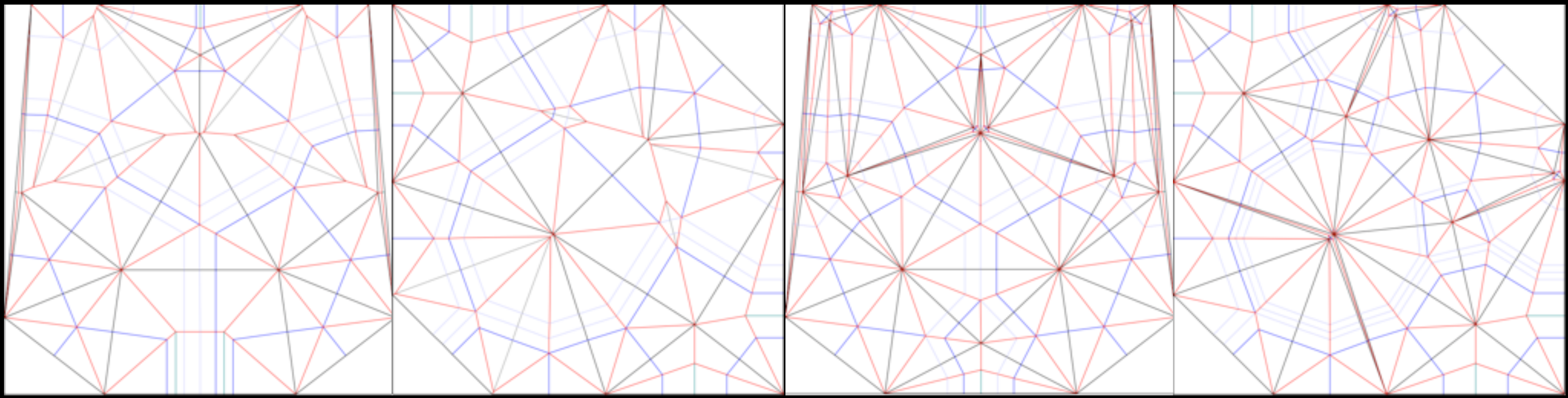
Problem: A polygon bounded by active paths contains an unconstrained node
Solution: add local strain to interior node to create additional active paths

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

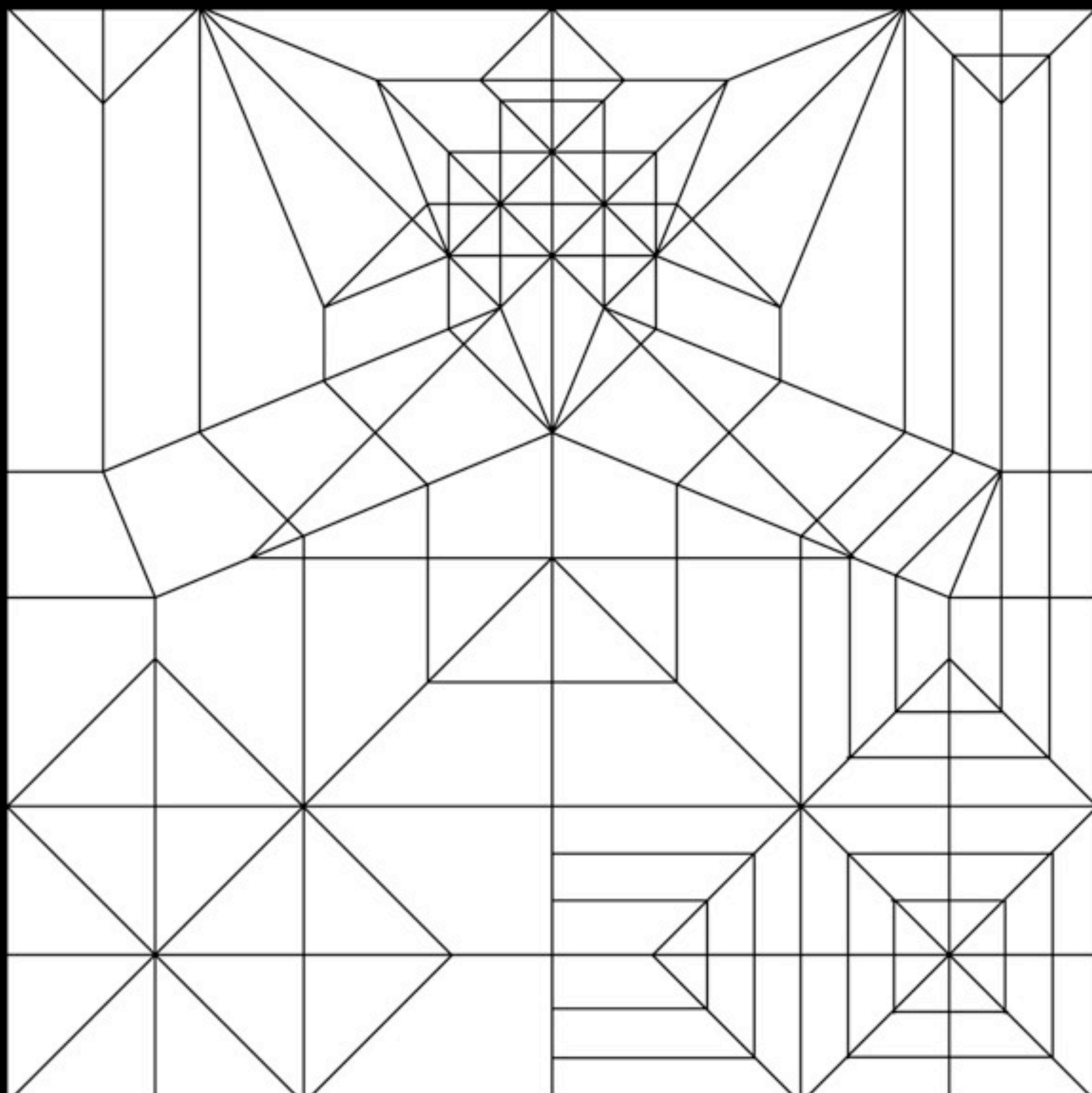
# Example Files

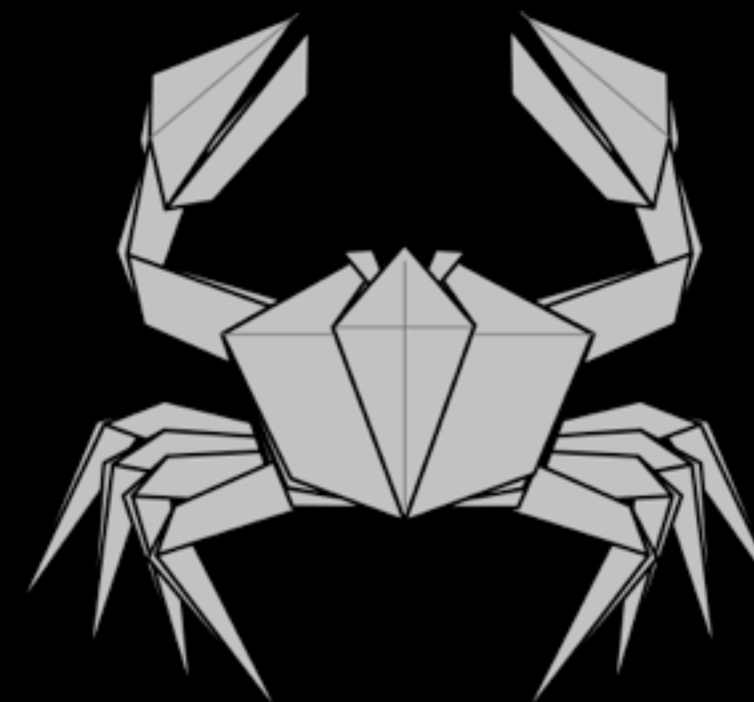
http://jasonku.scripts.mit.edu/misc/treemaker_examples.zip

- 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

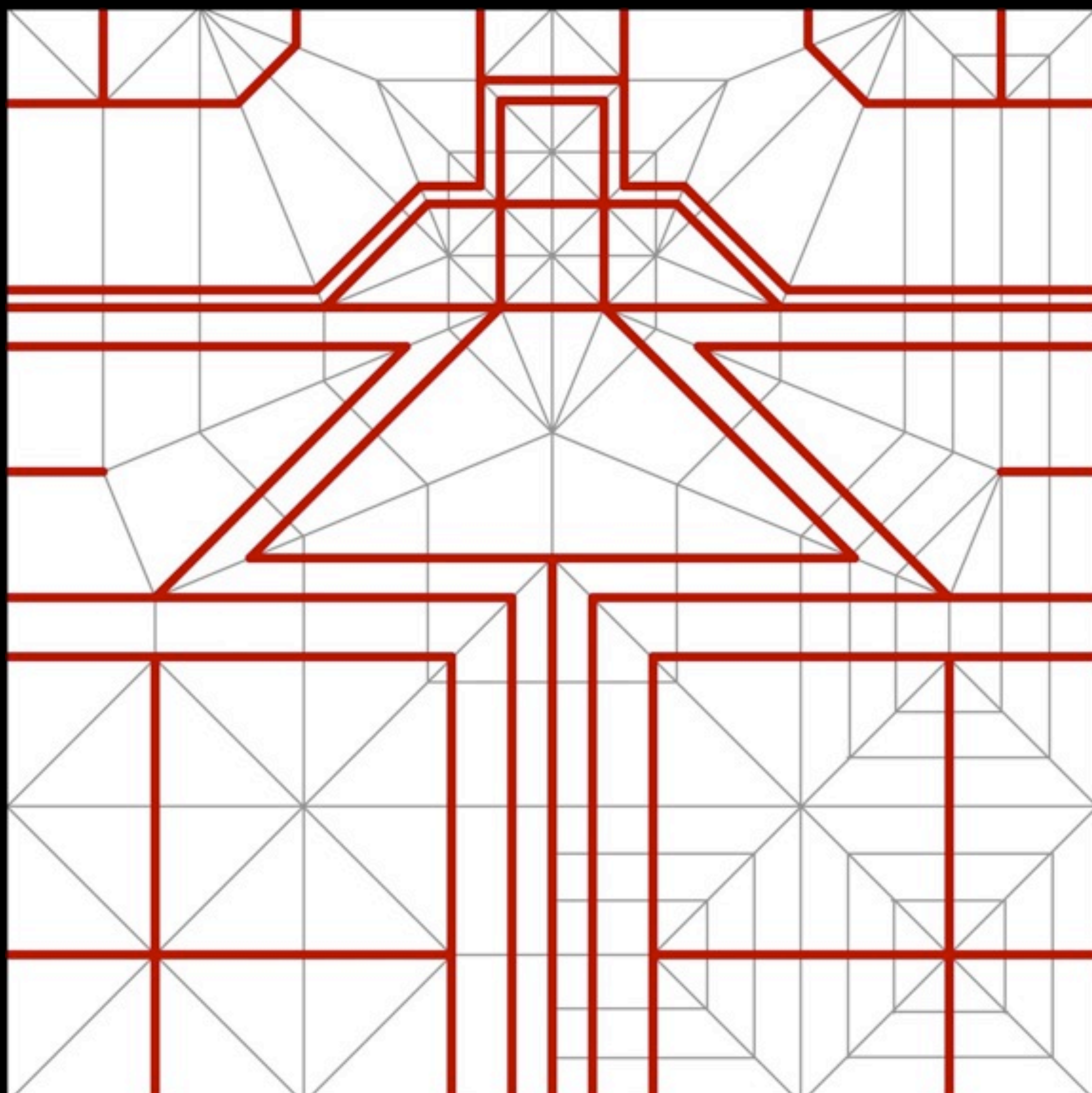


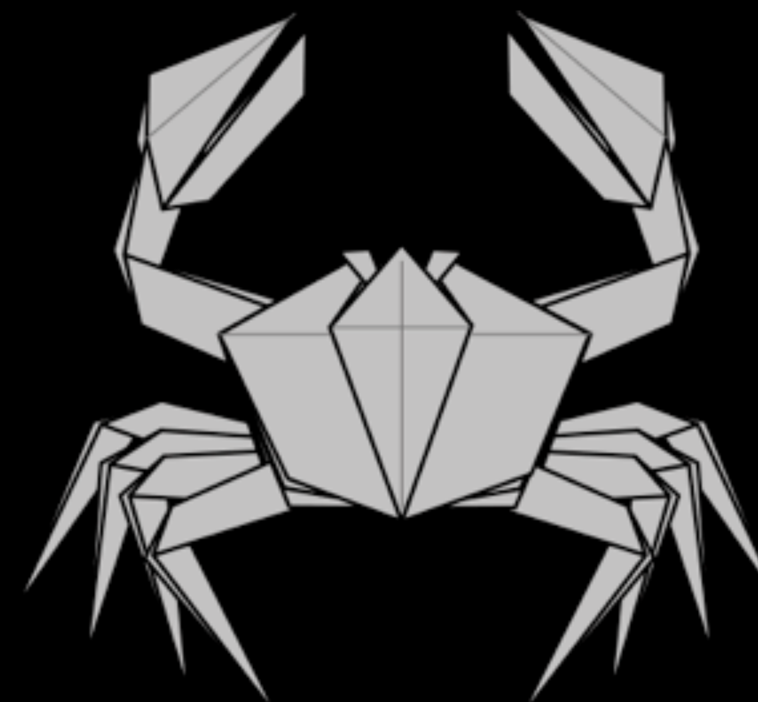




22.5 degree folding
Constrained under back geometry
Taking thickness into account
Non-uniaxial in ultimate folded form
Texture

# Non-TreeMaker Example







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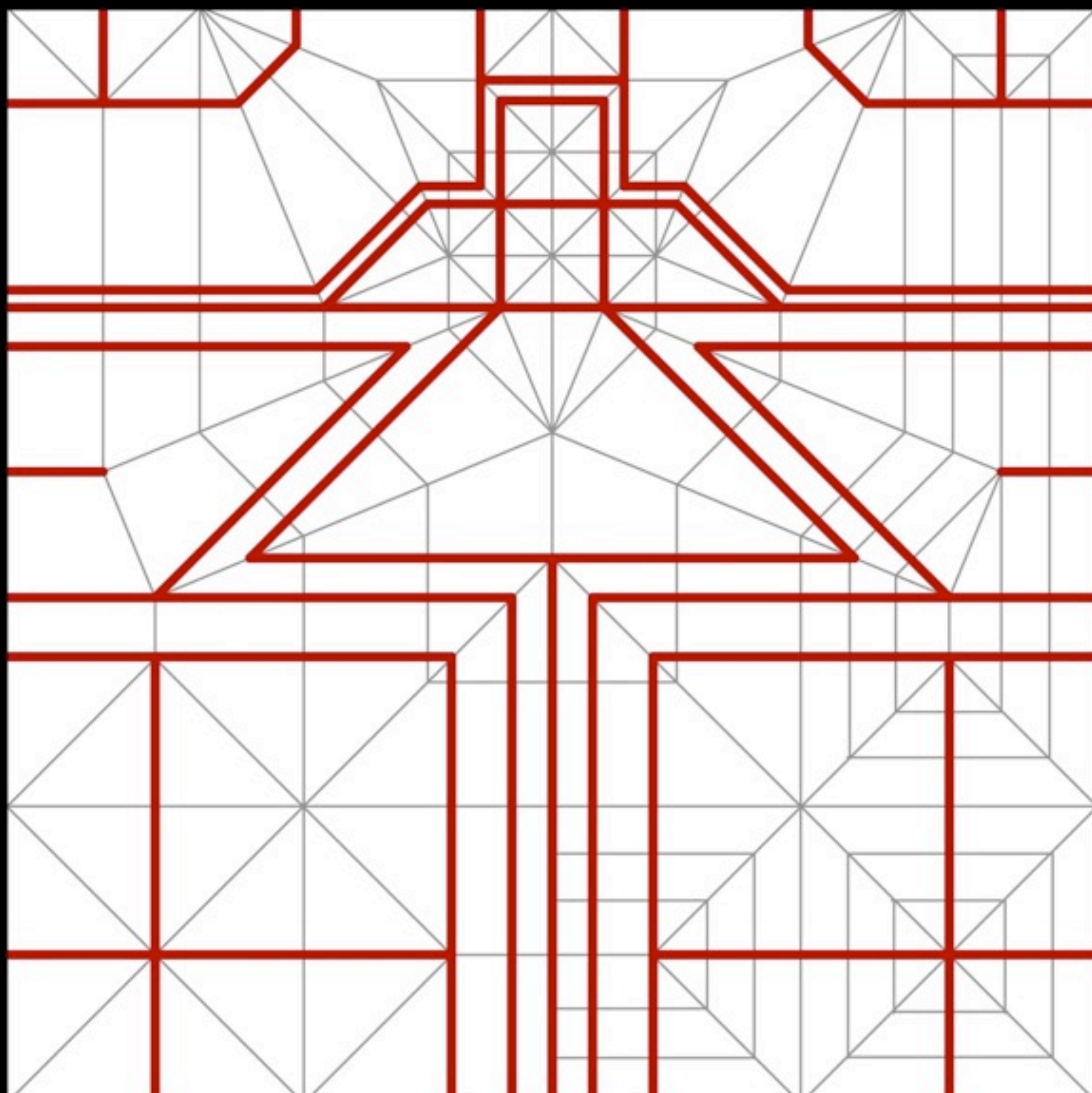

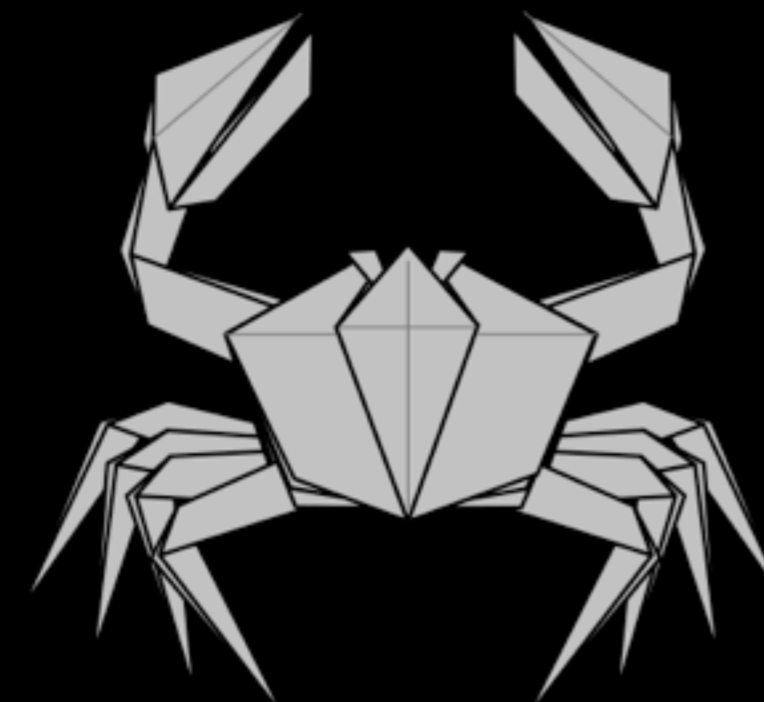

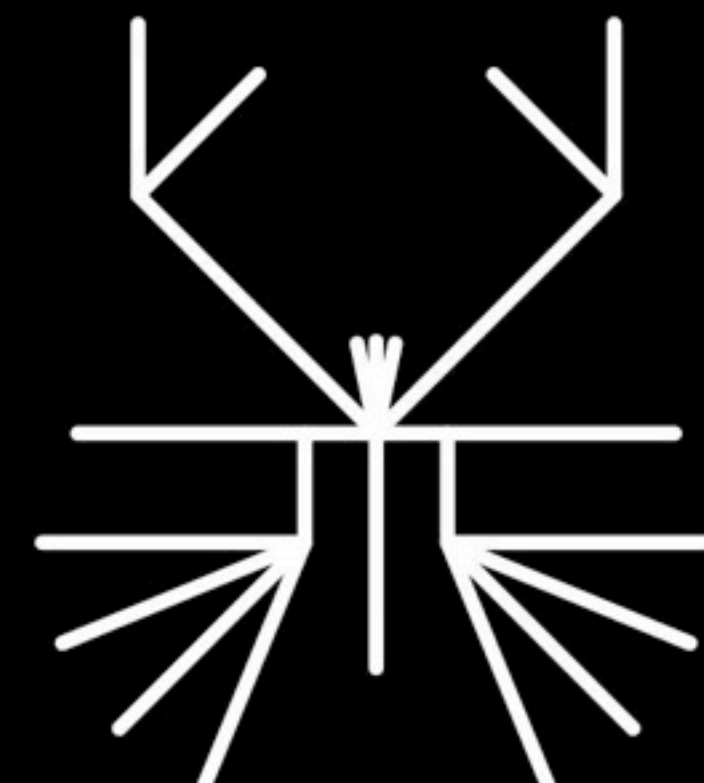



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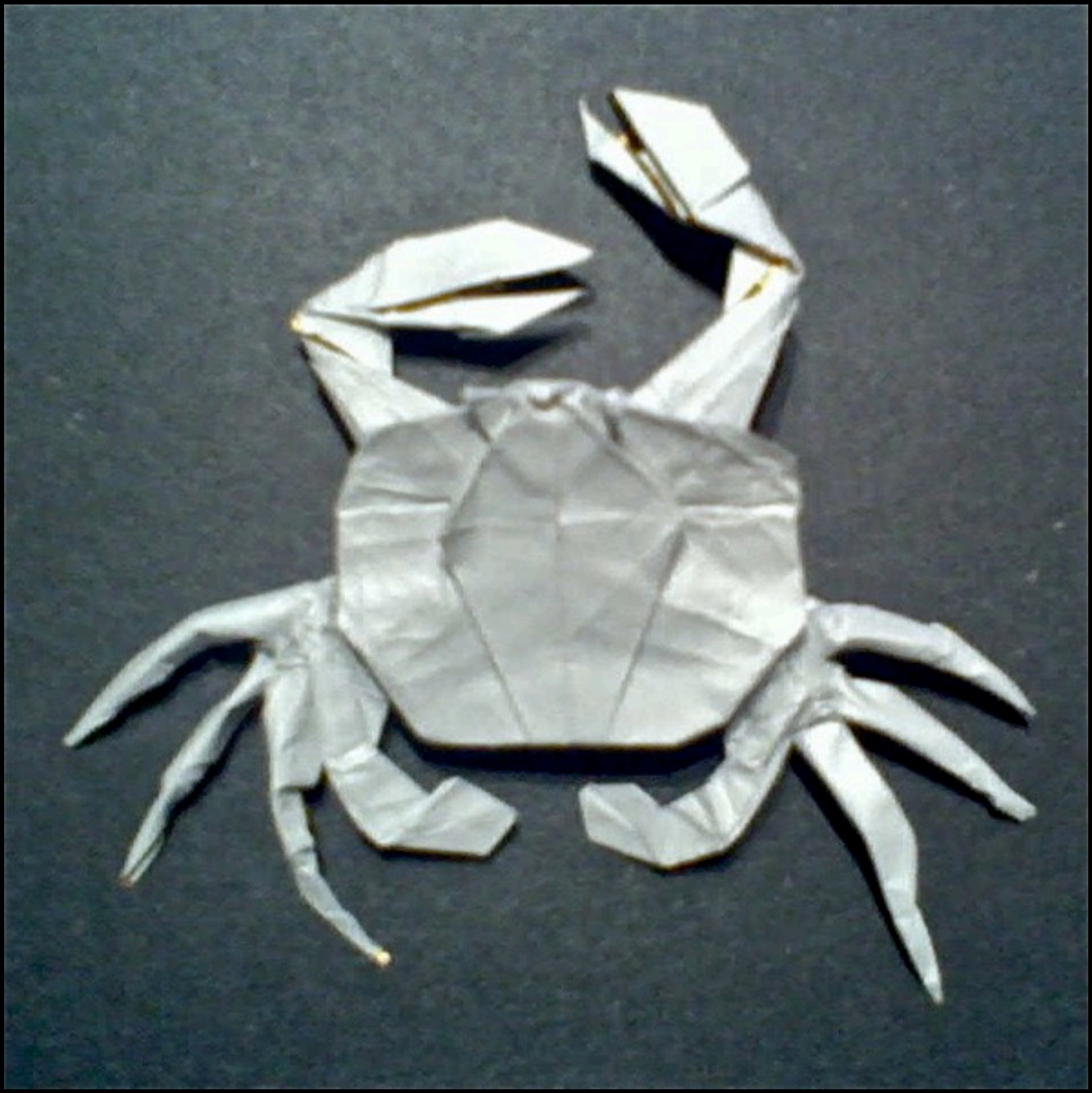
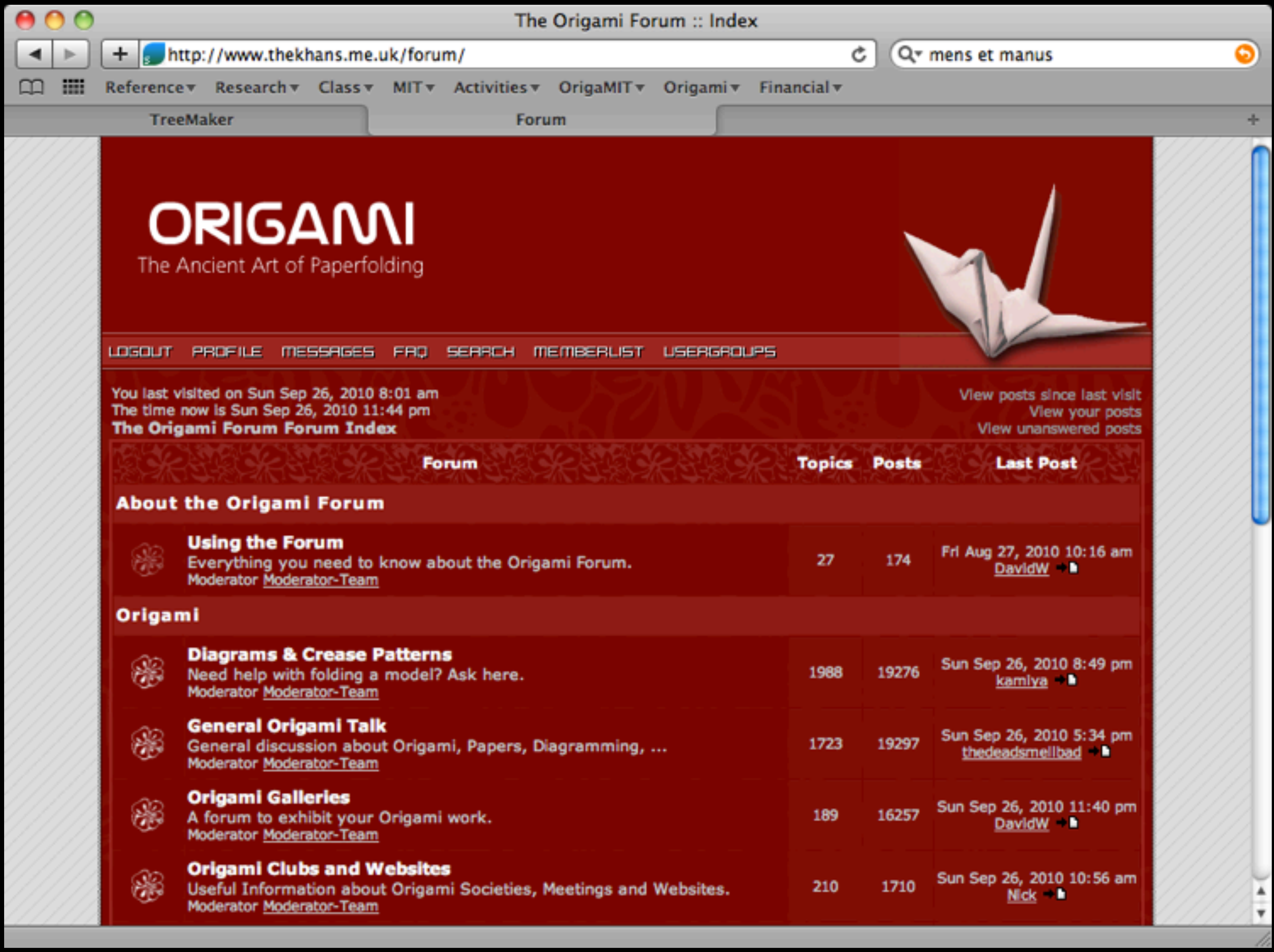




Proof of concept

# 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