

# Week 5

# Fabrication

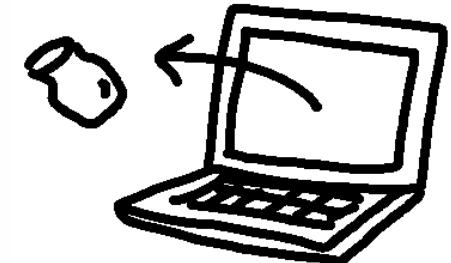
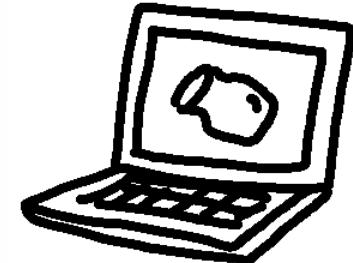


# Introduction

- Computer Graphics
  - Display imagery on the screen



- Fabrication
  - Construction of 3D physical objects.



# Personal Fabrication Machines

3D model in a computer → directly “print” physical objects.



“Mojo 3D Printer” by Intel Free Press  
CC BY-SA 2.0

3D printer



“Roland MDX-15/20-”  
by Creative Tools, CC BY 2.0

Milling machine



“Lasersaur” by Stefan Hechenberger  
CC BY-NC-SA 2.0

Laser cutter

# Fabrication

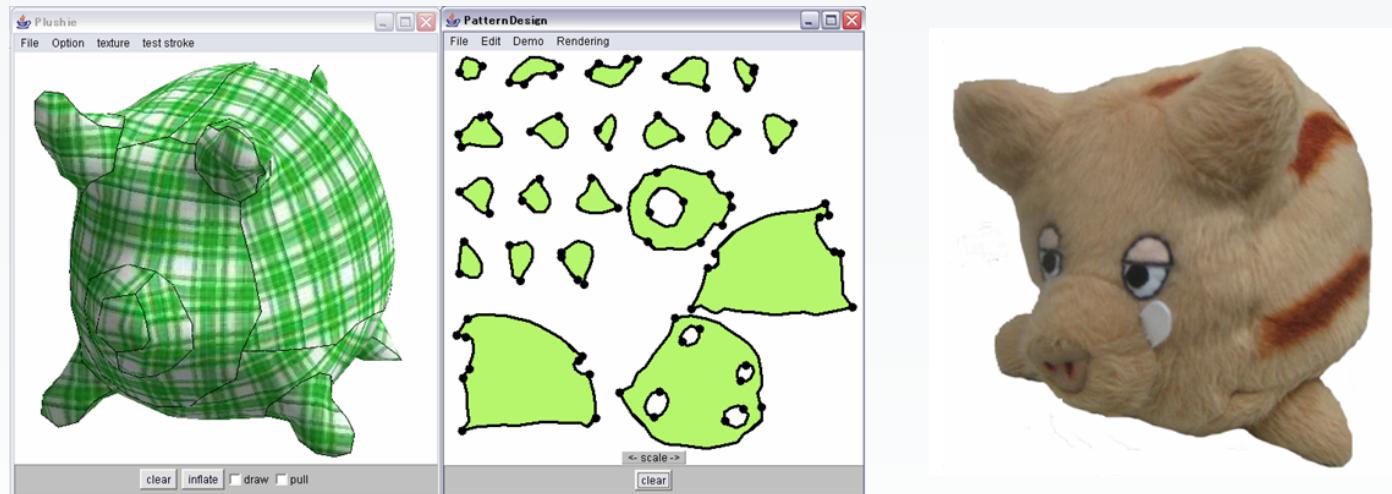
- Plush toys
- Beadworks
- Chairs
- Soft Folding
- Interactive Packing

# Fabrication

- Plush toys
- Beadworks
- Chairs
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# Plushie: An Interactive Design System for Plush Toys

Yuki Mori, Takeo Igarashi

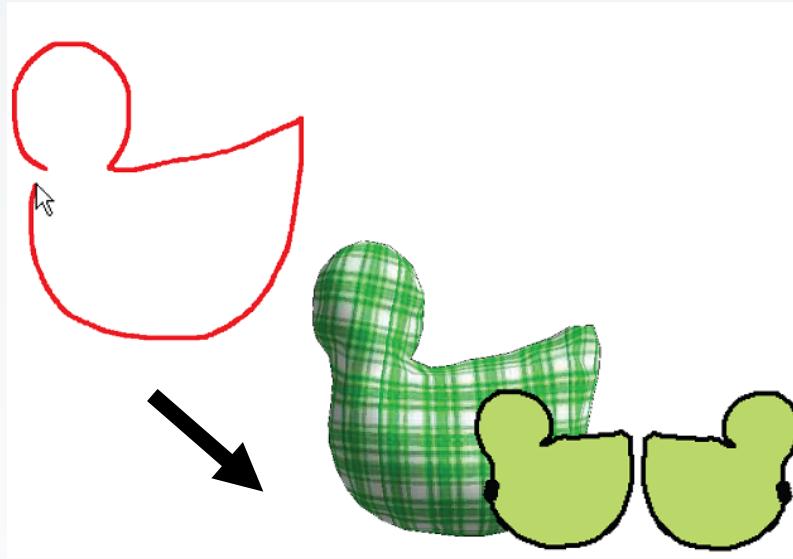


# Problem to Address

It is difficult for a non-expert to  
design 2D pattern appropriately...



# Our Approach



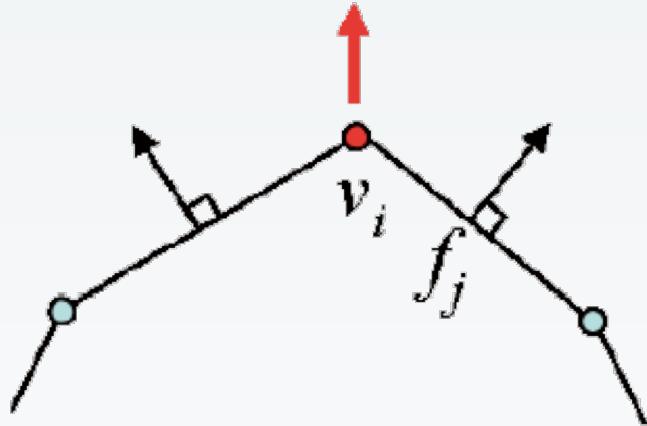
Automatically generate 3D model and cloth pattern for a sketch.

# Video

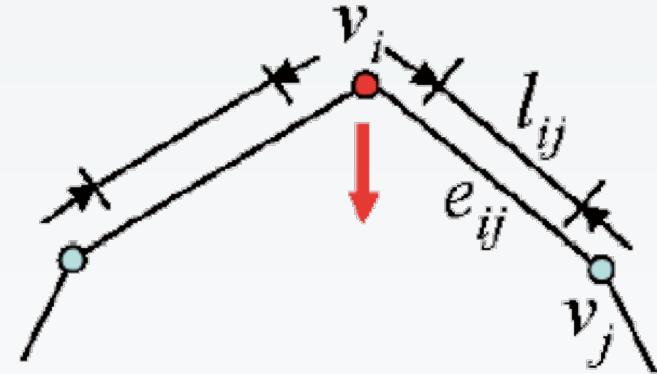
[plushie.mp4](#)

# Algorithm

# Inflation Simulation



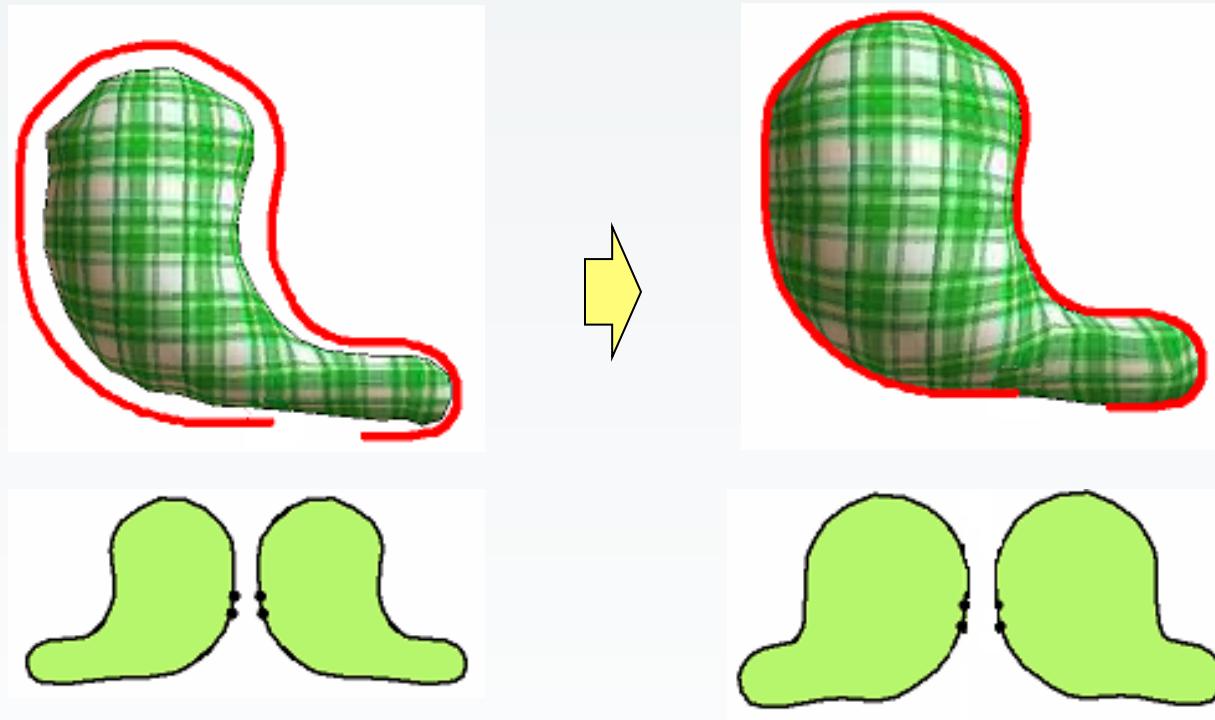
Pushing outwards  
(air pressure)



Pulling back  
(cloth tension)

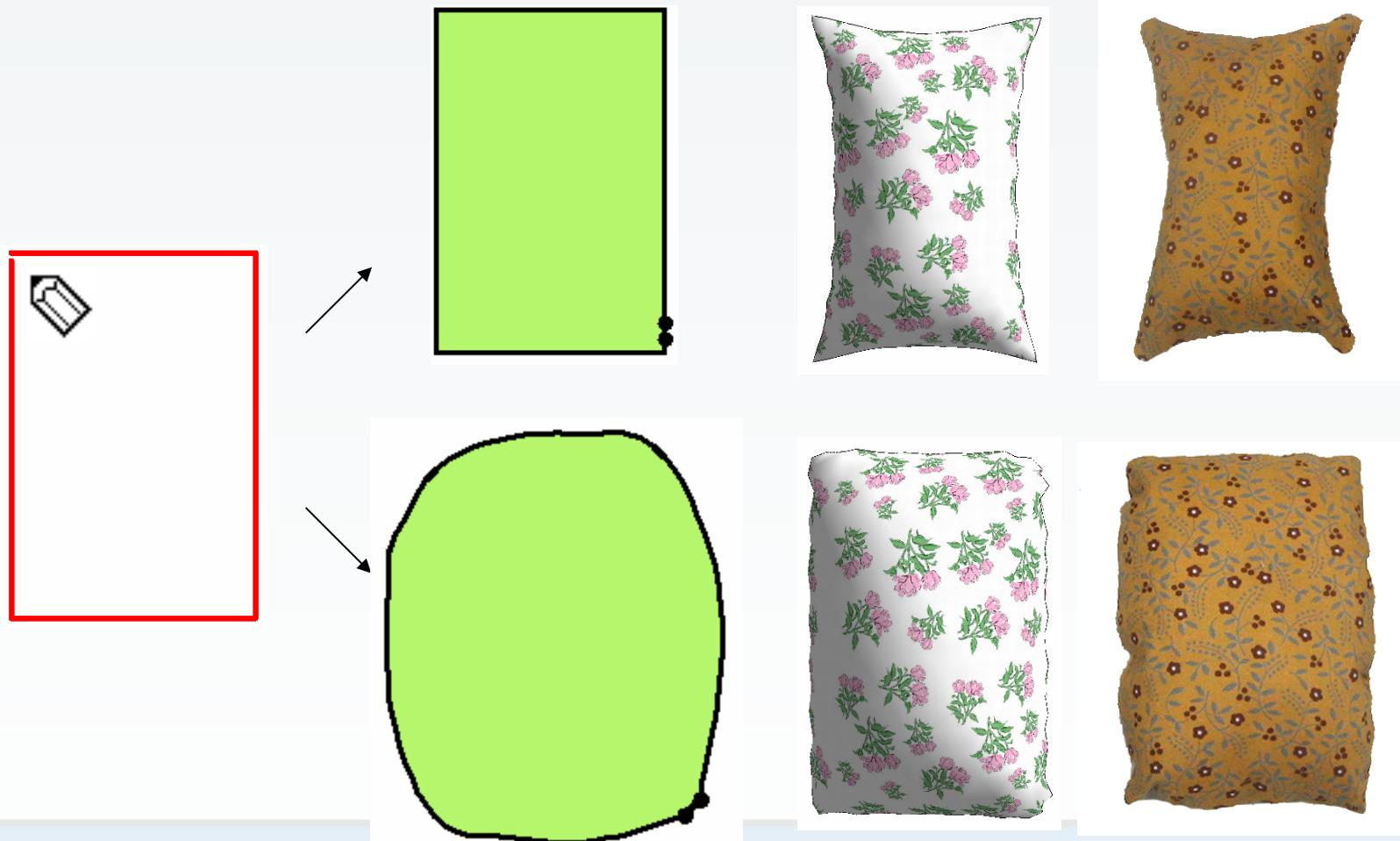
We use a simple mass-spring method.

# Adjustment Process



Adjusts the pattern so that simulation result matches with the sketch

# Physical Simulation & Shape Adjustment



# To Learn More...

## The original paper:

- Mori and Igarashi. Plushie: An Interactive Design System for Plush Toys. SIGGRAPH 2007.

## Paper craft model:

- Mitani and Suzuki. Making paper craft toys from meshes using strip-based approximate unfolding. SIGGRAPH 2004.

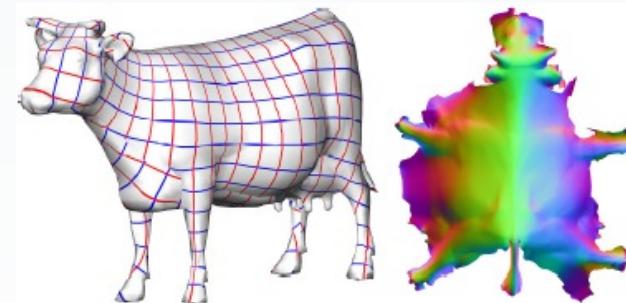


[Mitani and Suzuki 2004]  
(Figure obtained from

<http://mitani.cs.tsukuba.ac.jp/pukiwiki/>  
with permission)

## Surface flattening methods:

- Sheffer, et al. Mesh parameterization methods and their applications. Foundations and Trends in Computer Graphics and Vision. 2006.



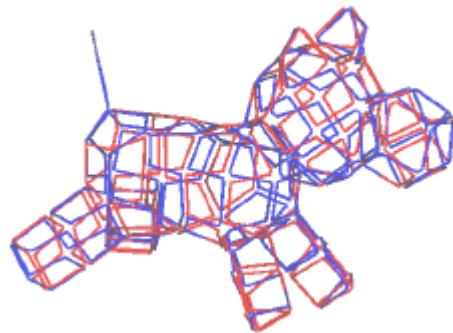
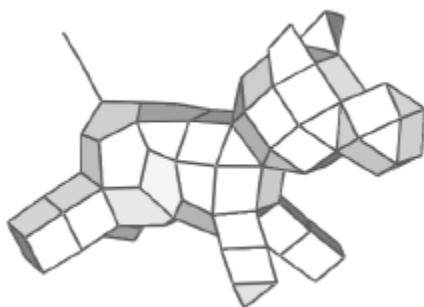
[Sheffer, et al. 2006]

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# Fabrication

- Plush toys
- Beadworks
- Chairs
- Soft Folding
- Interactive Packing

# Beady: Interactive Beadwork Design and Construction



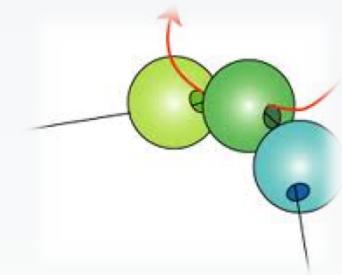
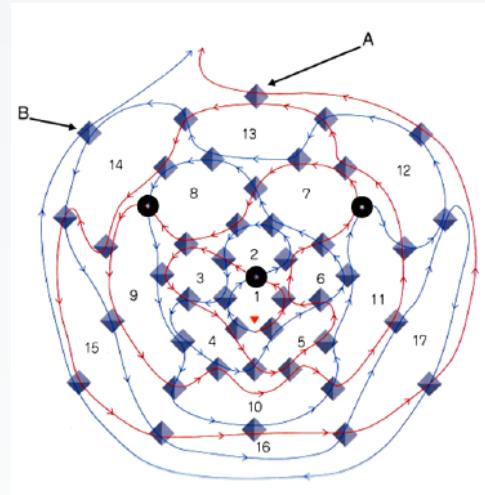
Y. Igarashi, T. Igarashi and J. Mitani

# Problem to Address

- Beadwork is the art of connecting beads together by wires.



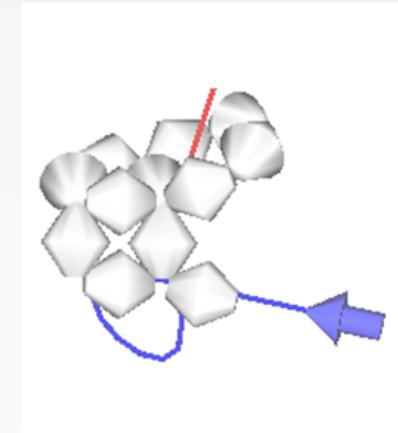
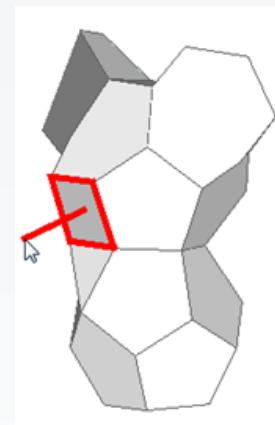
3D



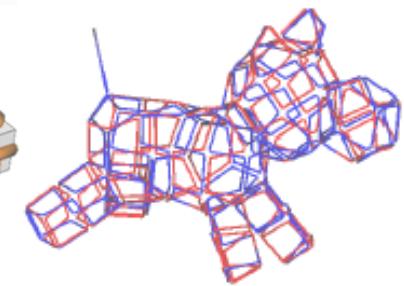
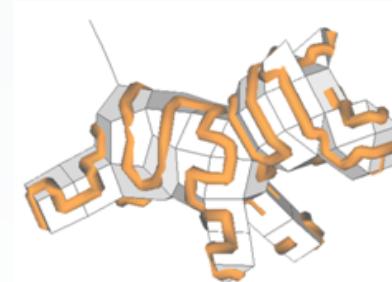
The design and construction of 3D beadwork are very difficult !

# Our Approach

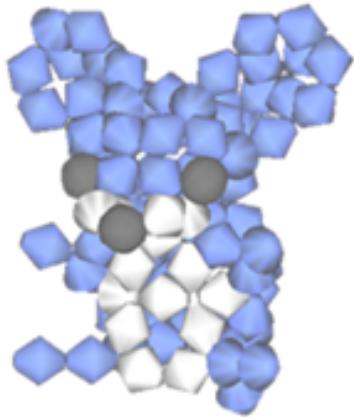
- Interactive Design and Construction



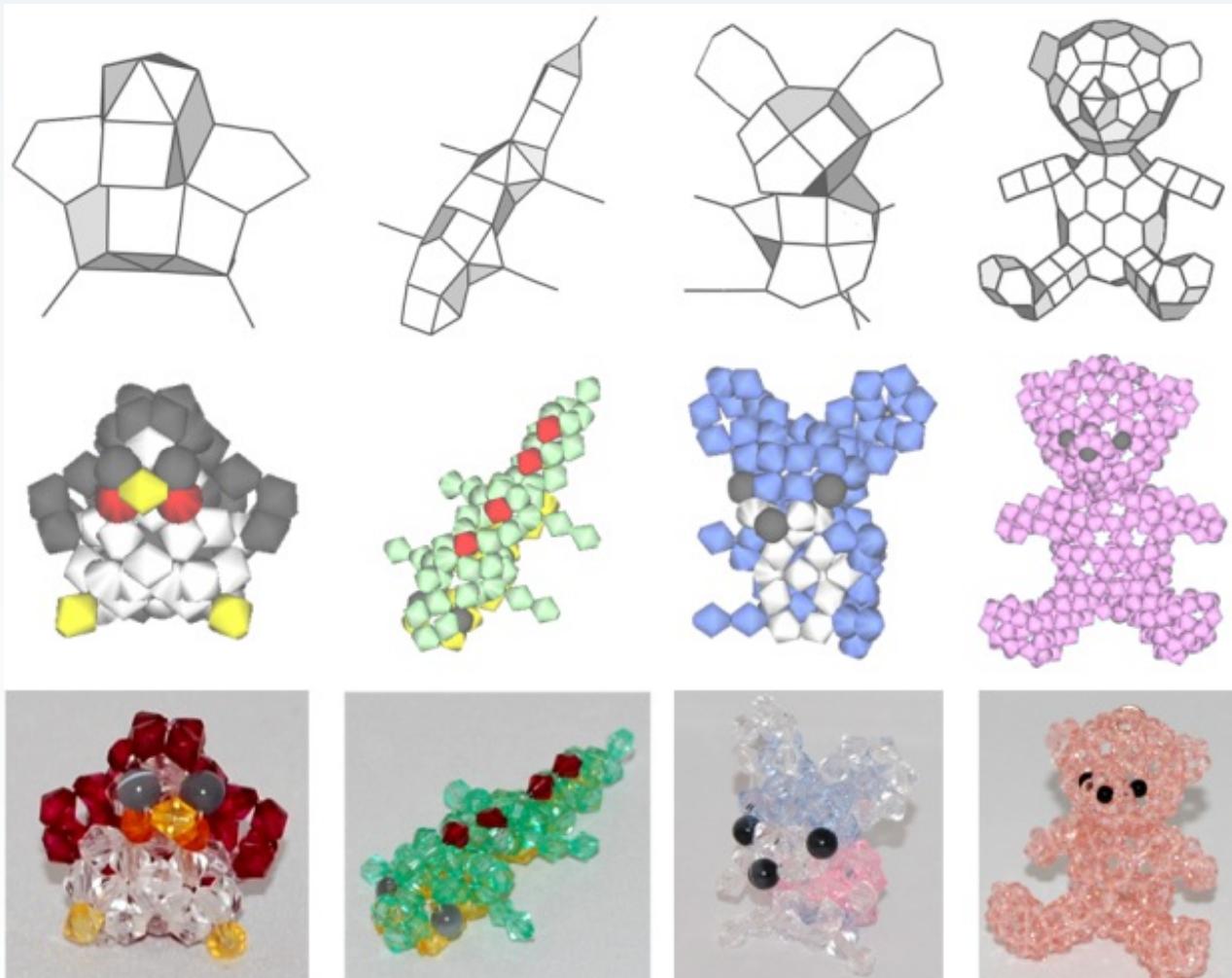
- Wire path planning algorithm



# Demo

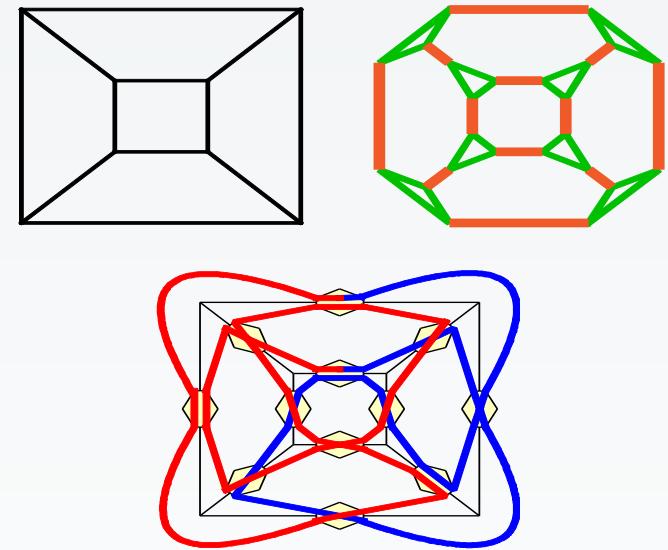
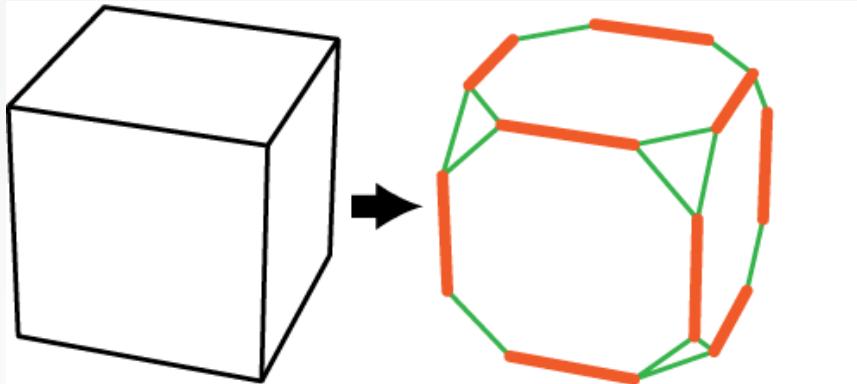


# Examples



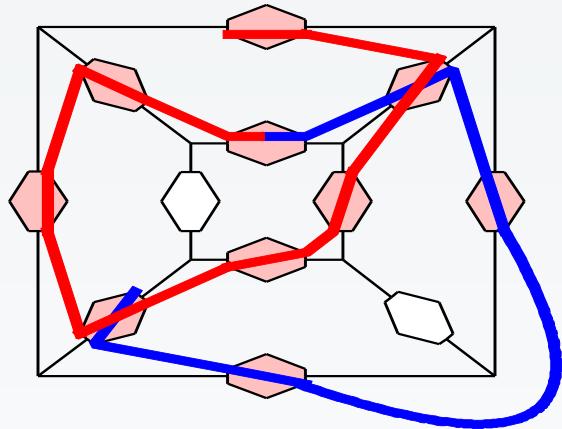
# Algorithm

# Computing Wire Path

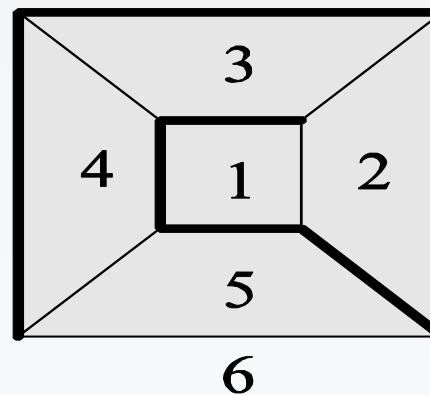


- An edge corresponds to a bead
- A wire path is given as an Eulerian Circuit

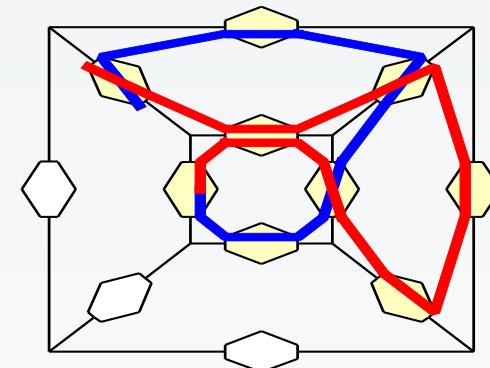
# Computing Wire Path



unstable (dangling) beads



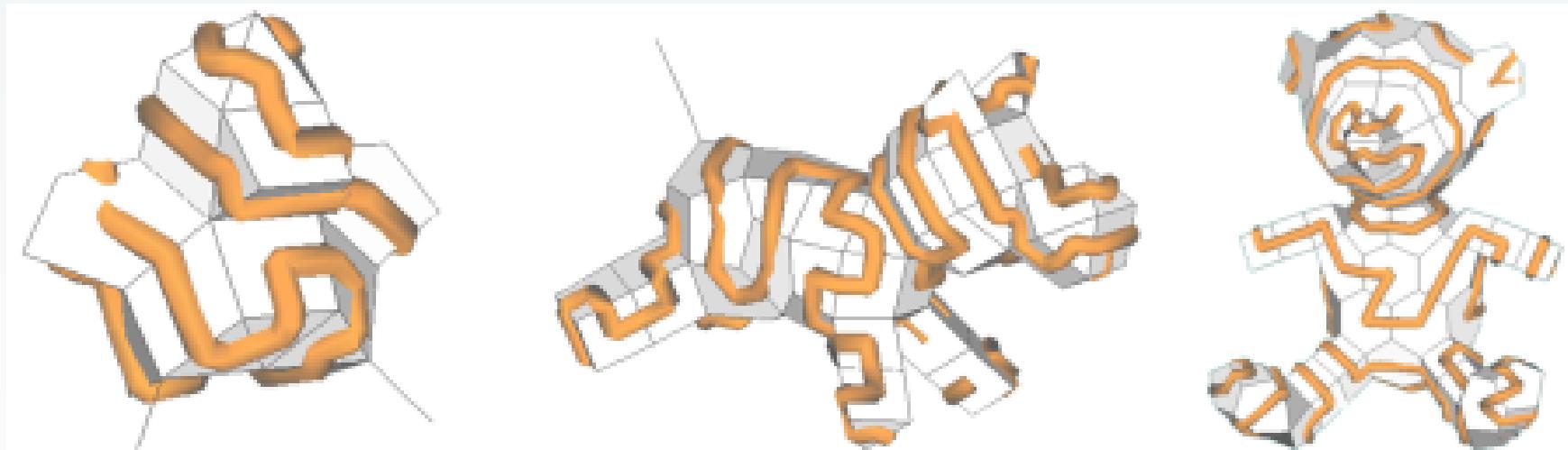
Face strip



Final wire path

- Arbitrary Euler cycle is not stable
- Make an Euler cycle along a face strip
- Face strip is given as a Hamilton path

# Stripification Results



# To Learn More...

## The original paper:

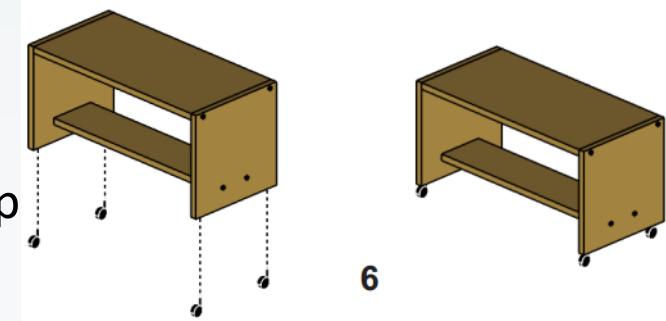
- Igarashi, et al. Beady: Interactive Beadwork Design and Construction.  
SIGGRAPH 2012.

## Step-by-step instruction:

- Agrawala, et al. Designing effective step-by-step assembly instructions. SIGGRAPH 2003.

## Surface Simplification :

- Cohen-Steiner, et al. Variational shape approximation. SIGGRAPH 2004.



[Agrawala, et al. 2003]

Copyright 2003 ACM. Included here by permission.



[Cohen-Steiner, et al. 2004]

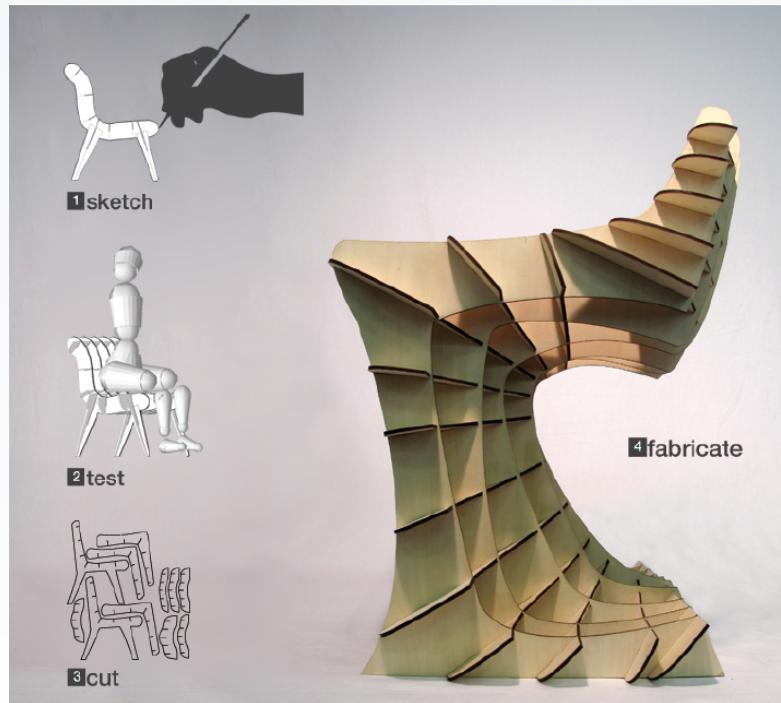
Copyright 2004 ACM. Included here by permission.

# Fabrication

- Plush toys
- Beadworks
- Chairs
- Soft Folding
- Interactive Packing

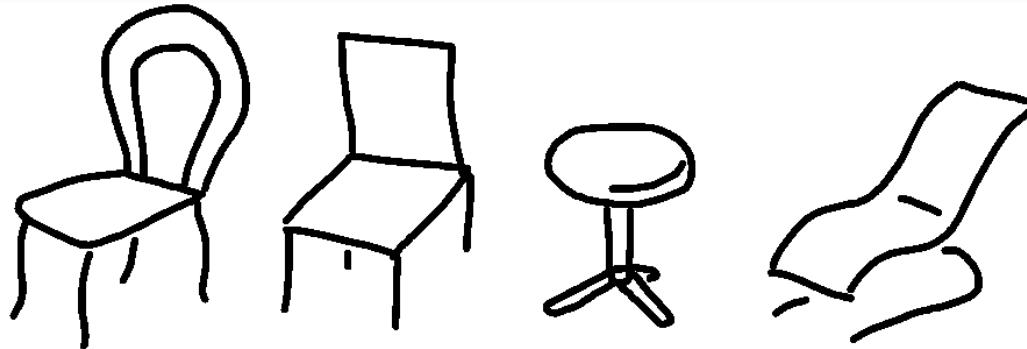
# SketchChair: An All-in-one Chair Design System for End-users

Greg Saul, Manfred Lau, Jun Mitani, and Takeo Igarashi



# Problem to Address

Design and construction of original chairs.

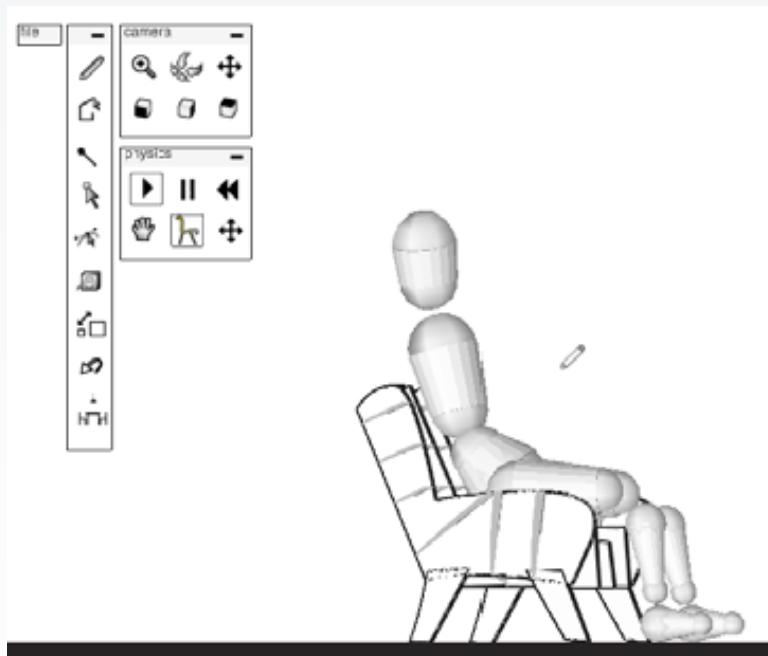


Many issues to consider

- Physical validity
- Construction

# Our Approach

A design system specialized for chairs.



- Design by sketching
- Balance test
- Construction plan

# Demo

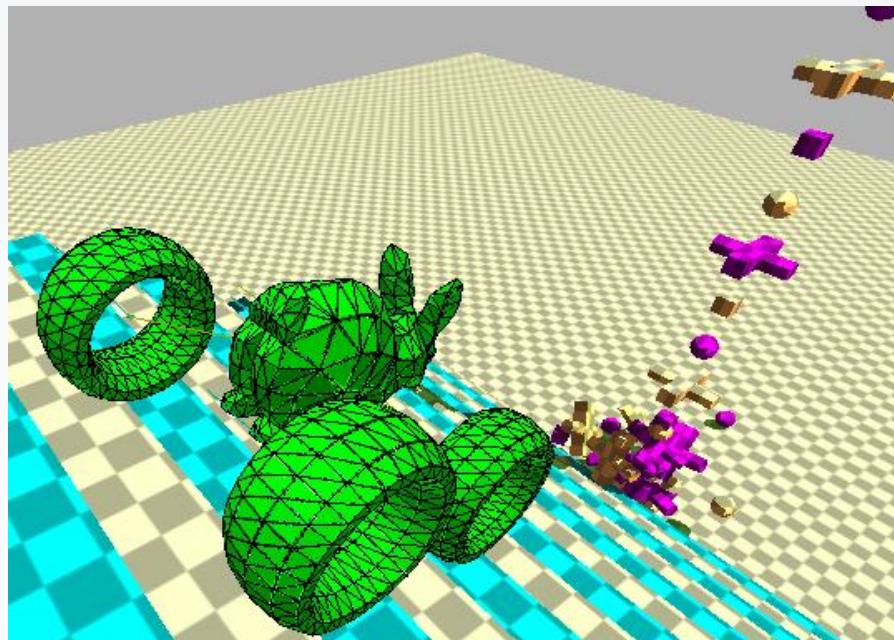
[chair](#)

[chair.mov](#)

# Physical Simulation

We use an open-source physics engine.

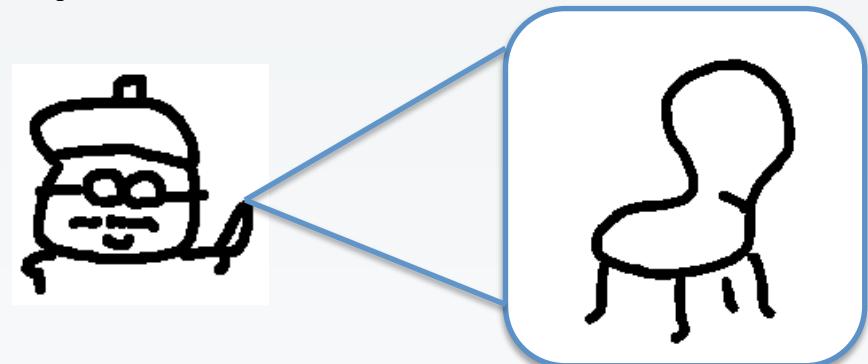
[Bullet [bulletphysics.org](http://bulletphysics.org)]



Bullet Collision Detection and Physics Library  
Copyright (c) 2012 Advanced Micro Devices, Inc.  
<http://bulletphysics.org>

# Meta-design

Designers design final products.

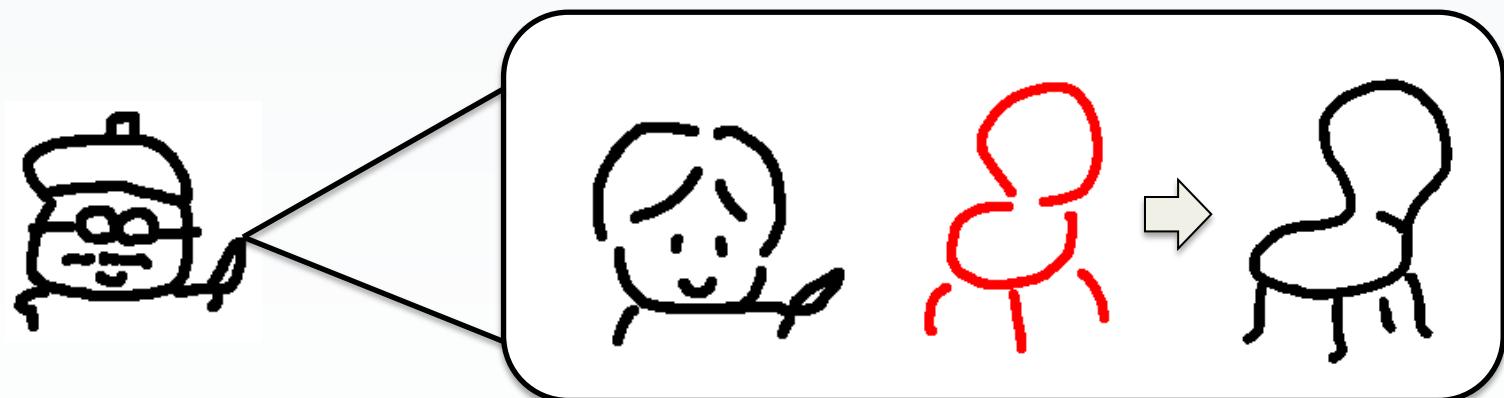


# Meta-design

Designers design final products.



Designers design “design processes.”



# To Learn More...

## The original paper:

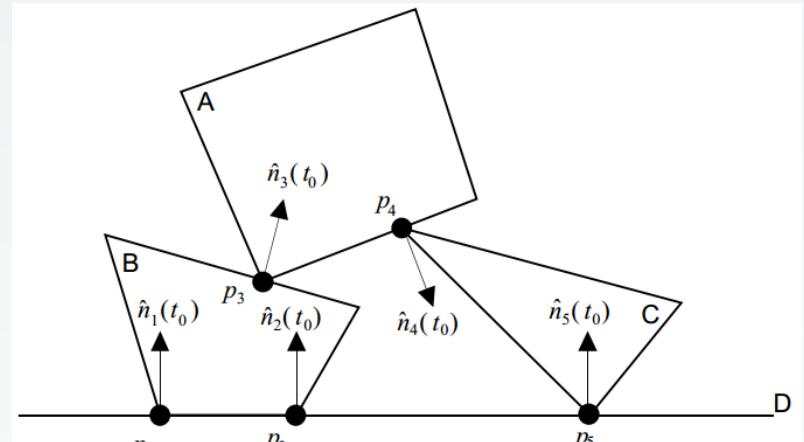
- Saul, et al. SketchChair: An All-in-one Chair Design System for End-users. TEI 2011.

## Rigid-body Physical Simulation:

- Baraff. Rigid body simulation. SIGGRAPH Course Notes 1995.
- bulletphysics.org

## Furniture design by sketching:

- FRONT Sketch Furniture. 2006,  
[http://www.youtube.com/watch?v=\\_UieXOHAjeU](http://www.youtube.com/watch?v=_UieXOHAjeU)



[Baraff 1992]  
(©2001 by David Baraff)



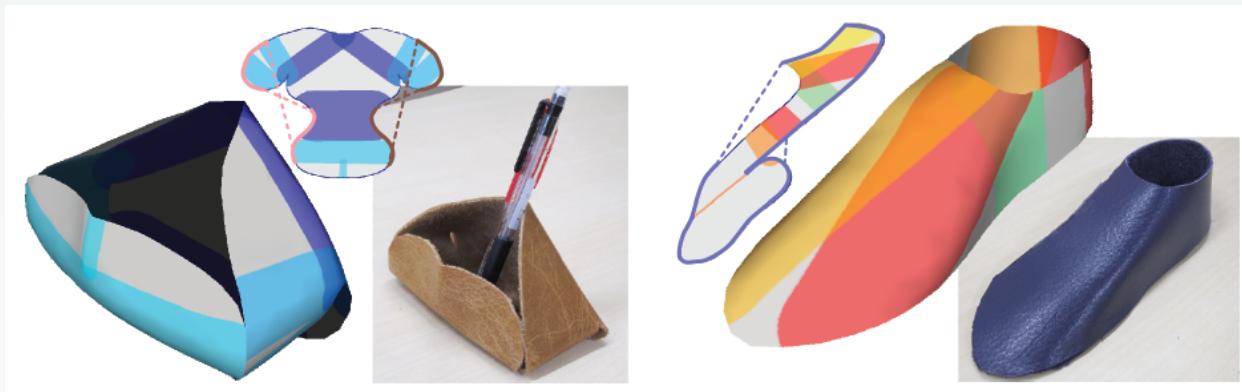
"Process" in "Collection: Sketch Furniture"

(Figure obtained from <http://www.designfront.org/category.php?id=81&product=191> with permission)

# Fabrication

- Plush toys
- Beadworks
- Chairs
- **Soft Folding**
- Interactive Packing

# Soft Folding



Lifeng Zhu

The University of Tokyo  
JST ERATO

Takeo Igarashi

The University of Tokyo  
JST ERATO

Jun Mitani

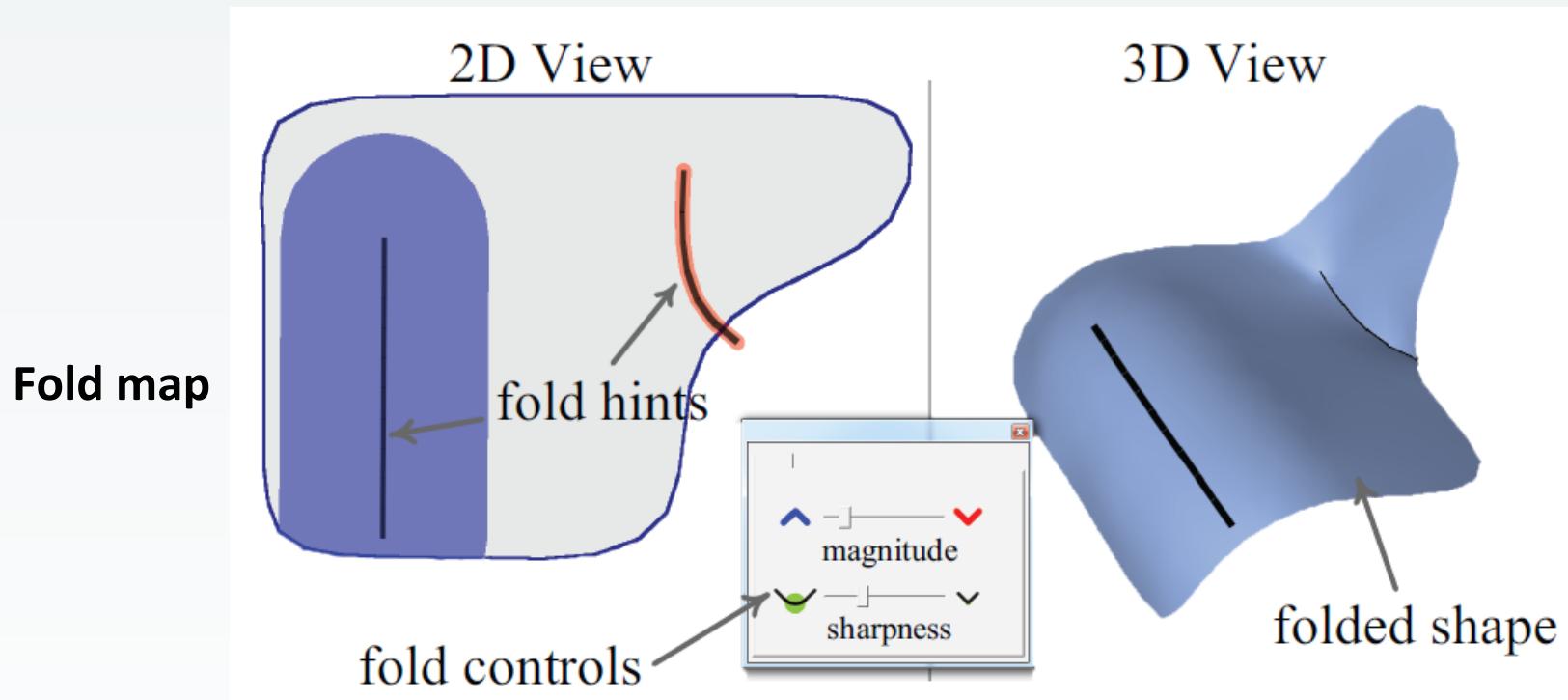
University of Tsukuba  
JST ERATO

# Motivation



Design of *softly* folded shapes

# Our Approach



Fold map with soft folds-> 3D shape

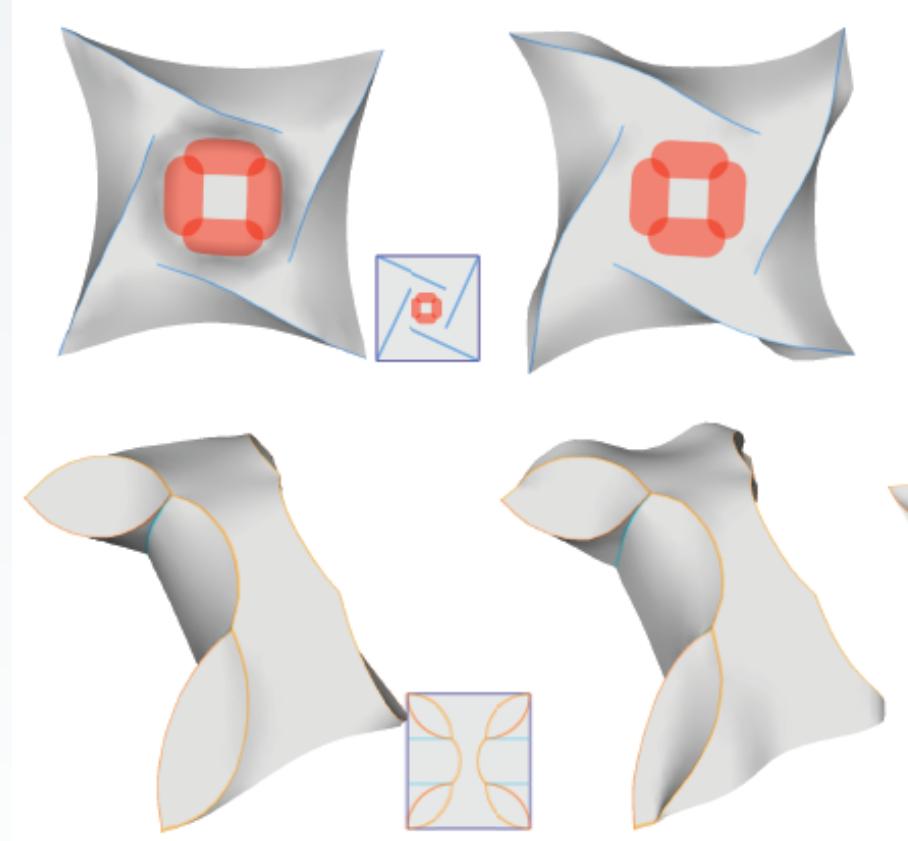
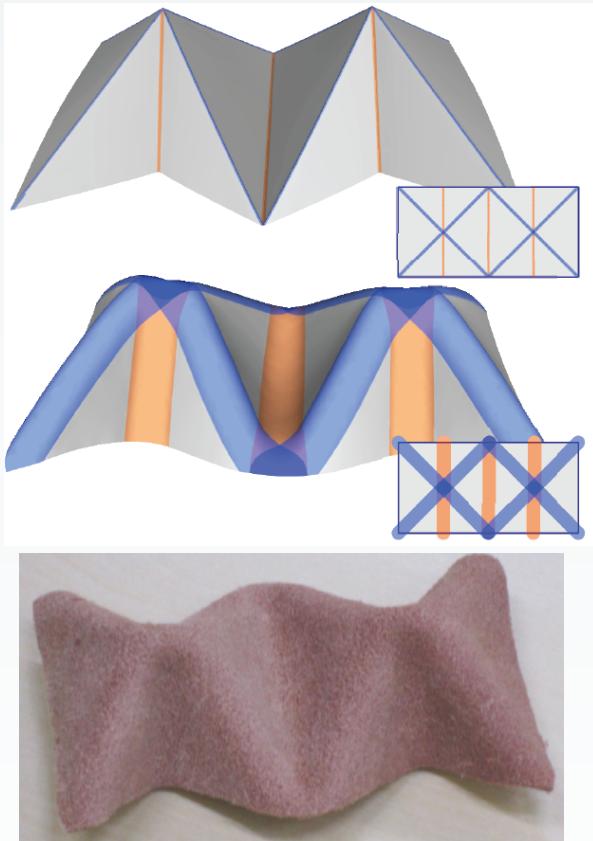
# Video

soft

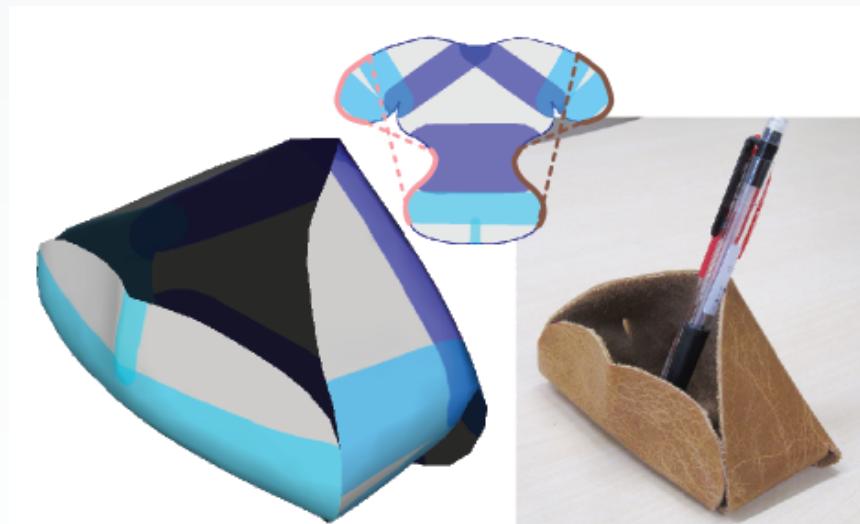
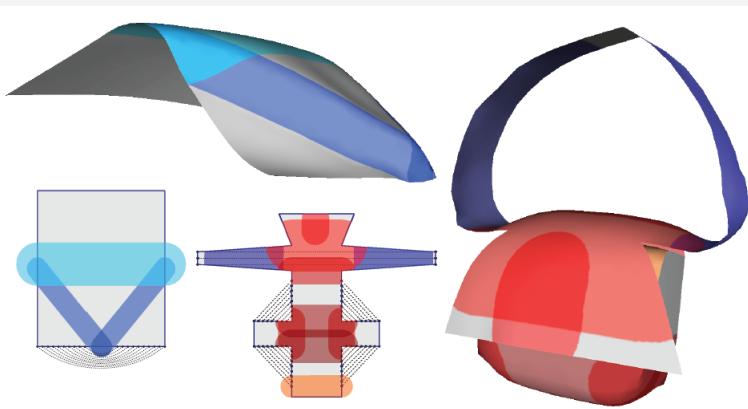


THE UNIVERSITY OF TOKYO

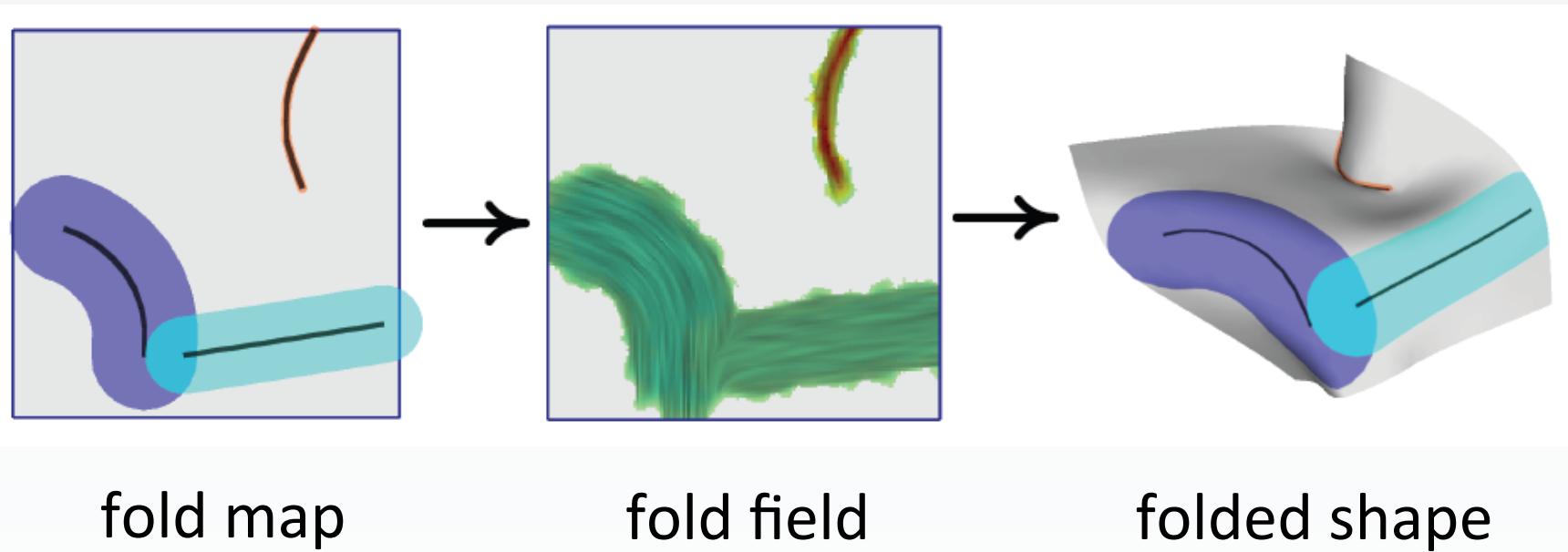
# Results



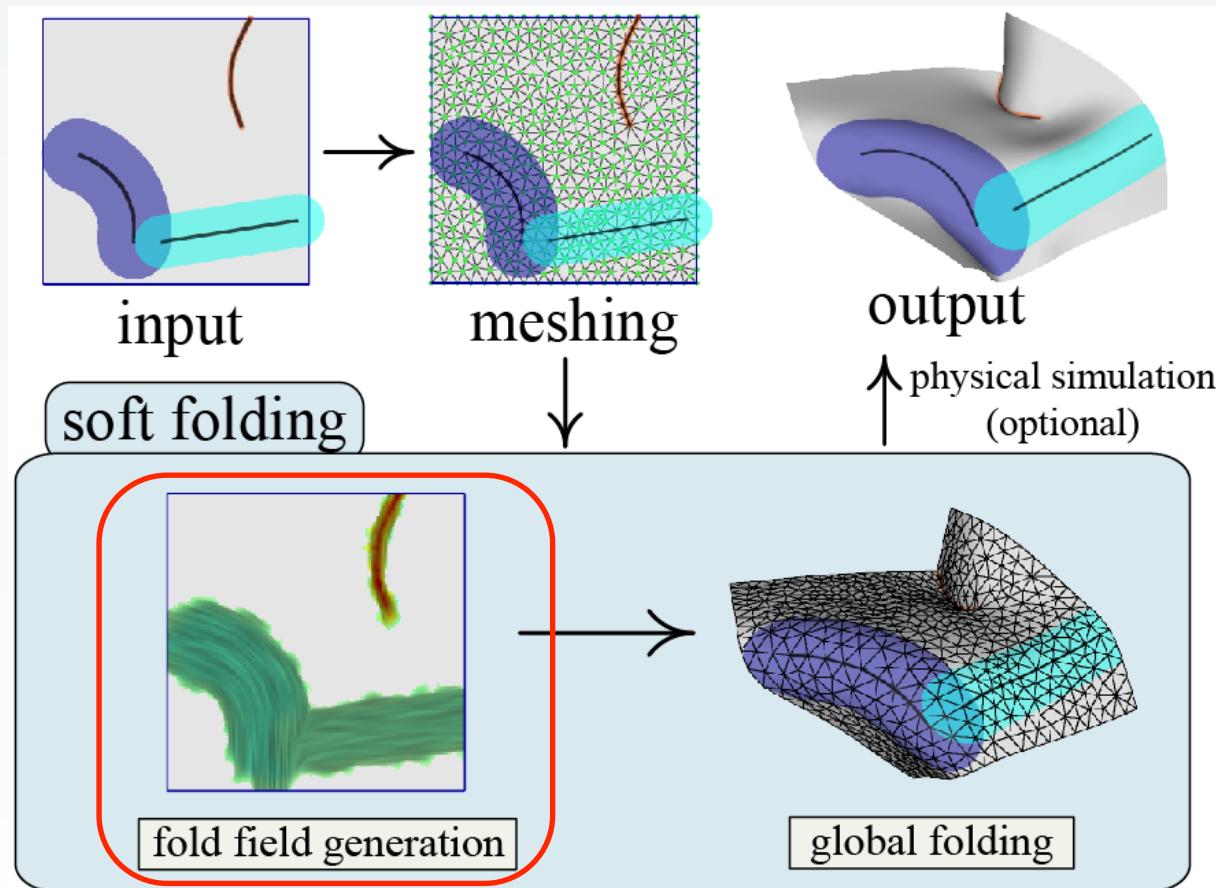
# Results



# Workflow

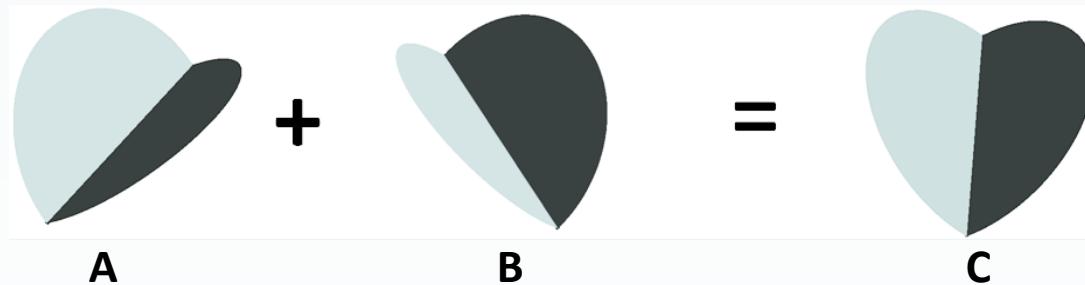


# Implementation

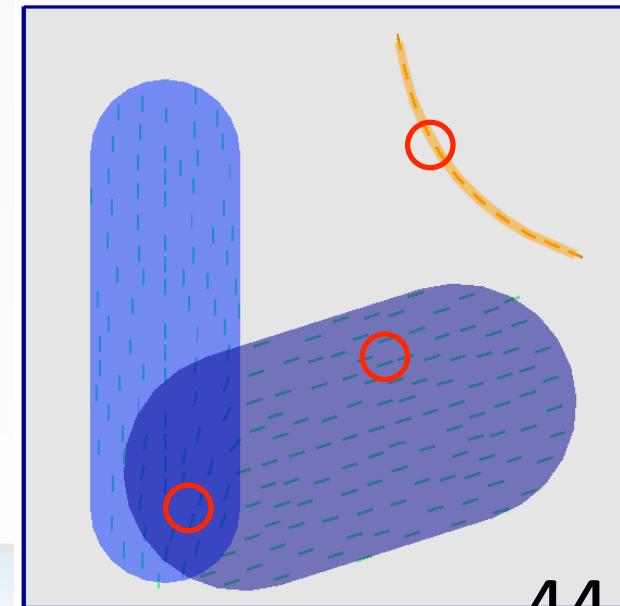


# Fold field generation

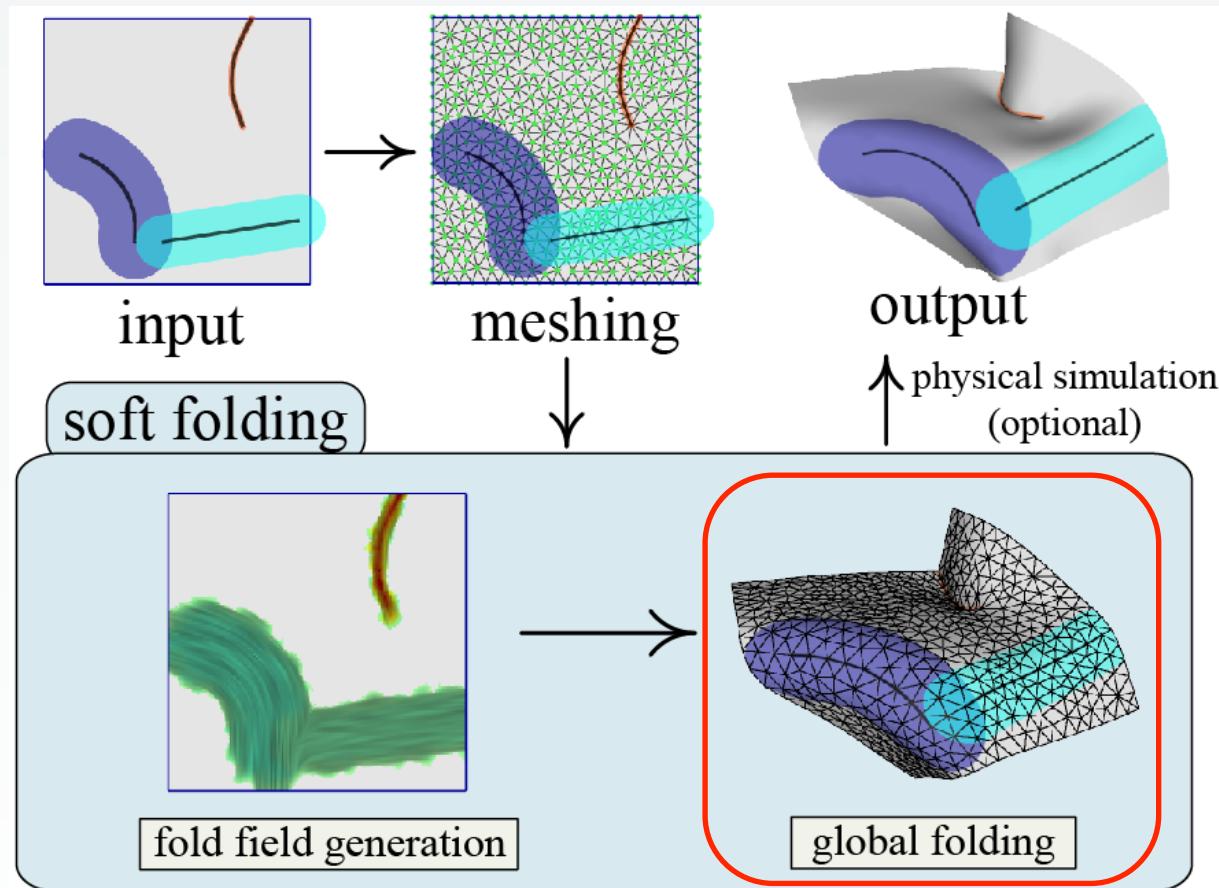
- Sharp folds: Align with fold curve's tangents
- Soft folds
  - Diffusion in non-overlapping region
  - Blending fold operations in overlapping region



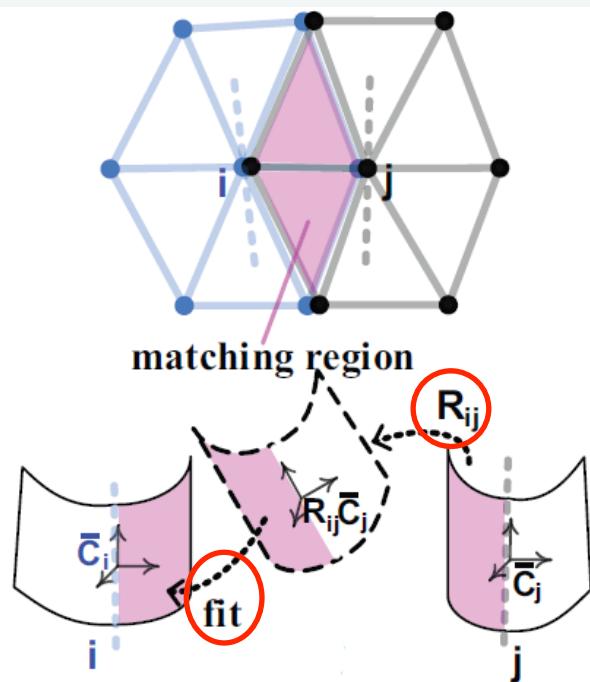
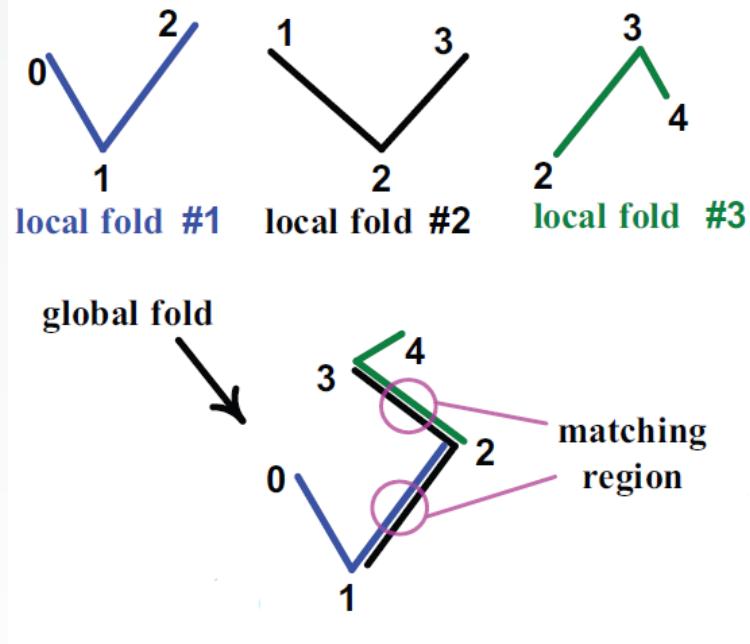
Find a fold C closest to both fold A and fold B



# Implementation



# Global folding



**Shape matching  
(local matching)**

**Linear rotational-invariant coordinates (global assembling)**  
[Lipman et.al 2005]

**Local/global operation**

# To Learn More...

## The original paper:

- Zhu, et al. Soft Folding. Pacific Graphics 2013.

## Developable Surfaces:

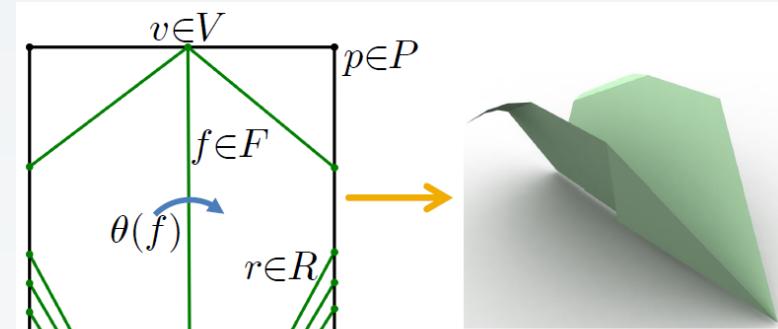
- Solomon. Flexible Developable Surfaces. SGP 2012.

## Origami Simulator

- Miyazaki, et al. An origami playing simulator in the virtual space. Visualization and Computer Animation. 1996.

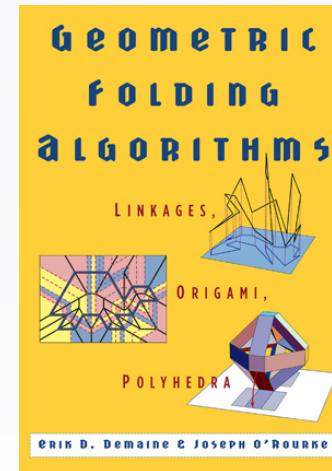
## Origami Theory:

- Demaine and O'Rourke: Geometric Folding Algorithms: Linkages, Origami, Polyhedra. Cambridge Univ. Press, 2007.



[Solomon 2012]

(Figure obtained from <http://web.stanford.edu/~justso1/>  
with permission)



[Demaine and O'Rourke 2007]

# Fabrication

- Plush toys
- Beadworks
- Chairs
- Soft Folding
- Interactive Packing

# PacCam: Material Capture and Interactive 2D Packing for Efficient Material Usage on CNC Cutting Machines



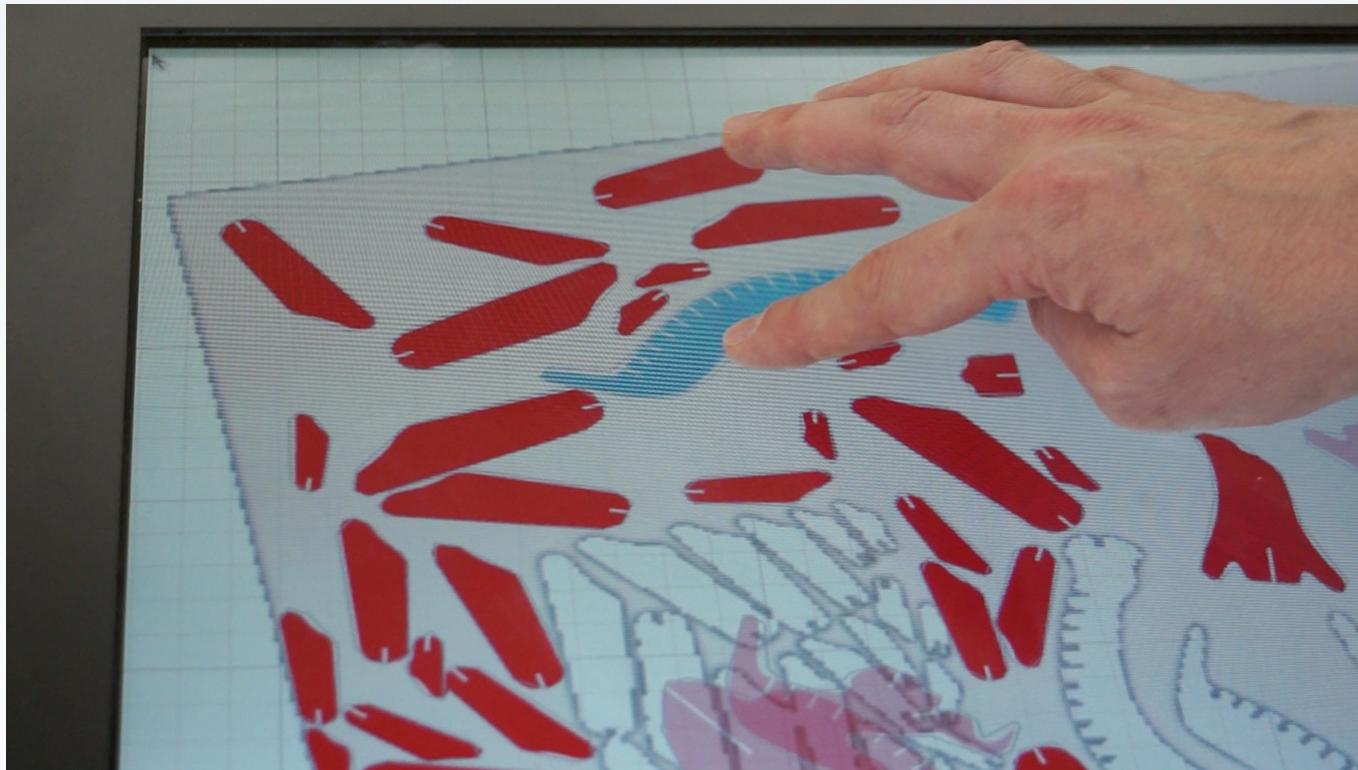
Daniel Saakes, Thomas Cambazard, Jun Mitani & Takeo Igarashi

# Motivation



How to make an efficient layout within a given Material?

# Our Approach

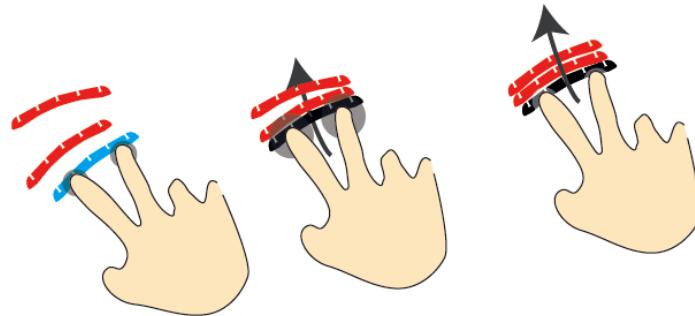


Overlap free layout that fits within the given material.

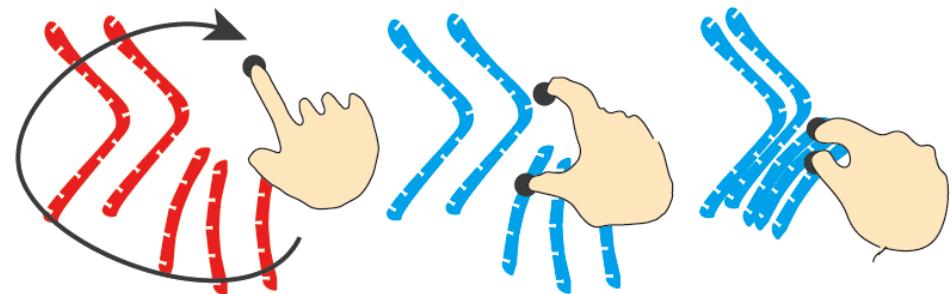
# Video

[paccam](#)

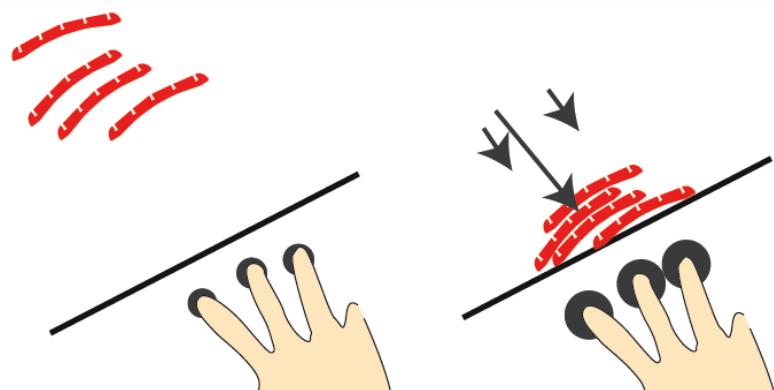
# Interactions



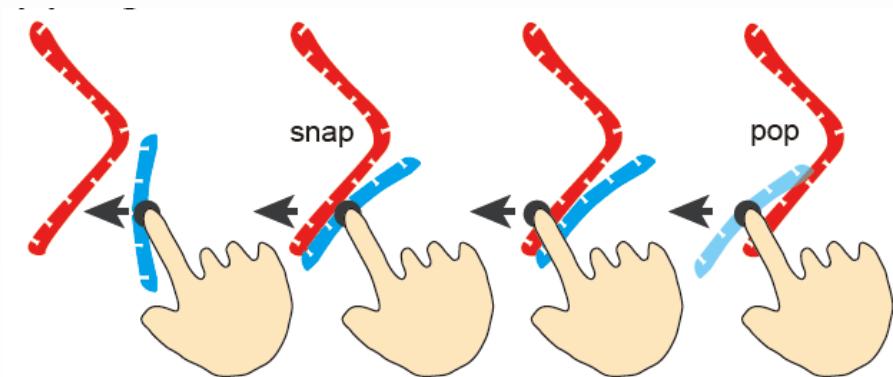
Push



Compress

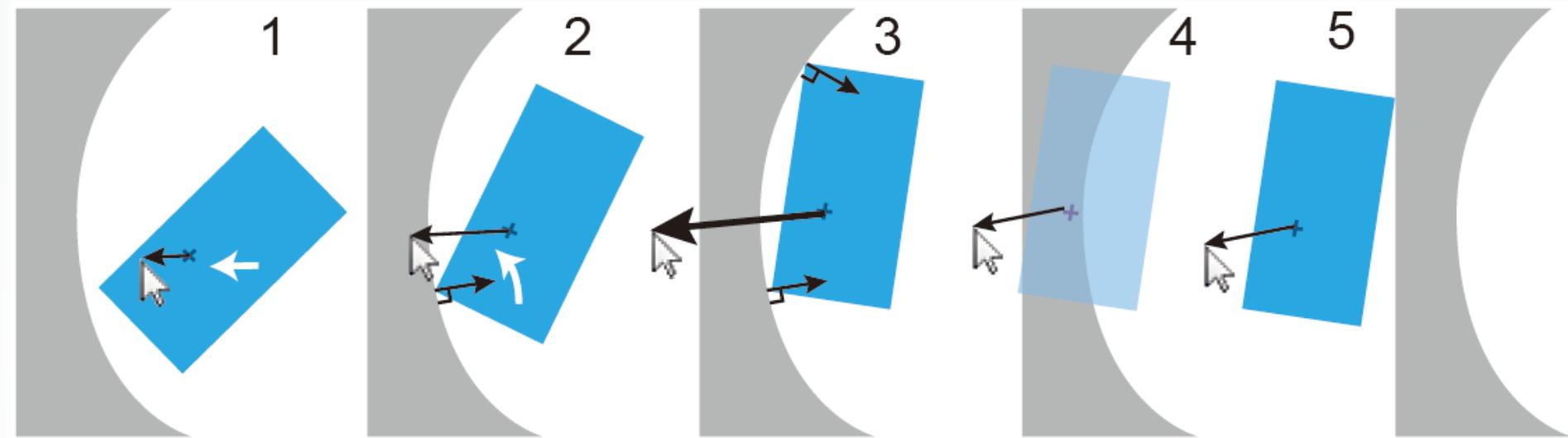


Tilt



Collision Snapping

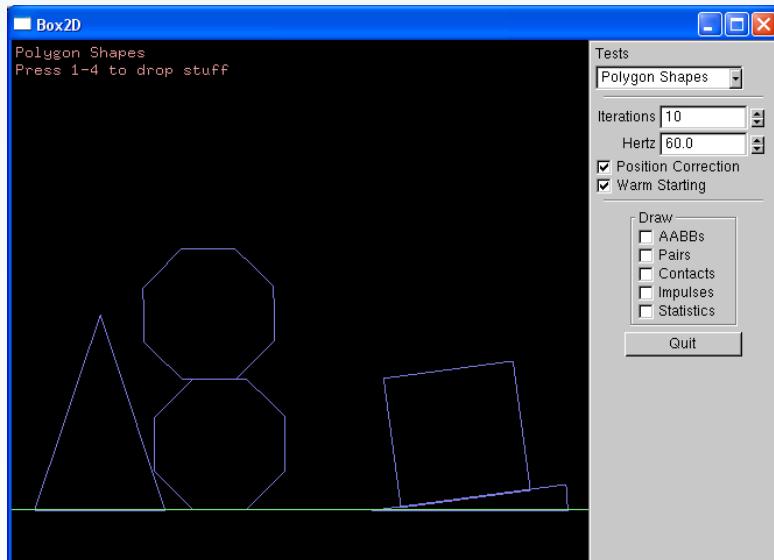
# Collision Snapping



Temporarily disable collision detection

# Implementation

We use an open-source physics engine.



[box2d <http://box2d.org> ]

# To Learn More...

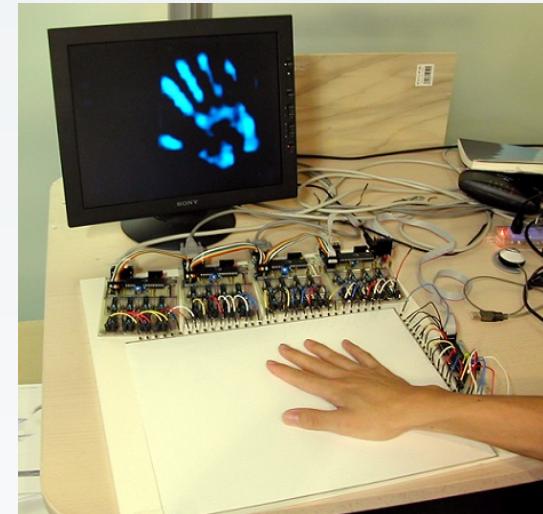
## The original paper:

- Saakes et al. PacCAM: Material Capture and Interactive 2D Packing for Efficient Material Usage on CNC Cutting Machines. UIST 2013.

## Multi-touch Interaction:

- Rekimoto. SmartSkin: an infrastructure for freehand manipulation on interactive surfaces. CHI 2002.

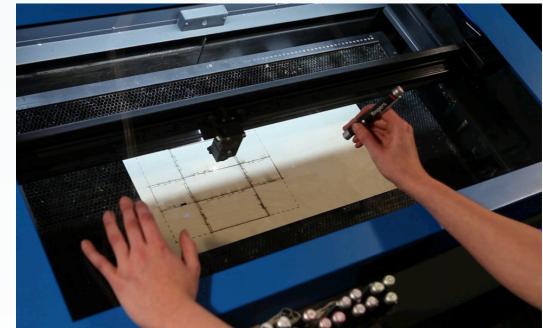
<http://lab.rekimoto.org/2011/12/28/rear-touch-user-interface/> with permission)



[Rekimoto 2002]  
(Figure obtained from  
<http://lab.rekimoto.org/2011/12/28/rear-touch-user-interface/> with permission)

## Controlling Laser Cutters:

- Müller, et al. Interactive construction: interactive fabrication of functional mechanical devices. UIST 2012.



[Müller, et al. 2012]  
(Figure obtained <http://stefaniemueller.org/constructable-interactive-lasercutting/> with permission)

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- Plush toys
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