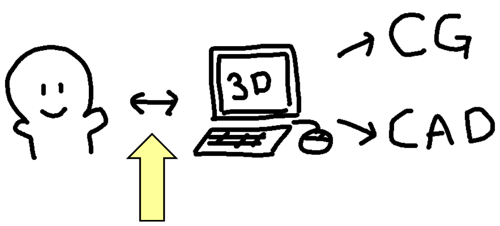
Interactive Computer Graphics

Schedule

6/7 Design and Evaluation
6/14 Selected Topics , 課題出題
7/21 User Centered Design by Nolwenn Maudet
6/28 Interactive Computer Graphics, 課題構想発表
7/5 Crowd Sourcing and Human Computation
7/9 課題レポート締切 (深夜)
7/12 課題成果発表

五十嵐 健夫 ⇨ / 講義情報 /

対話的形状モデリング

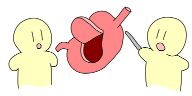


コンピュータで形状データを作成・編集する。

Goal

Dedicated construction by experts for later presentation

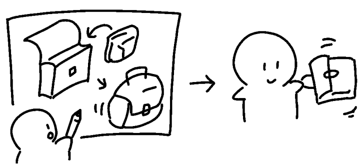
Instant construction by novices for live communication



Goal

Farewell to Mass Production and Consumption

"Design Your Own Artifacts by Yourself"



Interactive Computer Graphics

2D Graphics

3D Graphics

Fabrication

2D Graphics

UIST'97 & CHI'98

Pegasus:
a Drawing System for Rapid Geometric Design

Takeo Igarashi, Sachiko Kawachiya,
Satoshi Matusoka, Hidehiko Tanaka

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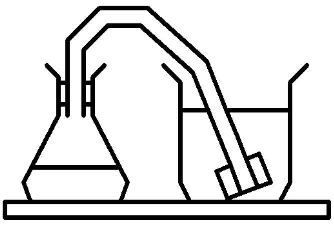
Problem



How do you draw this?

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Demo

pegasus

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Algorithm

1. Beautification
2. Prediction

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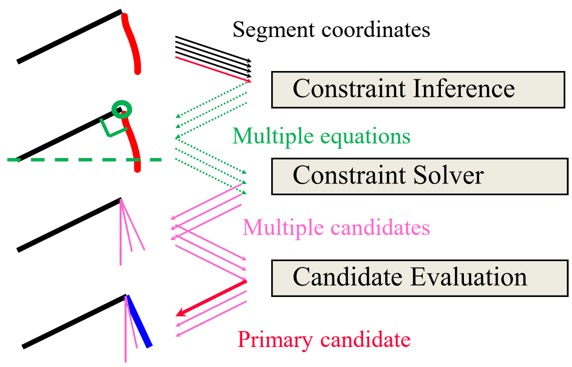
1. Beautification Algorithm



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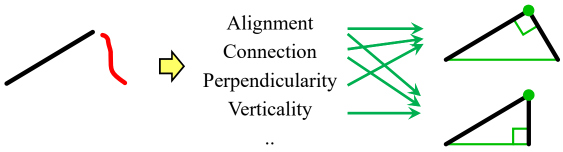
Constraint Solver



Find valid combination of constraints.

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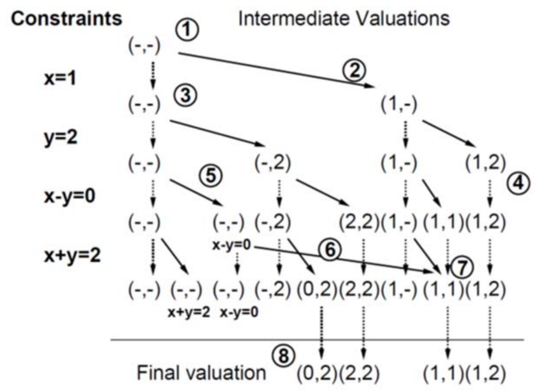

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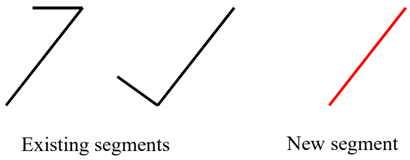
2. Prediction Algorithm



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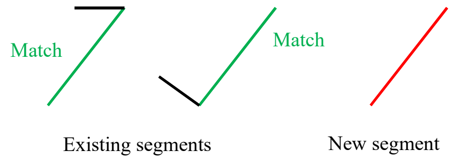
2. Prediction Algorithm



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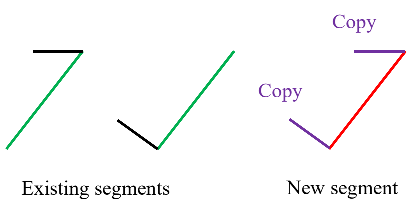
2. Prediction Algorithm



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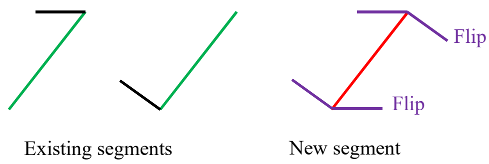
2. Prediction Algorithm



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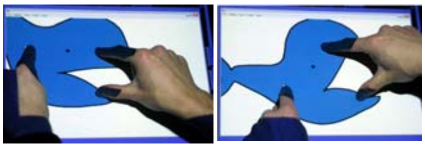
As-Rigid-As-Possible Shape Manipulation



Takeo Igarashi, Tomer Moscovich, John F. Hughes

The University of Tokyo / Brown University

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Goal

Move and deform 2D shapes as if manipulating real objects

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Space-Warp

Deform space, not object.
Different from reality…

Physics (mass-spring model)

Slow to converge…
Unstable, need tuning…

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Demo

rigid

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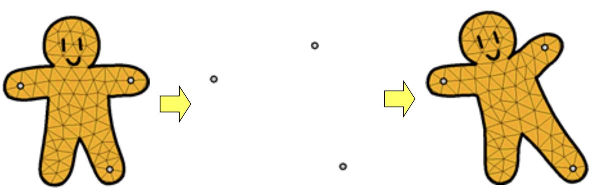
Algorithm



Minimize shape distortion, satisfying constraints.
Closed-from solution, not iterative.

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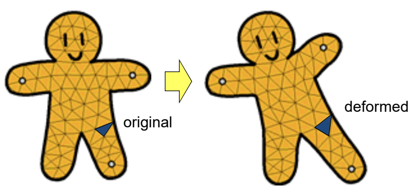
Input: coordinates of handles (**q**)

Output: coordinates of mesh vertices (**u**)

Minimize: distortion of triangles



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Minimize Distortion of Triangles

$$\underset{u \in MeshVertices}{\arg\min} \sum_{t \in Triangles} E_t(u)$$

We want such *E* that…

Translation, Rotation (rigid transformation) ~ $E=0$
Scale, Stretch, Shear ~ $E>0$

E should be quadratic in **u**

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Ideally,

Translation, Rotation ~ $E = 0$
Scale, Stretch, Shear ~ $E > 0$

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Ideally,

Translation, Rotation ~ $E = 0$
Scale, Stretch, Shear ~ $E > 0$

Unfortunately, there is no such "quadratic" energy!

We therefore combine two complementary energies.

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Ideally,

Translation, Rotation ~ $E = 0$
Scale, Stretch, Shear ~ $E > 0$

We combine two quadratic energies.

E_1 Translation, Rotation, Scale ~ $E_1 = 0$
Stretch, Shear ~ $E_1 > 0$

E_2 Translation ~ $E_2 = 0$
Rotation, Scale, Stretch, Shear ~ $E_2 > 0$

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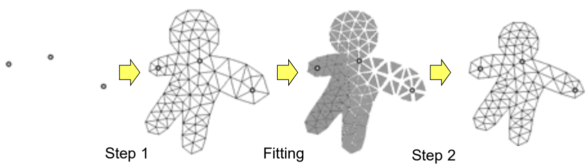
Two-Step Algorithm



Step 1: Obtain intermediate result by using E_1, allowing scaling.

Fitting: Fit correct-sized individual triangle to the result.

Step 2: Stitch fitted triangles by using E_2.

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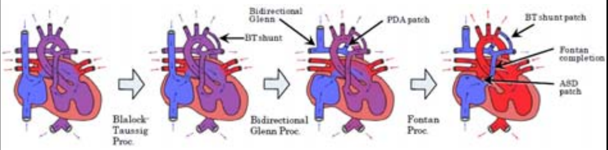
SIGGRAPH Asia 2011

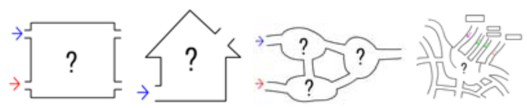
Sketch-based Dynamic Illustration of Fluid Systems

B. Zhu, M. Iwata, R. Haraguchi, T. Ashihara, N. Umetani, T. Igarashi, K. Nakazawa



30

Tedious to illustate fluid flow…



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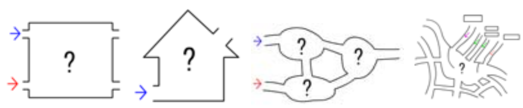
Tedious to illustate fluid flow…



Automatic flow visualizaition.

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Video

fluid

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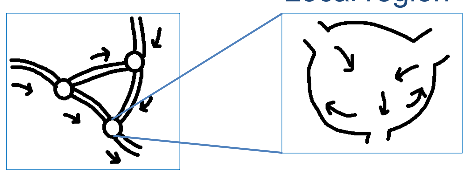
Hybrid Fluid Simulation

Global network

Local region



Hydraulics

Hydrodynamics

Node Inflow → Pipe Flow, Node Pressure → Details within regions

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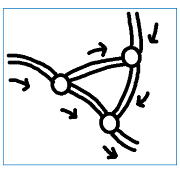
Global network



Hydraulics

Node Inflow → Pipe flow

$$Q_n = -\mathbf{M} Q_e$$

Pipe flow → Pipe pressure drop

$$Q_e = \mathbf{D}_e P_e$$

Pipe pressure drop → Node pressure

$$P_e = -\mathbf{M}^T P_n$$

Solve a global linear system.

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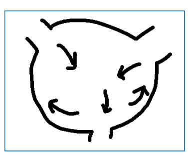
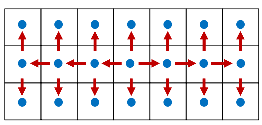
Local region



Hydrodynamics



Velocity

Pressure

$$\frac{\partial \mathbf{u}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{u} = -\frac{1}{\rho} \nabla p + \mathbf{g} + \nu \nabla \cdot \nabla \mathbf{u},$$

$$\nabla \cdot \mathbf{u} = 0,$$

(Navier-Stokes Equation)

Solve this on grid cells inside each region.

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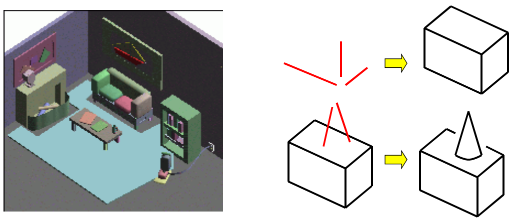
3D Graphics

SKETCH

[Zeleznik 96]



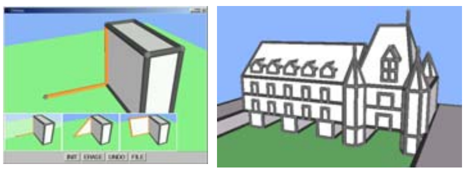
- 3D scene construction using gestures.
- "Every object is on top of another object"

sketch.avi

UIST 01

Chateau: a suggestive interface for 3D modeling

Takeo Igarashi, John F. Hughes



User interface using hints and suggestions

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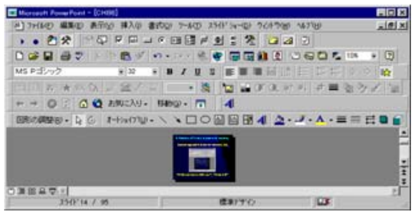
Motivation



So many commands in nested menus!

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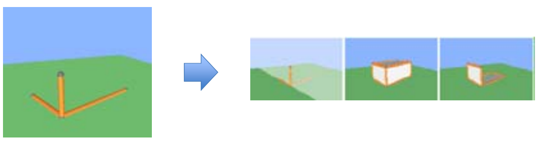
Our Approach



Hints

(arguments)

Suggestions

(commands)

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Demo

Chateau

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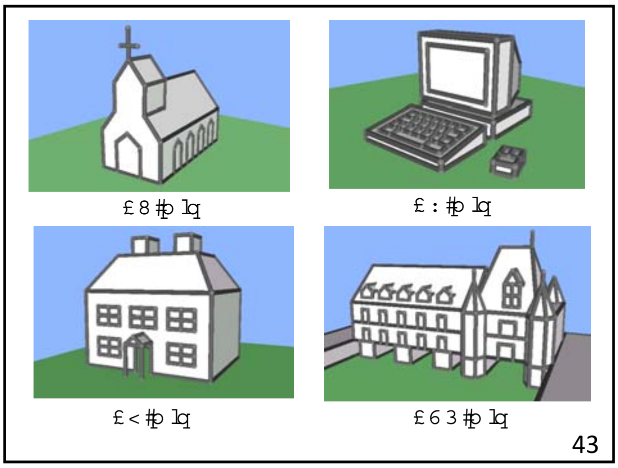
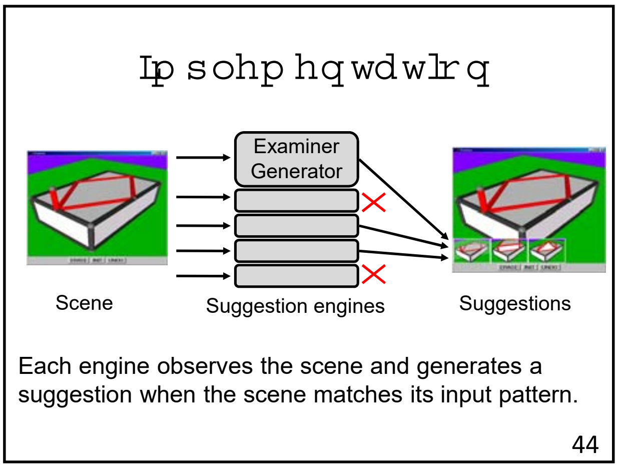

£8#p lq
£:#p lq
£<#p lq
£63#p lq
43


Ip sohp hqwdwlrq
Examiner Generator
Scene
Suggestion engines
Suggestions
Each engine observes the scene and generates a suggestion when the scene matches its input pattern.
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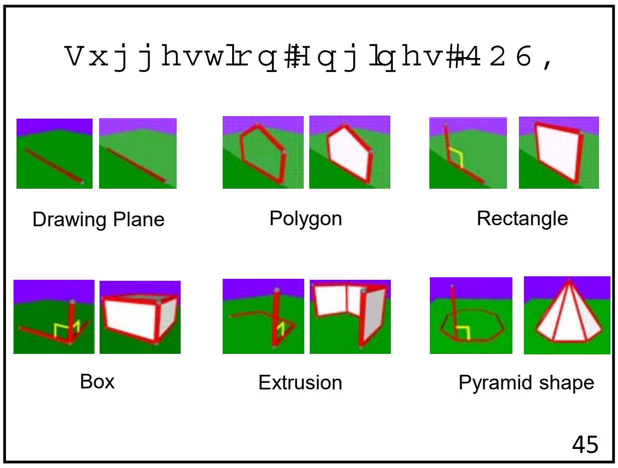
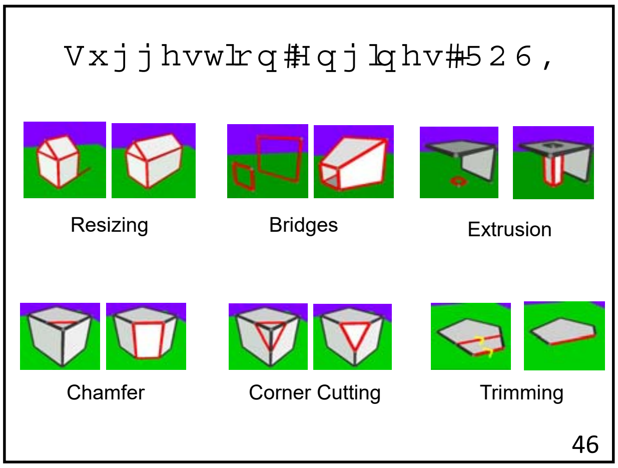
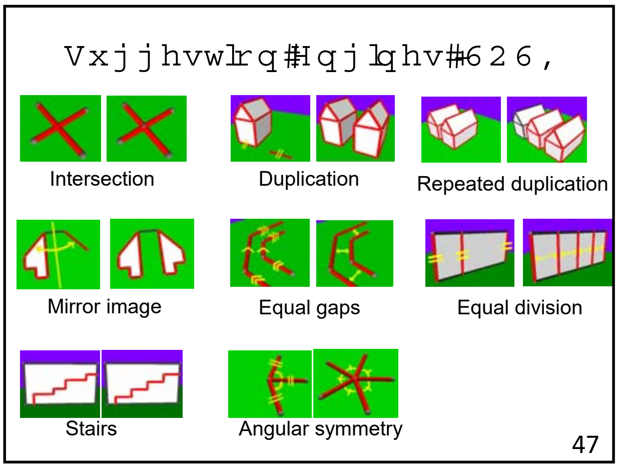
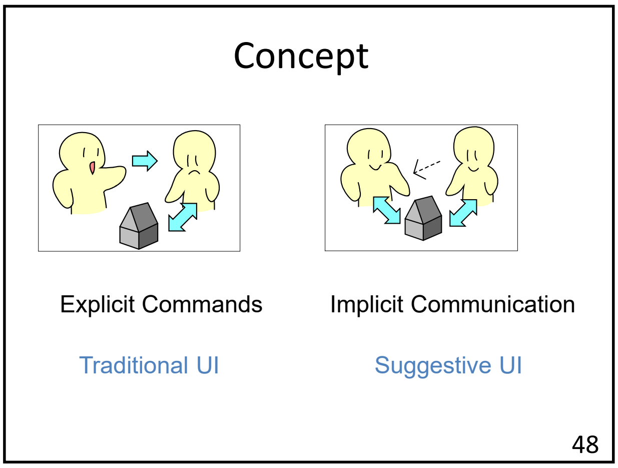

Vxjjhvwlrq#Hqjlqhv#4 2 6 ,
Drawing Plane
Polygon
Rectangle
Box
Extrusion
Pyramid shape
45


Vxjjhvwlrq#Hqjlqhv#5 2 6 ,
Resizing
Bridges
Extrusion
Chamfer
Corner Cutting
Trimming
46


Vxjjhvwlrq#Hqjlqhv#6 2 6 ,
Intersection
Duplication
Repeated duplication
Mirror image
Equal gaps
Equal division
Stairs
Angular symmetry
47


Concept
Explicit Commands
Implicit Communication
Traditional UI
Suggestive UI
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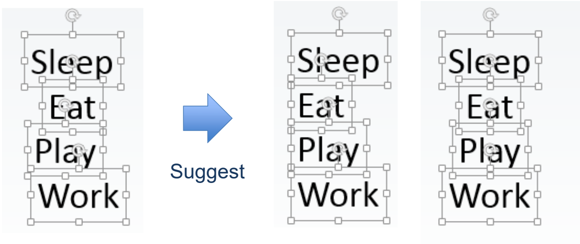
Ixwxuh#Z run

Other applications (e.g. PowerPoint)



Roughly aligned   Align left   Align center

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Teddy: A Sketching Interface for 3D Freeform Design

SIGGRAPH 99
Impact paper

Takeo Igarashi
Satoshi Matsuoka
Hidehiko Tanaka

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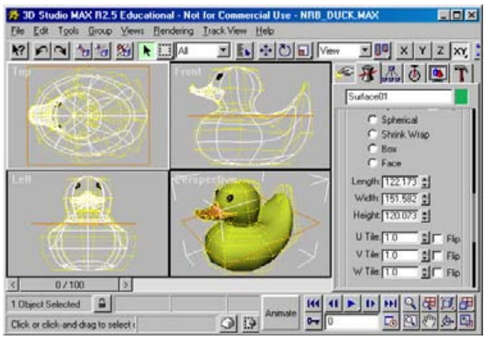
3D modeling is difficult



Sketching is easy!

Demo

teddy   video

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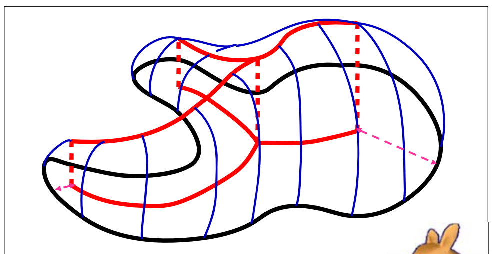
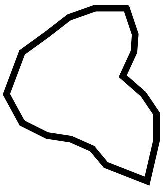
Algorithm



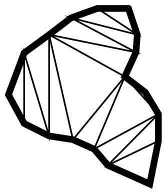
1. Find axes
2. Elevate axes
3. Wrap polygon and axes

Creation -Finding axes-



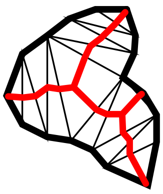
Input 2D polygon

Creation -Finding axes-



Constrained Delaunay Triangulation

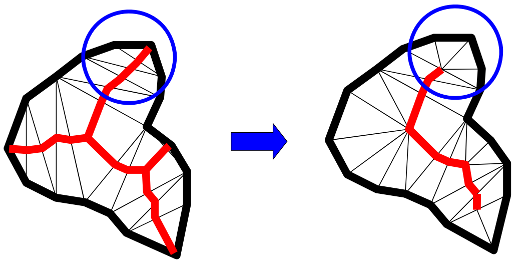
Creation -Finding axes-



Chordal axis (connecting mid-points)

[Prasad 1997]

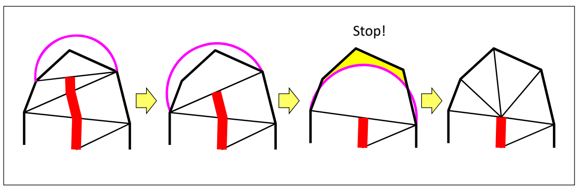
Creation -Finding axes-



Before trimming

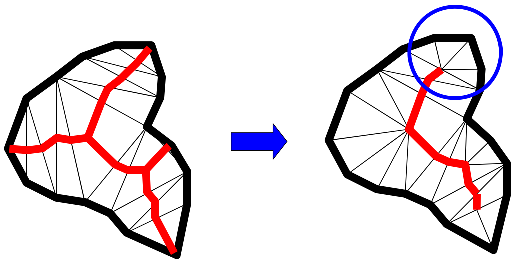
After trimming

Creation -Trimming-



Starting from each terminal,
search for the first significant edge.

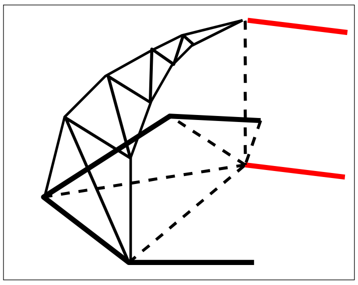
Creation -Finding axes-



Before trimming

After trimming

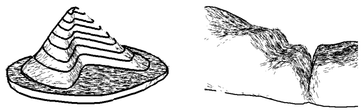
Creation -Wrapping-




Lift the axes, and generate 3D faces along the spine.

Applications

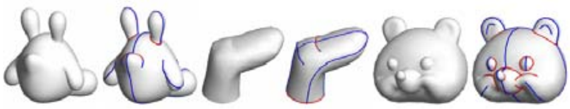
- Teaching Geography



teddy

SIGGRAPH 2007

FiberMesh: Designing Freeform Surfaces with 3D Curves



Nealen, Igarashi, Sorkine, Alexa

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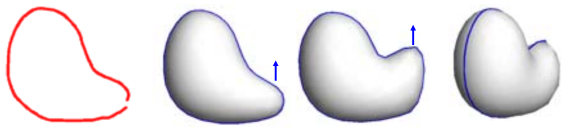
Designing with "Curves"

Original sketch stays and works as a handle.



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Demo

fibermesh

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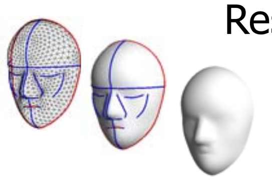
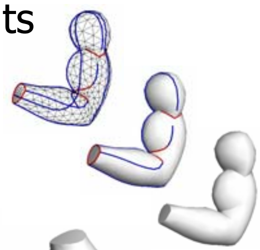
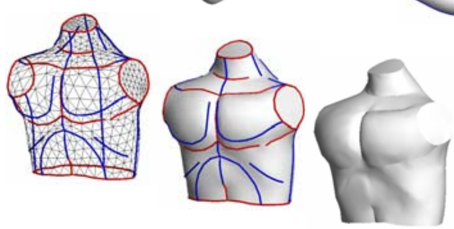
Results

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Algorithm

1. Curve Deformation
   Handle position -> Curve geometry
2. Surface Optimization
   Curve geometry -> Surface Geometry

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1. Curve Deformation

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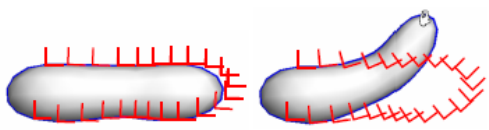
Curve Deformation

Explicitly represent rotations with 3x3 matrix.

Minimize the change of rotated laplacian and difference between neighboring rotations.



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Curve Deformation

Explicitly represent rotations with 3x3 matrix.

Minimize the change of rotated Laplacian and difference between neighboring rotations.

$$\arg\min_{\mathbf{v},\mathbf{R}} \Big\{ \sum_i \|\mathbf{L}(\mathbf{v}_i) - \mathbf{R}_i \delta_i\|^2 + \sum_{i,j \in E} \|\mathbf{R}_i - \mathbf{R}_j\|^2 + \sum_{i \in C_1} \|\mathbf{v}_i - \mathbf{v}'_i\|^2 + \sum_{i \in C_2} \|\mathbf{R}_i - \mathbf{R}'_i\|^2 \Big\},$$

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2. Surface Optimization

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Surface Optimization

Input: Curve geometry, mesh topology
Output: Smooth surface

Strategy: Minimize variation of curvature

$$E_c = \int_S \left(\frac{d\kappa_n}{d\hat{e}_1}\right)^2 + \left(\frac{d\kappa_n}{d\hat{e}_2}\right)^2 dA,$$

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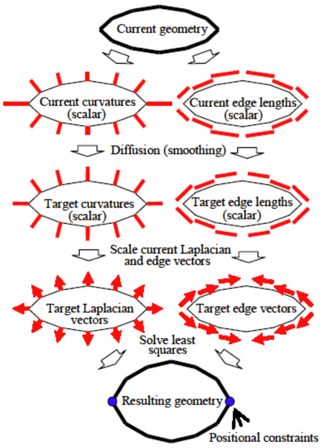

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SCA 2010

Spatial Keyframing for Performance-driven Animation

Takeo Igarashi, Tomer Moscovich, John F. Hughes
The University of Tokyo, Brown University

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Motivation

Creation of character animation is tedious.

- Keyframe
- Motion capture
- Physics simulation
- Scripting

We want to “sketch” animations quickly.

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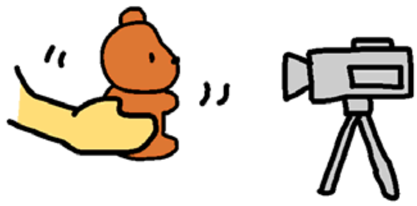
Basic idea



“To record the user’s direct operations”

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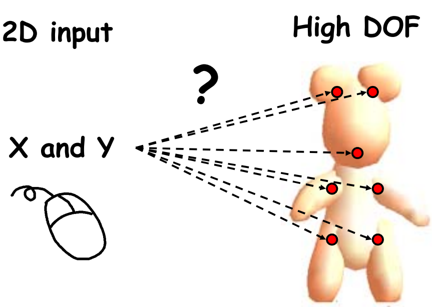
Problem



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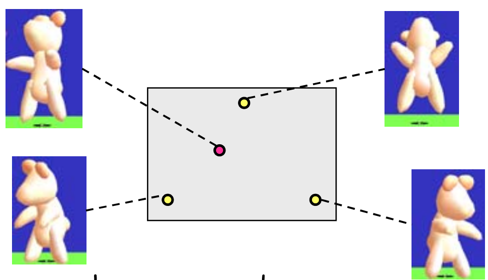
Spatial Keyframing



Prepare key poses and
blend them during performance

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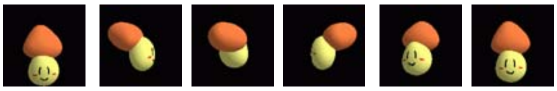
Demo



[squirrel]

79

Algorithm

80

Algorithm

Input: handle coordinates (x,y)

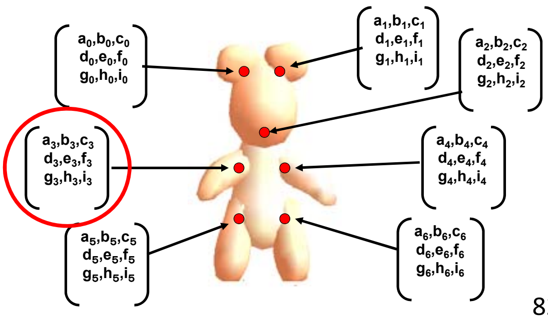
Output: orientation of each joint

How to represent orientation?

We use **rotation matrix** instead of euler angles or quaternions.

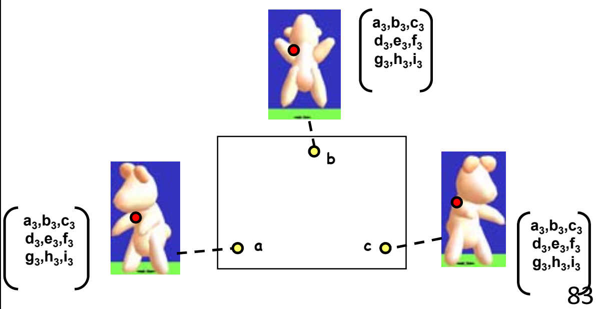
81

Representing poses with 3x3 rotation matrices



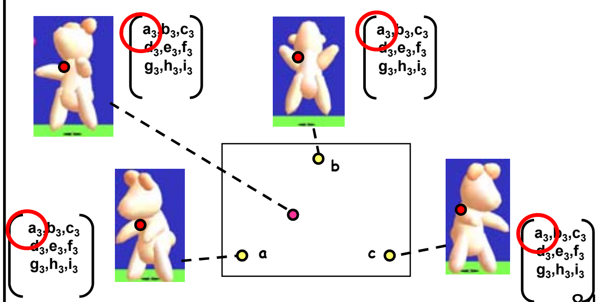
82

Individually blends each entry using PBFs



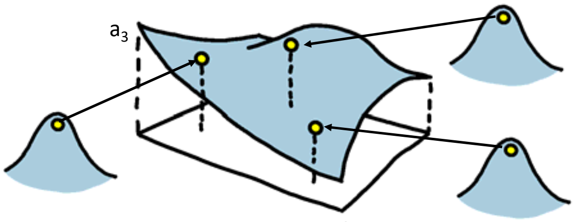
83

Individually blends each entry using PBFs



84

Scattered data interpolation using radial basis functions

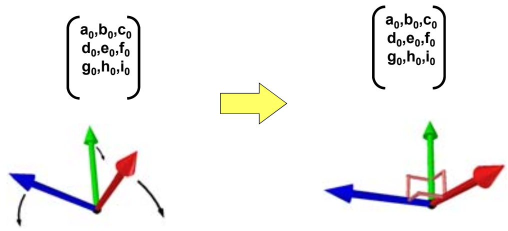


Construct smooth height field
as summation of RBFs.

[Turk 02]

85

Orthonormalization



Blended matrix might not be orthonormal.
So we orthonomazile them.

86

Summary

Spatial key-framing for character animation.

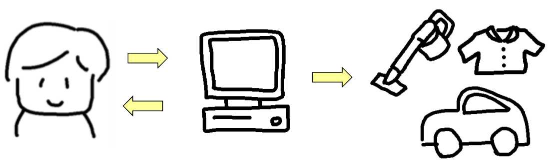
The user defines key poses in a space.
The system blends nearby poses.

Rotation matrix representation and
Radial basis function interpolation.

87

Fabrication

Computer-aided Design

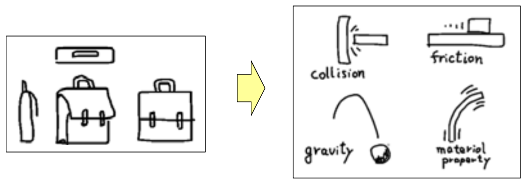


Designer Computer Products

89

Traditional Approach

Modeling and simulation are separated.



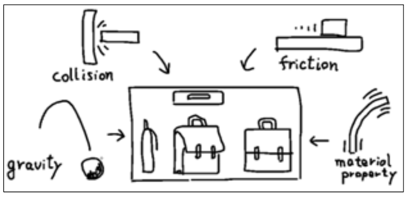
Design
(Modeling)

Test
(Simulation)

90

Our Approach

Integrate real-time physics into modeling.

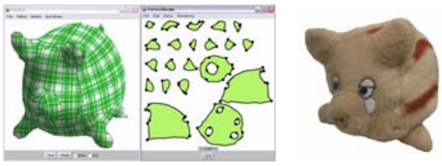


91

SIGGRAPH 2007

Plushie: An Interactive Design System for Plush Toys

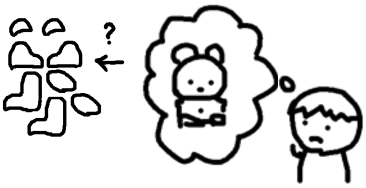
Yuki Mori, Takeo Igarashi



92

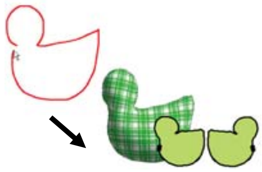
Problem to Address

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



93

Our Approach



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

94

Video

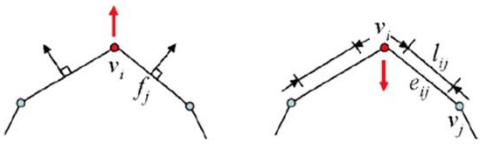
plushie.mp4

95

Algorithm

96

Inflation Simulation

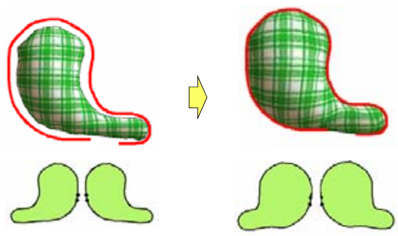


Pushing outwards (air pressure) | Pulling back (cloth tension)

We use a simple mass-spring method.

97

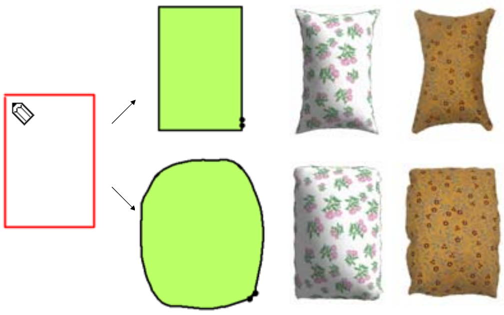
Adjustment Process



Adjusts the pattern so that simulation result matches with the sketch

98

Physical Simulation & Shape Adjustment



99

SIGGRAPH 2012

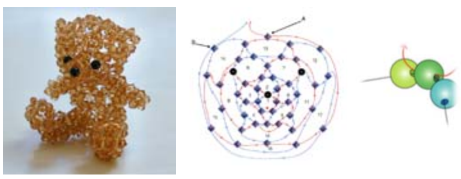
Beady: Interactive Beadwork Design and Construction

Y. Igarashi, T. Igarashi and J. Mitani

100

Problem to Address

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



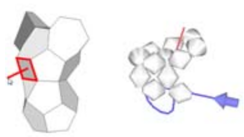
3D

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

101

Our Approach

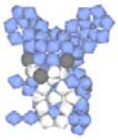
- Interactive Design and Construction



- Wire path planning algorithm

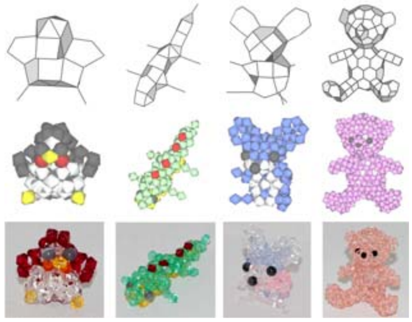
102

Demo



demo beady 103

Examples

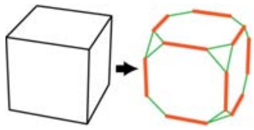


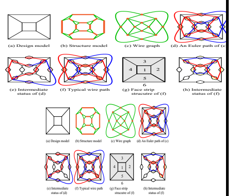
104

Algorithm

105

Computing Wire Path

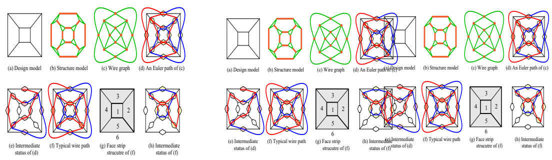




- An edge corresponds to a bead
- A wire path is given as an Eulerian Circuit

106

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

107

Stripification Results

(34, 0)   (95, 4), (4, 0)   (149, 3)

108

TEI 2011

SketchChair

With Greg Saul

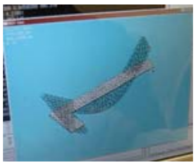
- Wkh#xvhu#gudz v#wkh#rxwolqh1#
- Wkh#v|vwhp #dqdo|}hv#wkh#hujrqrp lfv#dqg# vwuxfwxuh1
- Wkh#xvhu#frqvwuxfw#wkh#uhdo#fkdlu1

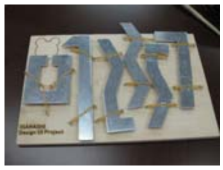
chair.mov chair

NIME 2010

Designing Custom-made Metallophone with Concurrent Eigenanalysis

N. Umetani, K. Takayama, J. Mitani, T. Igarashi





110

Motivation

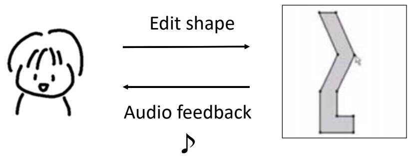
How to design an original musical instrument?

It is very difficult to find a shape that produce appropriate sound (tone).

111

Our approach

Design system with continuous tone prediction.



The user edits the shape, and the system provides audio feedback.

112

Video

delfem.mp4

113

Algorithm

- Wkh#suredp #lv#wr#lqg#iuhtxhqf|#ri#yleudwlrq1
- Z h#xvh#vwdqgdug#hljhqp rgh dqdo|vlv1

Mass matrix, Stiffness matrix, displacement

$$\mathrm{M}\ddot{\boldsymbol{u}} + \mathrm{K}\boldsymbol{u} = 0$$

$$\boldsymbol{u}(\boldsymbol{x}, t) = \emptyset(\boldsymbol{x})e^{i\omega t}$$

Amplitude, Harmonic Oscillation

Eigen value problem

$$\mathrm{K}\emptyset = \omega^2 \mathrm{M}\emptyset$$

$$f = \omega/2\pi$$

Eigen frequency

114

Summary

- P hwdoorskrqh ghvljq#z lwk# frqfxuuhqw#vlp xodwlrq#dqg#dxglr# ihhgedfn1
- H ljhq#p rgh#dqdo|vlv1

115

SIGGRAPH 2011

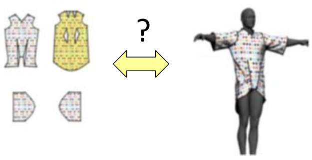
Sensitive Couture for Interactive Garment Editing and Modeling

N. Umetani, D. Kaufman, T. Igarashi, E.Grinspun

116

Motivation

How to design a new garment?



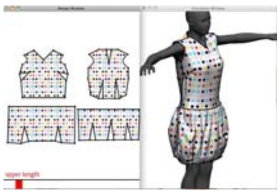
It is not easy to predict the result of draping

117

Our approach

Design system with continuous draping simulation.

User's edit



Concurrent simulation result

The user edits the 2D pattern, and the system shows simulation result.

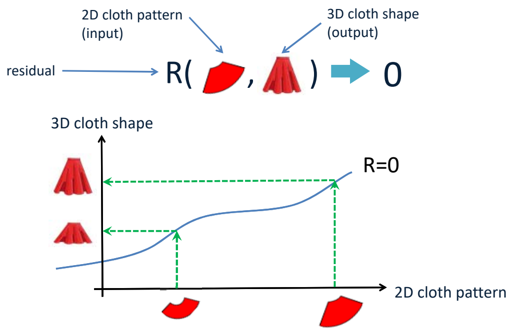
118

Video

cloth

119

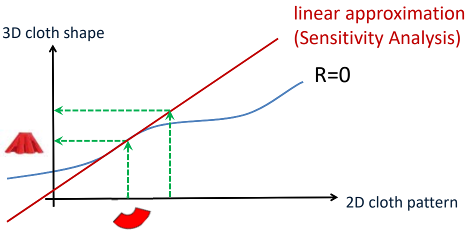
Algorithm



120

Algorithm

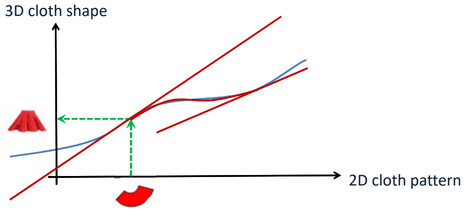
R is non-linear and slow to compute.
So, we use linear approximation around the current state.



121

Algorithm

Single linear approximation is not enough.
We *cache* multiple linear approximations and blend them.



122

Summary

- J dup hqw#ghvljq#z lwk#frqfxuuhqw# vlp xodwlrq1
- Vhqvlwlylw| #dqdo|vlv#dqg#p xowlsdh# fdfkhv#iru#ds lg#hhgedfn1

123

SIGGRAPH 2012

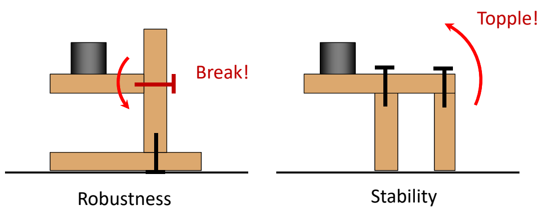
Guided Exploration of Physically Valid Shape for Furniture Design

Nobuyuki Umetani
The Univ. of Tokyo
Takeo Igarashi
The Univ. Tokyo / JST ERATO
Niloy J. Mitra
University College London

124

Motivation

How to design a furniture (shelf)?

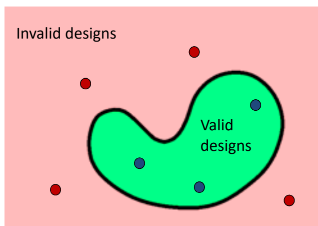


It is not easy to design valid furniture.

125

Our approach

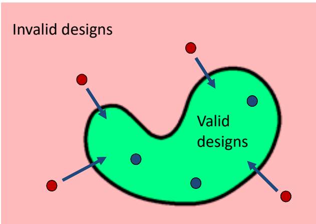
Continuous structure simulation.



126

Our approach

Continuous structure simulation.
+
Guidance to maintain validity.

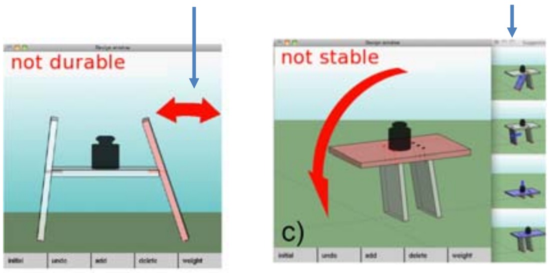


127

Our approach

Annotation Indicating valid range

Suggestions showing valid designs



128

Video

furniture

129

Algorithm

1. Prevent breaking.
   - analyze bend force at joints.
2. Prevent toppling.
   - analyze contact force at ground.

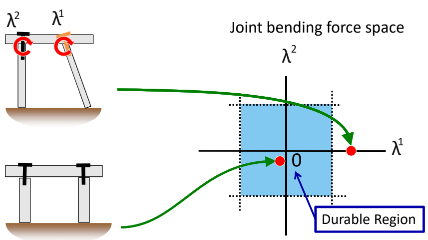
130

Algorithm

1. Prevent breaking.
   - analyze bend force at joints.
2. Prevent toppling.
   - analyze contact force at ground.

131

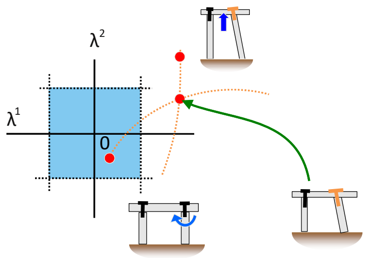
Prevent breaking



Consider a space spanned by nail joint bending forces.

132

Prevent Breaking



Test various parameter setting
around the current staet.

133

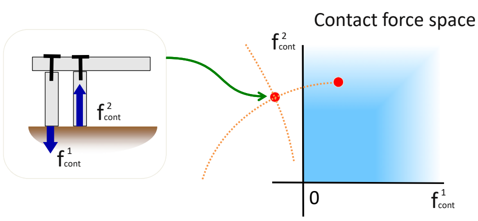
Algorithm

1. Prevent breaking.
   - analyze bend force at joints.

2. Prevent toppling.
   - analyze contact force at ground.

134

Prevent Toppling



Consider a space spanned by contact forces.

135

Summary

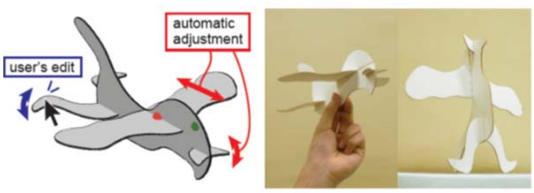
- Ixuqlwxuh#ghvljq#zlwk#gxudelolw|#dqg#vwdelolw|#dqdo|vlv1
- Mrlqw#irufh#dqdo|vlv#lq#wkh#irufh#vsdfh1

136

SIGGRAPH 2014

Pteromys: Interactive Design and Optimization of Free-formed Free-flight Model Airplanes

N. Umetani, Y. Koyama, R. Schmidt, T.Igarashi



video 137

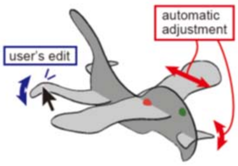
Motivation

How to design a paper airplane (glider)?

It is not easy to design a glider that flies well.

138

Our approach



Continuous simulation.
+
Automatic optimization.

139

Data-driven Approach

Accurate, analytic simulation is difficult.

⇨ We use many measured "data".

140

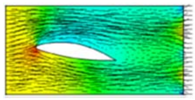
Video

pteromys

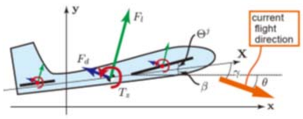
141

Algorithm

Fluid simulation is too slow.



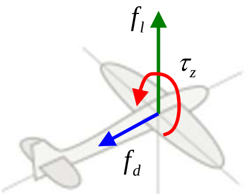
⇨ We use traditional "wing theory".



142

Wing Theory

Simple model that predicts lifting force



Velocity

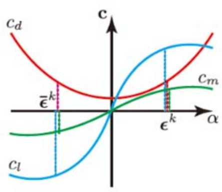
Area

$$\begin{pmatrix} f_d \\ f_l \\ \tau_z \end{pmatrix} = \frac{1}{2} \begin{pmatrix} C_d \\ C_l \\ C_m L \end{pmatrix} \rho V^2 A$$

Parameter depending on angle of attack α

143

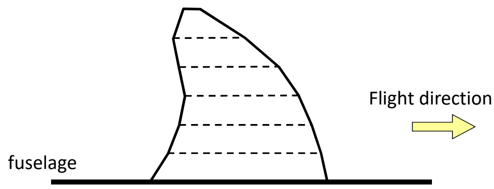
Data-driven parameterization



We estimate these parameters using measured data.

144

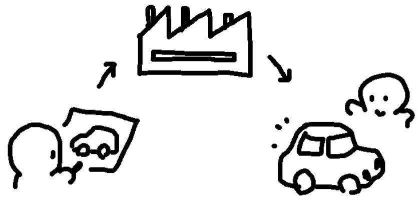
Wing Element Discretization



We compute force produced by each element, and aggregate them.

145

Future Vision



Design Everything !
Furniture, Clothing, Car, House…

おわり

2D 20min
Pegasus
Rigid
Fluid
3D 40min
Sketch
Chateau
Teddy
Fibermesh
volume
Squirrel
Fabrication 50min
Plushie
Beady
Chair
Metallo
Cloth
Furniture
Flight