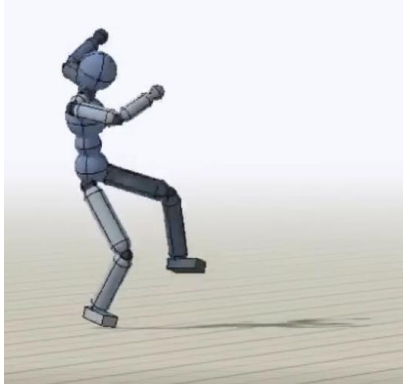


Advanced 3D Graphics

Part 1: Creative AI
Week 1: Expressive 3D modeling (continued)

Marie-Paule Cani

Advanced 3D Graphics
Focus : where Computer Graphics meets AI

Part 1. "Creative AI" *– Intelligent systems helping users in creative tasks*

1. Expressive 3D modeling
   - Background: Shape representations for constructive modeling
   - Expressive design: Gesture-based control on "smart" geometry
2. Extension to virtual worlds
   - Modeling and animating natural scenes
   - Expressive creation & control of animated scenes

Part 2. Autonomous characters *– animation & control*

3. Motion planning for characters and crowds
4. Animating and controlling individual characters

Standard Geometric Modeling
(MAYA, Blender, 3DS Max…Catia, Revit…)

Powerful representations

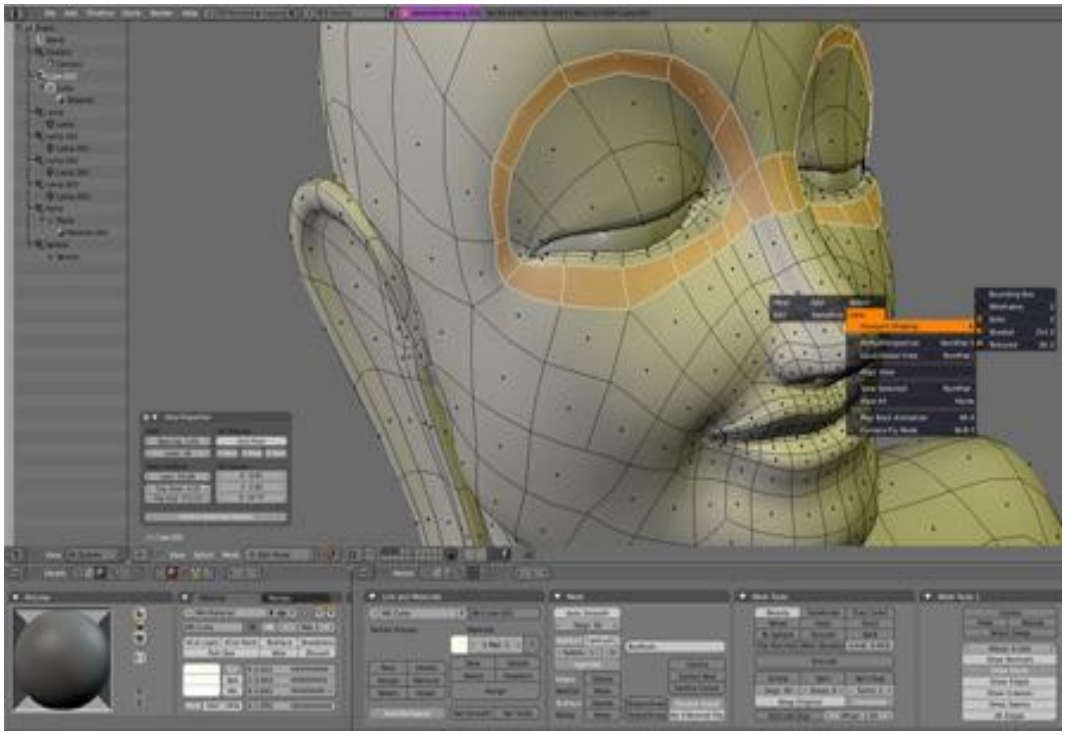
- Subdivision surfaces
- Spline surfaces
- Implicit surfaces

Complex interfaces

- Direct editing of DoF

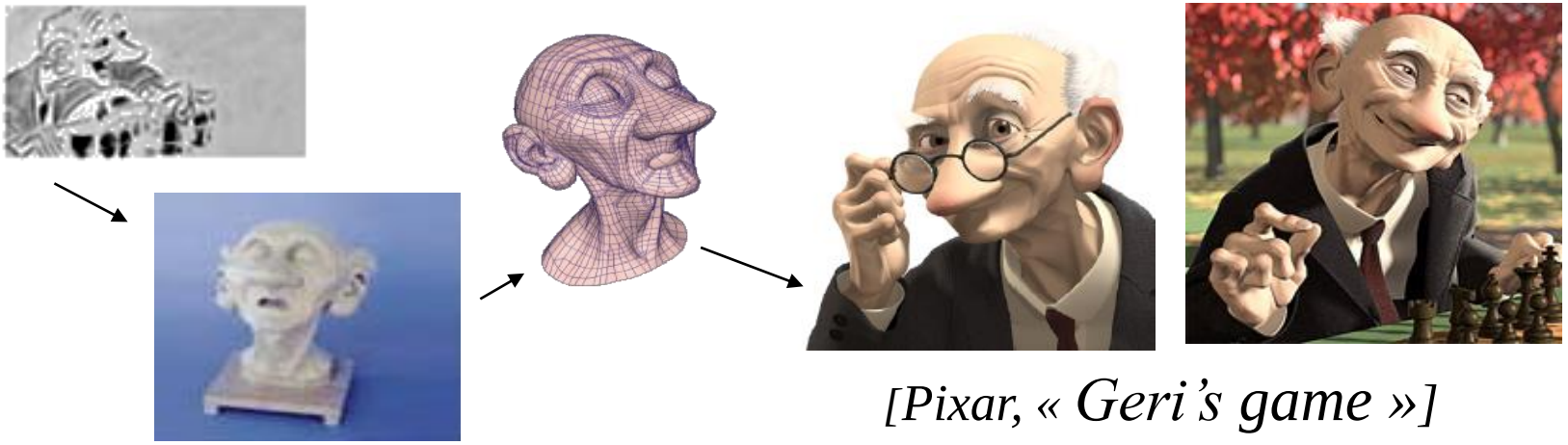
(control points, skeletons..)

- Years of training
- Lots of time and efforts!



Standard modeling…
A failure ?

- Artists do as much as they can *WITHOUT computers*



[Pixar, « Geri's game »]

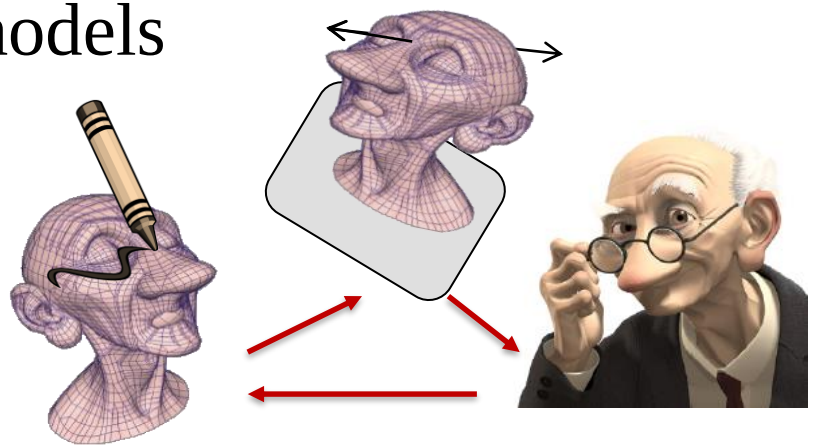
"Grand challenge", Rob Cook (2008) :

Make tools as transparent to the artists
as technical methods were made transparent to the public

Make tools transparent to the users?
"Expressive 3D Modeling"

Two design principles

- Enable seamless creation through **gestures**
- Embed **knowledge** in the models



This lecture

1. Which gestures?
2. Which knowledge and how?

1. ***Gestures for expressive modeling***
2. *Knowledge in the models*

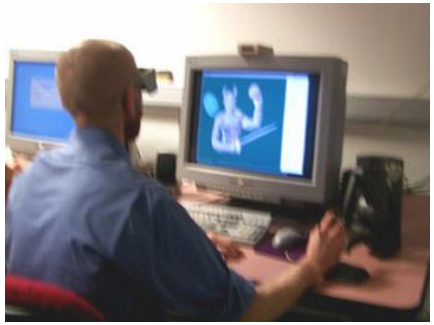
Inspiring from real world creation

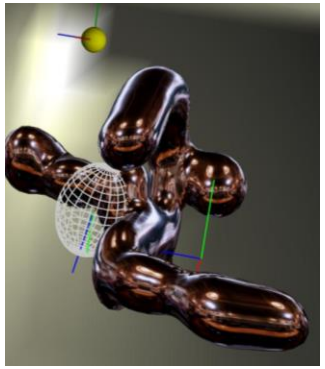
Painting in 3D space ?

- Lacks precision
- Tiring

Cave Painting *[Keefe 2001]*

Sculpting? *feel & deform*





[Ferley 2001]

1. ***Gestures for expressive modeling***
   - ***Sculpting***

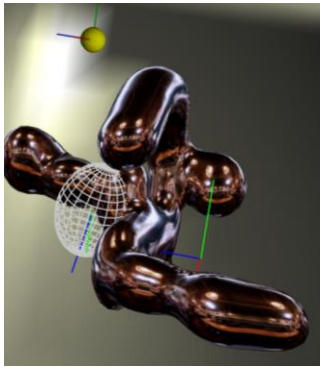
Representation for Sculpting in 3D?

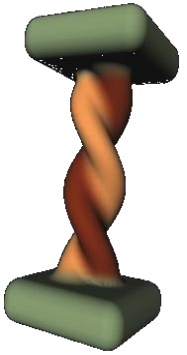
Needs

- Add or remove material
- Seamless blending
- Interactive shape display

Choice

- Implicit surface





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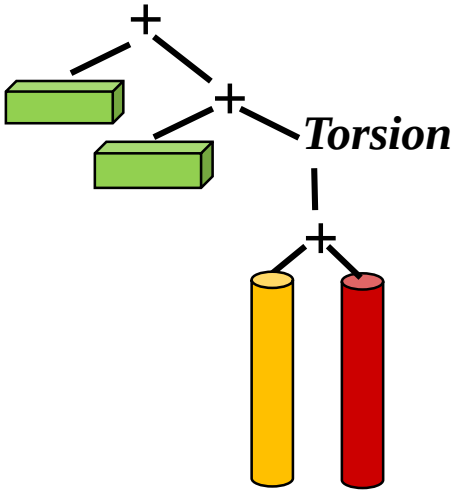
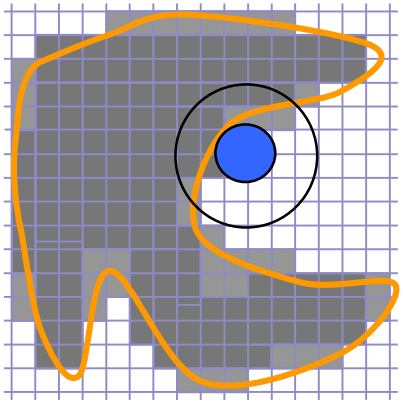


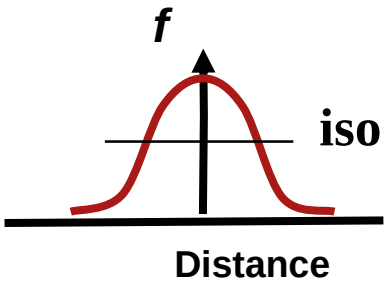
Blob-tree ?
Cost depends on number of edits
NOT ADAPTED!

Representation for Sculpting in 3D?

Needs

- Add or remove material
- Seamless blending
- Interactive shape display





Choice

- Implicit surface
- **Discrete field**
- Three H-tables :

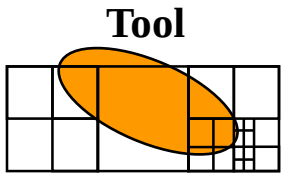
Non-empty cells **surface cells** **iso-surface**

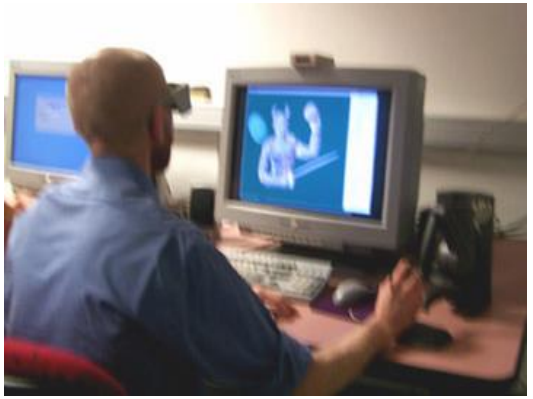
1. ***Gestures for expressive modeling***
   - ***Sculpting***

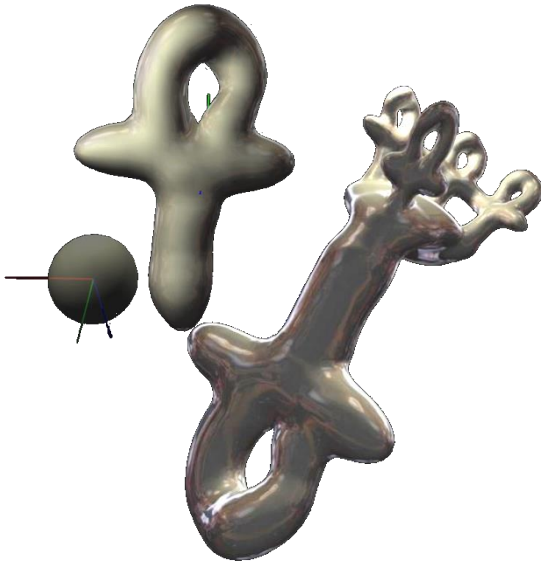
Practical volumetric sculpting

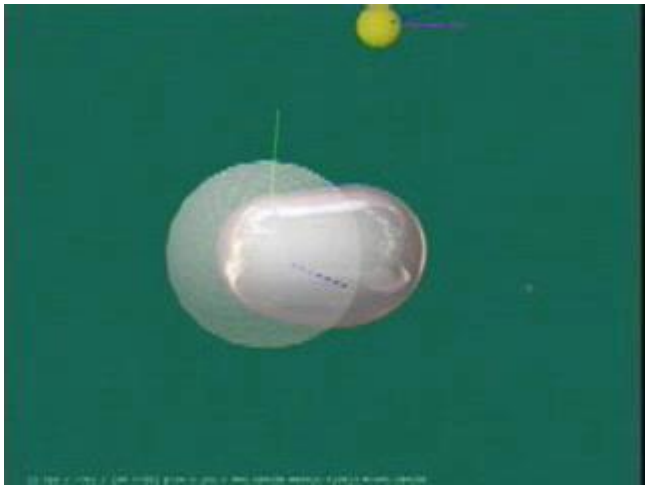
Improvements

- VR and Force feedback
- Multiresolution sculpting
- Use a previous sculpture as a tool:









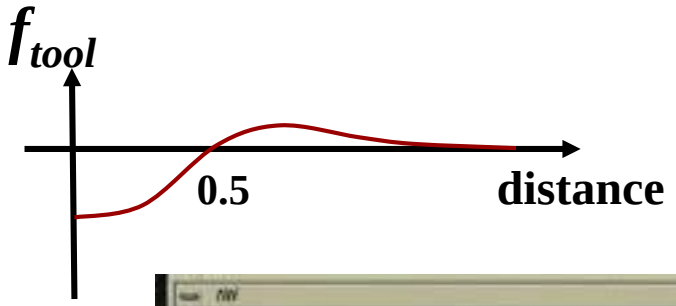
1. *Gestures for expressive modeling*
   - *Sculpting*

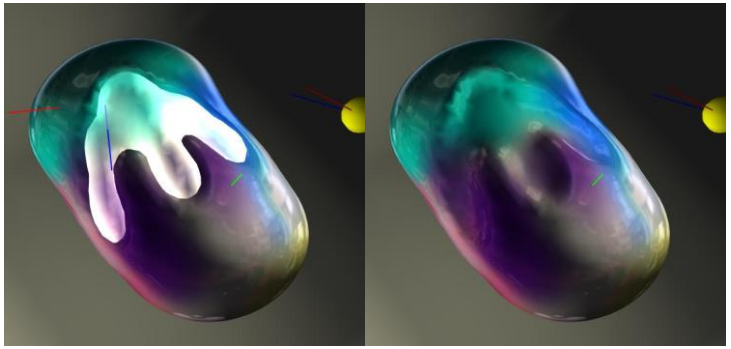
3D Sculpting
But clay also deforms!

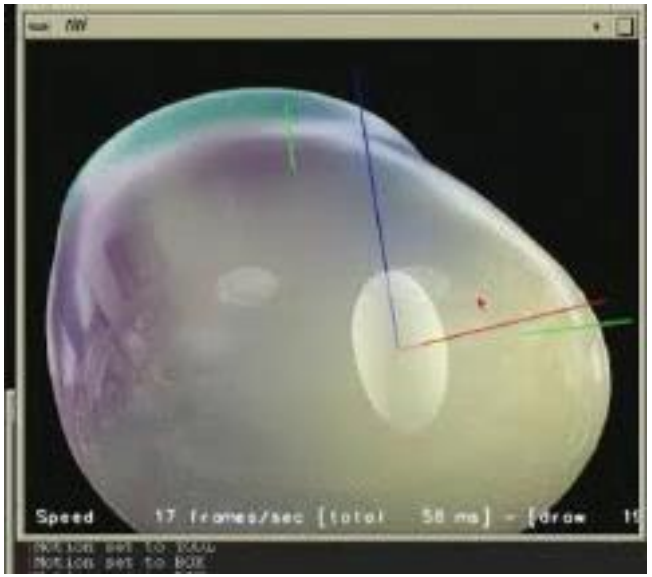
Local deformations

Tools that “push” material ?

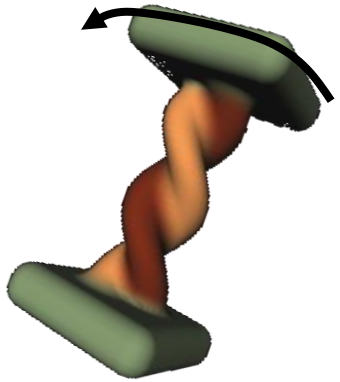
Create a hole plus a bulge !







3D Sculpting
But clay also deforms!



Global deformations ?

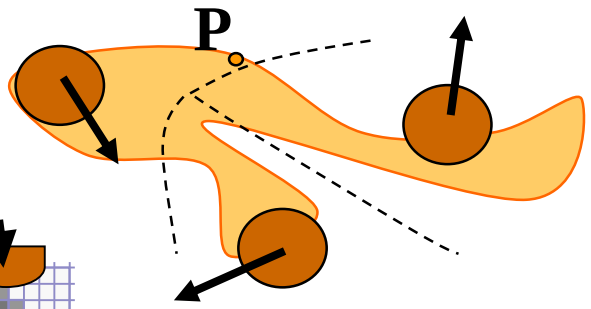
- Should propagate
- Constant volume constraint

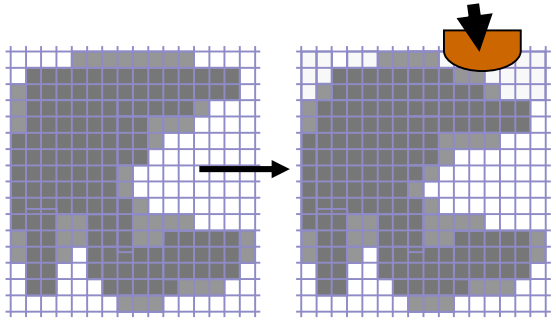
Solution: Physically-based animation [Dewaele 2004]

3 layers

1. Diffuse tool's motion
2. Constant volume
3. Surface tension

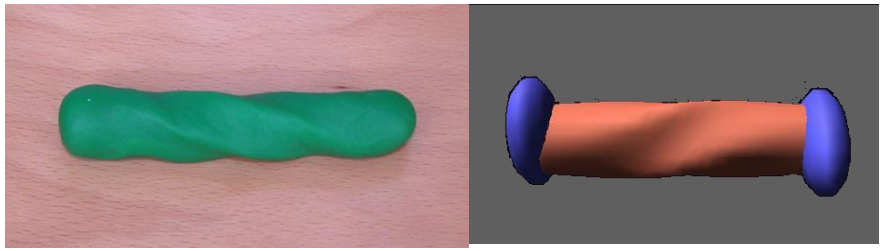
Avoid diffusing material!

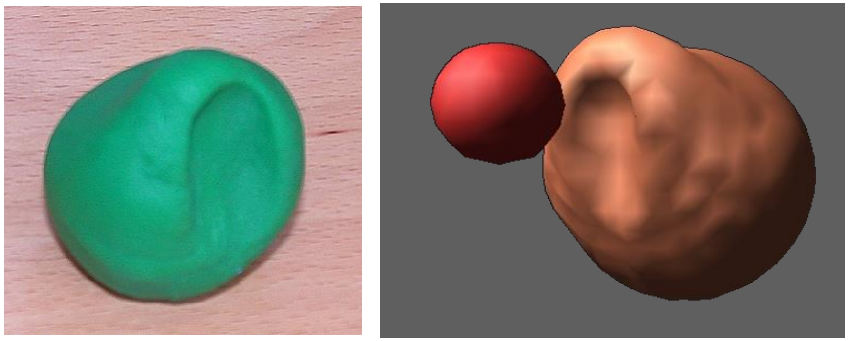




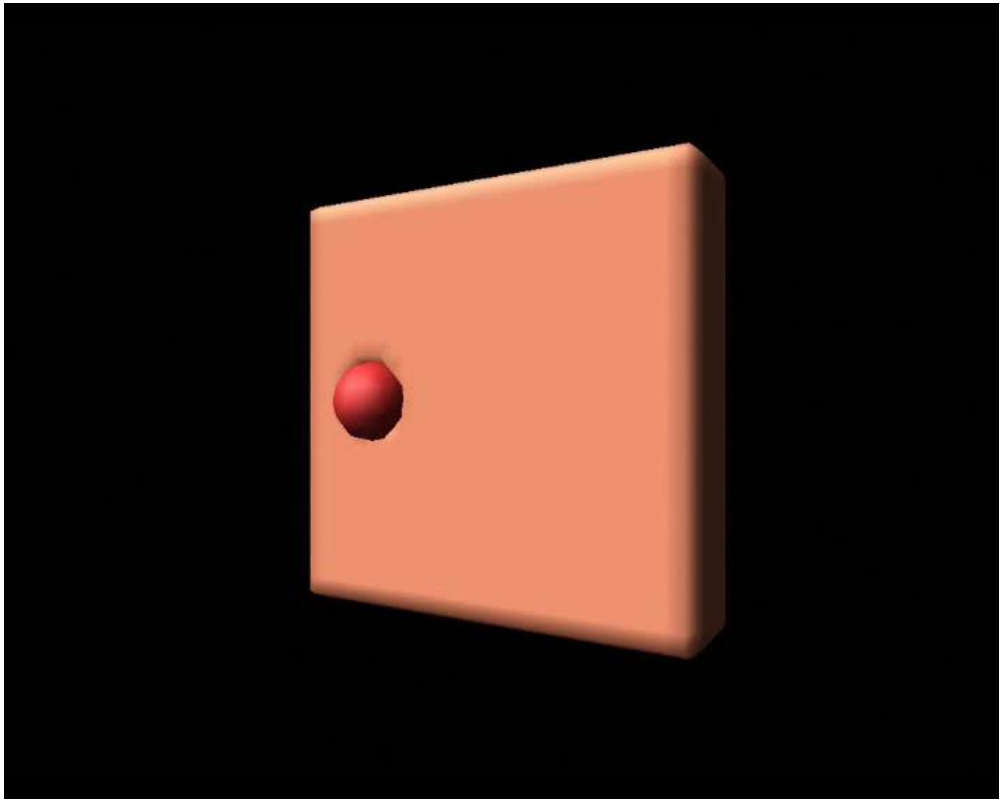
1. ***Gestures for expressive modeling***
   - ***Sculpting***

3D sculpting with Virtual Clay





Real clay Virtual clay

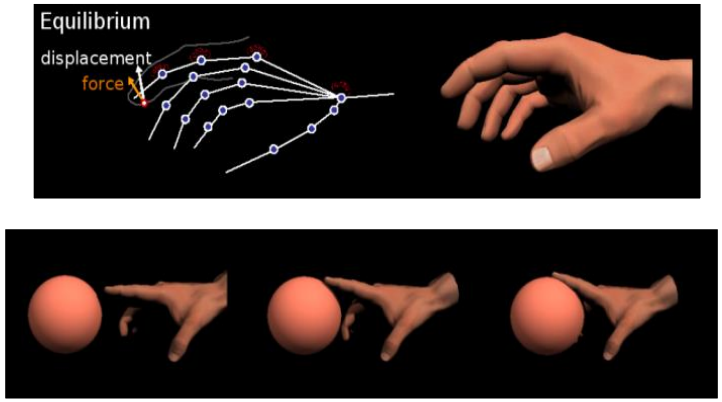


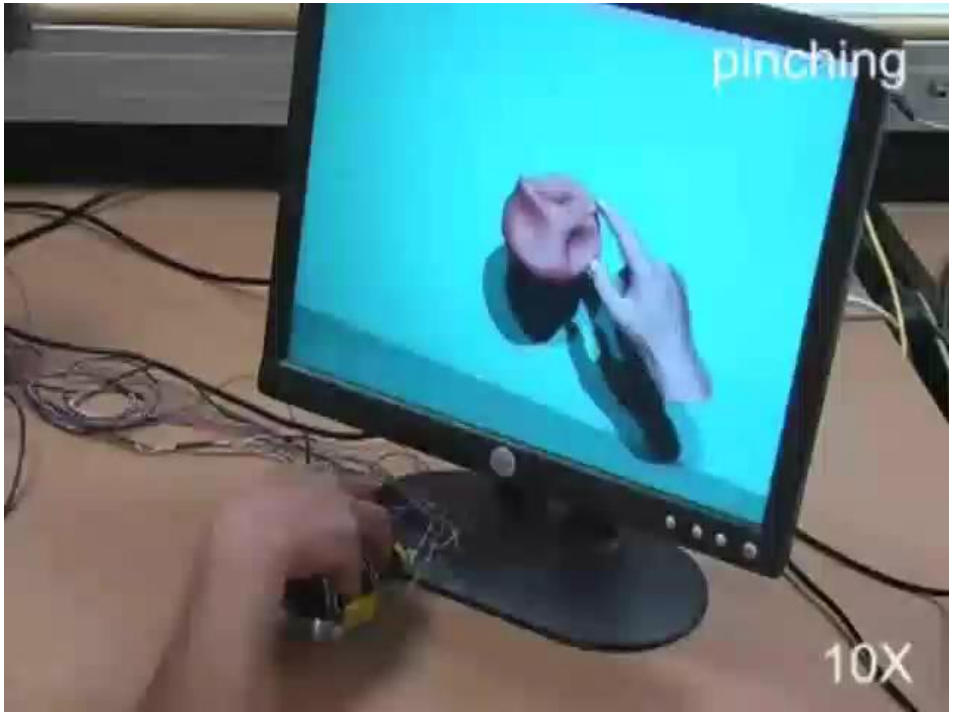
[Dewaele 2004]

1. *Gestures for expressive modeling*
   - *Sculpting*

3D sculpting with Virtual Clay

Control a virtual hand?: "Hand-navigator" *[Kry 2009]*





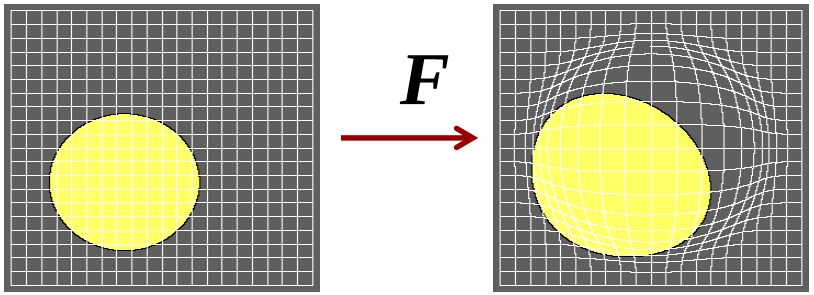
Nice innovation but …
not usable as a sculpting tool!

Alternative?
Sculpting with Space Deformations

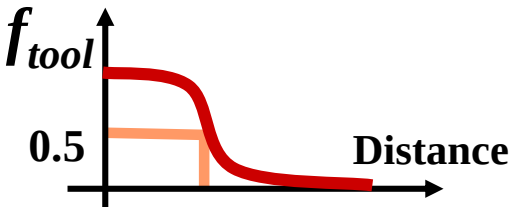
Sweepers [Angelidis 2004]

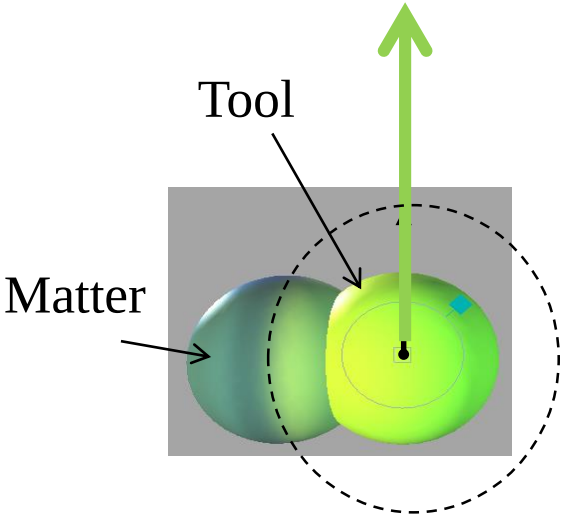
- Defined by sweeping a tool

$$F(P) = [\, f_{tool}(P) \circledcirc M_{tool} \,](P)$$



$f_{tool}(P)$: local influence of the tool

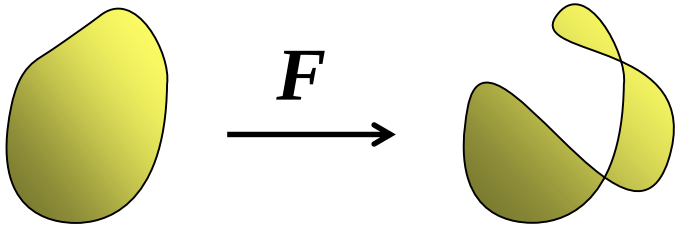




- ⊙ Power of transformation matrix *[Alexa 2002]*
  - Acts as a scalar multiplication
- Applicable to any representation : here a mesh!

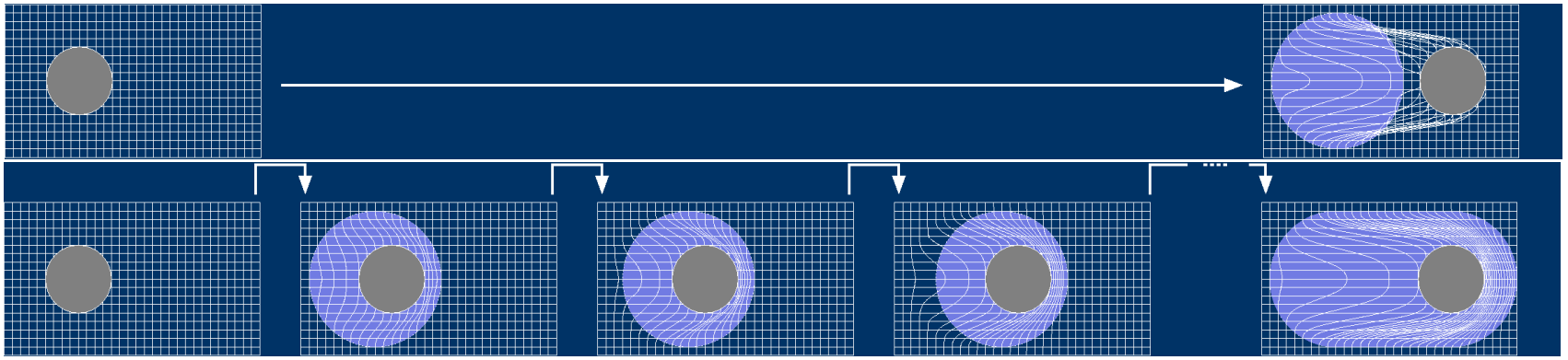
Sculpting with Space Deformations

Reversible deformations?



- Prevent space fold-over

  → Apply each deformation in small steps



- Drawback : No possible topology change!

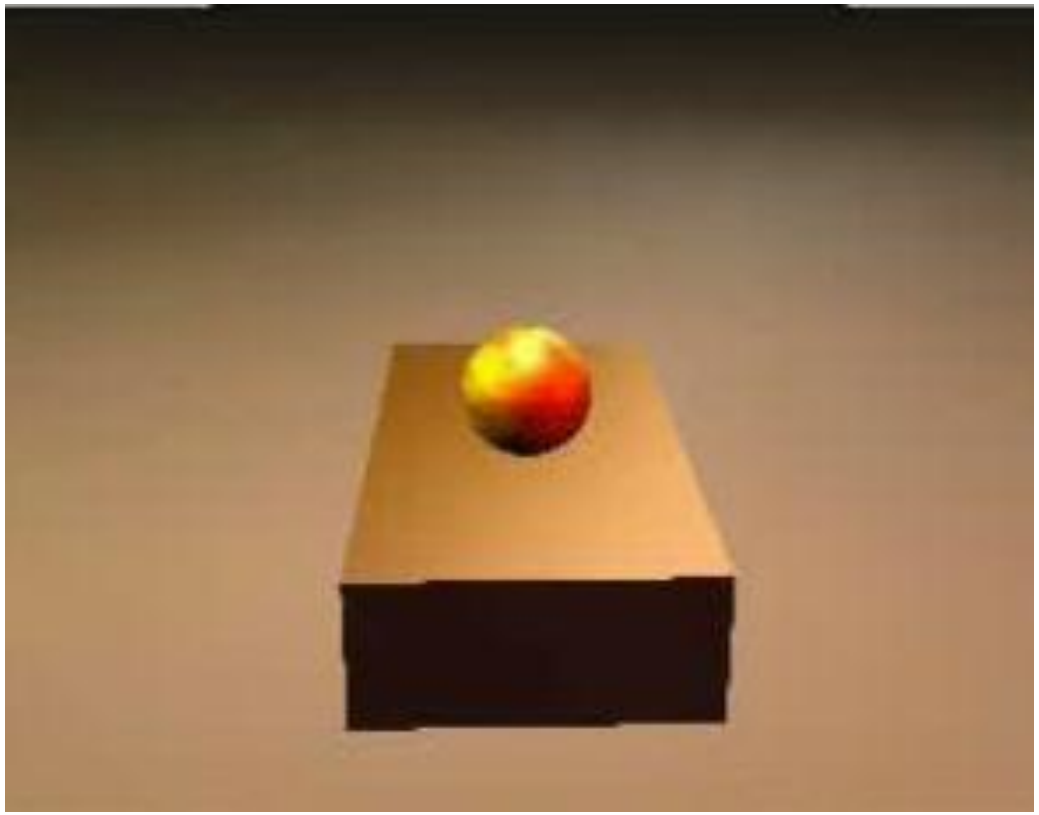
1. ***Gestures for expressive modeling***
   - ***Sculpting***

Sculpting with Space Deformations

Results

- Intuitive design
- No constant volume!

(looks like 3D painting)

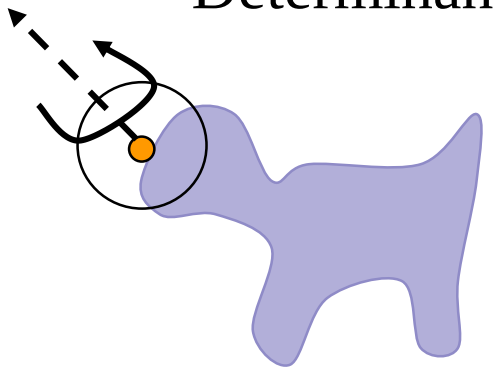


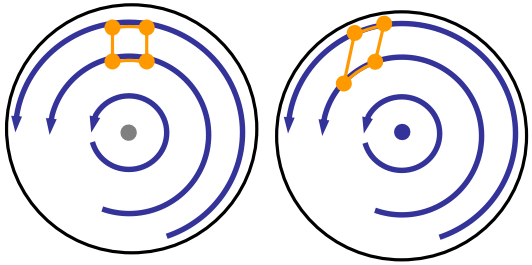
1. ***Gestures for expressive modeling***
   - ***Sculpting***

Constant volume Space Deformations?

“Swirl” (axis, rotation angle)

– Determinant (Jacobian *F*) = 1

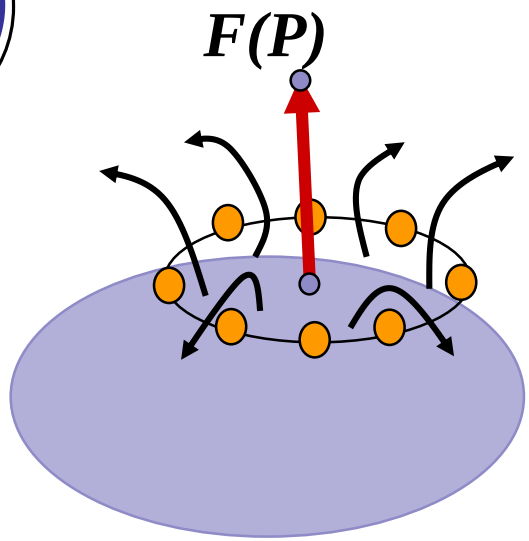




« Swirling sweepers »

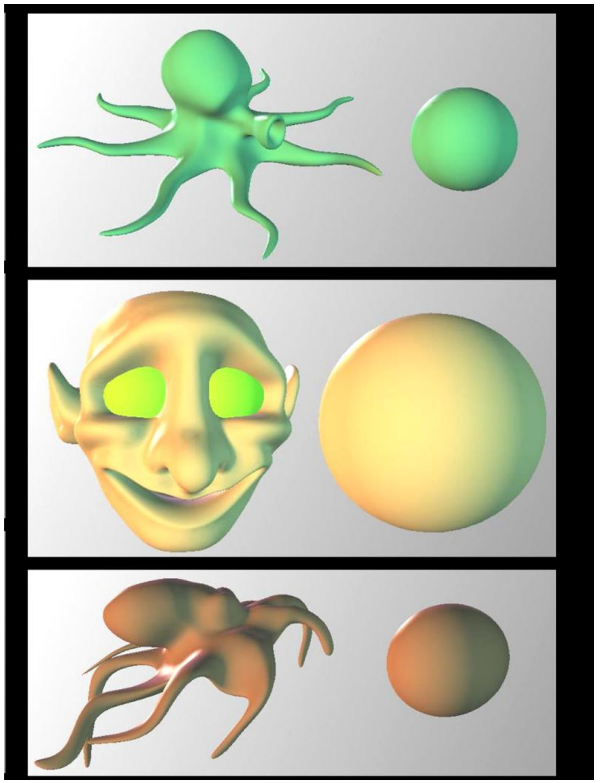
– A ring of swirls

– Controlled with a sweeping gesture



1. *Gestures for expressive modeling*
   - *Sculpting*

Swirling sweepers : Results



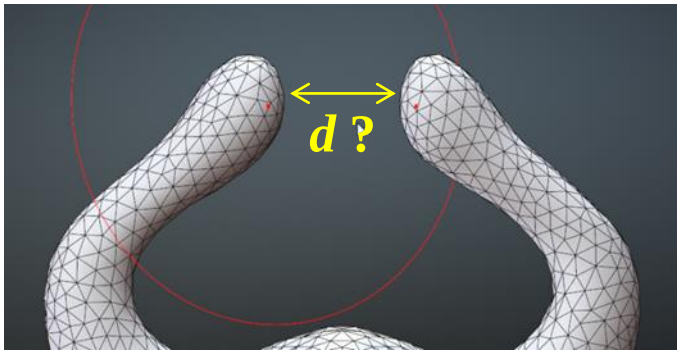
[Angelidis 2004]

Volumetric sculpting with topology changes

Adaptive, quasi-uniform mesh

1. All edges smaller than *d* (level of detail)
2. They try to remain larger than *d/2*

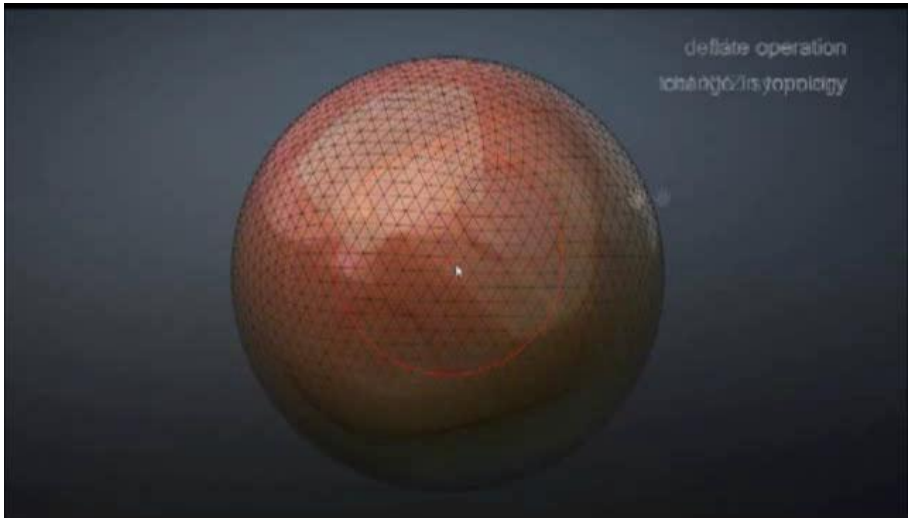
Enables to handle topological changes



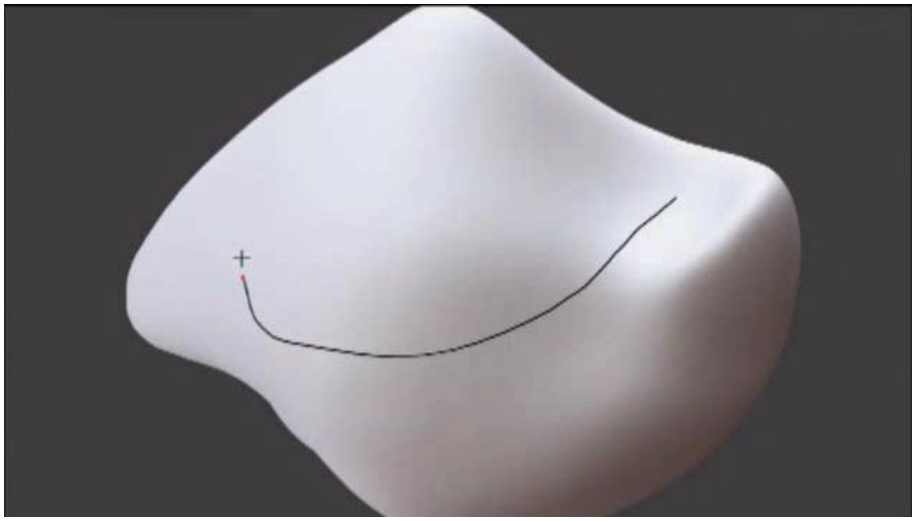
1. ***Gestures for expressive modeling***
   - ***Sculpting***

Extending Volumetric Sculpting

[Stanculescu 2011 & 2013]



Topological changes



Embedding sub-structures

1. ***Gestures for expressive modeling***
   - ***Sculpting***

Extending Volumetric Sculpting

Beautiful models from a trained artist

Impact of CG research : Digital sculpting

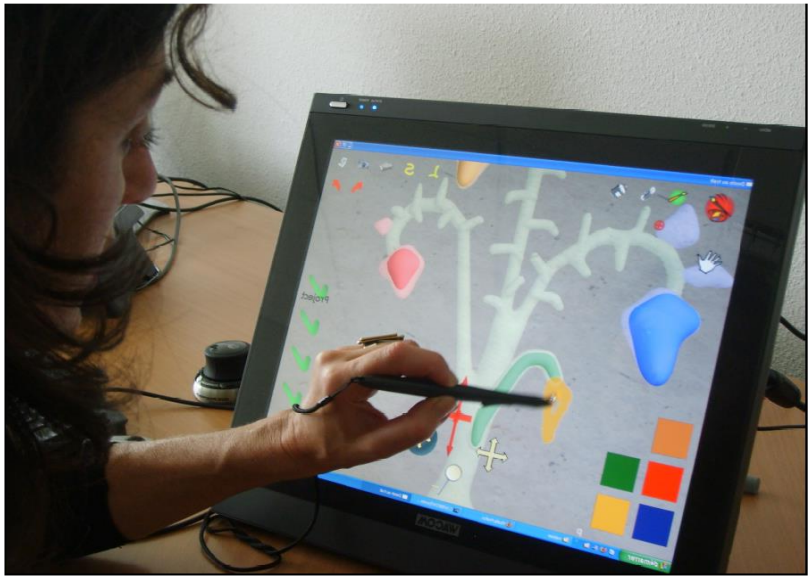
Zbrush (pixologic), Mudobx (sculpting an existing mesh)...

"Leave technical hurdles and steep learning curves behind!"

"You sculpt and paint with familiar brushes and tools…"

1. ***Gestures for expressive modeling***
2. *Knowledge in the models*

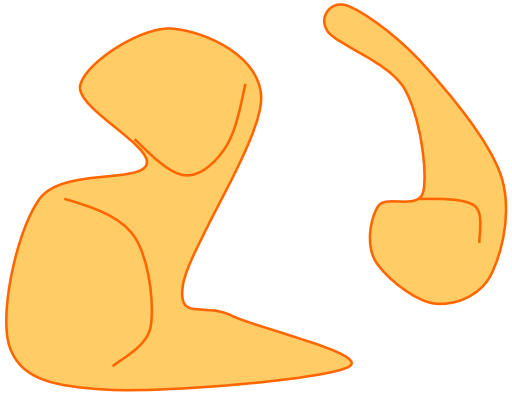
What is easier?



Sculpting in 3D? … or Painting in 2D?

1. ***Gestures for expressive modeling***
   - *Sketch-based modeling*

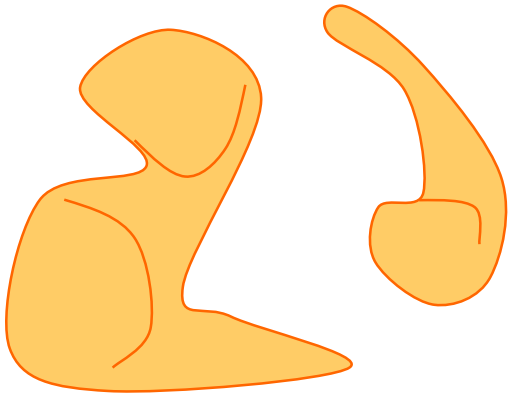
3D shape from a 2D sketch?



Why do we “see” 3D shapes ?

1. ***Gestures for expressive modeling***
   - *Sketch-based modeling*

3D shape from a 2D sketch?



Unknown shapes

- We “see” simplest shape
- The most symmetric!

Well known shapes

- We use a priori knowledge
- This helps us fill missing data

1. ***Gestures for expressive modeling***
   - *Sketch-based modeling*

Sketch-based modeling
Unknown shapes

“Teddy”: the first sketch-based system for 3D modeling

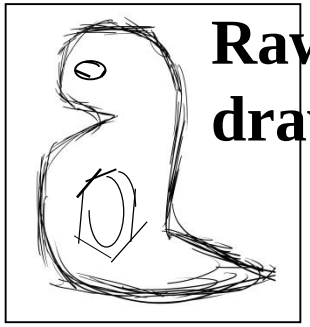
- Hypothesis
  - Contour = planar silhouette
- « Inflate » inside this silhouette
- Draw from different viewpoints
  - Assemble pieces
  - Coarse blending using meshes

[Igarashi 99 @ACM]

1. ***Gestures for expressive modeling***
   - *Sketch-based modeling*

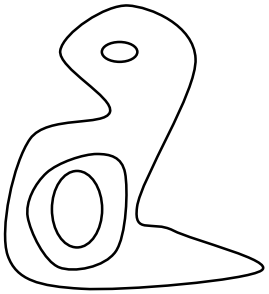
Should we draw contours or paint?

Drawing a closed contour

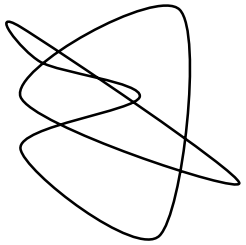


Raw drawing

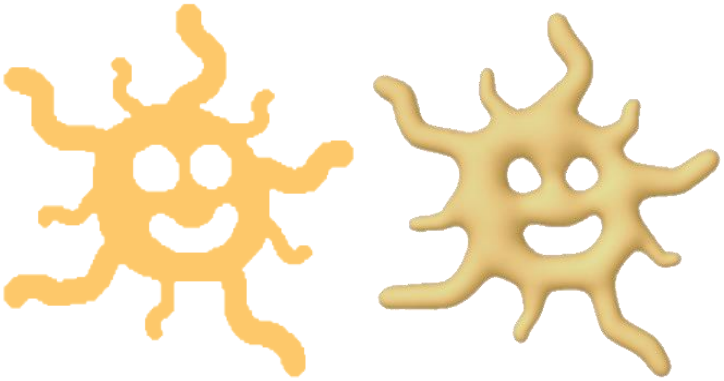
Vector drawing



- **How can we model holes ?**
- **Validity to check !**



Painting regions



- **Always valid**
- **Any topological genus!**

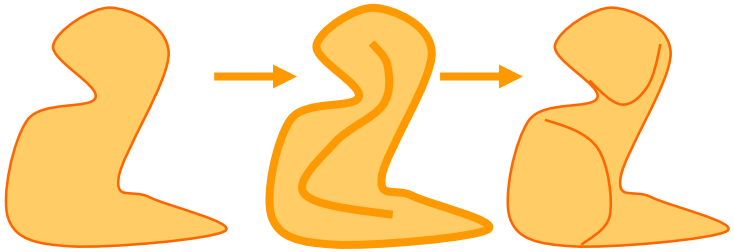
1. ***Gestures for expressive modeling***
   - *Sketch-based modeling*

Unknown shapes

Matisse system *[Bernhardt 2008]*

3D from a painted region?

- Use symmetry around a “skeleton”



Medial axis

How to add details?

- Over-sketch from another viewpoint
- Depth from the support shape

Needs

- Inflate shapes from skeletons
- Blend new parts with the main shape

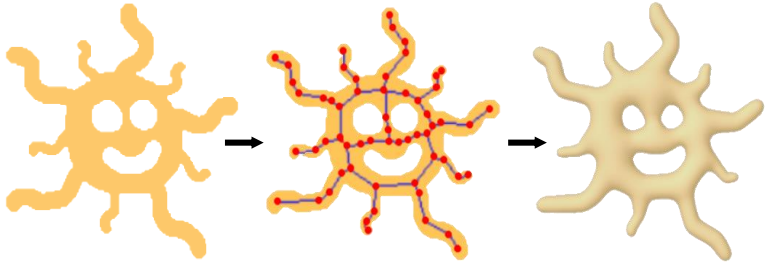
→ **Use Implicit Modeling!**

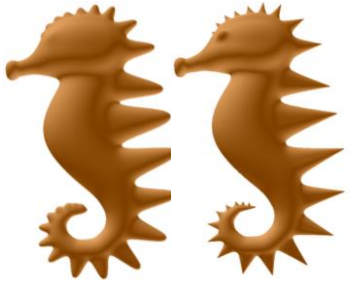
Using implicit surfaces "Matisse" system

Naïve solution: $S = \{P \,/\, f(P) = iso\}$

Convolution along skeleton: $f_S(P) = \int_S r(s)\ K(d(P,S))\ ds$

$f(P) = \Sigma f_i(P)$

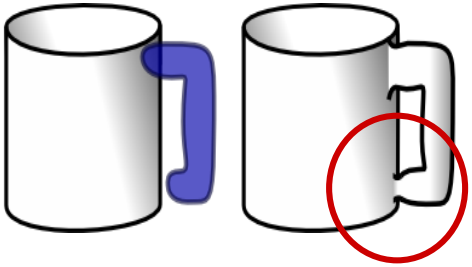




Convolution **SCALIS**

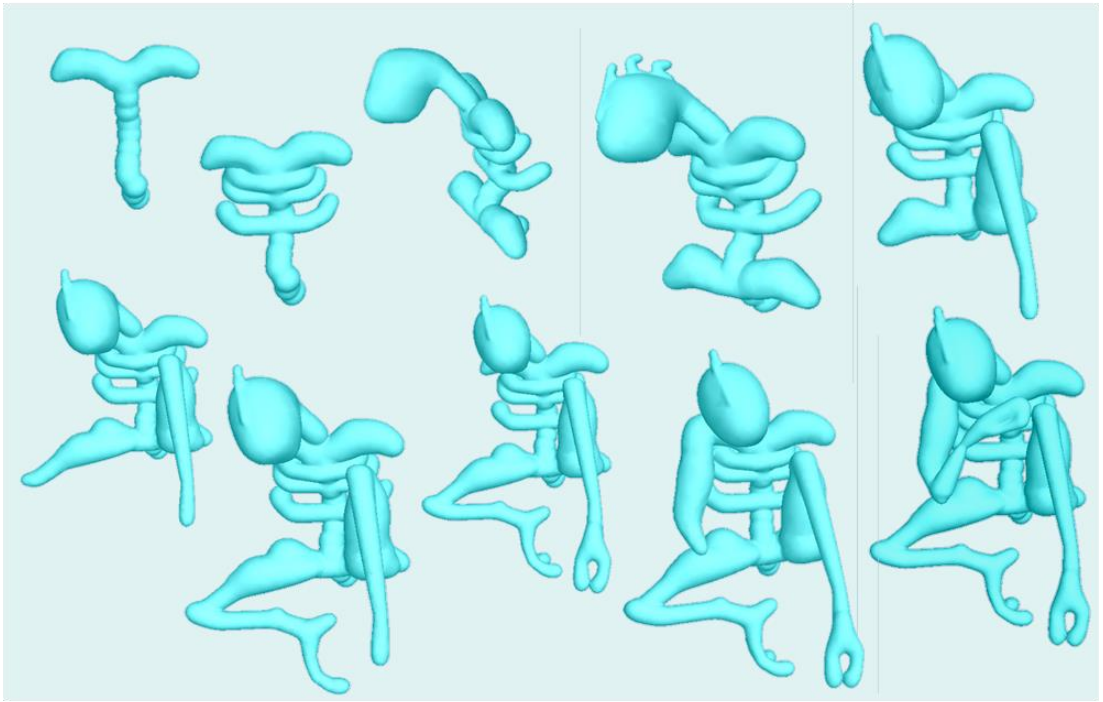
Use advanced implicit modeling!

1. Primitives exactly fit contours
2. Shapes do not blend at distance
3. Small details do not blur



1. ***Gestures for expressive modeling***
   - *Sketch-based modeling*

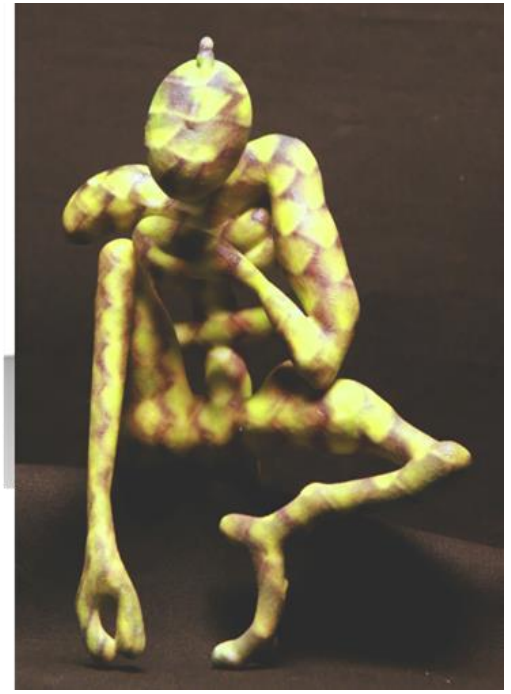
"Matisse" system
Results



Progressive creation

1. Draw
2. Change viewpoint

iterate



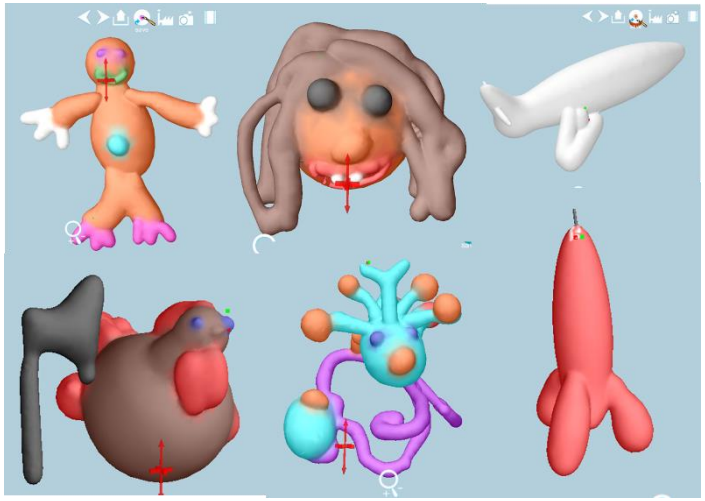
Designed in 30 mn

24 sketches

1. ***Gestures for expressive modeling***
   - *Sketch-based modeling*

Unknown shapes

Matisse system ***[Bernhardt 2008]***



New webGL version

https://www.lix.polytechnique.fr/geovic/software.html

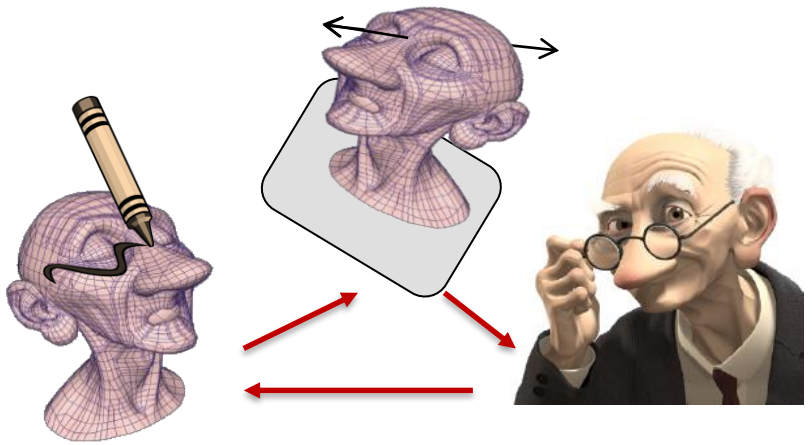
1. ***Gestures for expressive modeling***
2. *Knowledge in the models*

Expressive Modeling First conclusions

1. **Which gestures : Sculpting? Sketching?**
   - Sketching (painting, drawing) for first creation
   - Sculpting (iterative deformation) to refine shapes

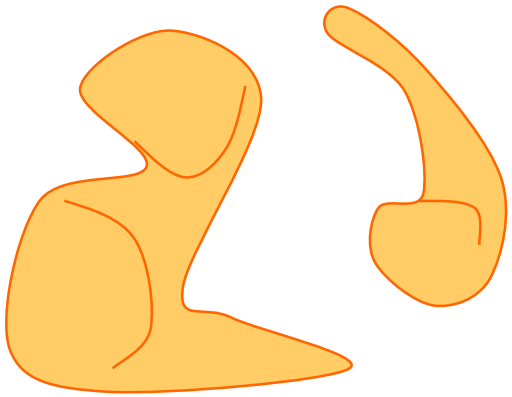
   Insight: Loosely inspire from real
   - Get rid of most real world constraints!

2. Which knowledge and why…



1. *Gestures for expressive modeling*
2. ***Knowledge in the models***

Adding knowledge?
Sketch-based Modeling of Well Known Shapes



Unknown shapes

- We “see” simplest shape
- The most symmetric!

Well known shapes

- We use a priori knowledge
- This helps us fill missing data

Expressive modeling

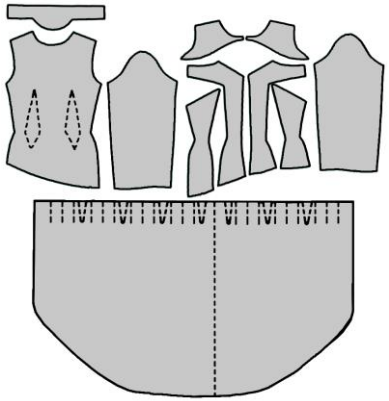
1. *Gestures*
2. ***Knowledge***

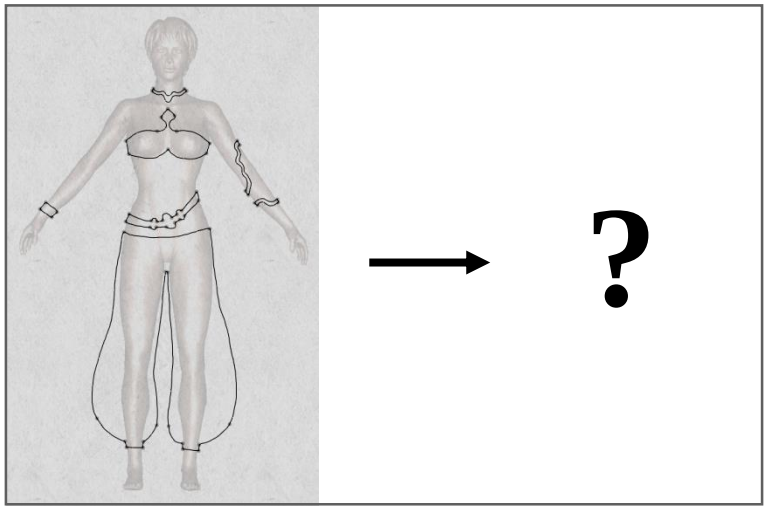
Sketching well known shapes?
Garments for virtual characters

Virtual clothing in Computer Graphics

- Design & place patterns
- Run physically-based simulation

Specific skills required!





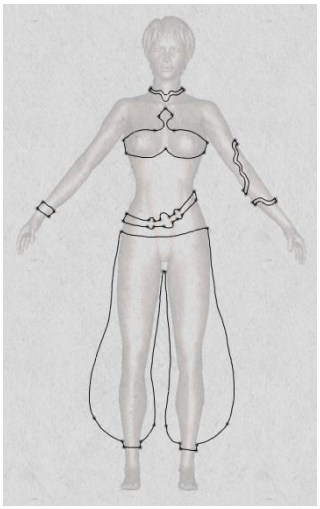
3D garments from 2D sketches?

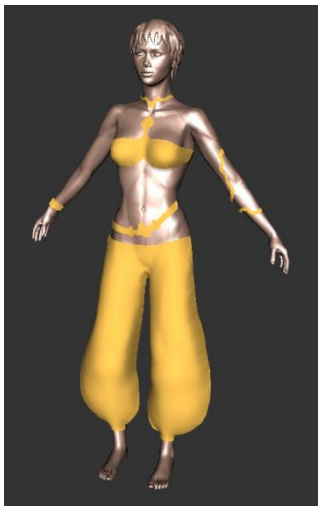
→ would give us the patterns!

Sketching garments
Which knowledge do we need?

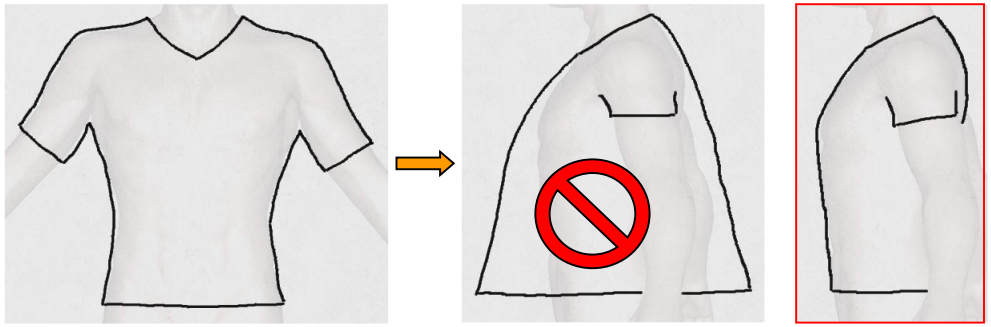
Virtual cloth from a sketch?

- Sketch on a view of a 3D model

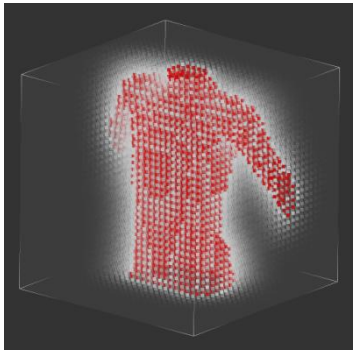




- Knowledge? Rule of thumb:
  - Fitting is the same in all directions!



Sketch in a distance field!

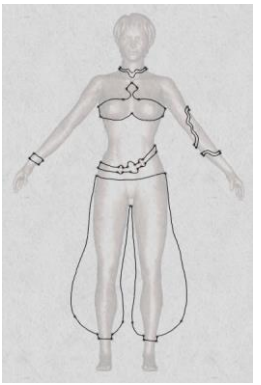


Expressive modeling

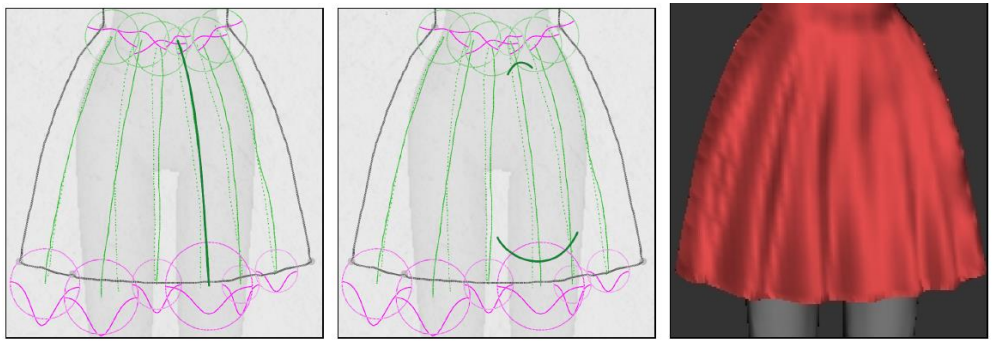
1. *Gestures*
2. ***Knowledge***

Sketching well known shapes?
Garments for virtual characters

Results lack folds!



- Allow the designer to sketch them?



[Turquin 2007]

Nice if the designer is good!

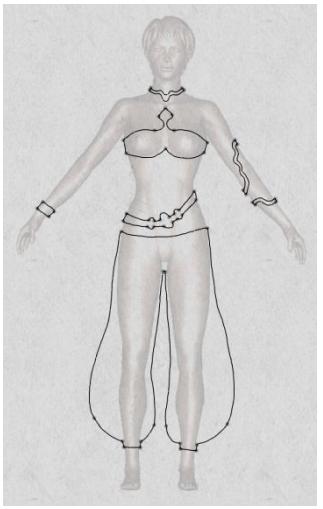
Expressive modeling

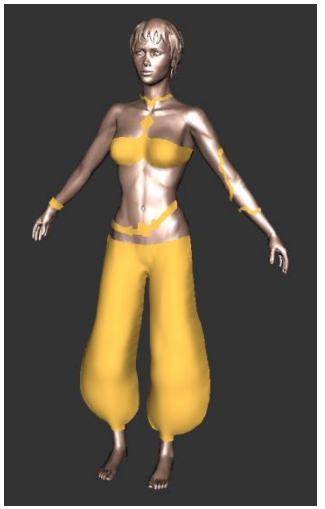
1. *Gestures*
2. ***Knowledge***

Sketching well known shapes?
Garments for virtual characters

Making it easier for beginners?

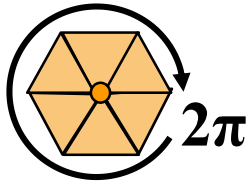
- Use more a priori knowledge
  - Cloth is a developable surface
  - Folds can be computed!



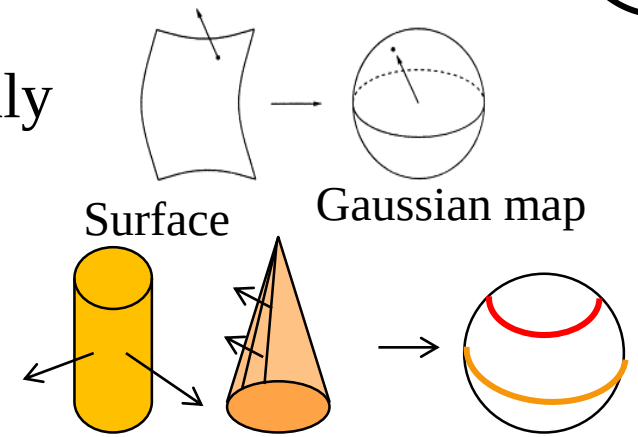


Developable surfaces
Several equivalent definitions

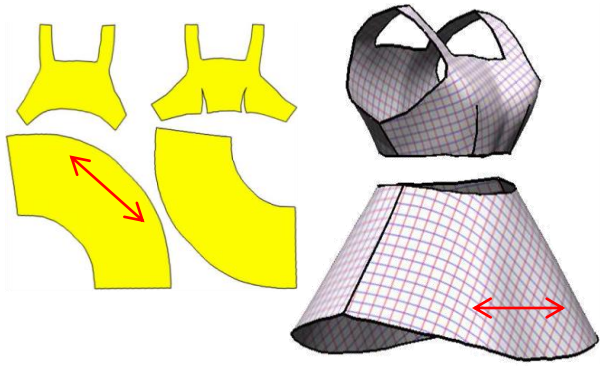
- Zero Gaussian Curvature: K = K1. K2= 0



- Gaussian map = curves only
  - Plane: a point!
  - Cylinder: a circle



- Ruled surfaces
  - with constant normal along rules

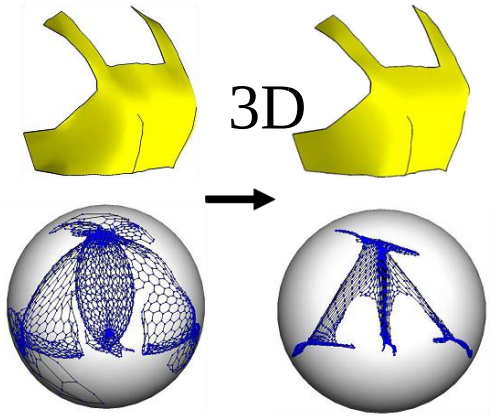


- Isometry to a 2D pattern

Sketching well known shapes? Developable garments

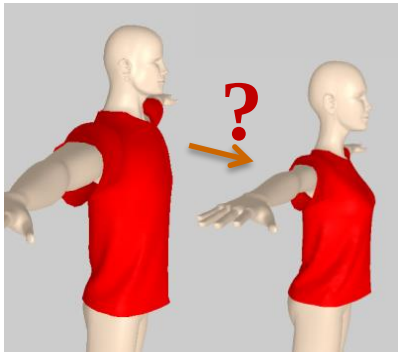
Possible solution: Optimize developability

- Initialisation : surface without folds
- Align normals of neighboring triangles
- Paste back triangles while preserving normals



Gaussian map

- Folds are added as a postprocess *[Decaudin 2006]*



« Smart » copy-paste? The example of garement transfer

Goals : dress characters of different morphologies

- Transfer garments ….(?)
  - The 3D shape changes
  - The 2D patterns change

- “Preserve design”

How to express this mathematically?

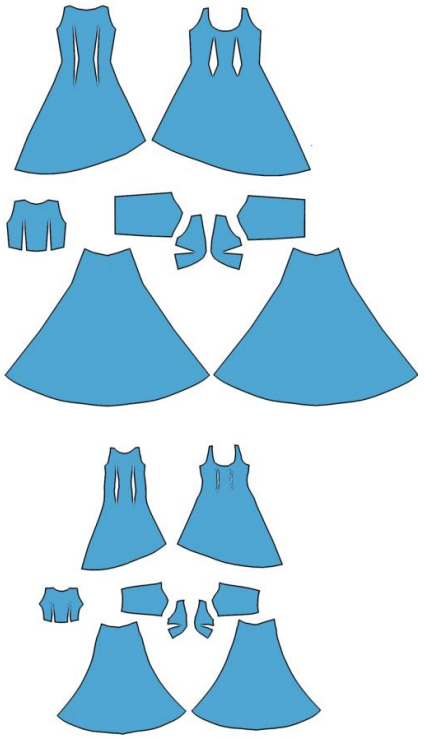
« Smart » copy-paste?
The example of garment transfer

Design preservation

- Proportions
- Fitting parts
- Same normals on loose parts

Preserve fabricability

- Developable surfaces
- Not intersecting the body

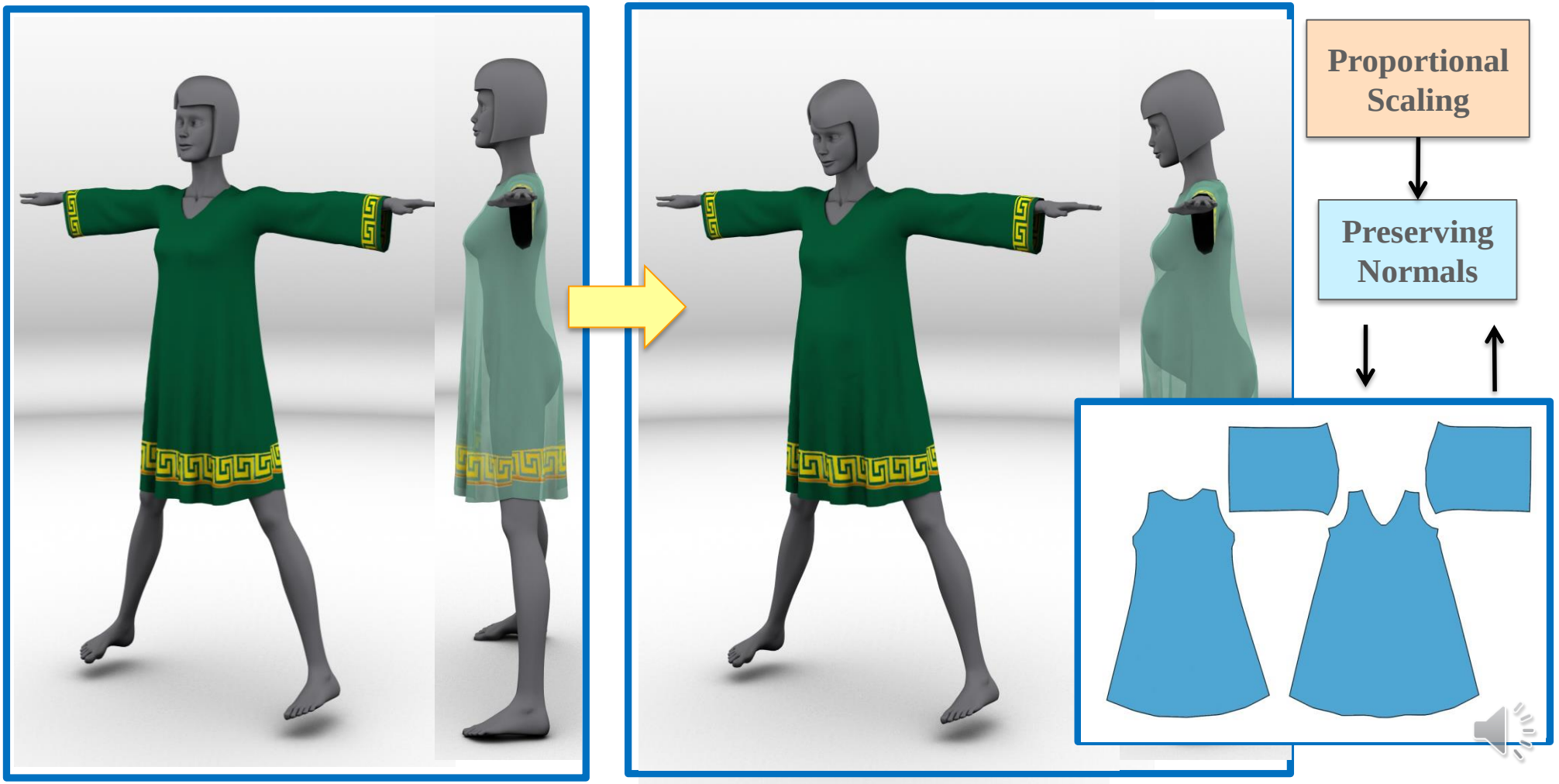


Expressive modeling

1. *Gestures*
2. ***Knowledge***

Design Preserving Garment Transfer

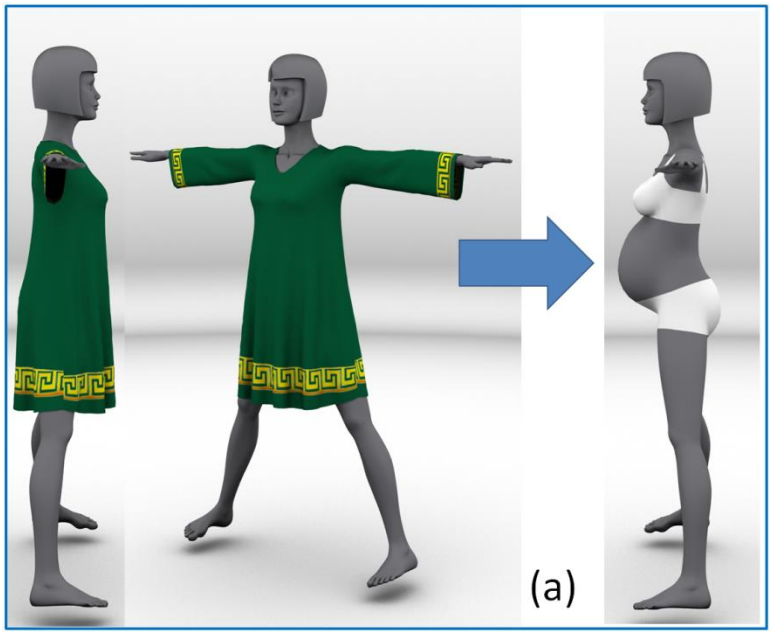
[Brouet 2012]



Design Preserving Garment Transfer
Criteria to algorithm

1. Proportionality

- Preserves relative location along body and limbs
- Based on bone & skin registration



Design Preserving Garment Transfer
Criteria to algorithm

2. *Design : preserve normals*

- Goal: penalize rotation form source to target
- Allow 2D deformation (more or less material)

$$\min \sum_{\text{triangles}} \left\| \tilde{P} - T\,P \right\|_F^2$$

New **Source**

Normal Preserving
"as 2D as possible"

Alternate:
- solve for T
- solve for $\tilde{P}$

Expressive modeling

1. *Gestures*
2. ***Knowledge***

Design Preserving Garment Transfer
Criteria to algorithm

3. ***Fit:*** keep offset to body in tight regions

4. ***Manufacturability***

   Prevent collisions with character

   - Solved for top to bottom
     - Adds material

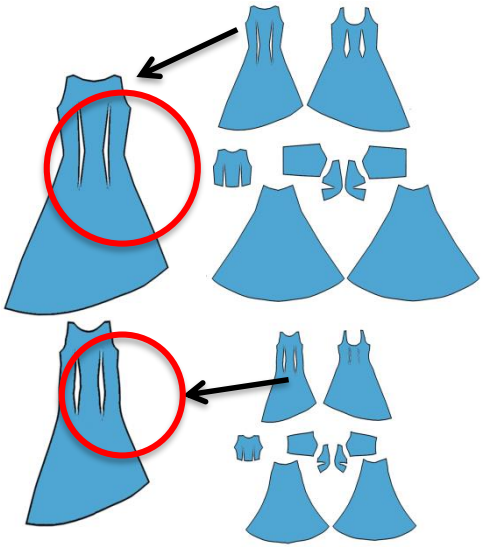
input

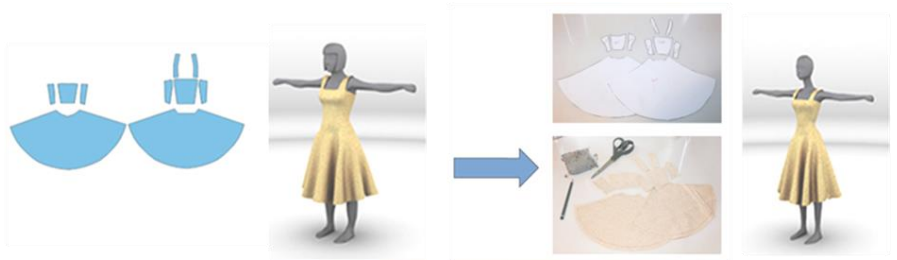
Expressive modeling

1. *Gestures*
2. ***Knowledge***

Design Preserving Garment Transfer Results ***[Brouet 2012]***

- Output: 3D models + 2D patterns
- Real prototype for validation

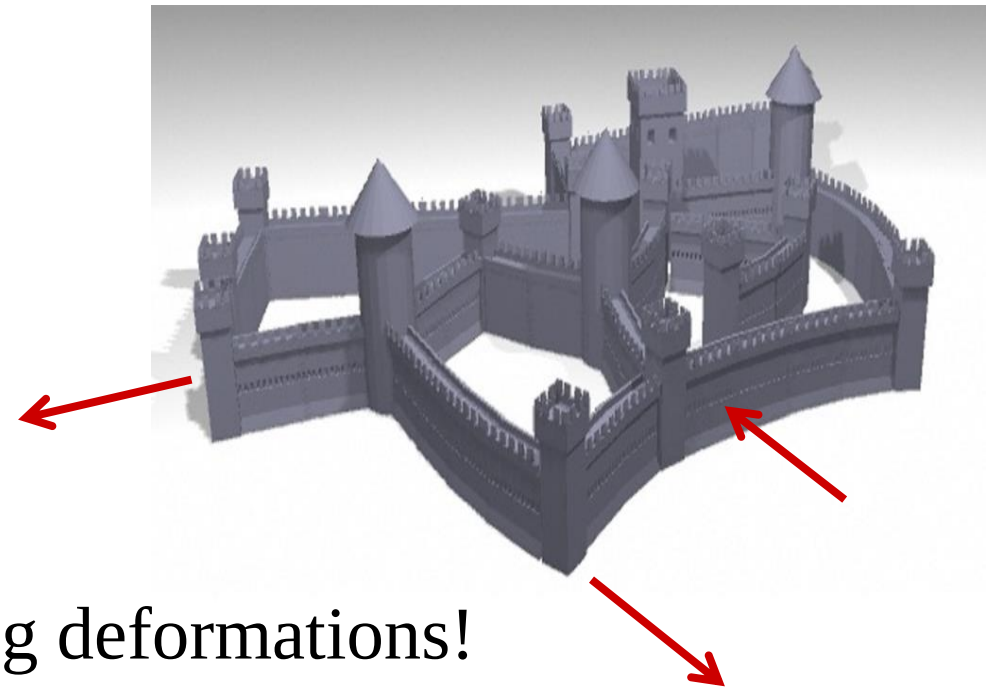




Sculpting metaphors
Sculpting man-made objects?

Many man made objects are structured

- Self similarities
- Local symmetries



Sculpt them as clay?

Requires structure preserving deformations!

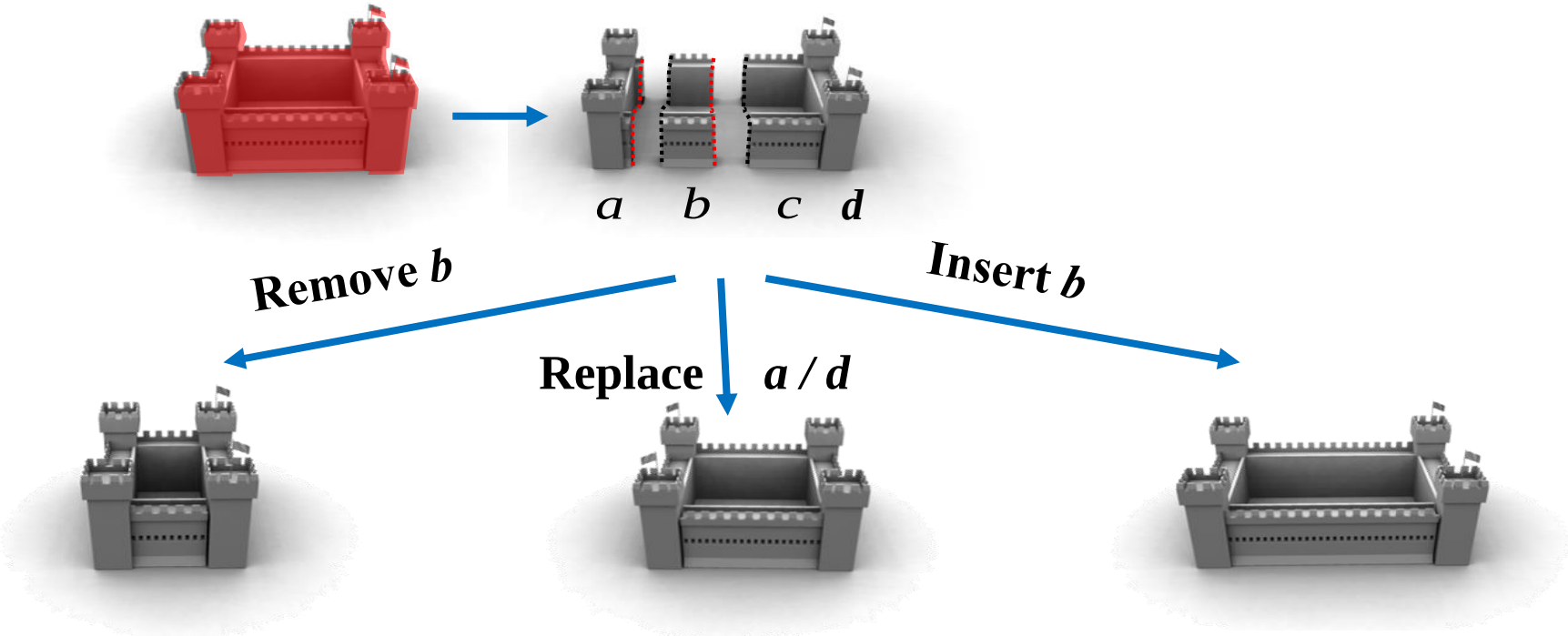
1. *Gestures for expressive modeling*
2. ***Knowledge in the models***

Structured virtual clay

Solution for "puzzle-shape-grammars" ***[Milliez 2013]***

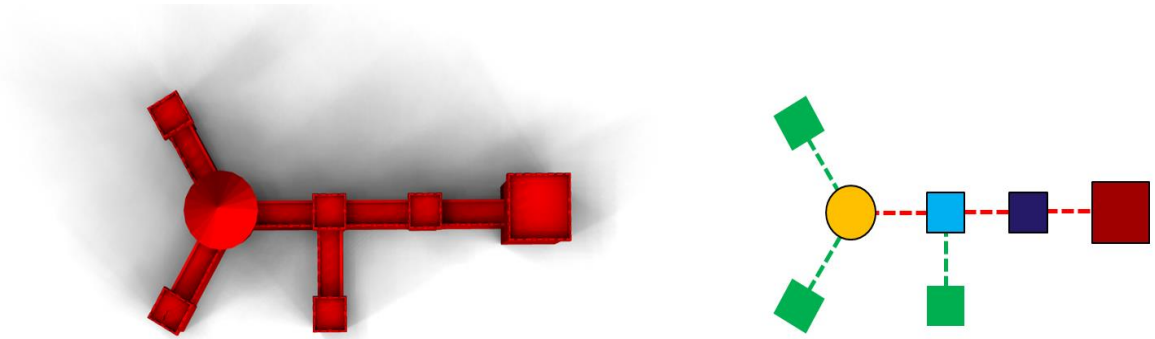
Shapes = assembly of blocks with possible repetitions

- Connection constraints derived from the input shape
- Production rules: all valid **insert** / **remove** / **replace** operations



1. *Gestures for expressive modeling*
2. ***Knowledge in the models***

Structured virtual clay
Physically-based behavior



$$E_r(f) = \sum_{p_i \in \mathcal{P}} \mathrm{dist}\left(\mathbf{R}_i\left(\mathcal{X}_i\right), f(\mathcal{X}_i)\right)^2$$

Piece rotation

Rest state

Deformed configuration

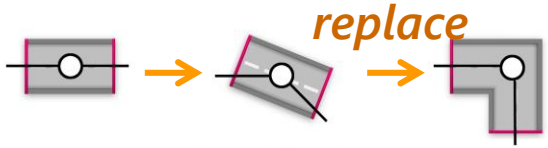
- Elastic deformation model
  - Minimize energy

  « As rigid as possible » *[Sorkine 2007]*
- Plastic behavior : ***mutable elasticity***
  - Nodes with multiple rest states

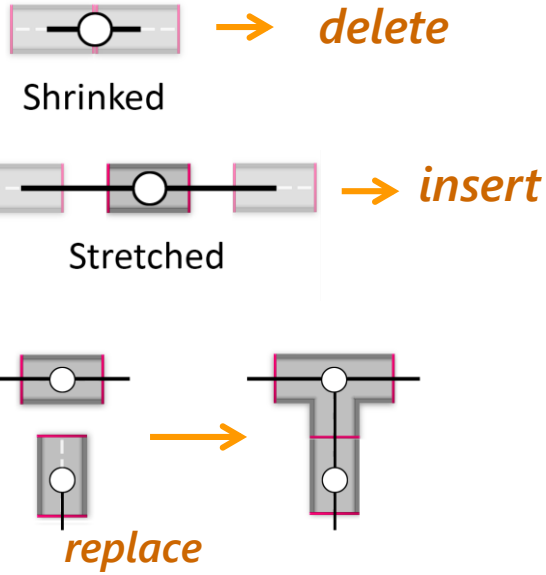
1. *Gestures for expressive modeling*
2. ***Knowledge in the models***

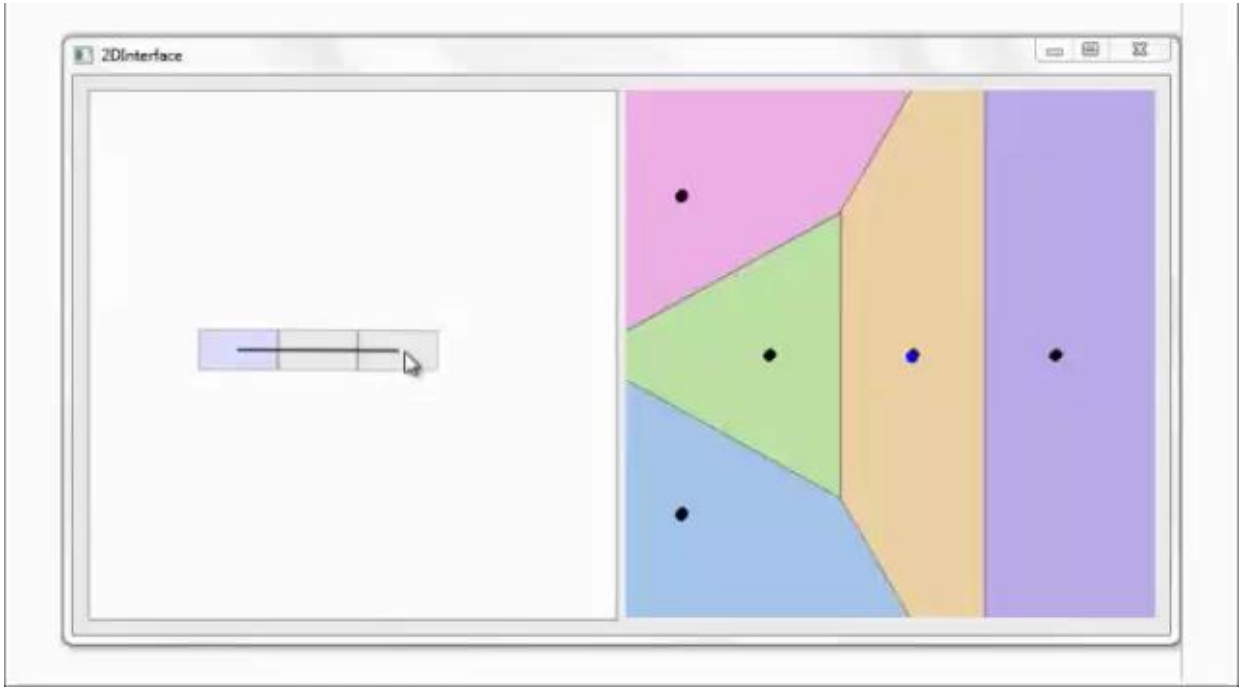
Structured virtual clay

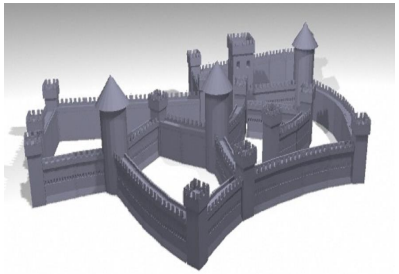
Editing the graph of components



Topology changes





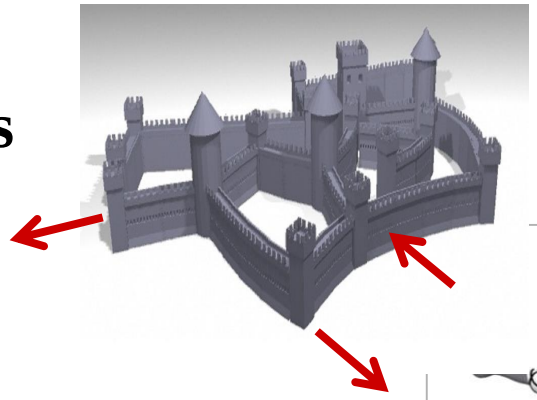


Structured virtual clay : Results

[Milliez 2013]

Synthesis

Creative flow for Complex Shapes!



Three interaction modes

1. Sketch
2. Sculpt
3. Transfer (copy-paste)

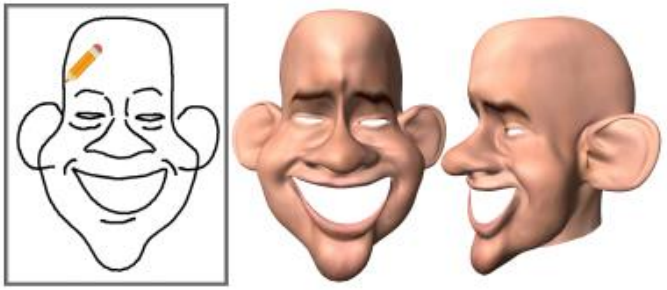
“Smart” models

- They imbed knowledge

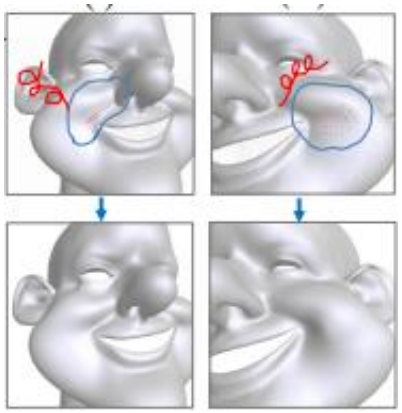
Expressive design : Recent trends
Using learning instead of knowledge

« DeepSketch2Face » *[Han 2017]*

1. 3D face from a 2D sketch
2. Draw local deformation on the 3D face

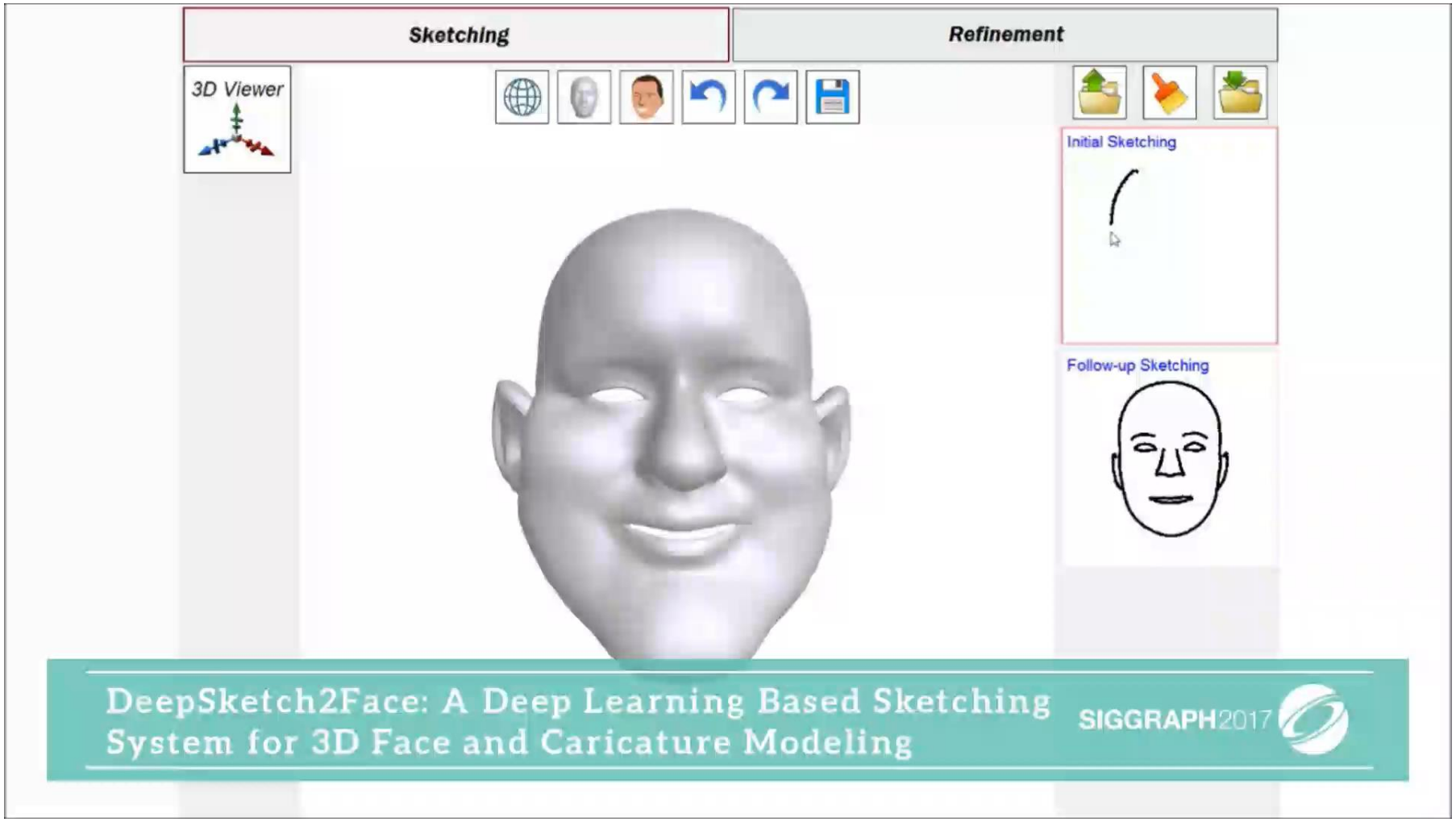


- Input: Faces database (meshes of same topology)
  - Artificially extended using exaggeration
  - Parametrization (Identity, Expression)
  - Use line-rendering to get training examples



- CNN with two branches
  - Learns correspondence between a sketch and (Id, Expr)

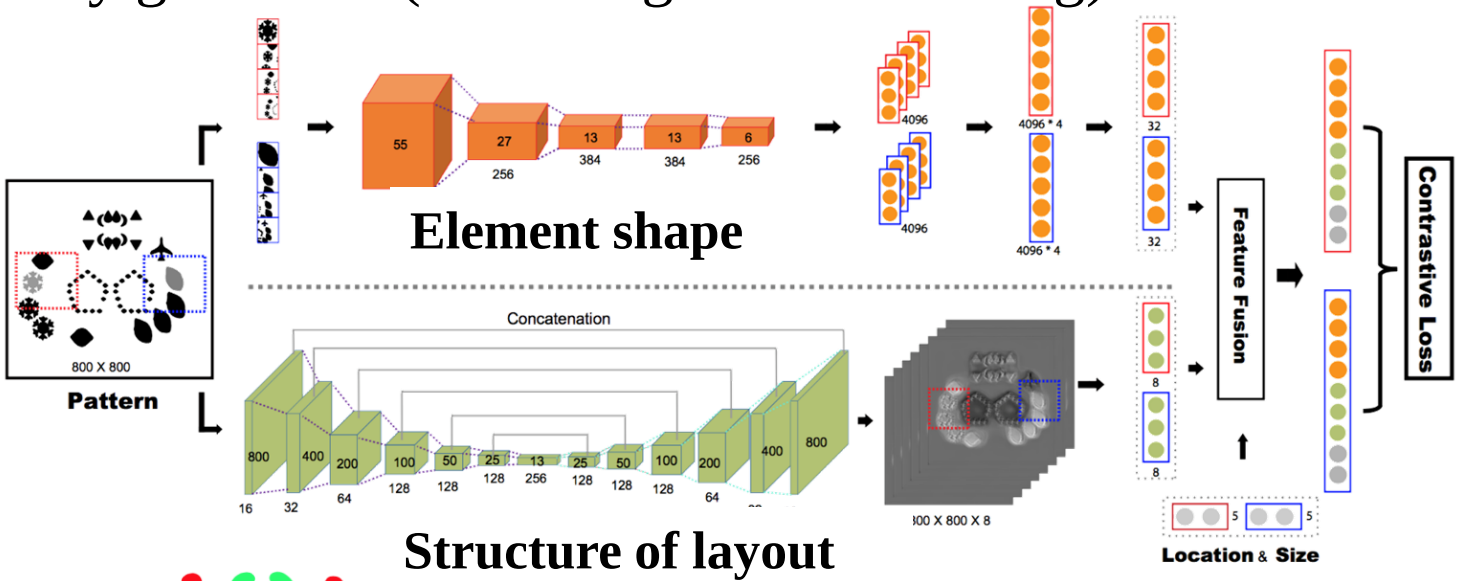
Recent trends: using deep learning
« DeepSketch2Face » [Han 2017]

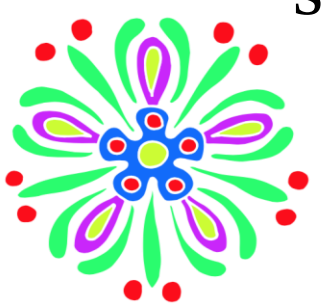


Expressive design
Recent trends: using deep learning

Learning principles of human perception → Group editing

- Examples partly generated (extending crowd sourcing)



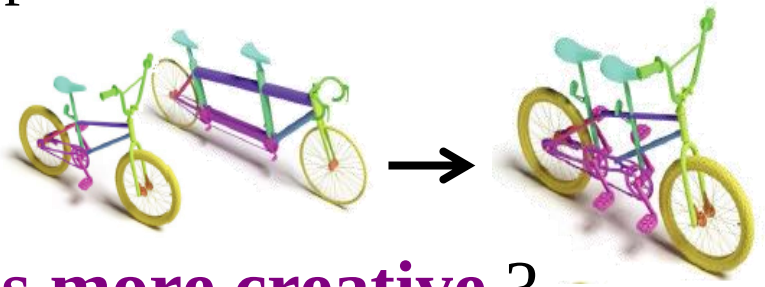


[Lun, Siggraph Asia 2017]

Conclusion
Possible futures for Creative AI ?

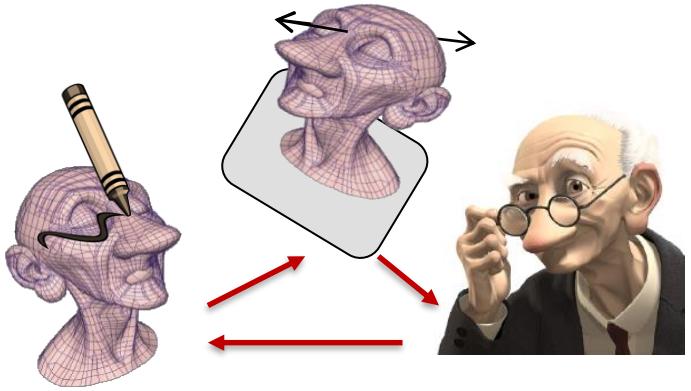
1. Ease creation from existing contents (images, videos, 3D…)
   - ML can ease contents selection, adaptation and re-use…

[Liu 2015]



2. Building on AI to **make humans more creative** ?

- Control to the user
- Smart models to help
  - Interpreting gestures
  - Duplicating details
  - Maintaining constraints
- Combination of prior knowledge (semantic AI) + learning



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