Shaping Imaginary Content

from 3D Digital Design to Animated Virtual Worlds

Marie-Paule Cani
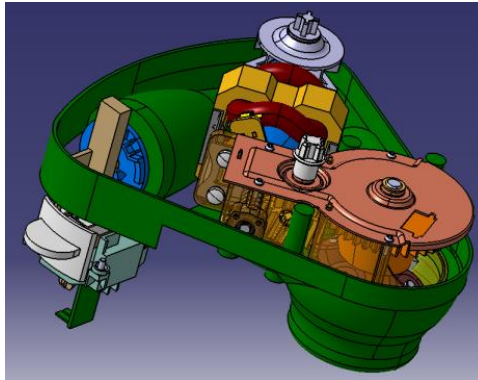
Univ. Grenoble-Alpes, CNRS & Inria

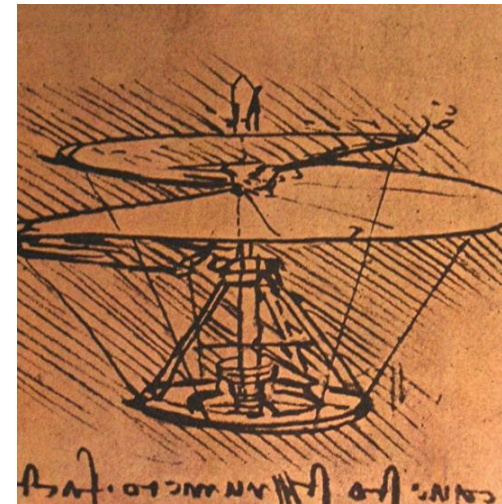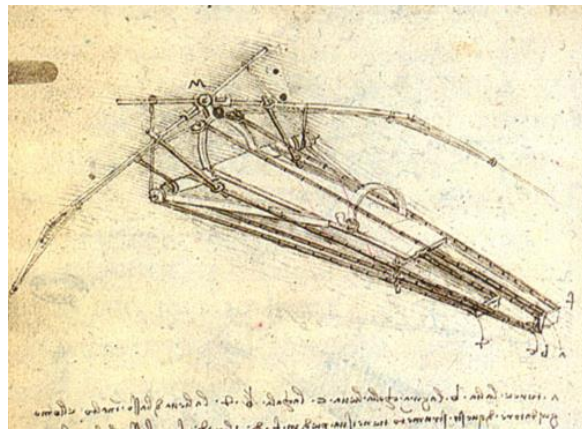# 3D Graphical Creation
See and touch imaginary worlds?

- Shaping and printing an imaginary 3D shape
- Giving life to a populated and animated virtual world…

Playful dimension… and a wonderful tool!

3D Graphical Creation
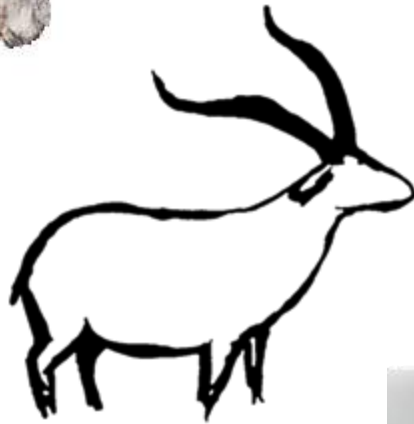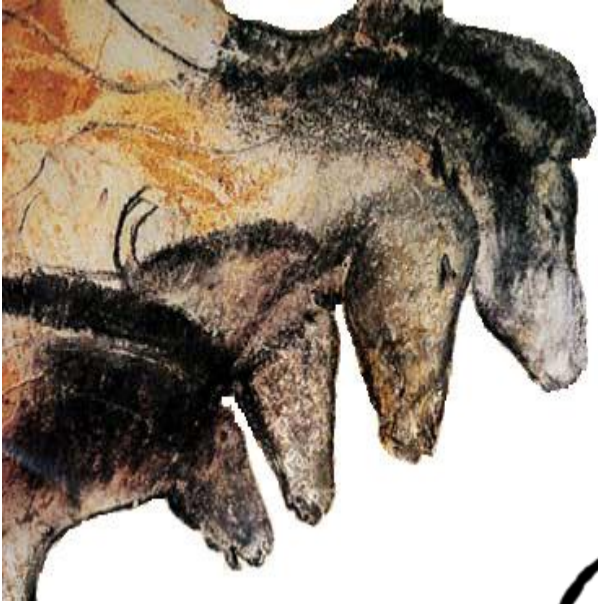# *Understanding and Inventing*

@Leonard de Vinci

"**Graphics designs must be seen as cognitive tools, enhancing and extending our brain .**"

Colin Ware

3D Graphical Creation
Which tools?

@Macho Cabrio

La chute @JB Martin

- Painting… drawing… sculpting…

@Sayd

- Digital media
  - « Drawing », but in 3D?
  - « Sculpting » shapes and motions?
- Overcoming constraints
  - Size of the support, of fingers, of tools
  - Undo/Redo… Copy/Paste…

Can we do better than a pen, to shape imaginary content ?

Organization of this lecture

1. Creation of 3D digital content

2. Towards "expressive" modeling

   – Which gestures to create in 3D?

   – Knowledge in the models!

   – Controlling animated virtual worlds

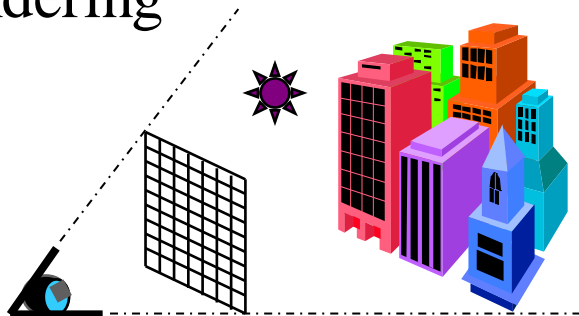3. Shaping imaginary content: Challenges

Digital creation in 3D Computer Graphics

Not "image processing", not "imaging"

- – Input: mathematical models… Output: images!

3 steps

1. Geometric modeling
2. Animation
3. Rendering
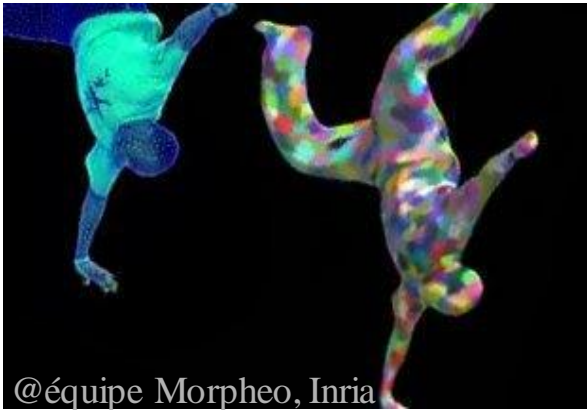
Digital creation in 3D
"Realistic" virtual worlds
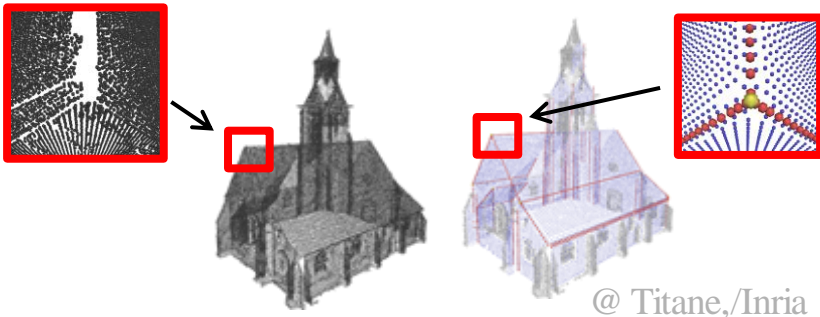

[@Crytek]

But how can we create all this content?

Digital creation in 3D
Data reconstruction? / Automatic generation?

@équipe Morpheo, Inria

@Grenoble-INP, Lyon1, Inria

- We cannot capture everything!
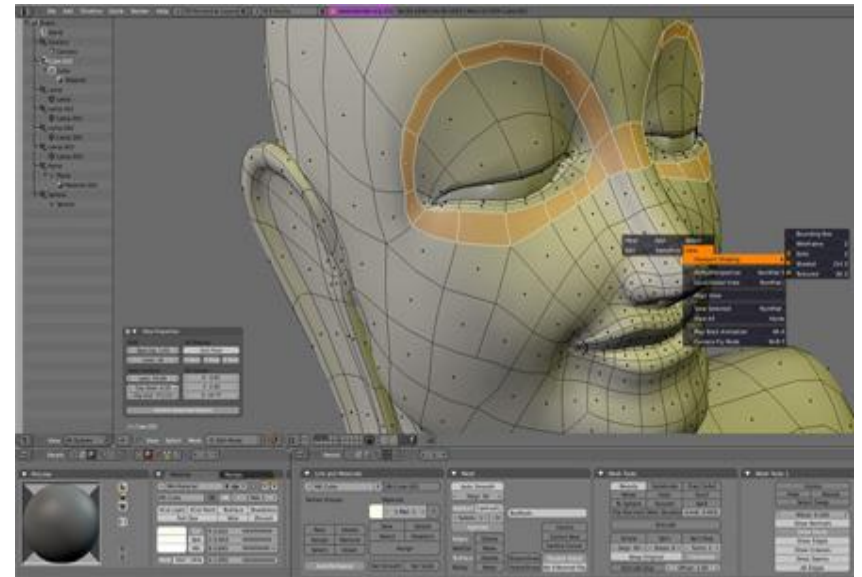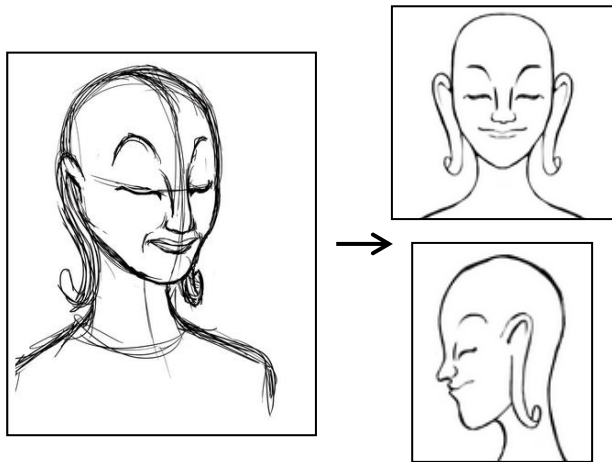
- How can we create new content?

@ Titane,/Inria

- Peut-on tout exprimer par des lois ?

- Quel contrôle ?

Digital creation in 3D
Interactive modeling?

Standard software
(Blender, Maya, 3ds max)

Main challenge: *"Make tools as transparent to the artists   as special effects were made transparent to the public!"*

[Rob Cook, scientific director of Pixar, Siggraph Asia 2008]

Shaping imaginary content!
Towards « Expressive » modeling

Make tools and models "transparent"?

Two principles

- Enable gesture-based design
- Develop "user-centered" graphical models, integrating knowledge

Questions

1. Which gestures?
2. Which knowledge, and how?
3. Adaptation to a full virtual world?

Painting in 3D

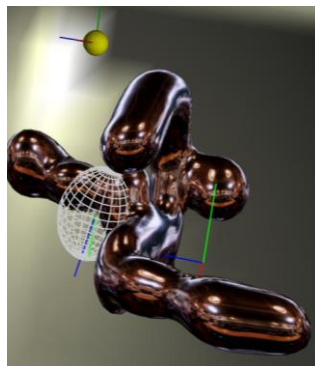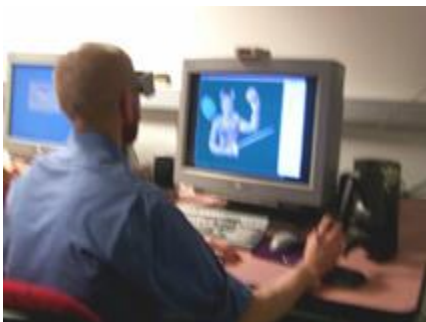## *Painting in 3D space?*

- Lacks precision
- Tiring

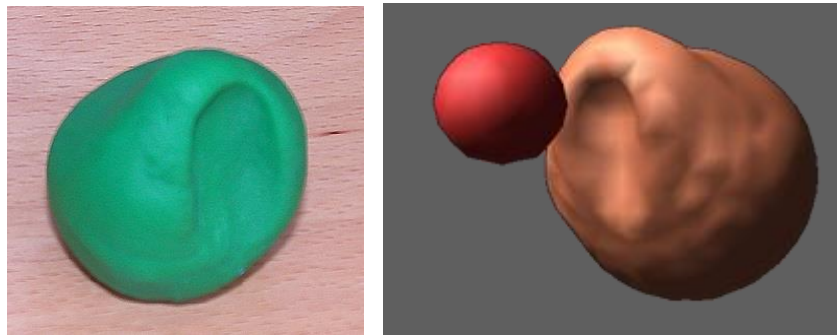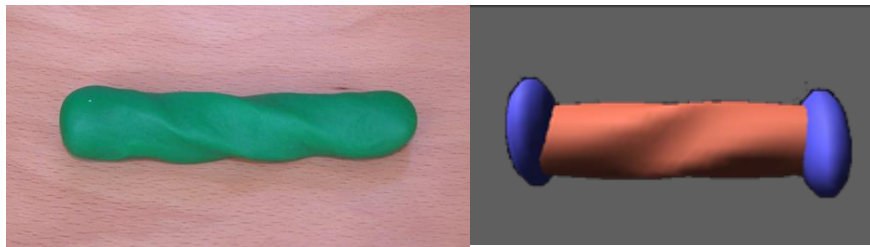## *Force feedback: rely on the objet*

Cave Painting @ACM, 2001
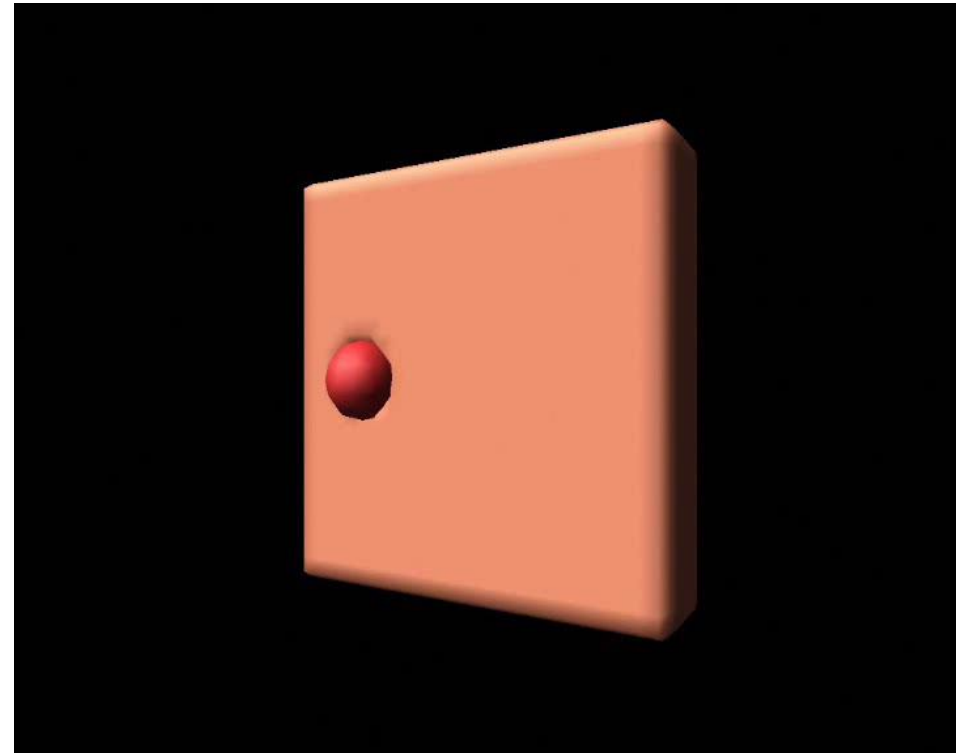
@Grenoble-INP, Inria, 2001

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Sculpting

Modeling some realistic virtual clay?
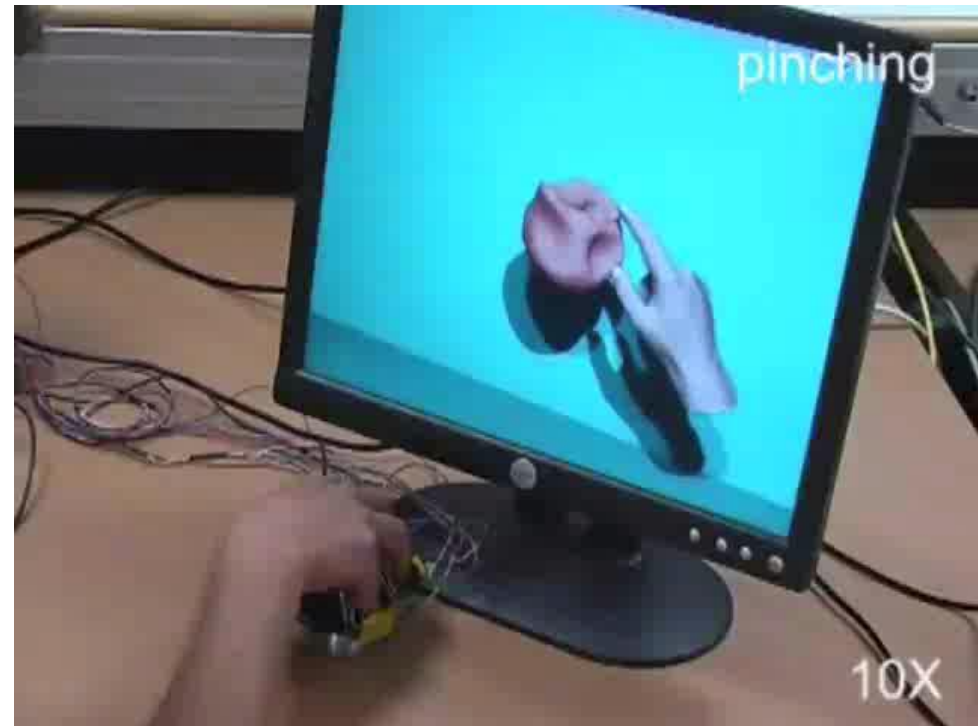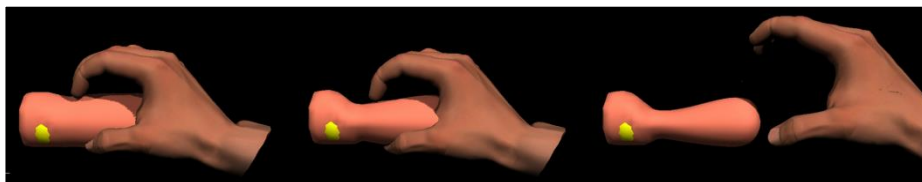

Real clay/ Virtual clay

Expressive modeling

✓ *Which gestures to create in 3D ?*
✓ *Knowledge-based models*
✓ *Extension to Virtual Worlds*

Sculpting

Controlling a virtual hand?
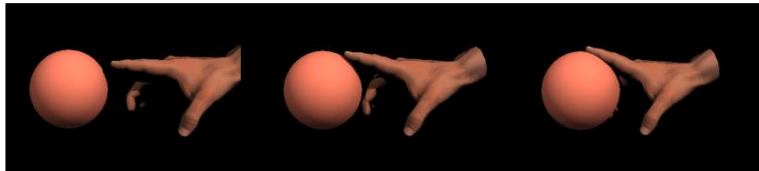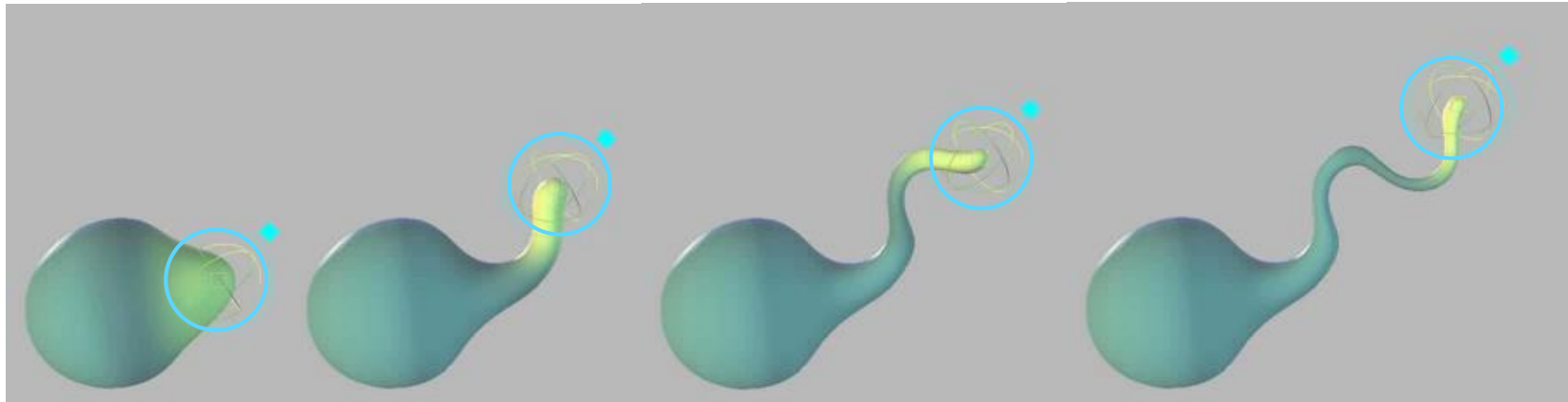
- "Hand Navigator"

@Grenoble-INP, Inria, 2008

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
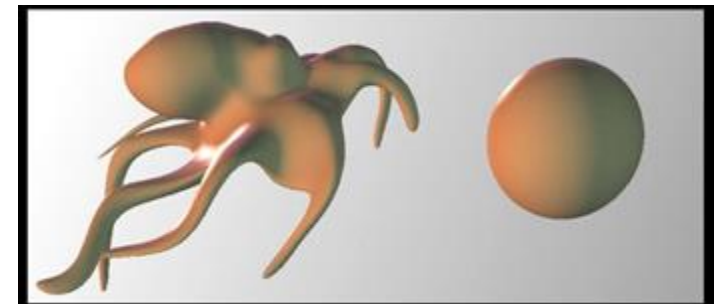- ✓ *Extension to Virtual Worlds*

Sculpting

Constant volume space deformations?

@Grenoble-INP, Inria, 2004

In summary

- *Inspire* from real, do not copy it!

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

2D drawing

Sculpting virtual clay?

or ***drawing in 2D***?

- « sketch-based modeling »

Why do we "see" 3D shapes?

Unknown shapes

- We « see » the simplest one
- i.e. the most symmetric one!
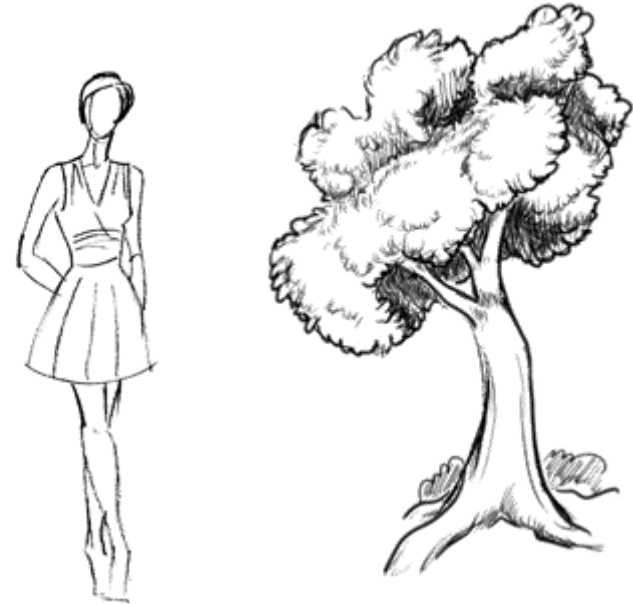
Well-known shapes
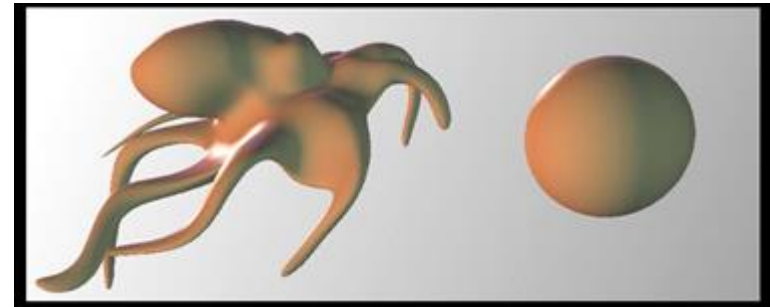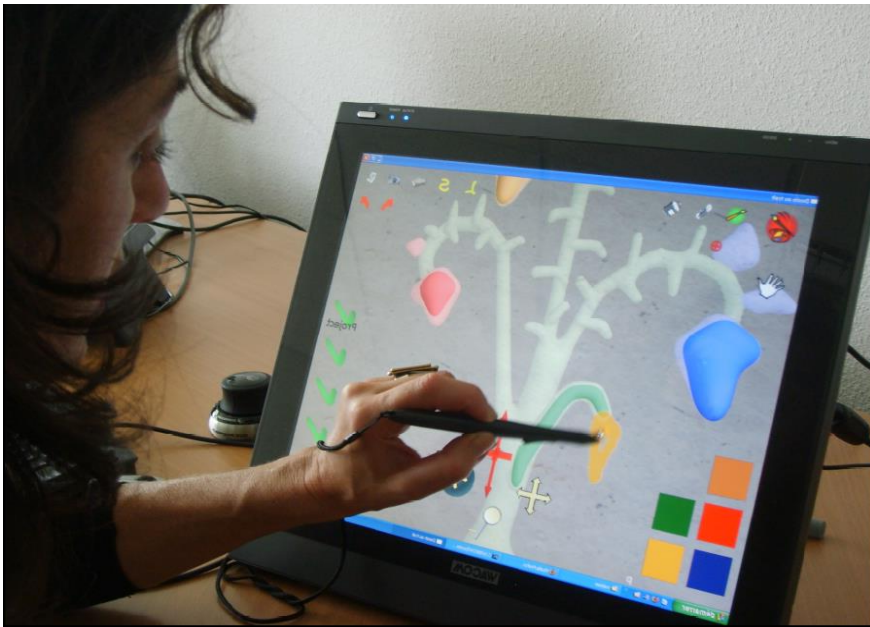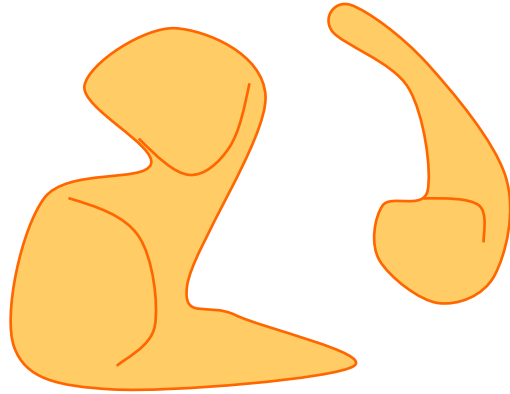
- We use existing knowledge
- Enables to infer missing data

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Sketching: Unknown shapes

Squelette

How can we infer depth?

- • Symmetry around a skeleton!

How can we add details?

- • Over-sketch from another viewpoint
- • Depth from the support surface

Needs

- • Create volumes from skeletons
- • Seamlessly blend shapes
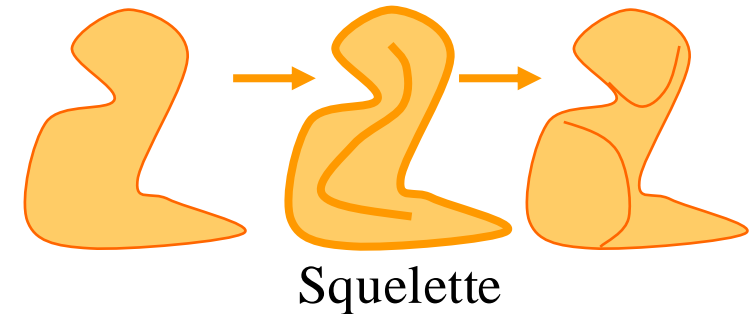
⟹ **Implicit modeling!**

Expressive modeling
✓ *Which gestures to create in 3D ?*
✓ *Knowledge-based models*
✓ *Extension to Virtual Worlds*

Sketching: Unknown shapes

@Grenoble-INP, Inria, 2010

Creation: 24 sketches, 30 minutes   Virtual shape   3D print

Why do we "see" 3D shapes?

Well-known shapes

- We use **existing knowledge**
- Enables to infer missing data

Organization of this lecture

1. Creation of 3D digital content

2. Towards "expressive" modeling
   - Which gestures to create in 3D?
   - **Knowledge in the models!**
   - Controlling animated virtual worlds

3. Shaping imaginary content: Challenges

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
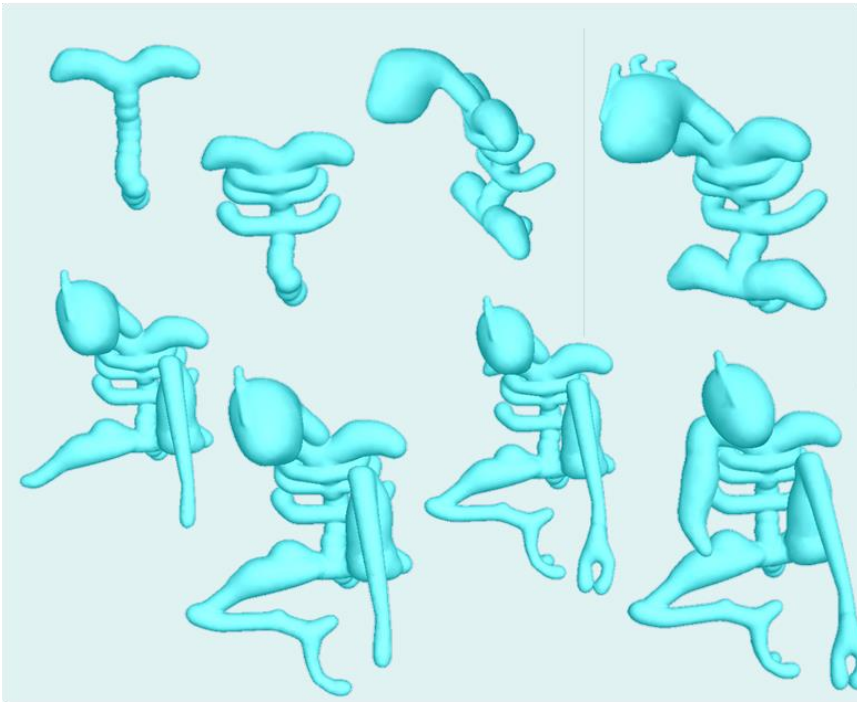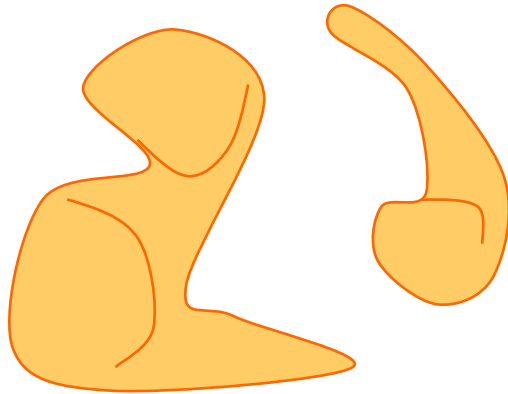- ✓ *Extension to Virtual Worlds*

The example of Garments

- Piece-wise developable surface
- Difficult to design in real
- Needed for dressing virtual characters
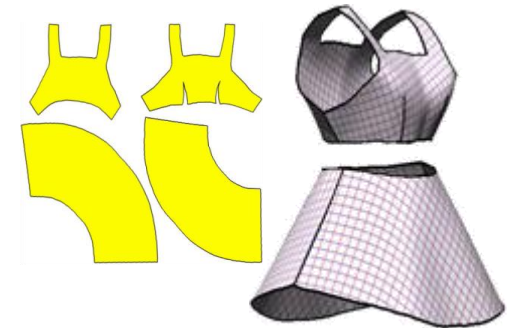
Which knowledge? (sketch-based modeling, animation, transfer)

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Garments from sketches

Standard pipeline

- Sketch and position 2D patterns
- Simulation under gravity
- Iterate to tune parameters!

→ ?

3D model from a sketch?

→ automatic computation of patterns!

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Garments from sketches

- Draw over a view of the mannequin

- Knowledge? Rule of thumb:
  - Fitting is constant all around the body!
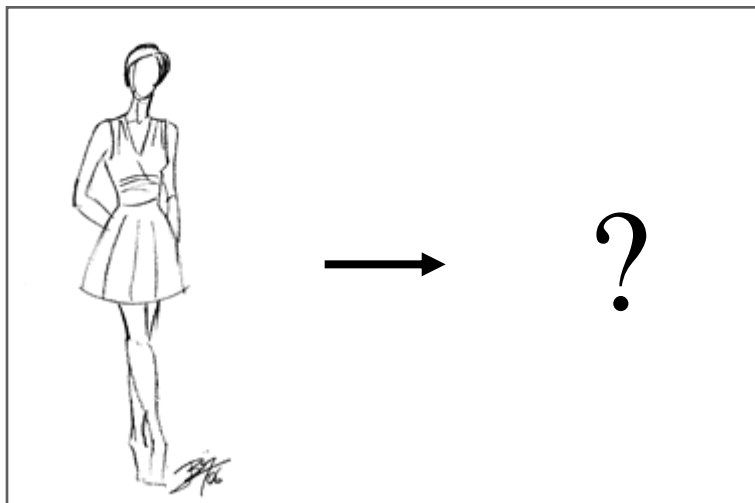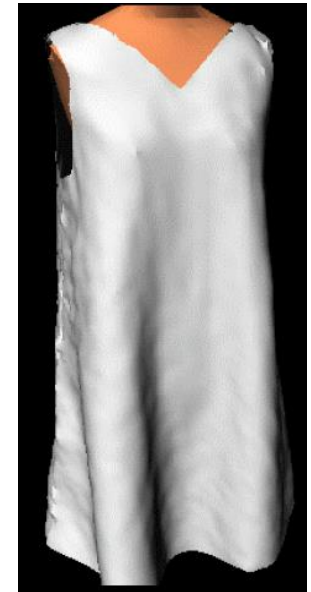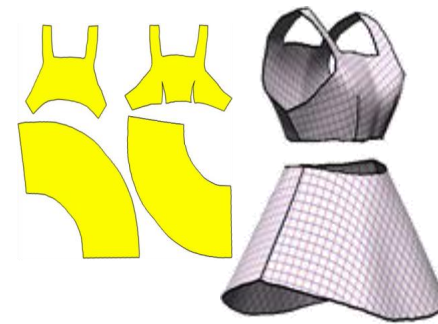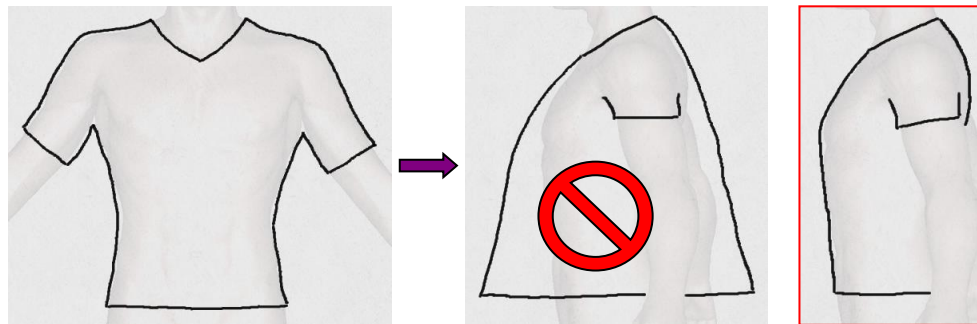
Sculpt in a distance field!

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Garments from sketches

The result lacks folds!

- Enable to draw them?

- … or make use of more knowledge?
  - A garment is piece-wide developable
  - Folds can be computed

@Grenoble-INP, Inria, 2007

25

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Garments from sketches

Input

Validation
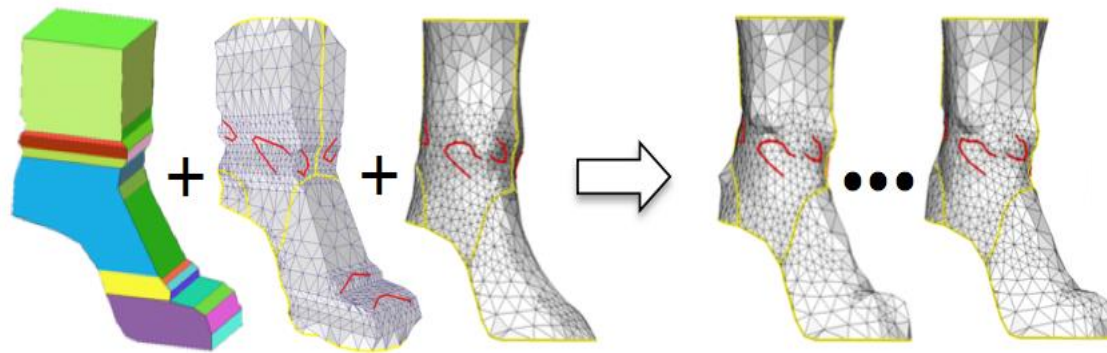
Solution: optimize developability and identify silhouette points!
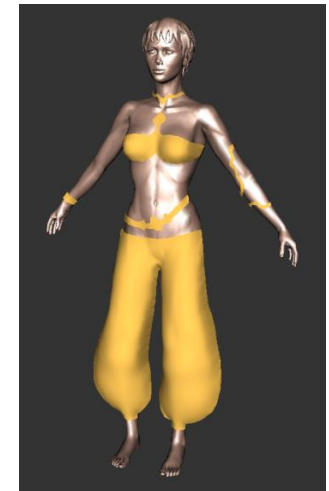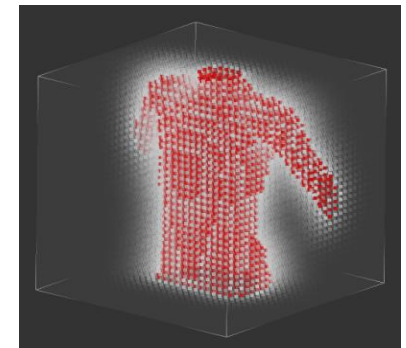
Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Animating garments

- Real-time simulation
- Measure isometry
- Add folds

@Grenoble-INP, Inria, UBC, 2009

Input Simulation

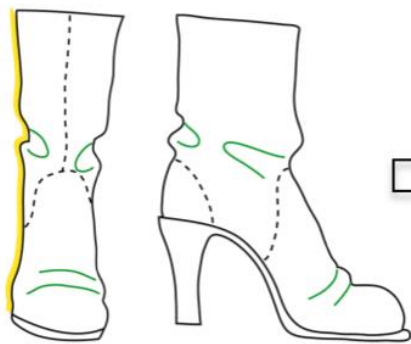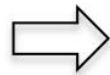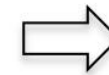Our results

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Transferring garments

Aim: Automatic adaptation

Can be fabricated
- No self-intersection or collision
- Piece-wise developable

Design preserving
- Proportions
- Fitting parts
- Orientation of surfaces

@Grenoble-INP, Inria, 2012

To express mathematically and convert into algorithm!

Transferring anatomy

Second example: Anatomical knowledge

- Straight symmetric bones, muscles (not skeleton) proportional to fat

- Adequate processing pipeline to be developed

Organization of this lecture

1. Creation of 3D digital content

2. Towards "expressive" modeling

   – Which gestures to create in 3D?

   – Knowledge in the models!

   – **Controlling animated virtual worlds**

3. Shaping imaginary content: Challenges

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
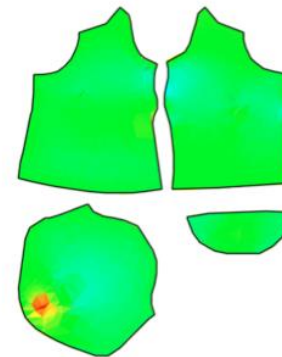- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Managing complexity

Complexity of shapes, motion, and in terms of number of elements

- Opportunity to collaborate with other sciences

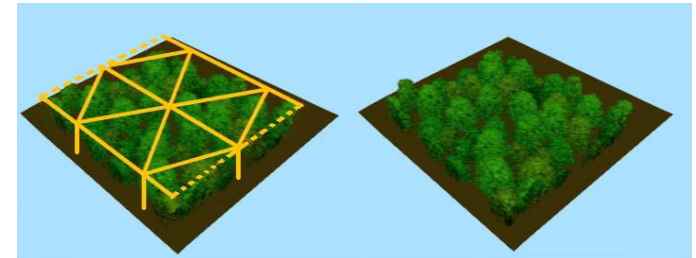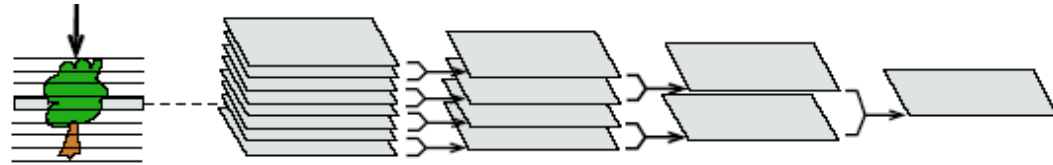- Specific needs

@Inria, Grenoble-INP, U. Toronto 2005-2009

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
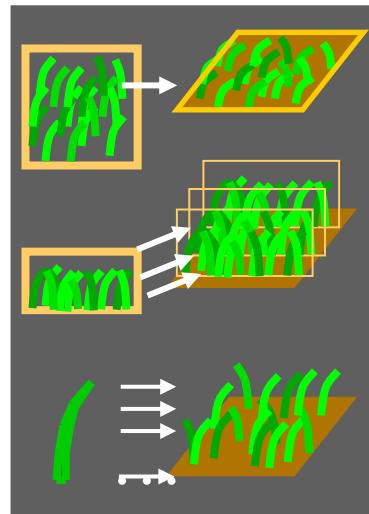- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Managing complexity

Solution: Adaptive models

@Grenoble-INP, Inria, 2004

- Objects appear when looked at
- Adaptive level of details

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

Challenges for content creation

Lots of elements + rules to be maintained

- ✓ Shapes: laws from biology, geology, statics
- ✓ Motion: dynamic laws, action-reaction

Three challenges

- How can we design all these elements?
- How to animate them efficiently?
- Can we combine realism and control?
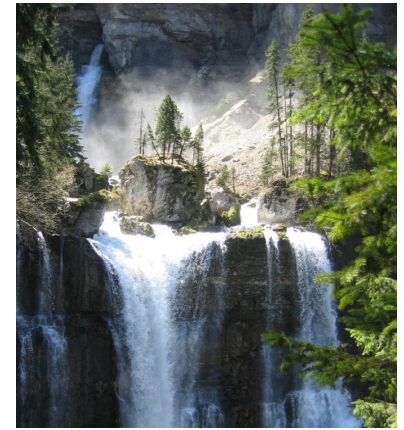

Methodology: *Control to the user, knowledge to the system!*

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

1. Too much content for design

Example: Modeling a tree

- Need to control its specific shape

- Biological and statistical laws to be maintained

- Drawing each branch, and each leaf, would take too long!

Inspiration

Idea

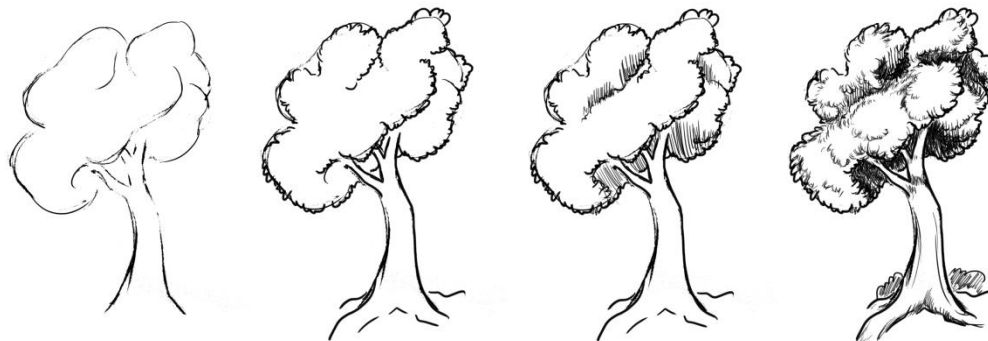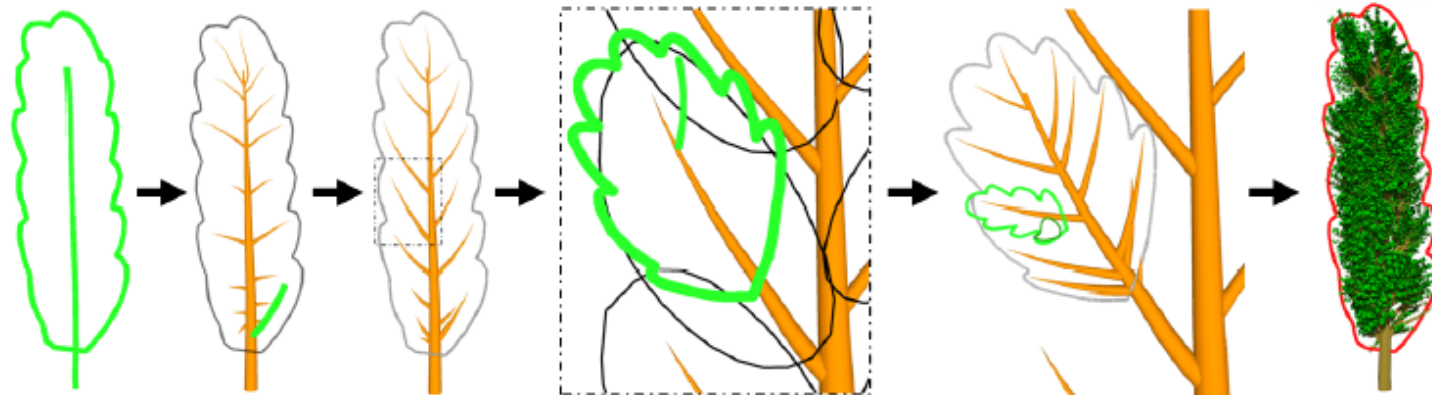Combine multi-resolution sketches with procedural generation!

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

1. Too much content for design

Tree: Sketching multi-resolution distributions

- Structure from silhouette!
- Use rules from botanic and probabilities to:
  - Infer sub-structures
  - Adapt branching style
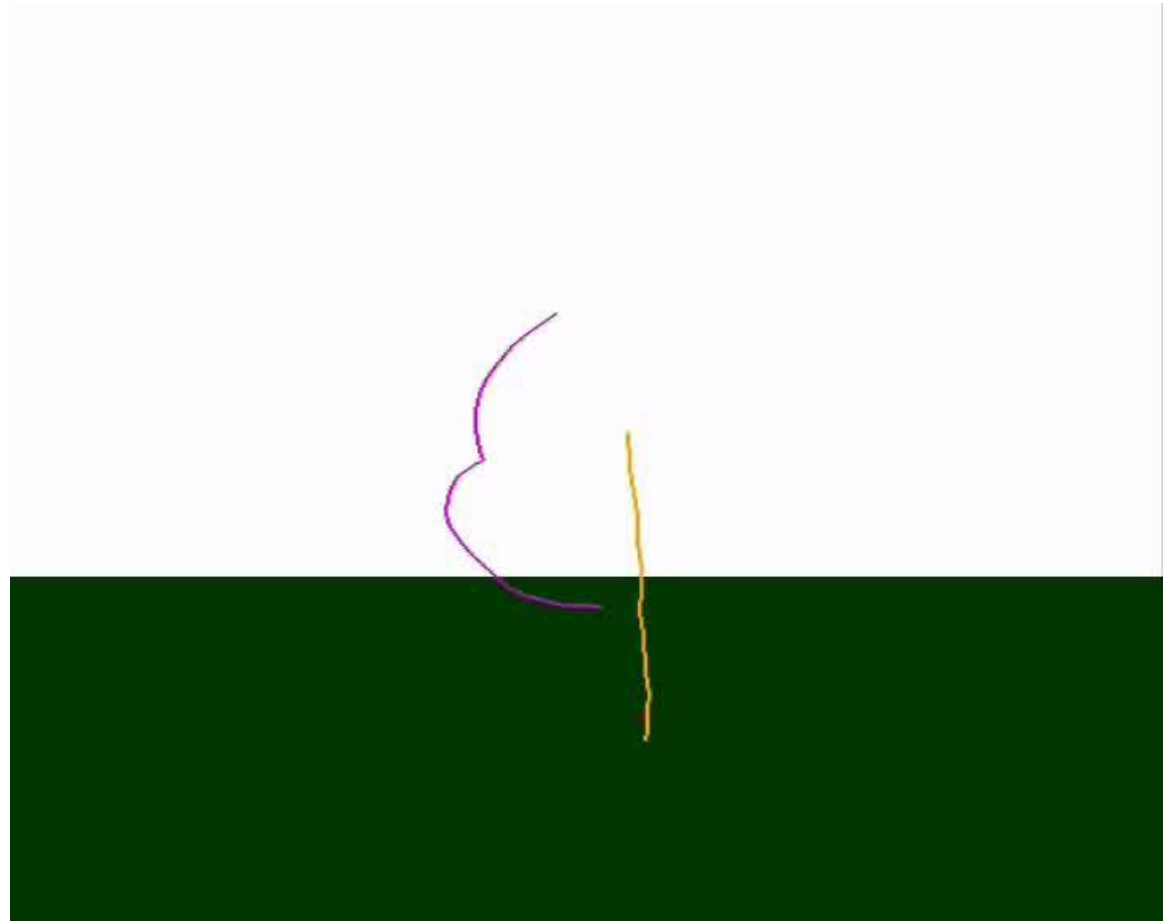 - Extend branches to 3D

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

1. Too much content for design

Tree: Results

@Grenoble-INP, Inria, 2006

Expressive modeling
✓ *Which gestures to create in 3D ?*
✓ *Knowledge-based models*
✓ *Extension to Virtual Worlds*

2. Too many objects to simulate

Example : creating and animating a full head of hair

- 100 000 non-extensible, interacting hair-strands
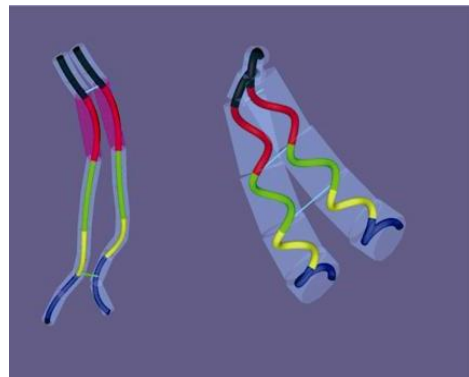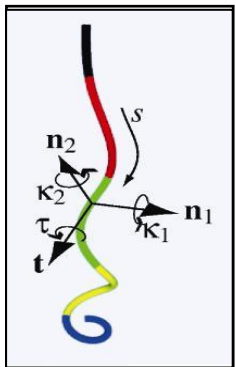- Both static shape and dynamic motion emerge from interactions

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

2. Too many objects to simulate

Solution: layered model

- Animate a few « guide hair » (super-helices)

- Process interactions at the scale of hair wisps

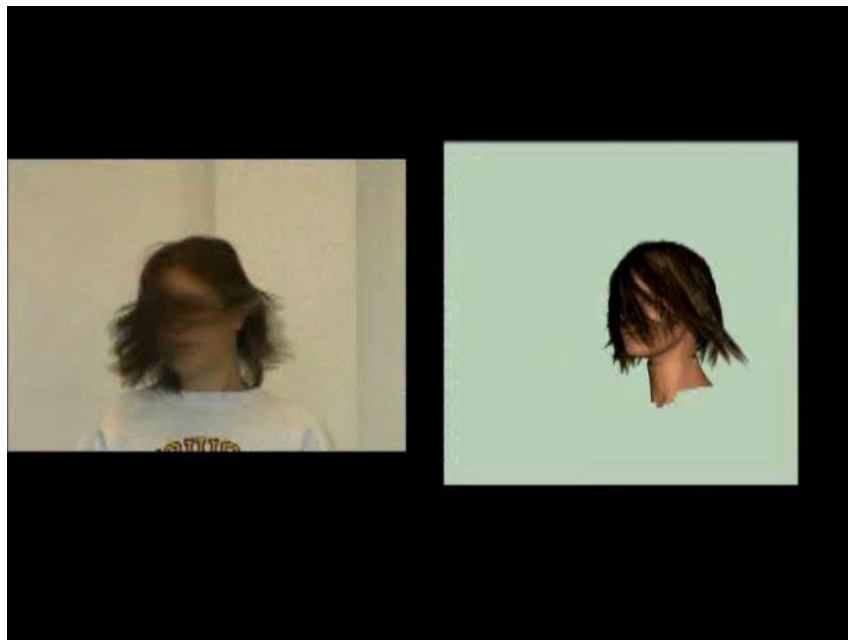- Add stands using interpolation or extrapolation

Expressive modeling
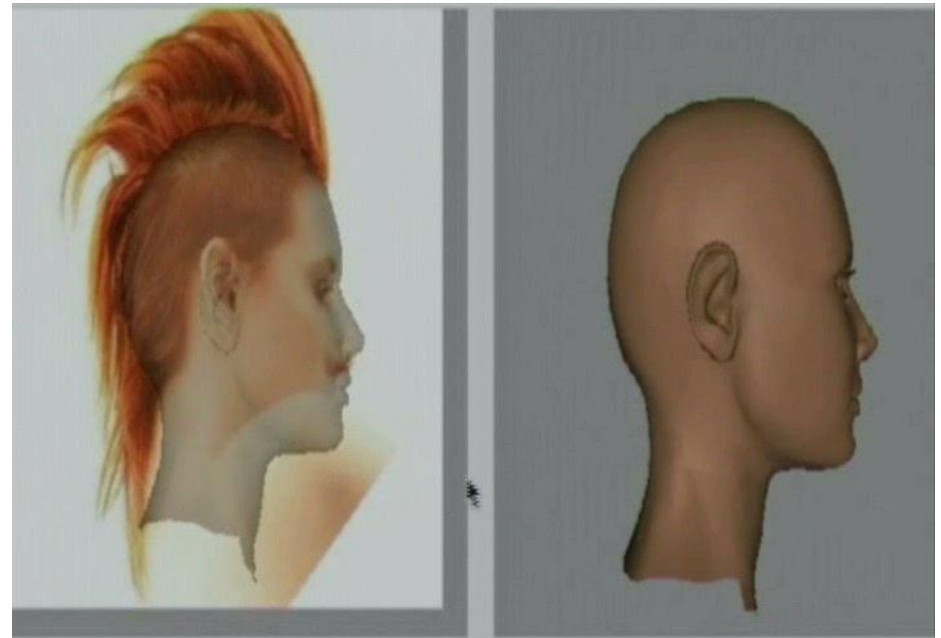- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
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2. Too many objects to simulate

Results

@Inria, CNRS, Grenoble-INP, l'Oréal 2006

@Grenoble-INP, Inria, UBC 2007
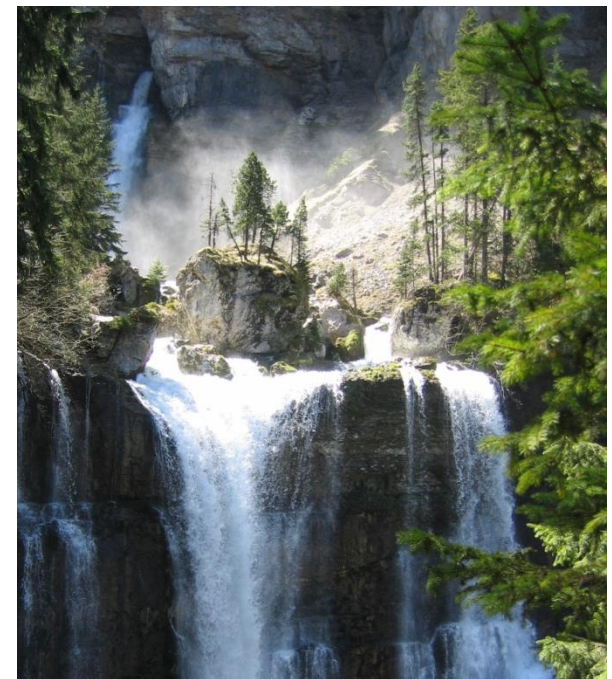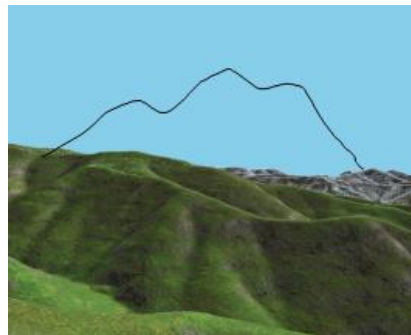
Expressive modeling
- ✓   *Which gestures to create in 3D ?*
- ✓   *Knowledge-based models*
- ✓   *Extension to Virtual Worlds*

3. Realism and/or Control ?

Example: Creating a waterfall scene

- Trajectory and type of running water dictated by the terrain slope

- Flow consistency to be maintained

- But the user would like some control!

@Grenoble-INP, Inria, Cambridge 2014

Expressive modeling
- ✓ *Which gestures to create in 3D ?*
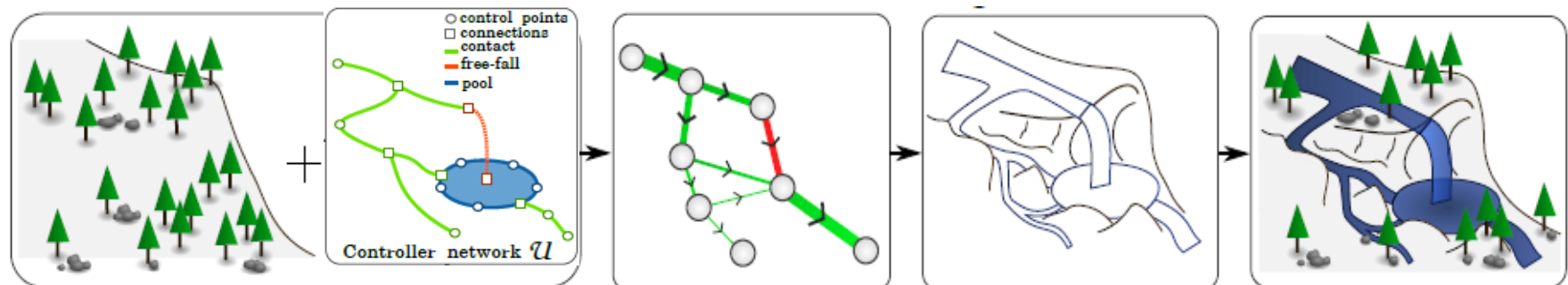- ✓ *Knowledge-based models*
- ✓ *Extension to Virtual Worlds*

3. Realism and Control

Solution: interleave control and generation

- The user sketches a network

- Consistent flows are computed

- The terrain deforms to match the flow

@Grenoble-INP, Inria 2014

Part 1: Creating Digital 3D Shapes

- Geometric representation: Implicit surfaces
- Interaction metaphors: sculpture, sketches, re-use and transfer

Seminars: Loïc Barthe, Sylvain Lefebvre, Adrien Bousseau, Tamy Boubekeur

Part 2: Designing animated virtual worlds

- Creating and animating nature
- Populating virtual worlds
- Combining realism and control!

Seminars: Eric Galin, François Faure, Julien Pettré, Florence Bertails-Descoubes

Shaping imaginary content
# *Open challenges*

- Adapt to the user
  - New interactions and plasticity of models

- Abstract from specific shapes
  - Draw/Sculpt 1D, 2D, 3D models + distributions
  - Infer function from shape? Preserve it under deformation!
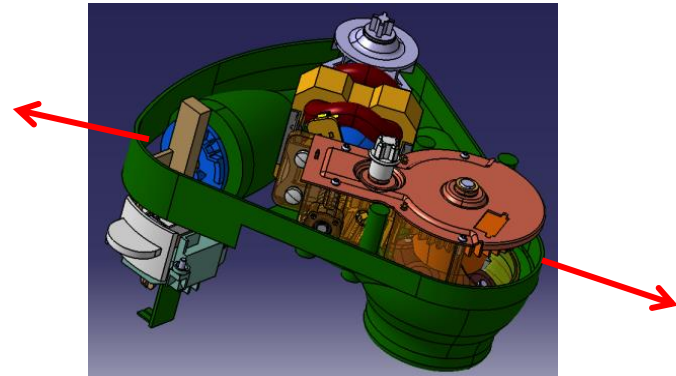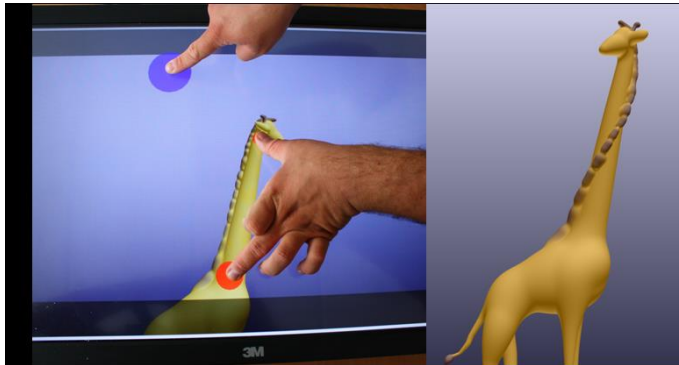
Shaping imaginary content
Open challenges

- Extension to animated content
  - Which gestures to design new animations?
  - Can we "sculpt" motion, i.e. deform and refine it?
 - *Which knowledge should we embed in the models?*
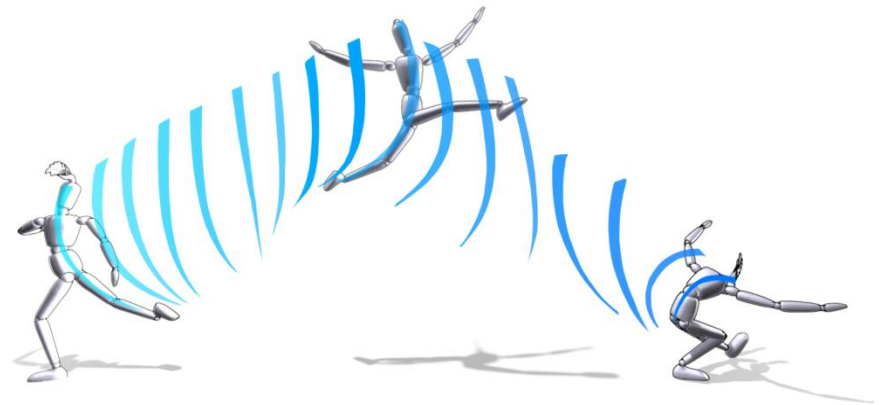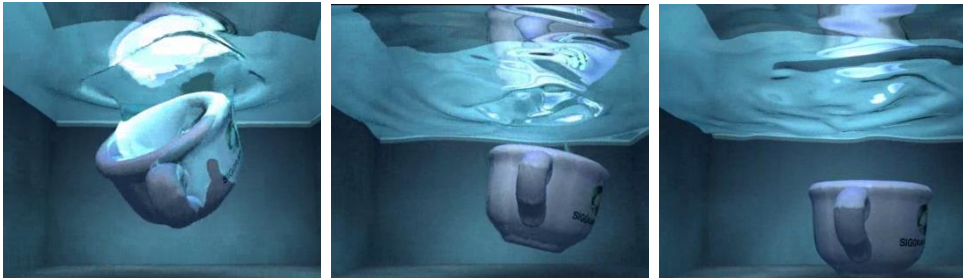
Conclusion

Revolution of 3D graphical design

- Reaching commercial software

  Zbrush, Sculptris, SketchUp, Jweels... Minecraft, Spore

- Digital design, support for imagination?

  – Create, see and manipulate 3D creations

  – Design shapes & motions from coarse to fine

  – Abstract from difficult or repetitive tasks

Towards augmented humans...
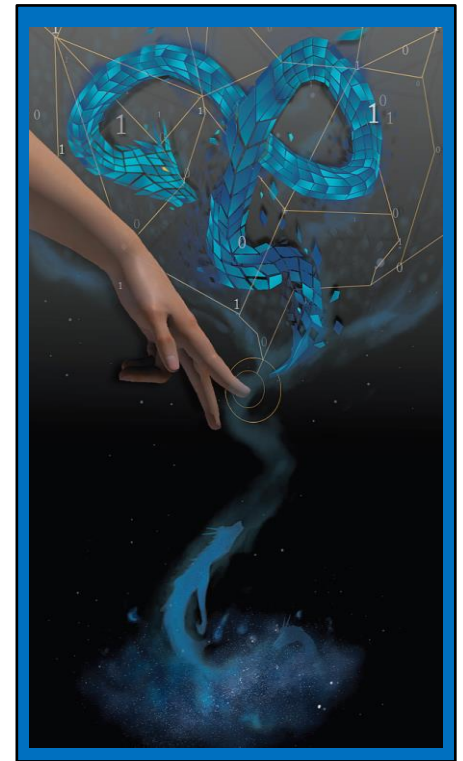
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- To my collaborators in France and abroad
- To the French Computer Graphics community

And to all the listeners!