STREAM/LIX

ÉCOLE POLYTECHNIQUE
UNIVERSITÉ PARIS-SACLAY

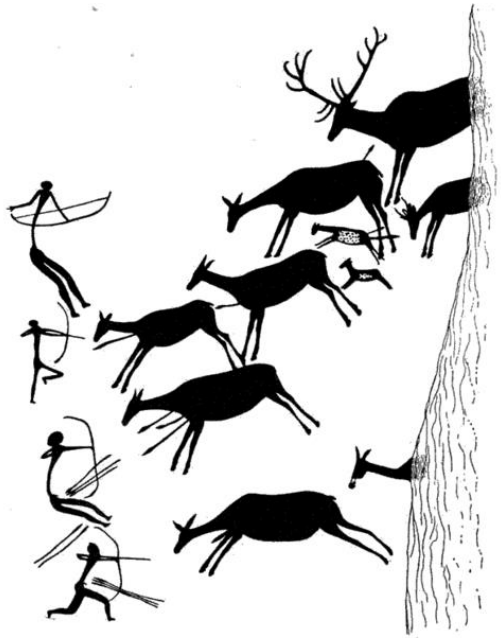
Across Disciplines?

Towards Expressive 3D Modeling for Visual Communication

Marie-Paule Cani
Ecole Polytechnique

European Computer Science Summit, October 24-25 2017, Lisbon

Visual communication
Sharing our understanding of the world

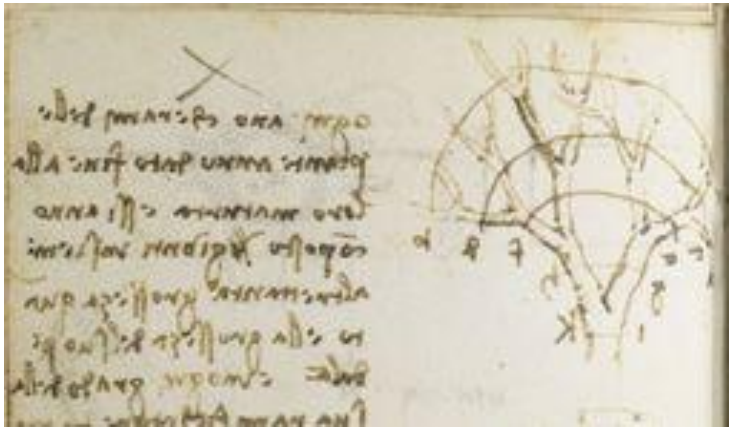


Shapes…

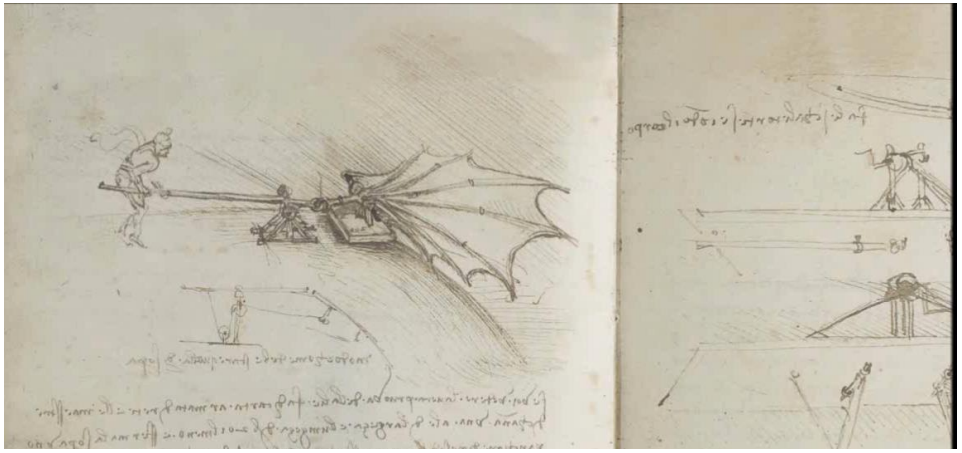
Motions …

Stories…

Visual representation Helps to Understand & Create!



Leonardo da Vinci



@ Renaud Chabrier

“We should think about graphic designs as cognitive tools, enhancing and extending our brains.”

Colin Ware, *Visual Thinking for Design, 2008*

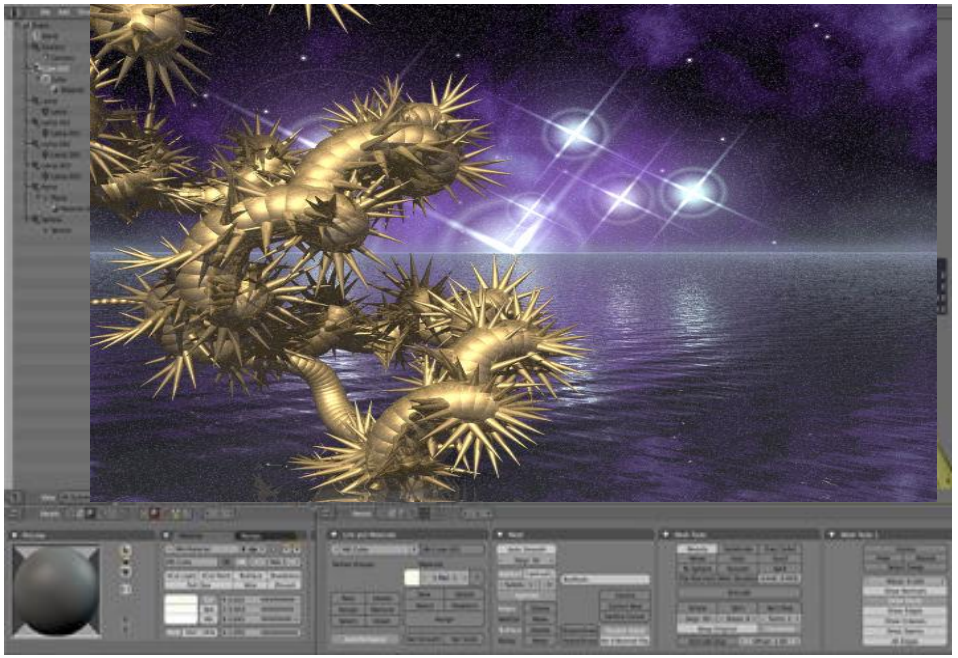
Modern creation media for visual contents?
Computer Graphics

3D modeling software

Editing DOFs of complex models

Only usable by trained artists

Refrains direct design !



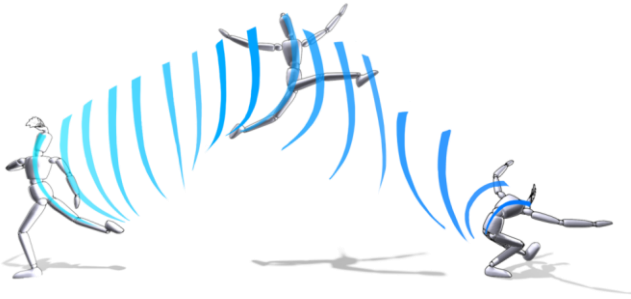
Uses for other sciences?

- Vision from a scientist
- Explained to an artist…
- Multiple trials and errors!

Pre-created contents. The scientist cannot interact with them !

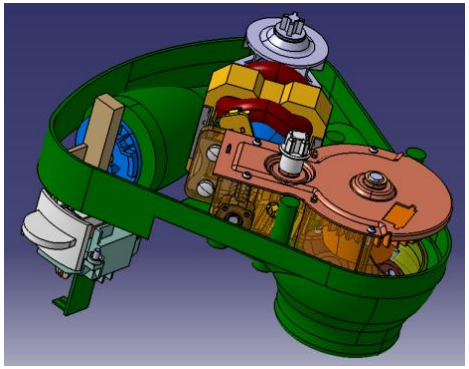
Computer Graphics
Should bring much more than paper and pen!

- New capabilities
  - « Draw » but in 3D ?
  - « Sculpt » but also motion?
- Get rid of constraints
  - Size of support, pen
  - Undo/redo…
  - Copy/paste…



Could it evolve into a new expressive media?

In this talk
Expressive 3D modeling

A revolution of digital content creation

1. Gesture-based creation in 3D
2. Interactive models embedding knowledge
3. Extension to animated virtual worlds

Towards novel uses of 3D in Engineering and Science ?

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

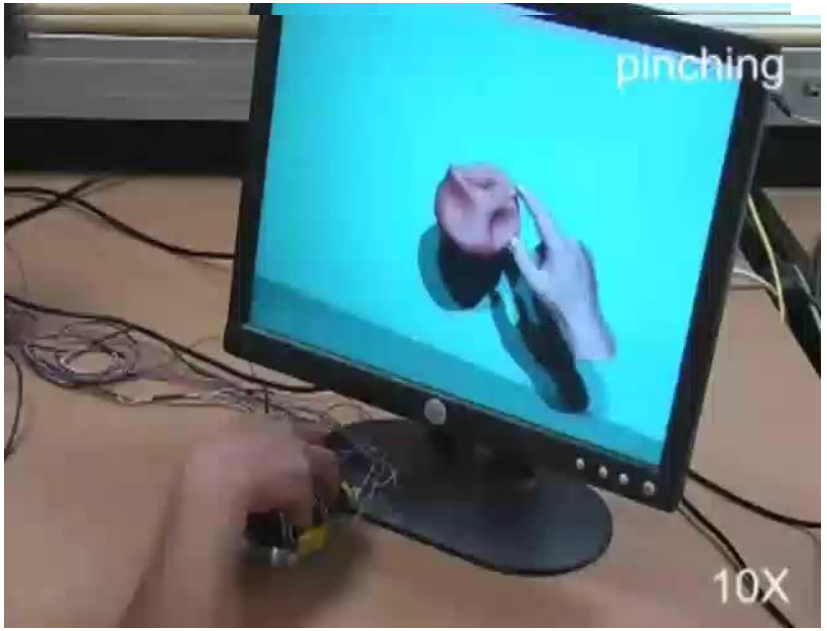
Expressive modeling
Gesture-based design!

Inspiring from traditional creation media…

Cave Painting @ACM, 2001

- 3D painting in Virtual Reality

@Grenoble-INP, Inria, 2008

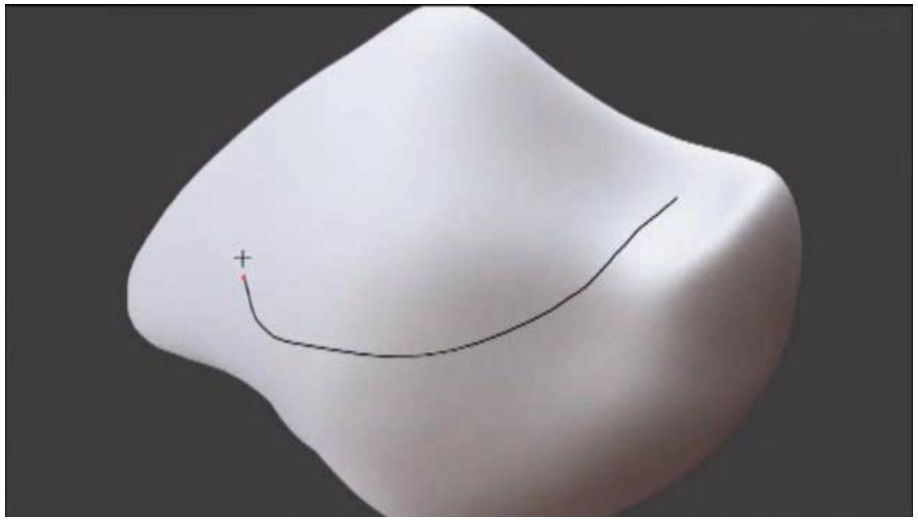


- Modeling virtual clay

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

Extending the Sculpting paradigm

[Stanculescu, Chaine, Cani 2013]

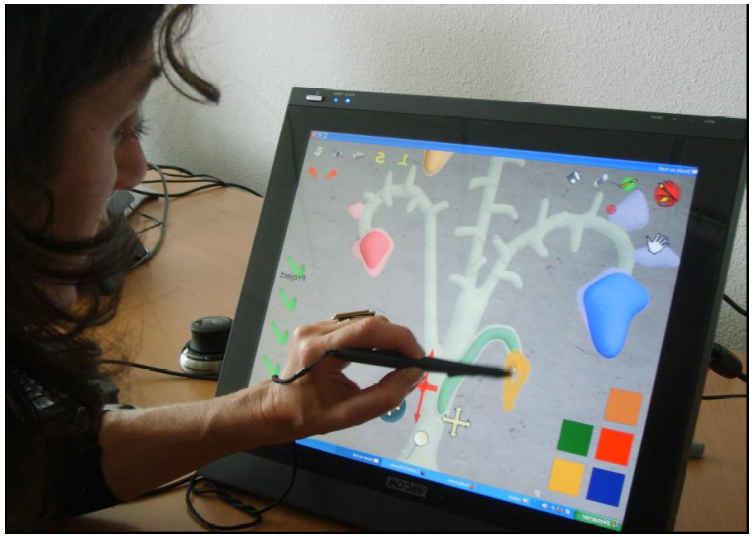


- Mixing sketching & sculpting
- A clay with sharp edges

Extending the Painting paradigm

Paint in 2D to create in 3D!

- Implicit surfaces
- Controlled blending



- ✓ *Which gestures to create in 3D ?*
- ✓ *Knowledge-based models*
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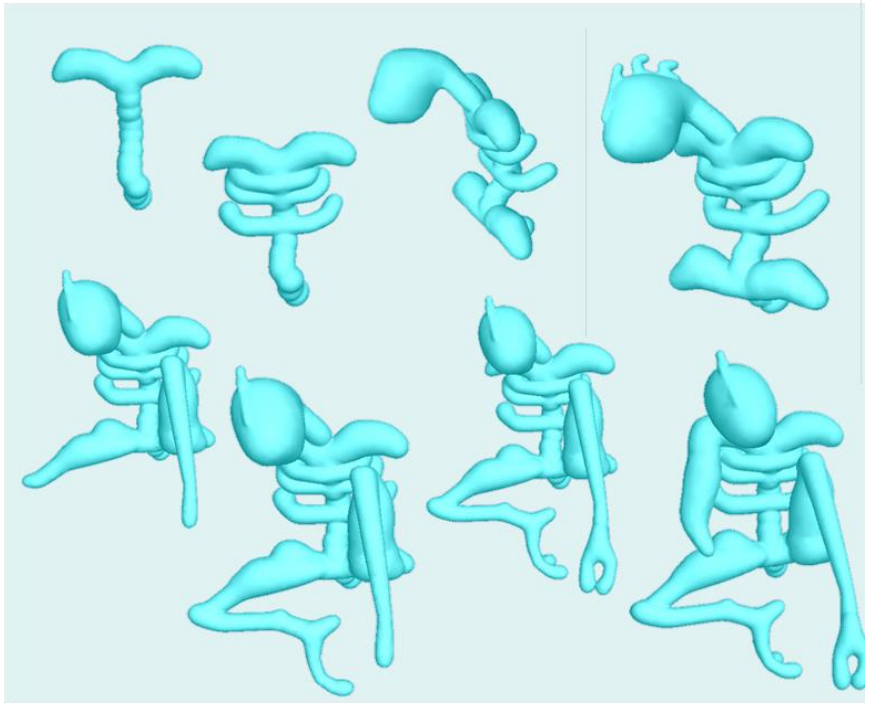
Extending the Painting paradigm
Anyone can create in 3D!

@Grenoble-INP, Inria, 2010



Progressive creation in a few minutes

Image

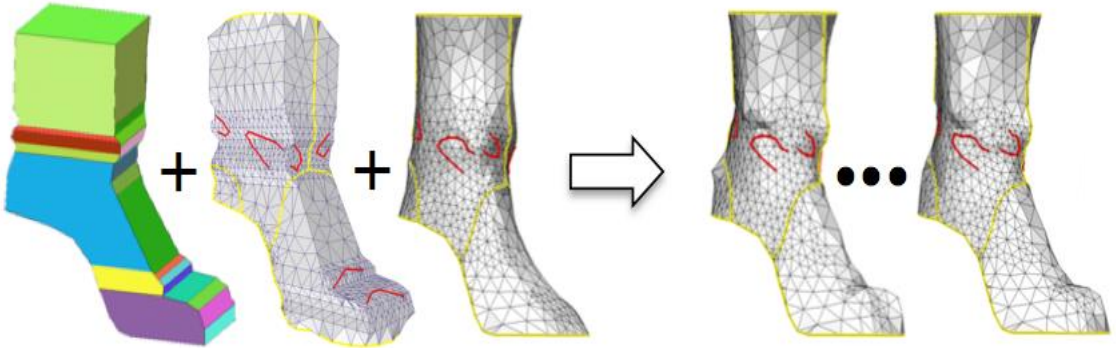
Real prototype

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

Embedding knowledge
Complex shapes from a sketch!

Input

Validation :
Real prototype



Free design

The model matches constraints (developpable surface)

Embedding knowledge
Extending Copy-Paste

- ***Transfer*** with automatic adaptation to the new context

Constraints to be preserved

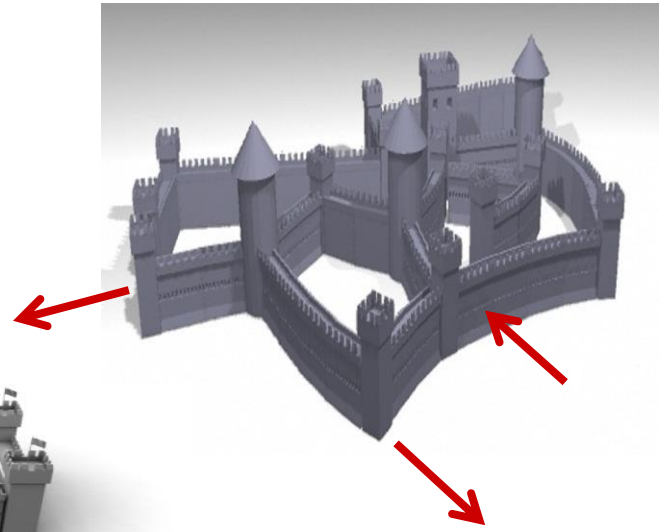
- Developable surface
- Proportions
- Tightly fitting parts
- Orientation of loose parts

Algorithm…

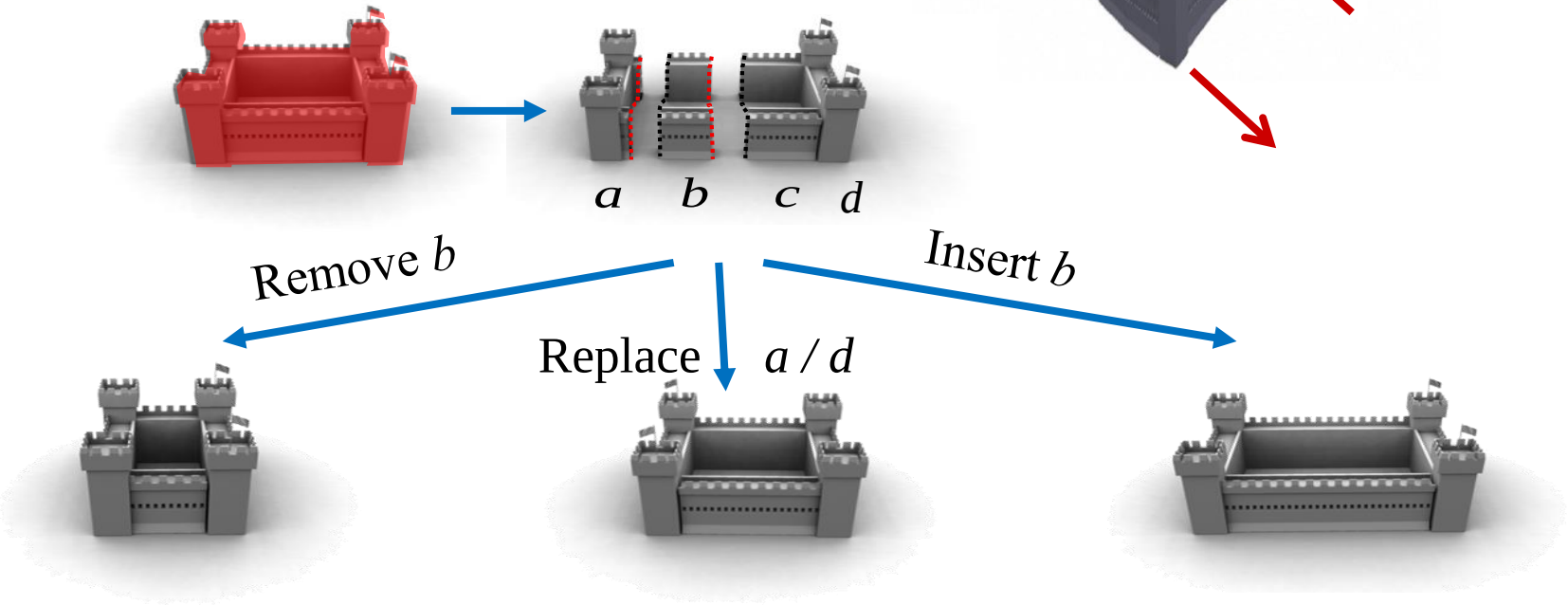
Embedding knowledge
Sculpting Structured Shapes

Man-made shapes

- Self similarities
- Local symmetries



Puzzle shape grammar



✓ *Which gestures to create in 3D?*
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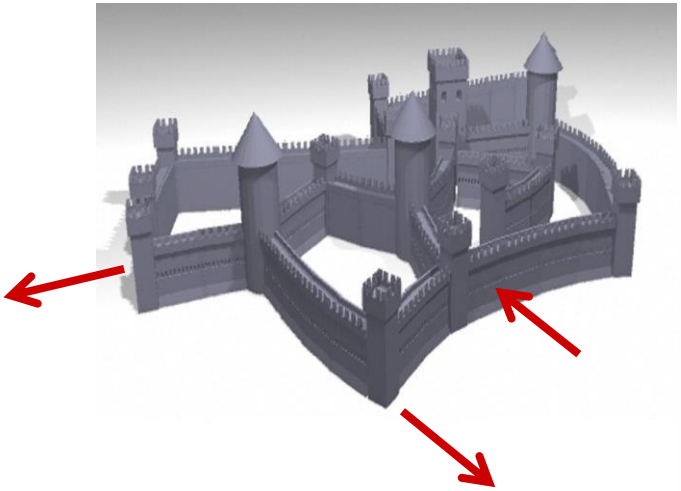
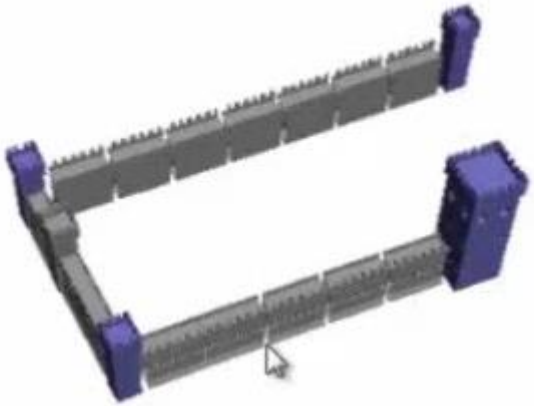
Sculpting Structured Shapes

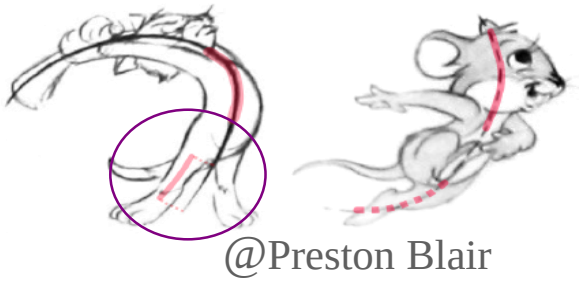




Mutable elastic models

- Energy minimization
- Rules applied on the fly

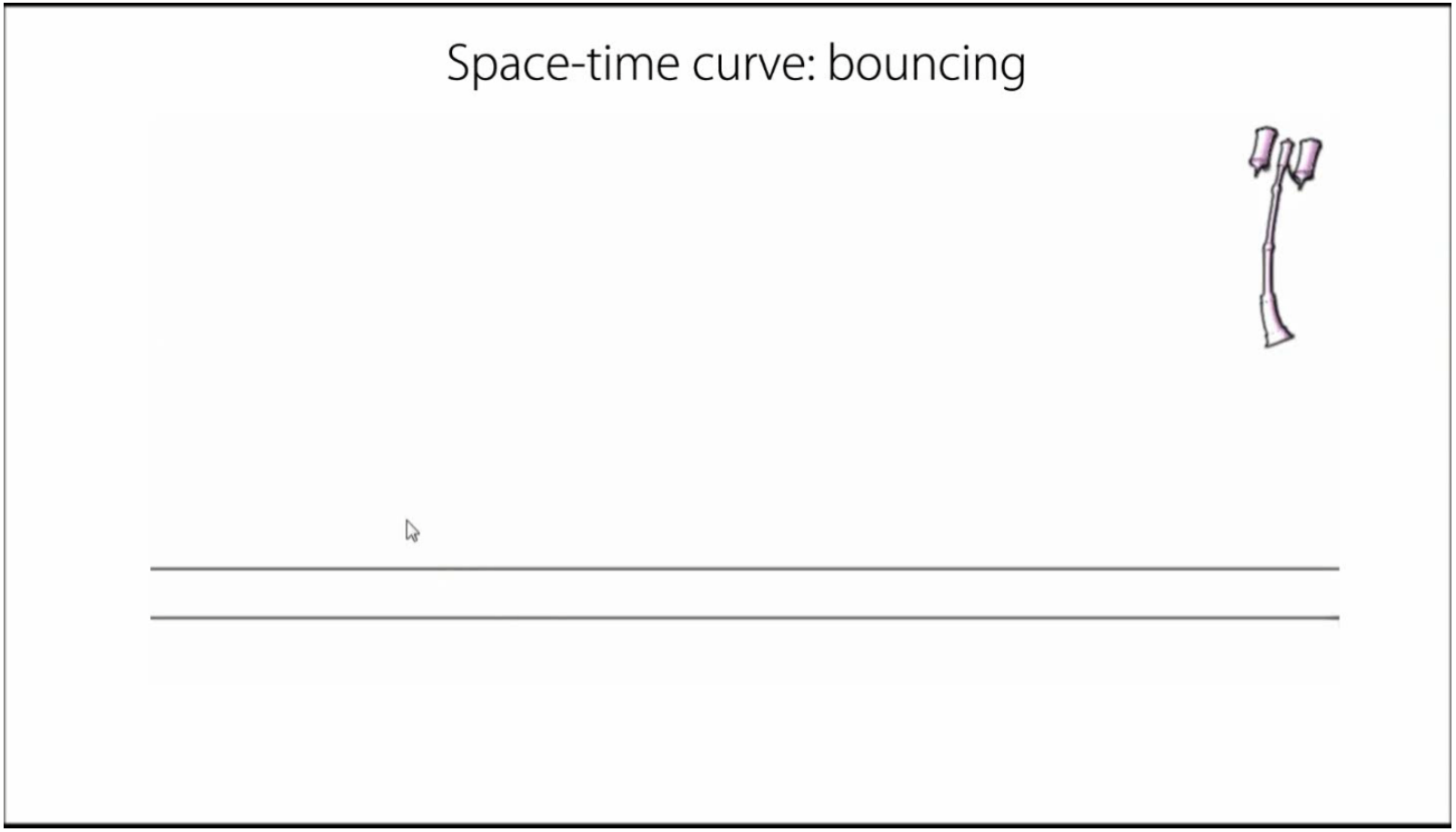
[A. Milliez, M. Wand, M.-P. Cani, H.-P. Seidel, Eurographics 2013]



@Preston Blair

Sketching & Sculpting Motion!

[*Guay, Ronfard, Gleisher, Cani 2015]*



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

Virtual 3D Worlds

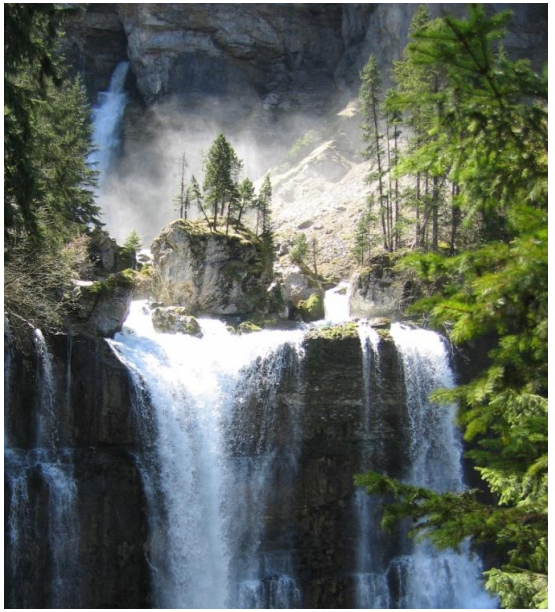
Many elements + rules to maintain

✓ Shapes

Laws from biology, geology, statistics…

✓ Motion

Laws from mechanics, fluids, interactions…



Can we extend expressive modeling?

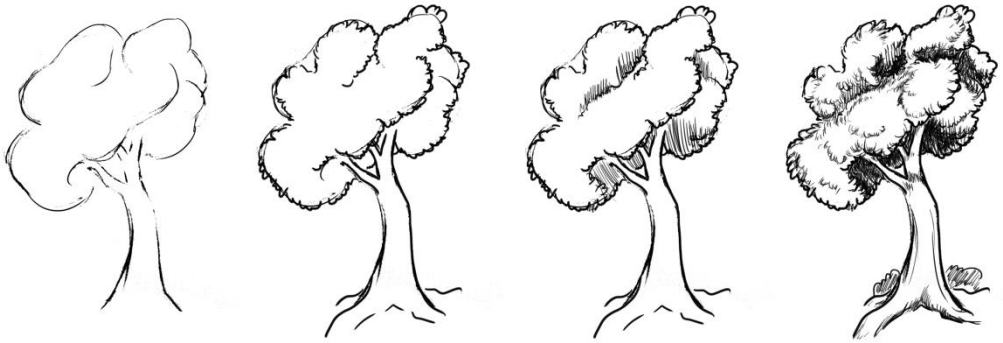
« Control to the user… Constraints to the system! »

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

Create a Consistent Tree by Sketching ?

- Freedom to create a specific shape
- Biological and statistical laws
- Too many branches for interactive modelling!

Inspiration



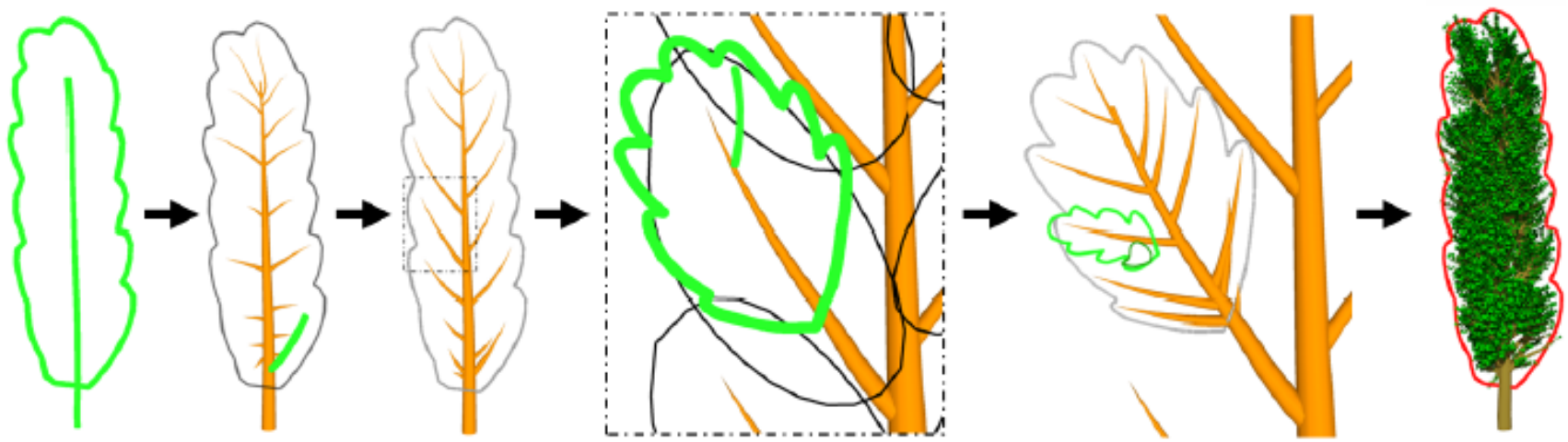
Idea

Combine multi-resolution sketches with biological laws!

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

Create a Consistent Tree by Sketching

- Structure from silhouette
- To fill missing information
  - Rules from biology, statistics and perception



✓ *Which gestures to create in 3D?*
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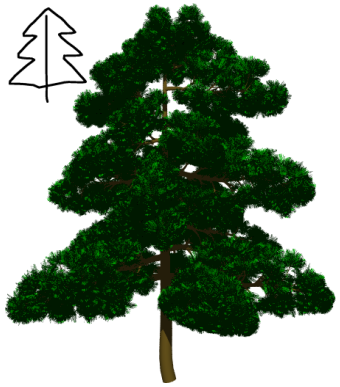
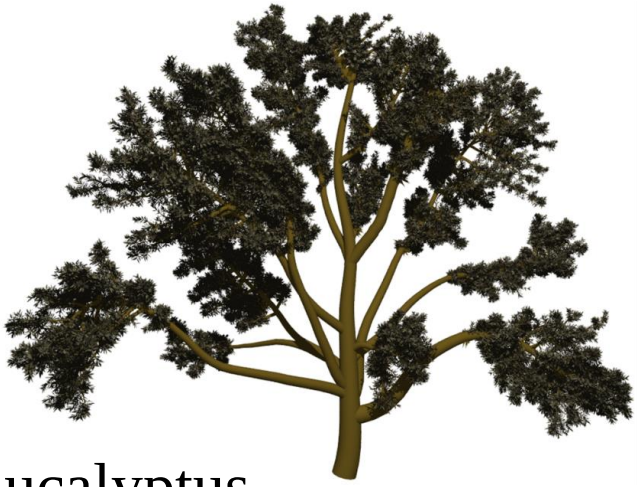
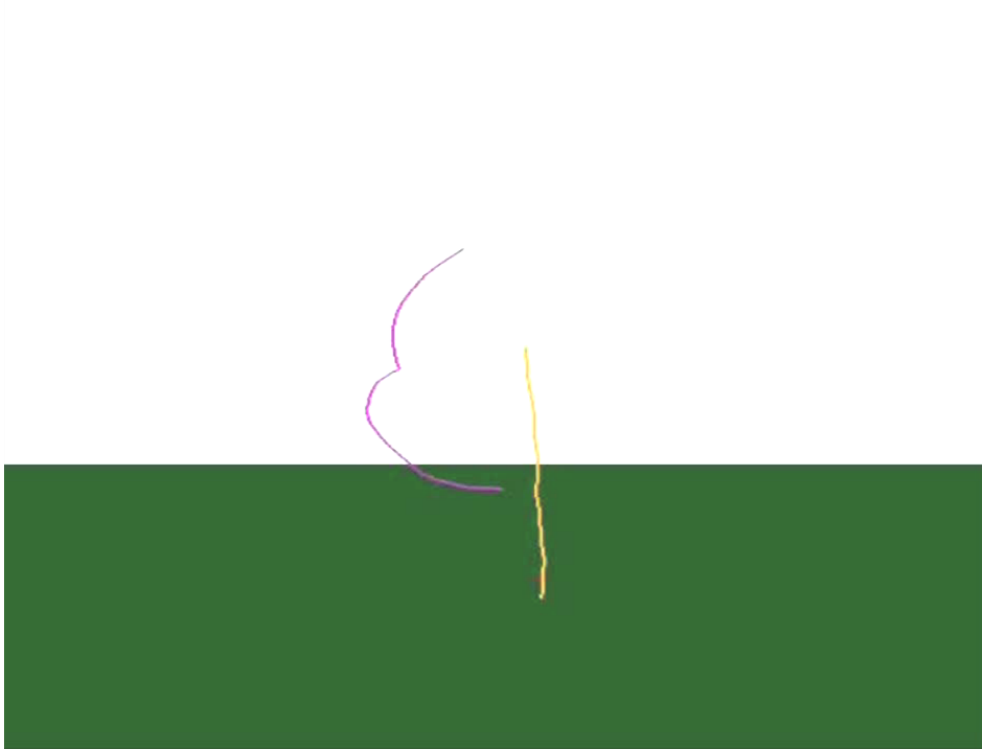
Create a Consistent Tree by Sketching





Eucalyptus



✓ *Which gestures to create in 3D?*
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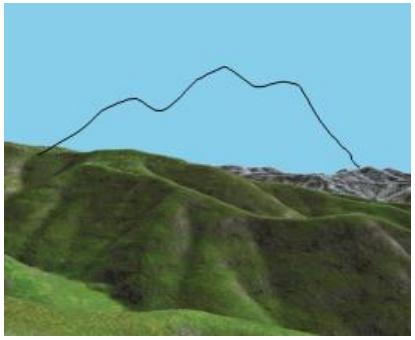
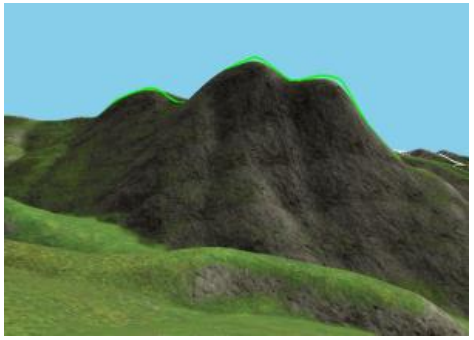
Streams & Waterfalls?

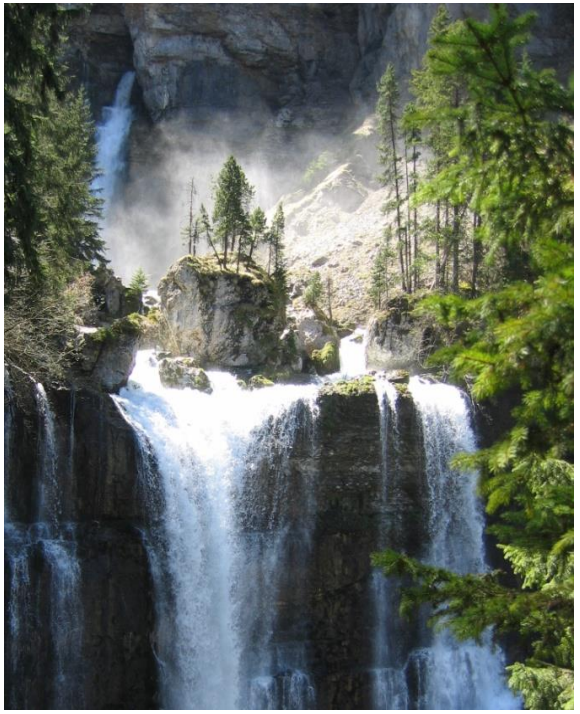
Challenges

- Trajectories dictated by terrain slope
- Flow consistency to be maintained
- But the user would like control !

Sketching mountains? … too indirect!







✓ *Which gestures to create in 3D?*
✓ *Knowledge-based models*
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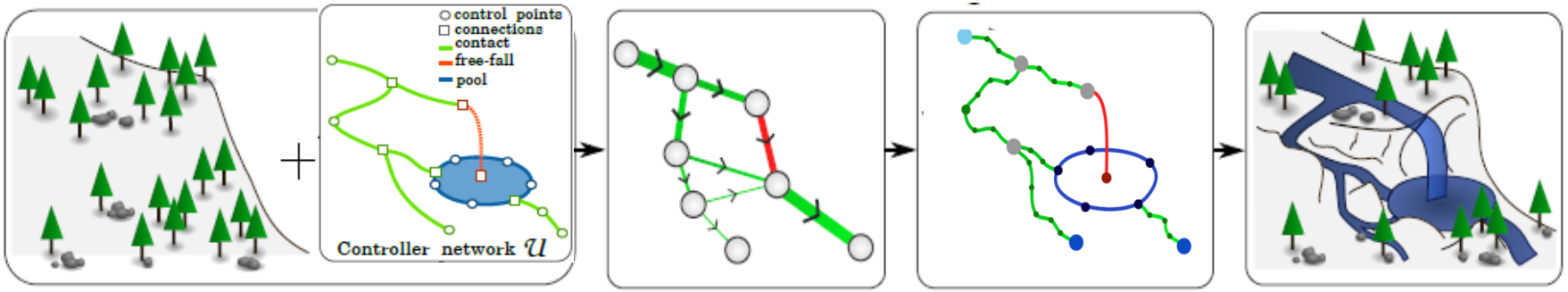
Insight

Leave waterfalls sculpt the terrain!

Interleave control & rule-based generation

1. The user sketches a network
2. Consistent flows are computed
3. The users selects a refinement type
4. The terrain deforms & details are added

@Grenoble-INP, Inria 2014



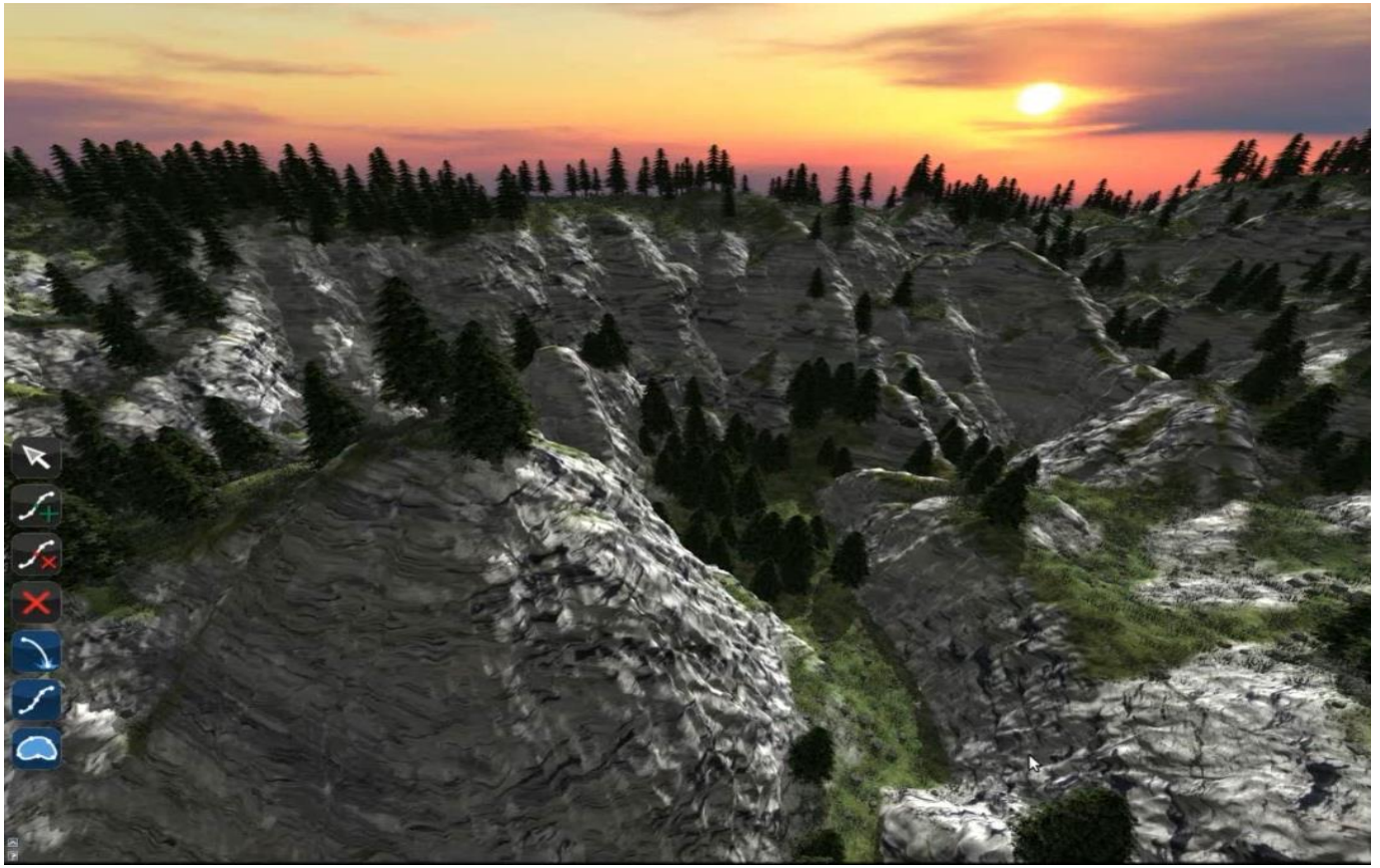
✓ *Which gestures to create in 3D?*
✓ *Knowledge-based models*
✓ *Extension to Virtual Worlds*

Designing waterfall scenes

[Emilien Poulin Cani, CGF 2015]

Validation:
Iron hole waterfalls
La réunion, France

@Serge Gélabert



✓ *Which gestures to create in 3D?*
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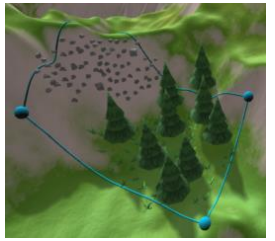
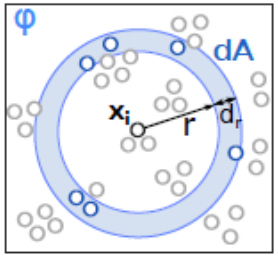
World-Brush
A Painting Paradigm for Distributions

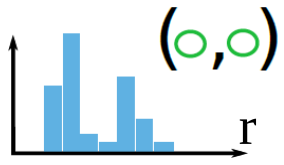
Color = {Statistics on distributions of objects} (trees, stones …)

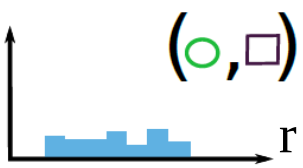
- ✓ Learnt from a user-defined exemplar
- ✓ Correlated with slope
- ✓ Stored in a « palette »

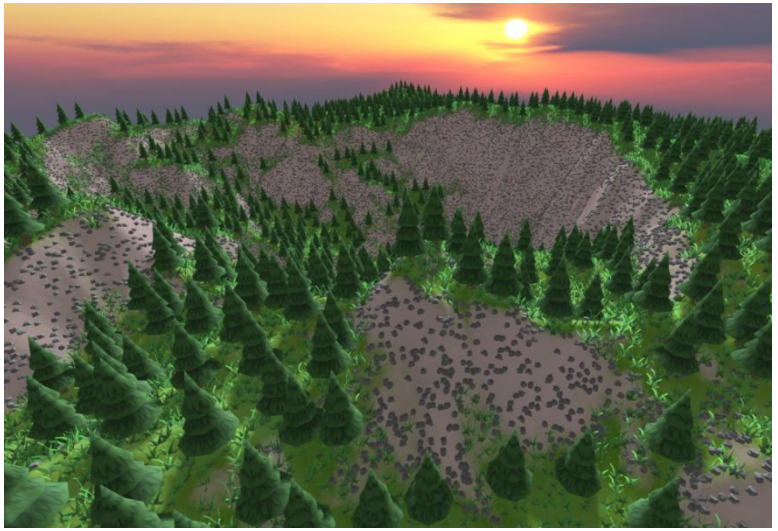
Exemplar →

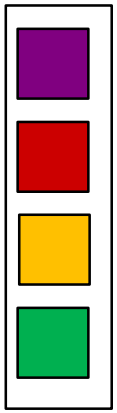












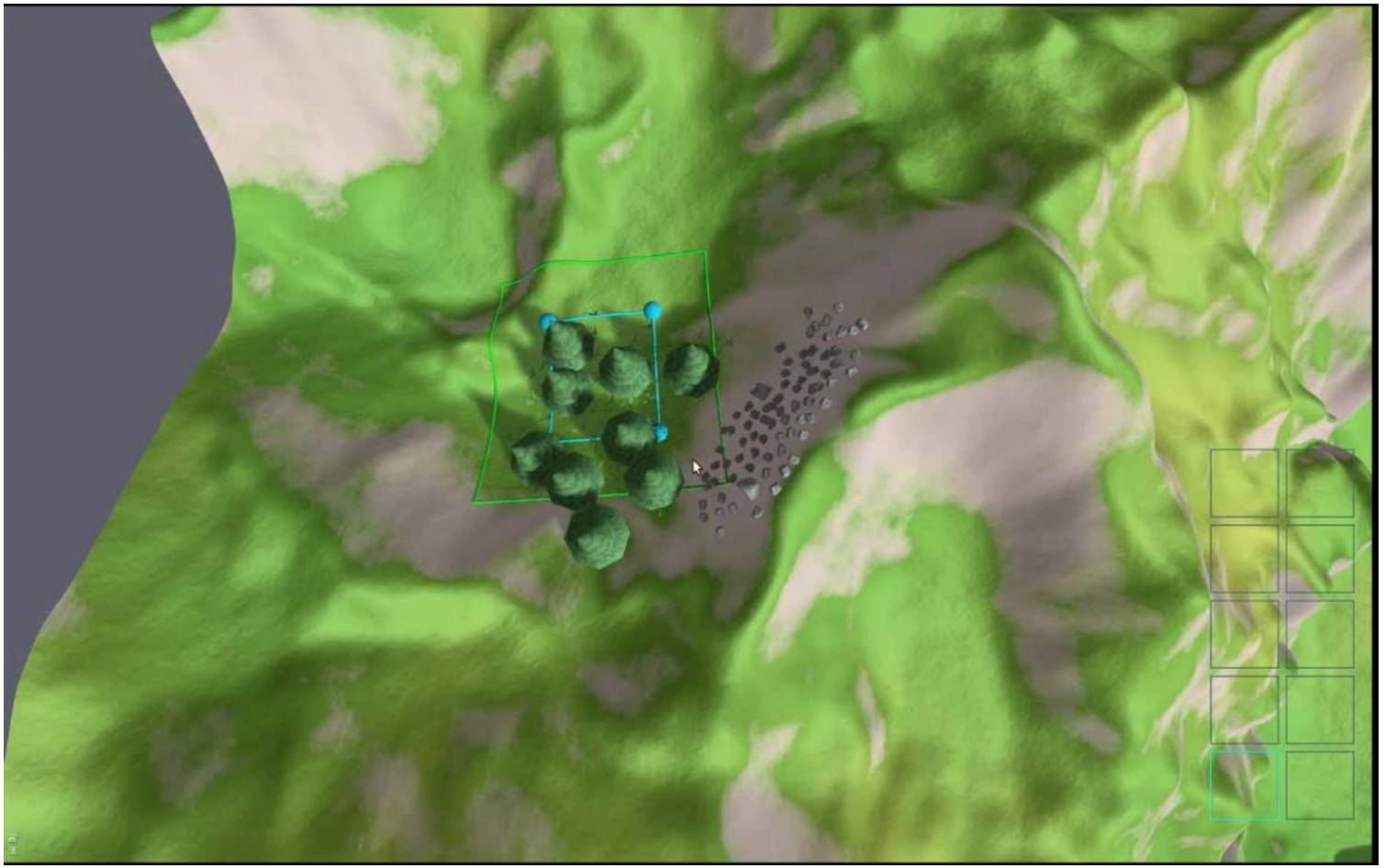
A variety of tools

Pipette, brush, deform, gradient….

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

World-Brush

[Emilien, Cani, Benes, SIGGRAPH 2015]



✓ *Which gestures to create in 3D?*
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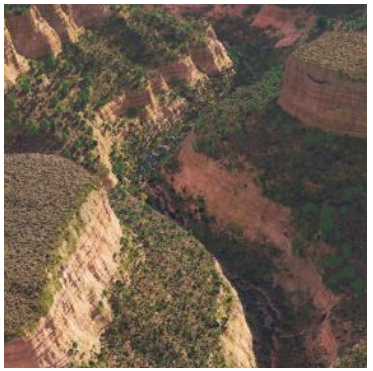
EcoBrush

Consistent Large Scale Ecosystems

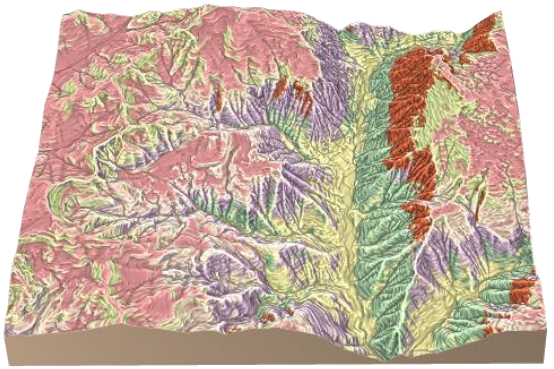
Challenge : Consistent vegetation + user control



Idea: Combine simulation with world-brush

- Multi-dimensional terrain clustering
- Sand-box simulations for each cluster
- Learn statistics and synthesis in the clusters
- High-level brushes: age, density…



✓ *Which gestures to create in 3D?*
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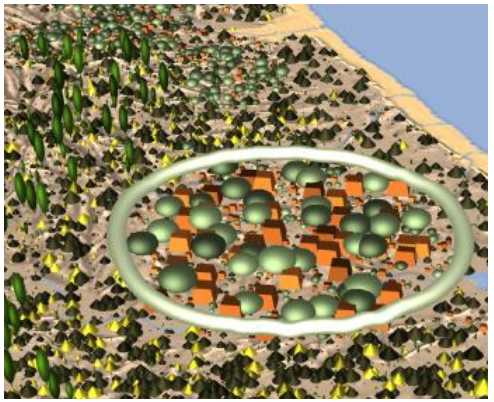
EcoBrush

Interactive editing: Semantic brushes

Combining consistency and control ?

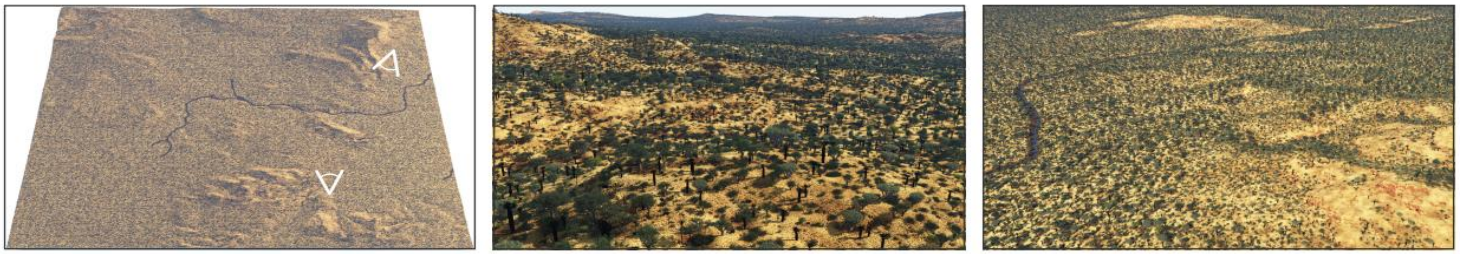
Semantic brushes

- Local action of humans, animals, fire
- Ex: Age, density, re-planting other species



Ex: African savanah

- without



- with destruction by fire & animals

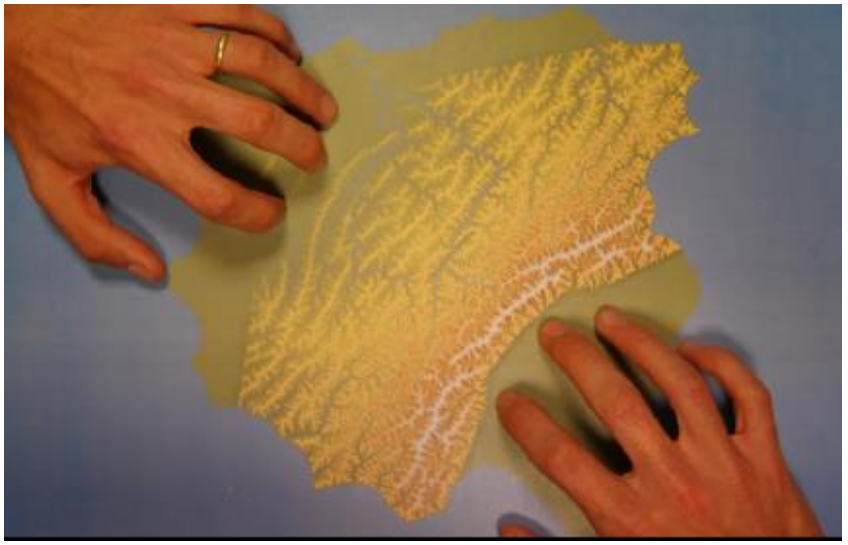
1. *Expressive modeling*
2. *Novel uses of 3D for other disciplines?*

Expressive modeling
Novel uses of 3D for other disciplines?

Two recent projects

- Embodiment for education in anatomy
- Interactive prototypes in morpho-geology

The Living Book of Anatomy



Sculpting Mountains

The Living Book of Anatomy

Background: Anatomy transfer (2013)

Anatomy transfer = advanced “copy-paste”

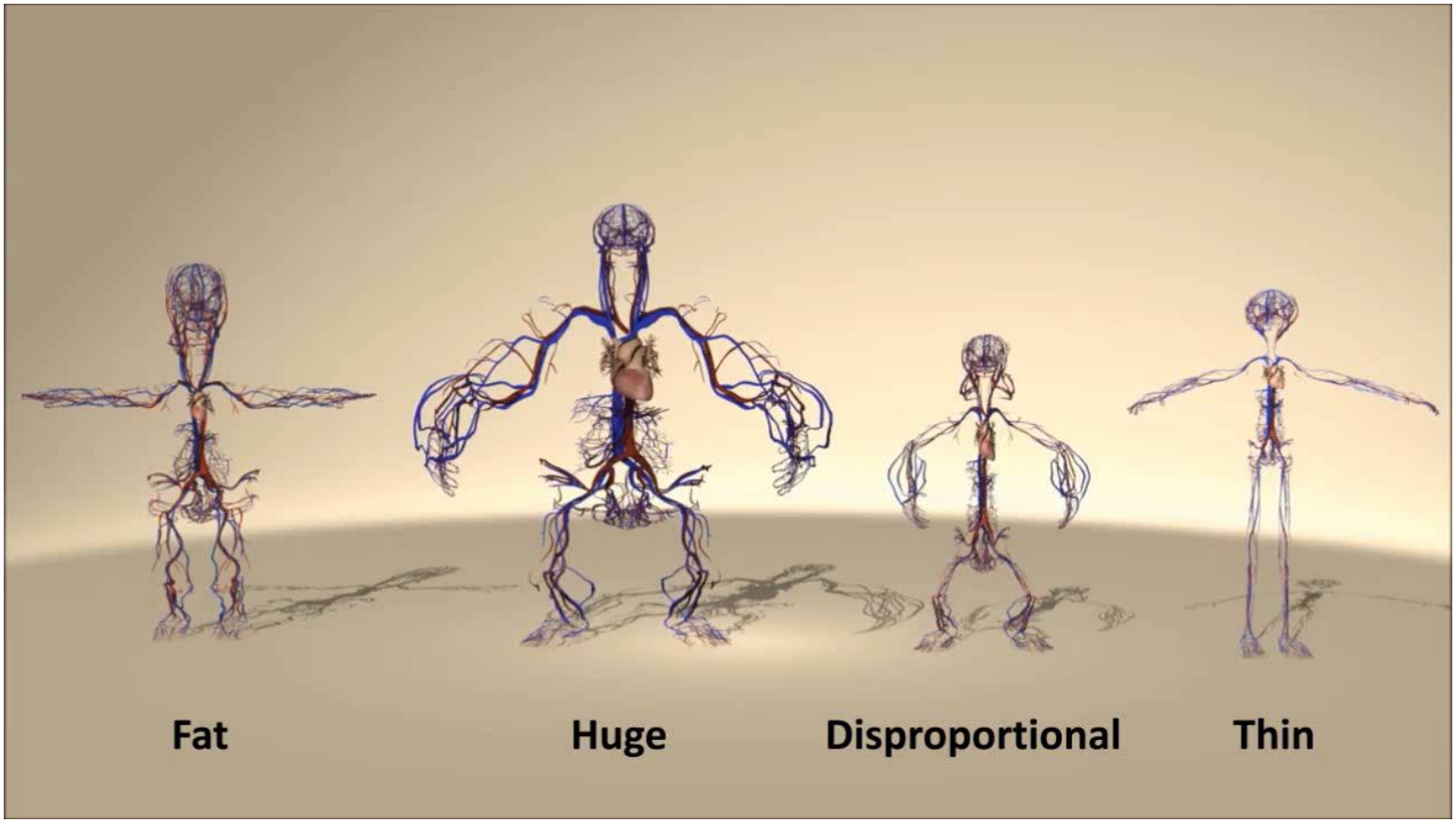
Based on rules to be maintained

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

1. *Expressive modeling*
2. *Novel uses of 3D for other disciplines?*

The Living Book of Anatomy

Background: Anatomy transfer (2013)



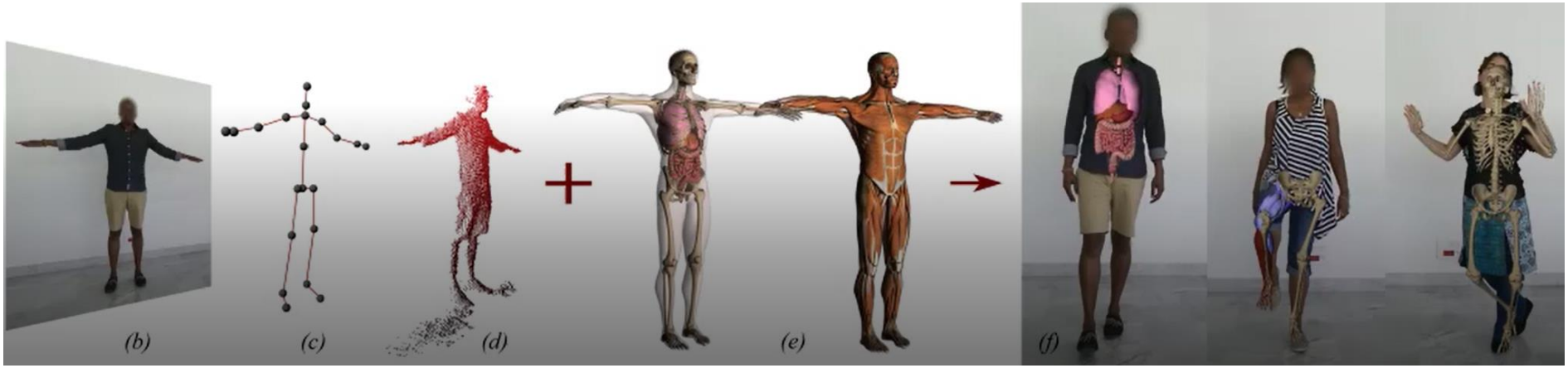
[Dicko, Liu, Gilles, Kavan, Faure, Palombi, Cani, Siggraph Asia 2013]

1. *Expressive modeling*
2. *Novel uses of 3D for other disciplines?*

The Living Book of Anatomy
Follow – up project

Embodiment for Education

- We ARE our own book of Anatomy!
- Animate our insides in a virtual mirror by moving



1. *Expressive modeling*
2. *Novel uses of 3D for other disciplines?*

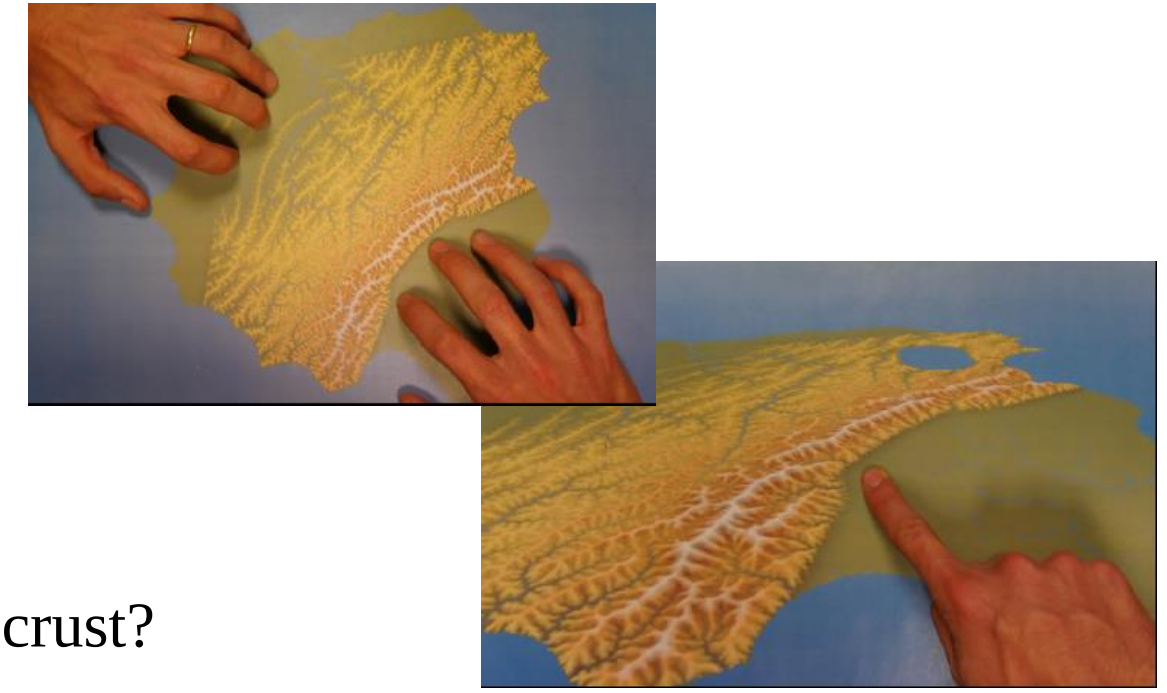
The Living Book of Anatomy
Follow – up project

@Armelle Bauer, François Faure, Jocelyne Troccaz, Olivier Palombi, UGA 2016

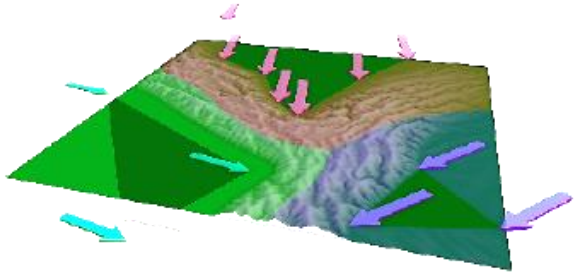
1. *Expressive modeling*
2. *Novel uses of 3D for other disciplines?*

Sculpting Mountains…
Could we sculpt terrains as if they were clay?

Inspiration: virtual clay



- Interactive model for earth crust?
- 2D interaction on a touch table
  - Create and push tectonic plates

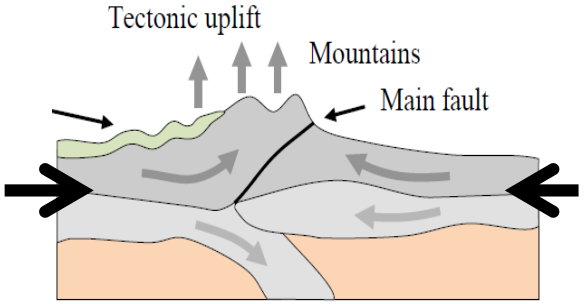


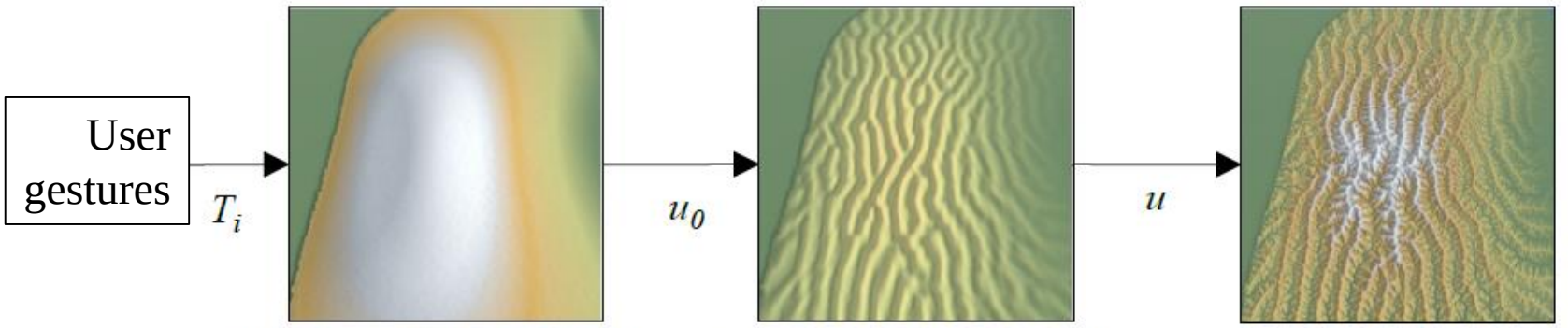
Sculpting mountains…

Collaboration with Jean Braun, geo-morphologist

Interactive earth crust model

- Constant volume : thickens when compressed
- Sheets of rocks : folds of various wavelengths
- Erosion while mountains grow

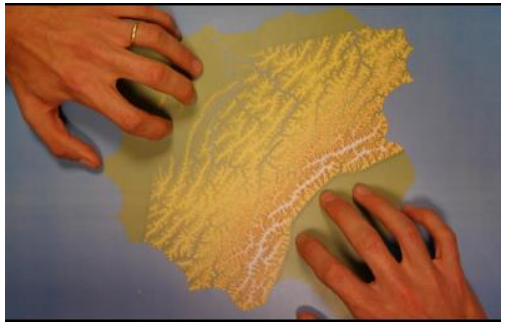


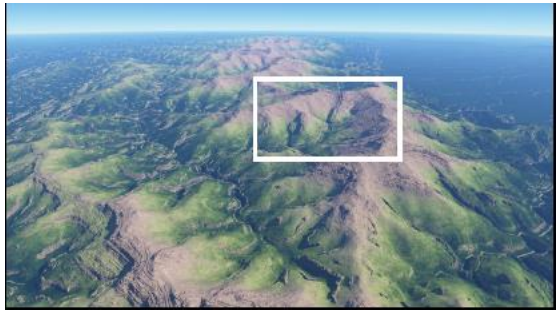


1. *Expressive modeling*
2. *Novel uses of 3D for other disciplines?*

Sculpting Mountains

[Cordonner Cani, Braun, Benes, Galin 2017]

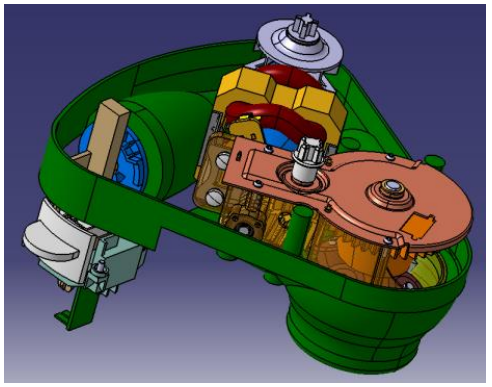




Conclusion : Expressive 3D Modeling

New space for collaboration across disciplines!

ERC advanded grant « EXPRESSIVE »

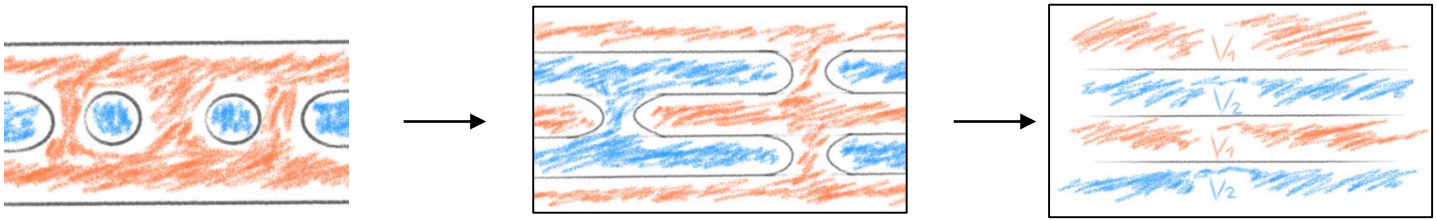
Materialize visions from engineers & scientists

- Draft, refine, test interactive virtual prototypes
- Express, explore, interact with models from sciences

A wonderful tool to learn & create!

Future Work: direct creation of mental models?

Example: Phases of membranes in liquids



Isolated bubbles | Sponge phase | Strip phase

Vision
Didier Roux
Physico-chemist

3D illustration
@ Thomas Buffet

Challenges
Shape & motion from sketches?
Adding knowledge on the fly!