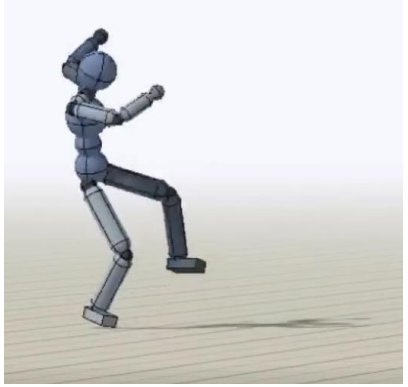


Advanced 3D Graphics

Part 1: Creative AI

Week 2: Extension to Virtual Worlds (continued)

Marie-Paule Cani

In this course
How to create, animate & control virtual worlds?

Methodology

A. Procedural modeling ↗ **Indirect control**

B. Layered models for animation ↑

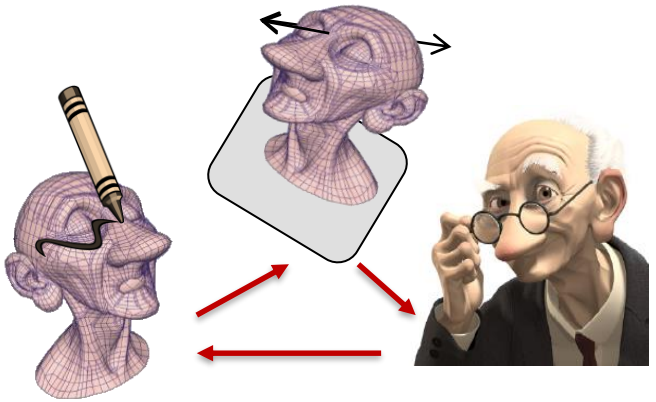
C. Expressive design ?

Reminder: Expressive 3D modeling

– Gesture-based control

– Knowledge in the models

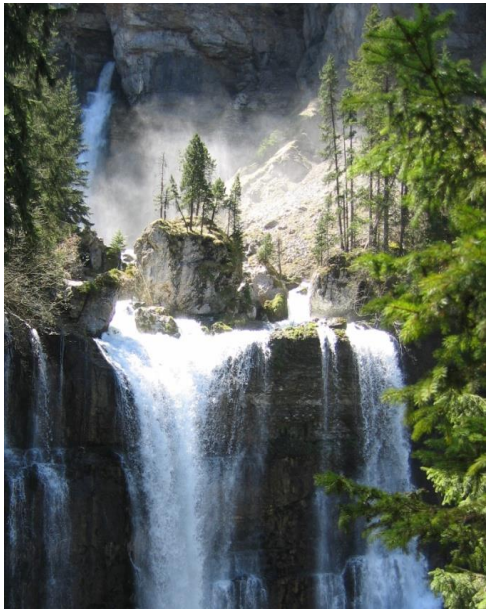
… from priors or learnt !



A. Procedural modeling
B. Layered animation
C. Expressive design

Virtual Worlds
Main challenges

- Huge numbers of elements, all different
- Multiple rules to maintain
  - Shapes: geology, biology, statistics
  - Motion: dynamics, mass preservation
- Complex interactions & time-evolution
  - Water with terrain
  - Ecosystems with resources



Expressive creation and control?

- How can we combine knowledge with user control?

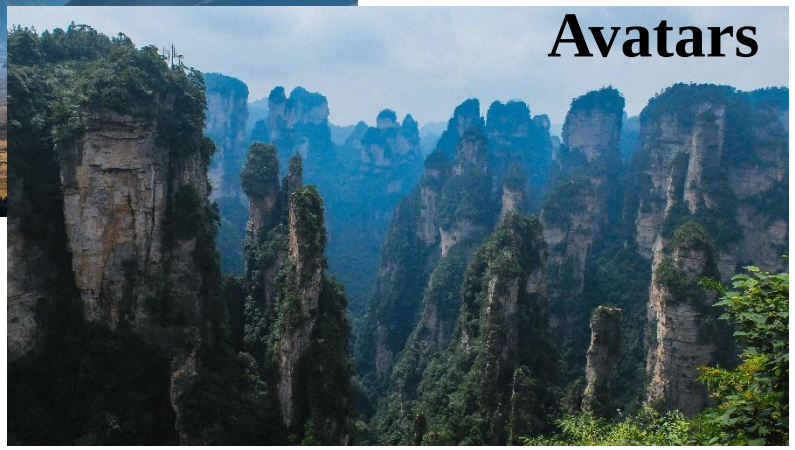
Case studies : terrains, streams & falls, vegetation…

A. Procedural modeling
B. Layered animation
C. Expressive design

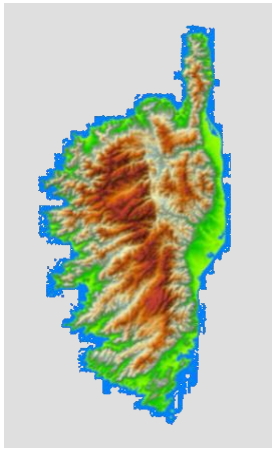
Case 1 : Terrains
First person authoring?

Challenges

- Complex shape, geophysical rules
- To be designed from a specific viewpoint



Editing a highmap?
Not applicable!



Hightmap = 2D grid with altitudes

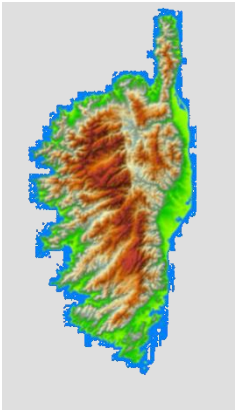
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
First person authoring?

Challenges

- Complex shape, geophysical rules
- To be designed from a specific viewpoint!

Editing a highmap not applicable. →

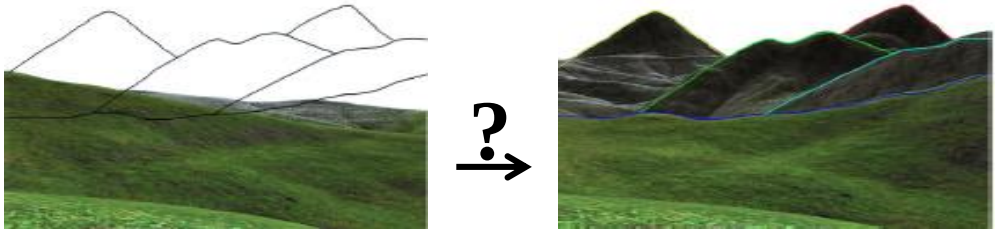


Key ideas

- Draw silhouettes from the view-point of interest
- Deformation of an existing, detailed terrain!

Extend sketch-based modeling

- Complex sketches
- Non planar silhouettes
- Use silhouettes as deformers!



A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
Analyzing complex sketches

Sweeping algorithm *[Tasse 2014]*

- From left to right, compute relative depth

Input strokes

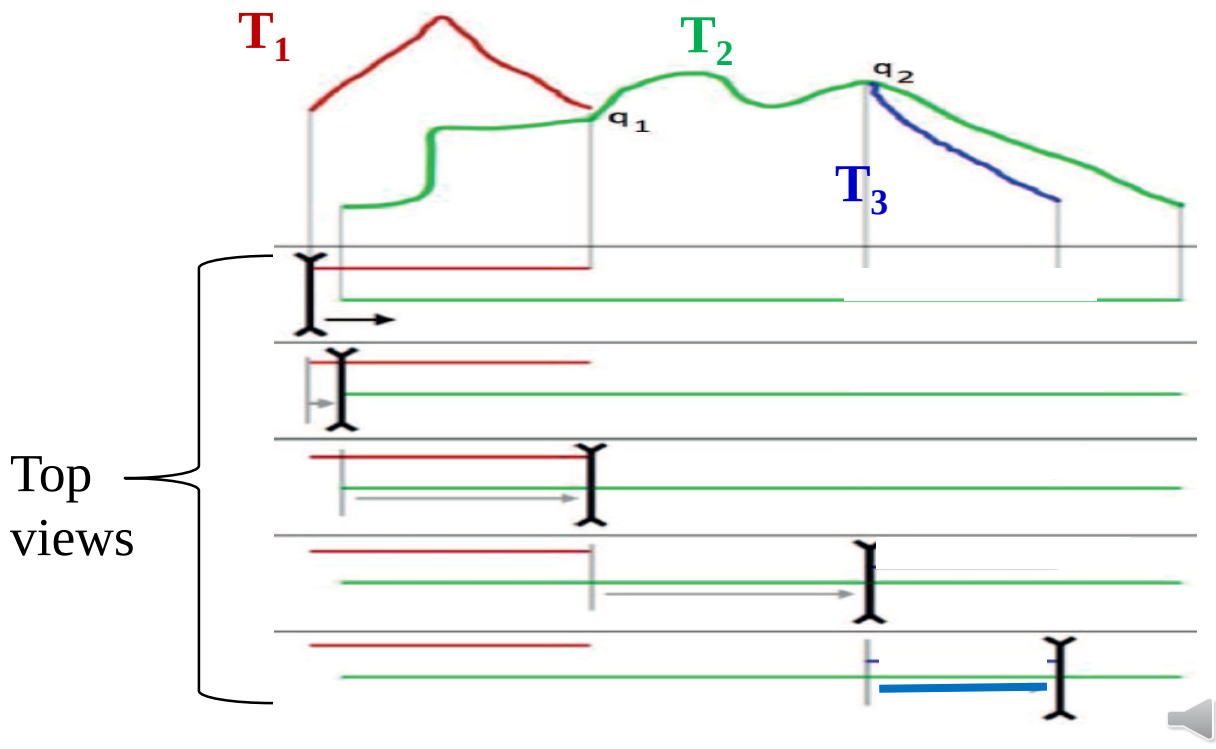
Start with T_1 T_2

T_1 behind T_2

End T_1

T_3 in front of T_2

End T_3



A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
Matching strokes & terrain features

Precompute terrain features

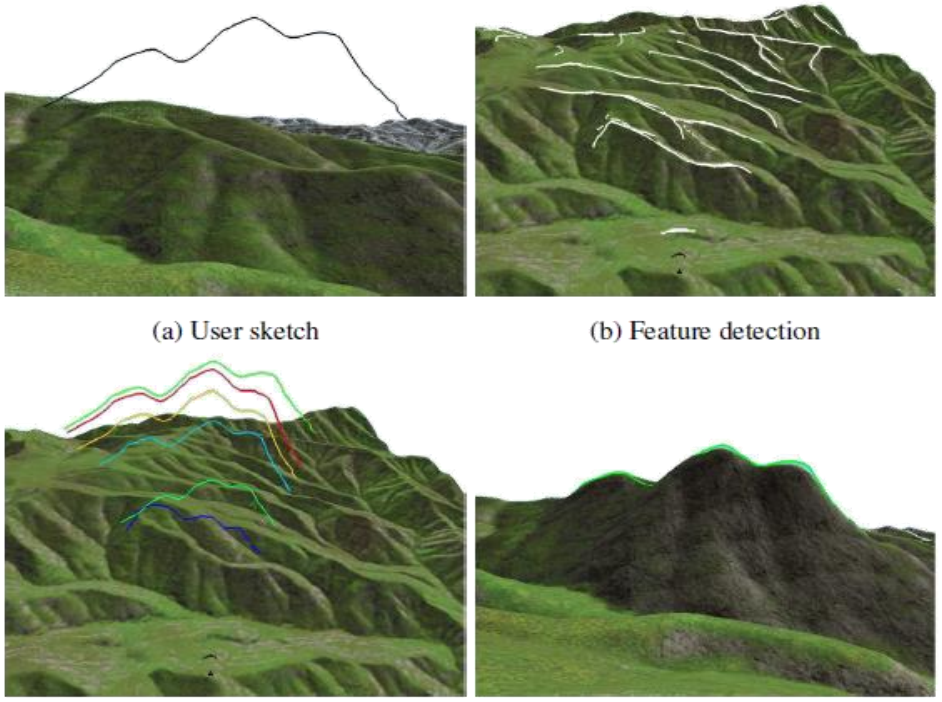
- Silhouettes & ridges

For each pair (stroke, feature)

- Compute deformation cost from viewpoint of interest

Branch & Bound matching

- Preserve order, favor closest



(a) User sketch (b) Feature detection

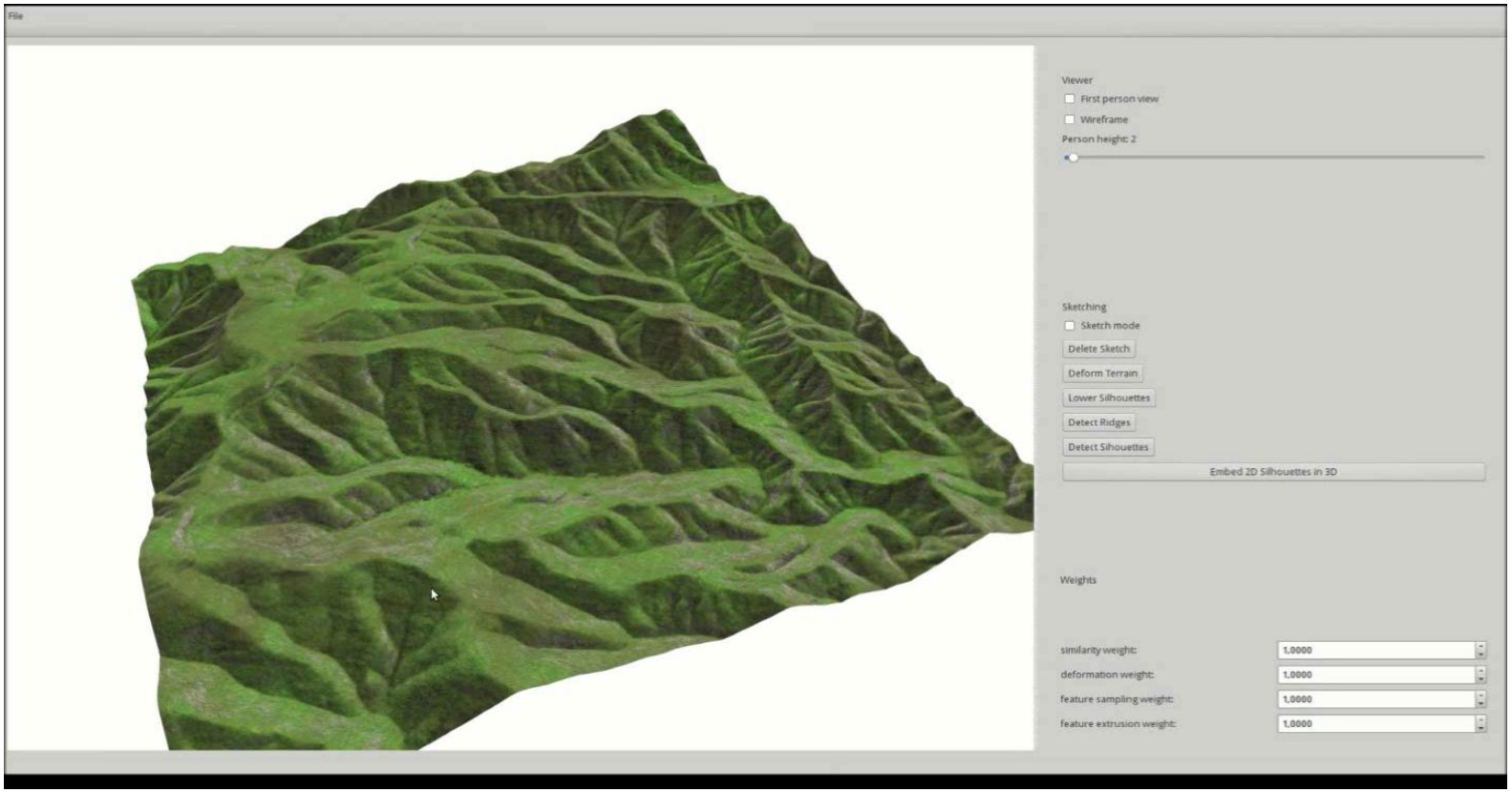
Diffuse elevation changes to match strokes (Multi-grid Poisson solver)

- Lower unwanted silhouette if needed, and iterate

A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
First person authoring

[Tasse 2014]



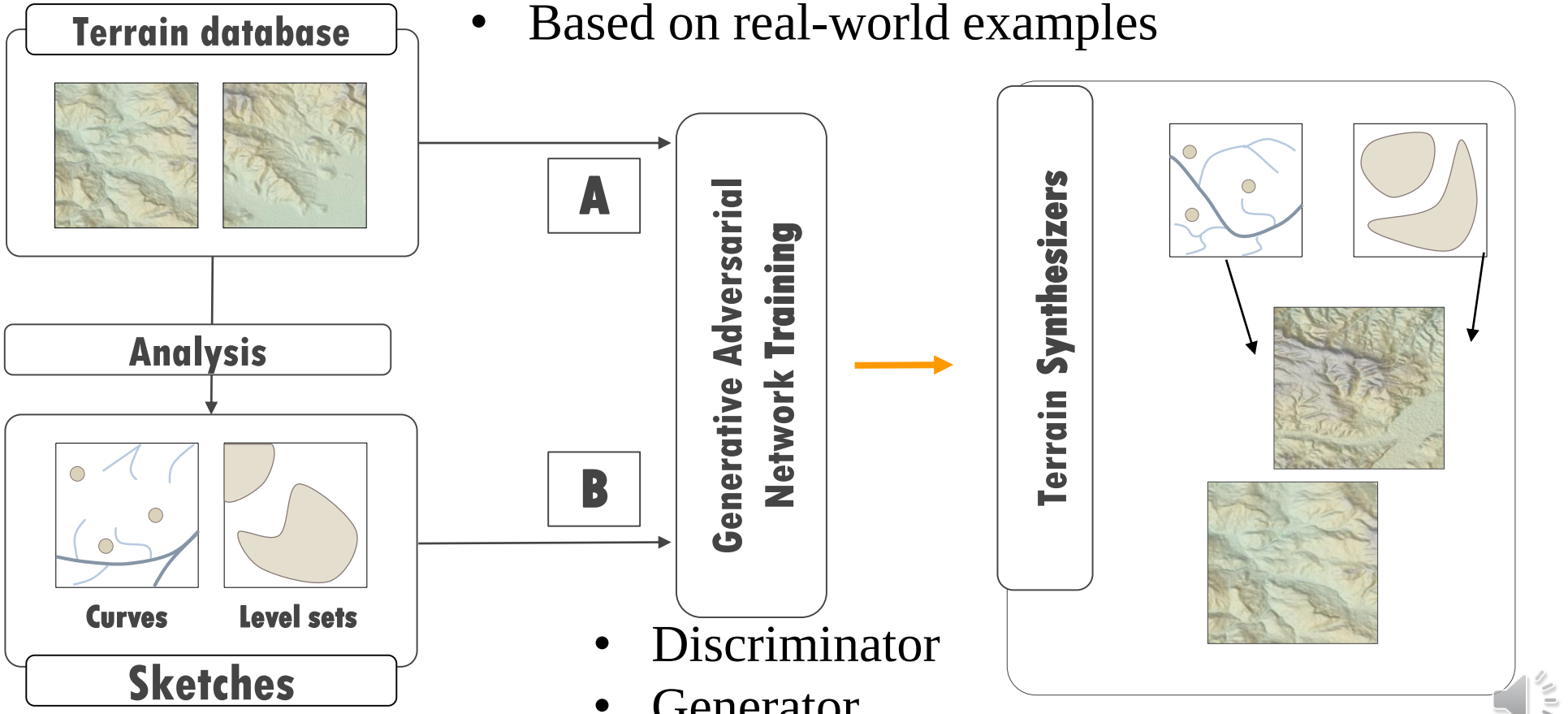
No guarantee of any geomorphological consistency !

A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
Deep sketch-based modeling

[Guérin2017]

- Adversarial neural network (generator, discriminator)
- Based on real-world examples

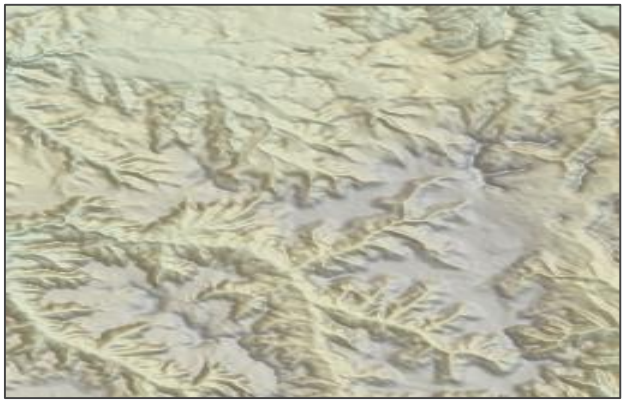


- Discriminator
- Generator

Case 1 : Terrains
Deep sketch-based modeling

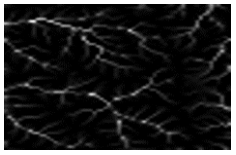
[Guérin2017]

Data preparation : detecting rivers



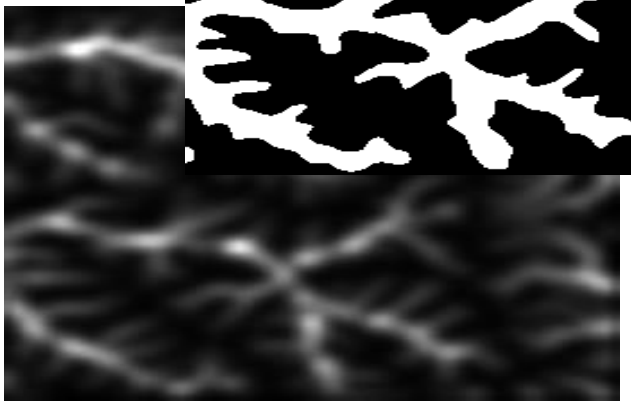
Input DEM 256^2

Low resolution DEM 64^2



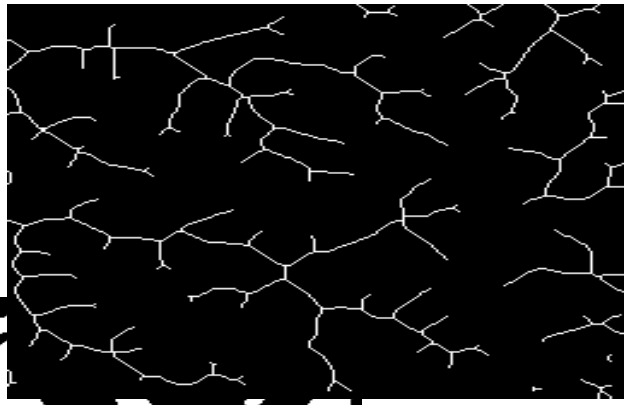
Flow simulation

Upsample and blur



Threshold

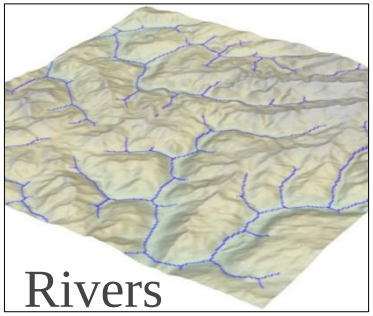
Skeleton

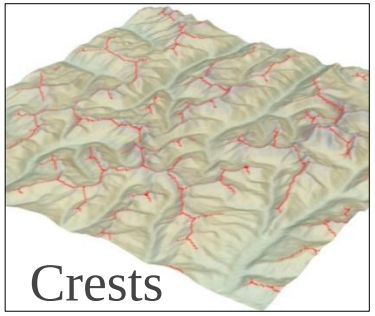


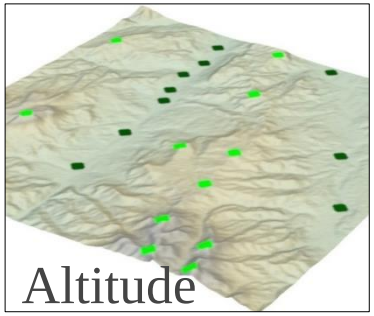
Case 1 : Terrains
Deep sketch-based modeling

[Guérin2017]

- Data preparation

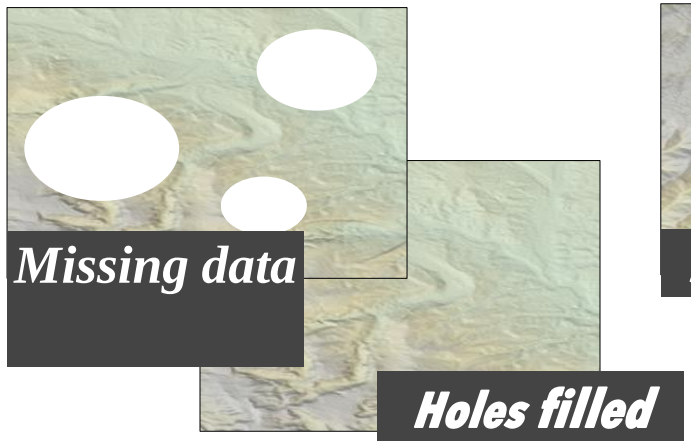




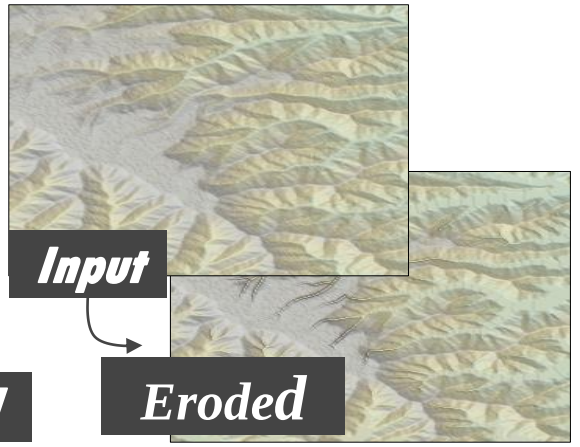


- Several synthetizers

Level-set



Eraser

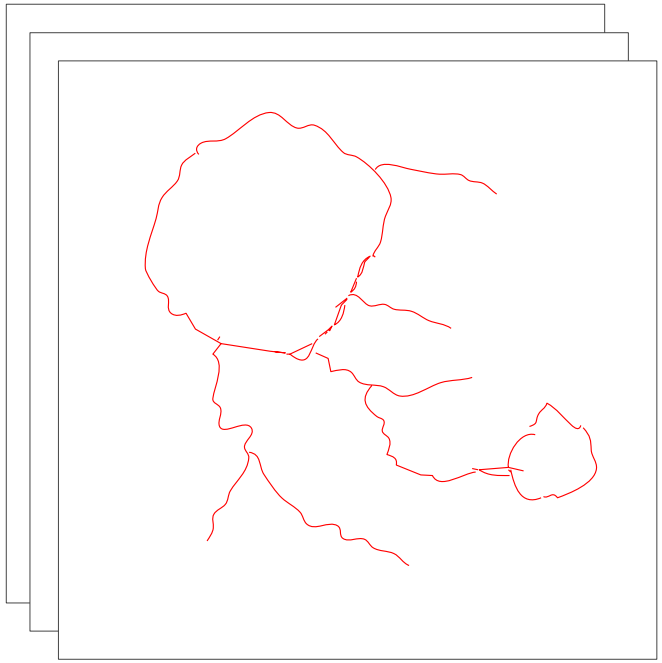


Erosion

A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
Deep sketch-based modeling

Sketch

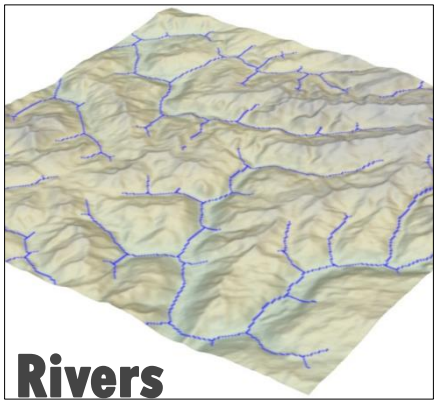


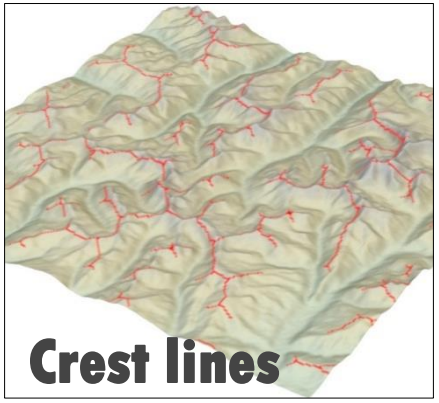
Generated terrain

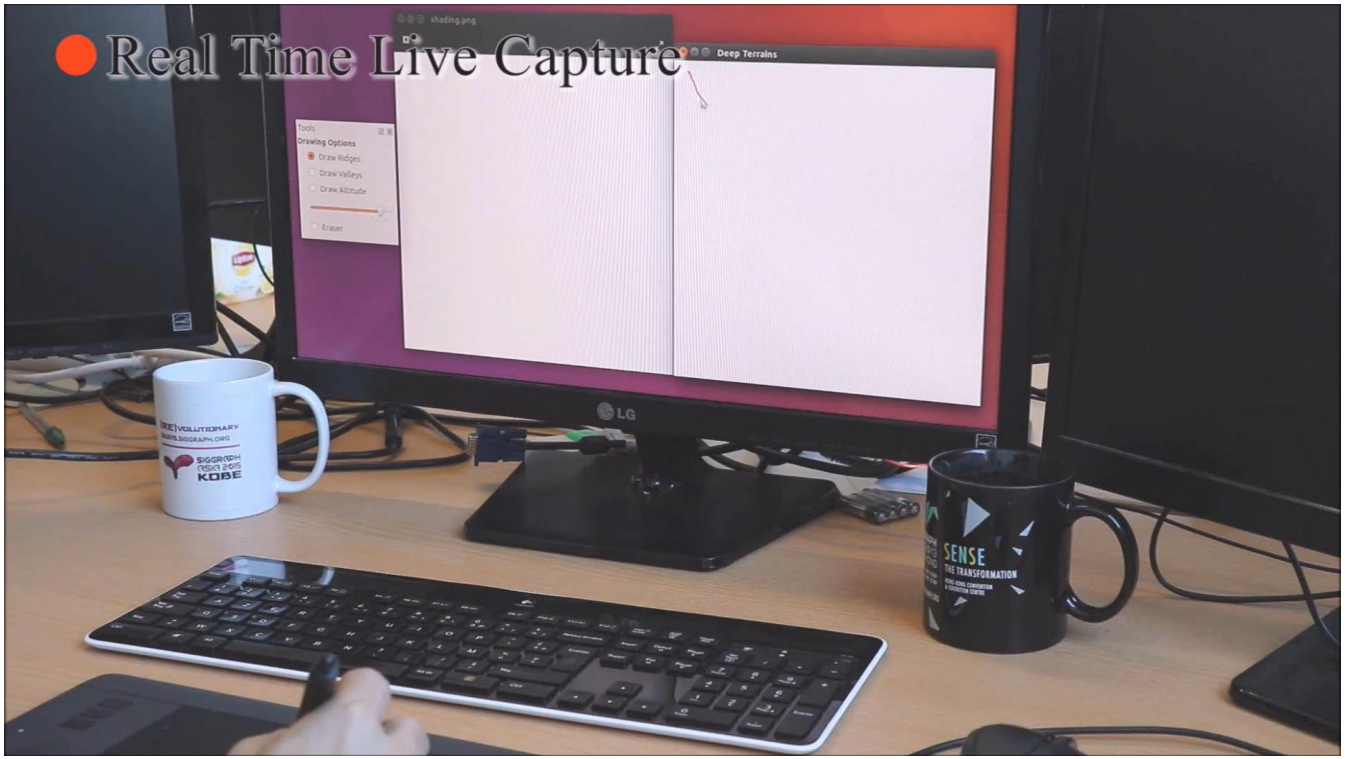
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
Deep sketch-based modeling

Synthetic examples, Adversarial networks (generator, discriminator)





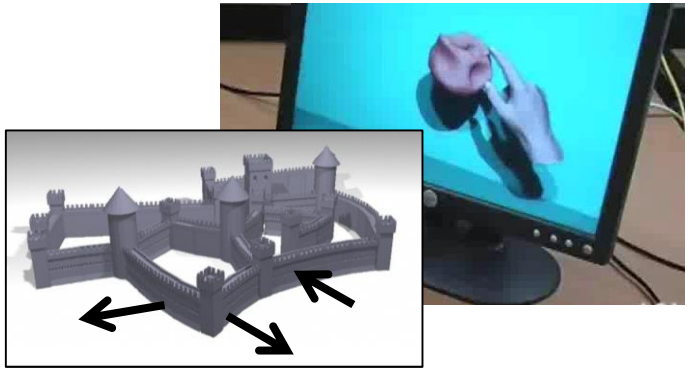


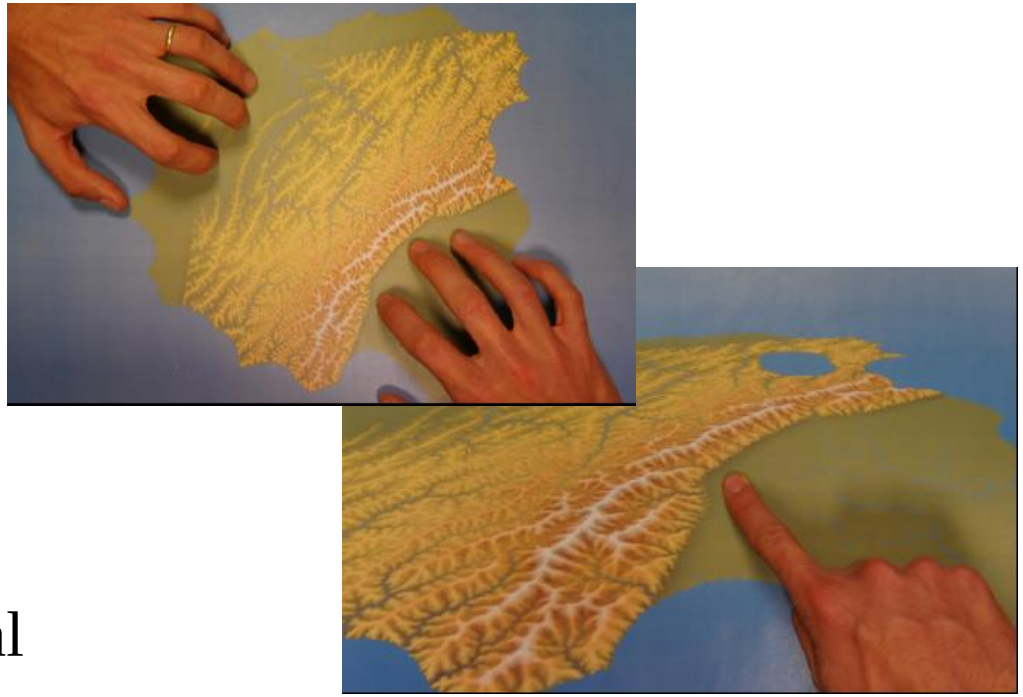
[Guérin 2017]

A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
Sculpt them as if they were clay?

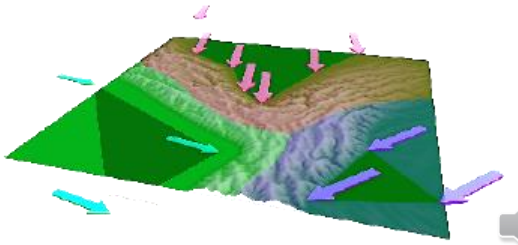
Inspiration: virtual clay





Sculpting terrains?

- Earth crust is a specific material
  - use knowledge from geology
- 2D hand interaction is sufficient!
  - Can define shape and speed of tectonic plates

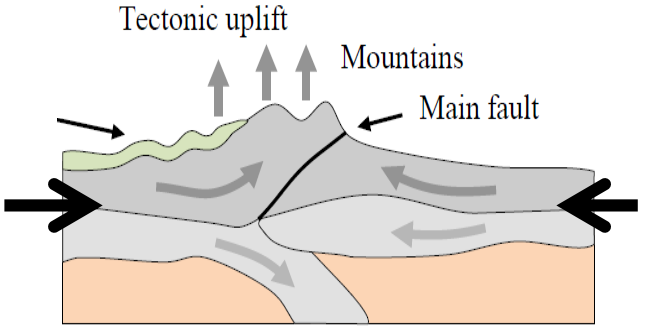


A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains

Sculpt them as if they were clay?

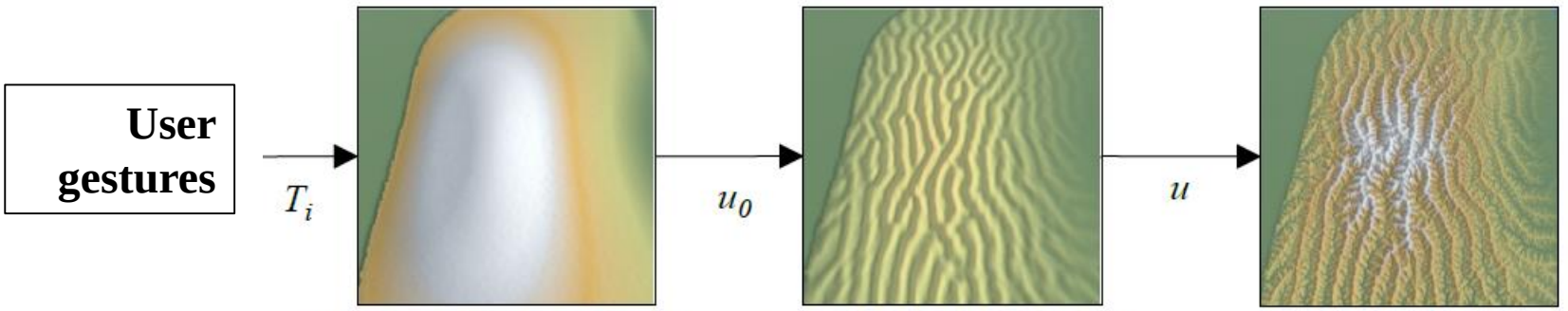
Layered model for earth crust *[Cordonnier 2017]*



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

Solution

- A **layered model** that decouples these phenomena

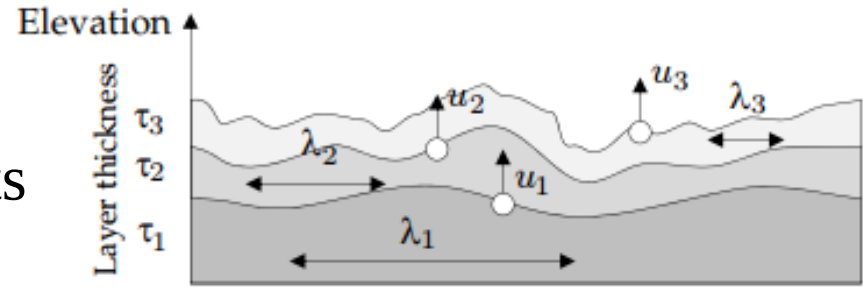


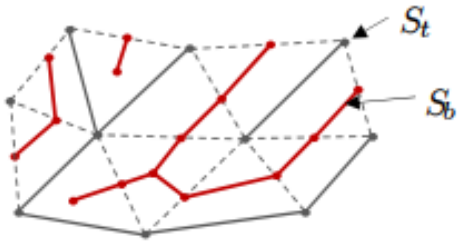
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 1 : Terrains
Sculpt them as if they were clay?

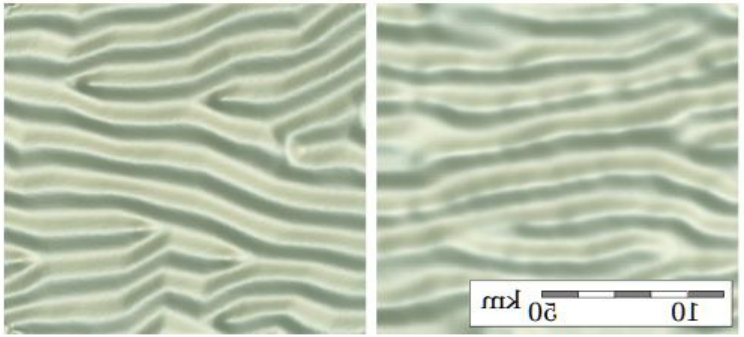
Procedural folding behavior

- Fct of thickness & viscosity of sheets
- Can be computed procedurally!





→ Procedural modeling of fold skeletons over a mesh

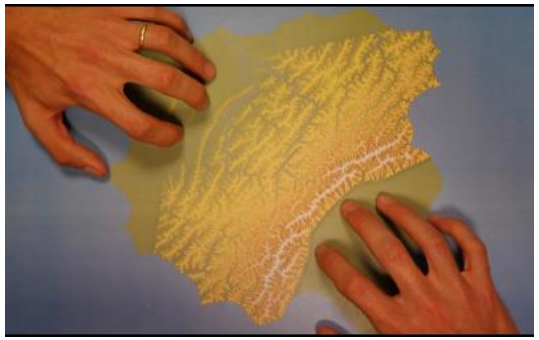


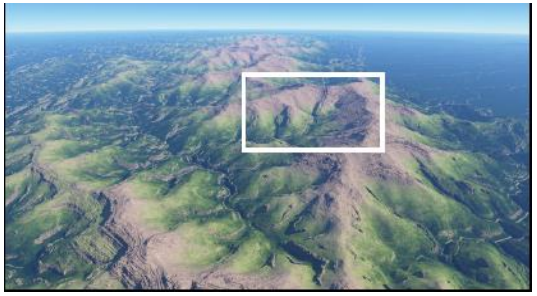
← Simulation in Geomorphology

A. Procedural modeling
B. Layered animation
C. Expressive design

[Cordonnier 2017]

Case 1 : Terrains
« Sculpting mountains »



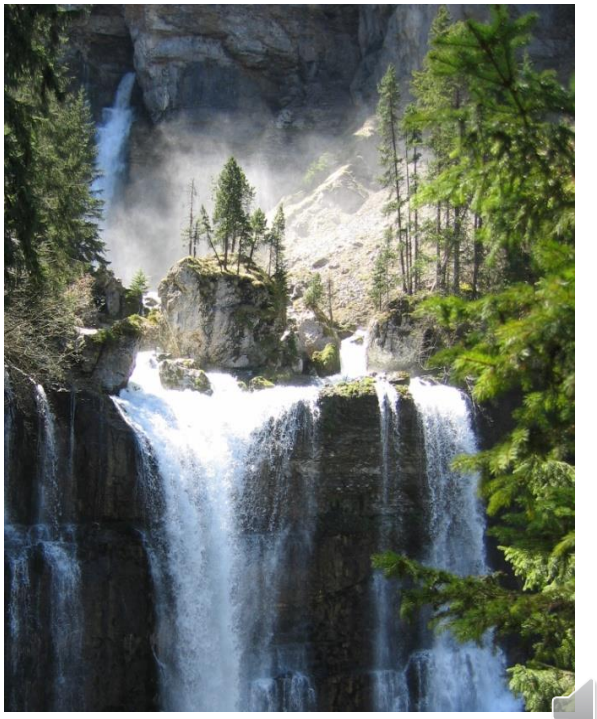


A. Procedural modeling
B. Layered animation
C. Expressive design

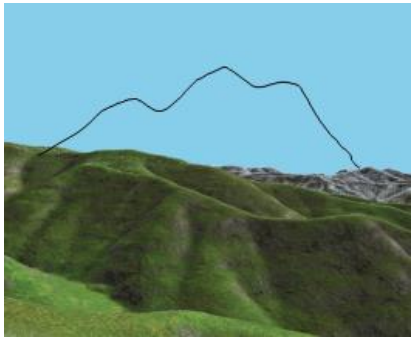
Case 2: Streams & waterfalls
Combining knowledge and control?

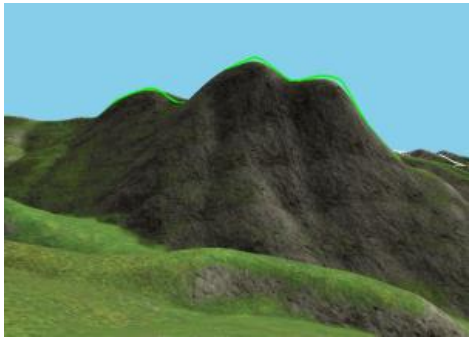
Challenges

- Stream types & trajectories uniquely dictated by terrain slope
- But the user would like control!
- Flow consistency should be maintained



Editing mountains? … too indirect!



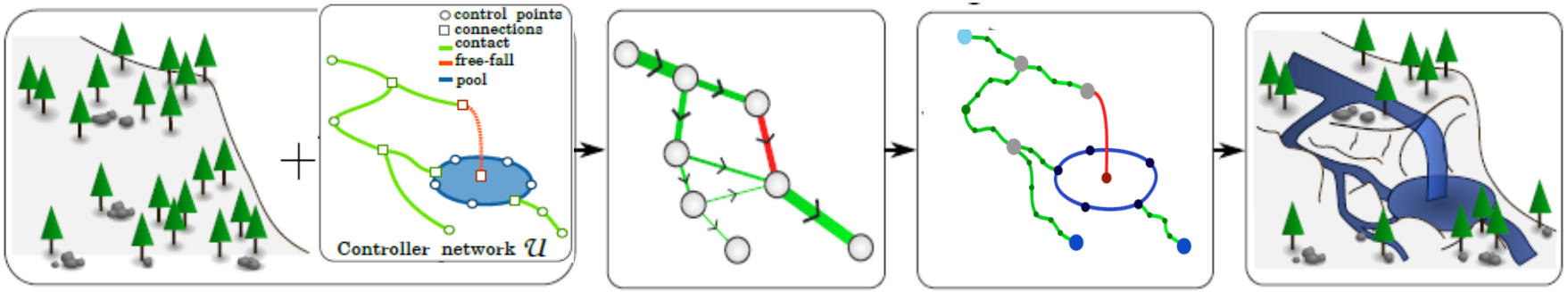


A. Procedural modeling
B. Layered animation
C. Expressive design

Case 2: Streams & waterfalls
Leave the rivers sculpt the terrain!

***Solution:* interleave control & 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

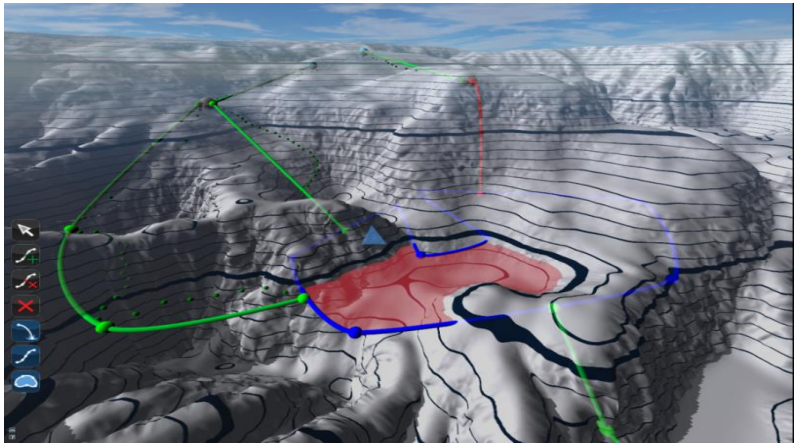


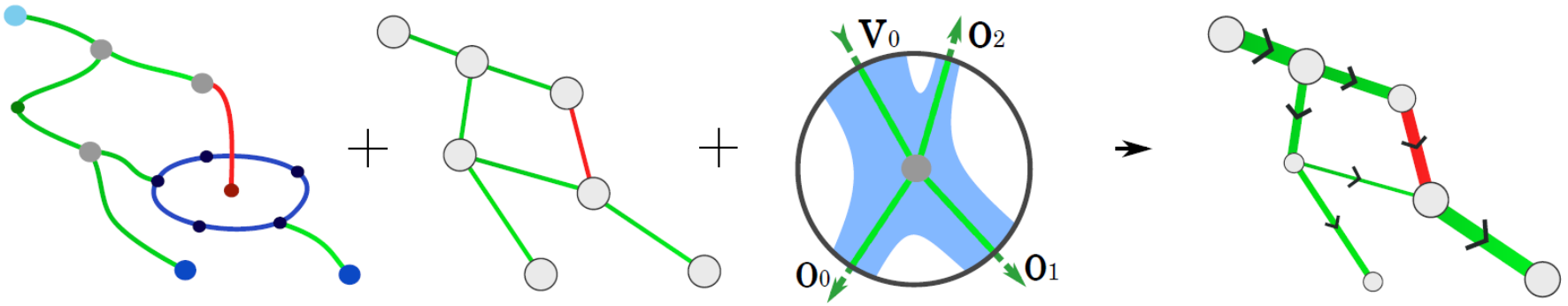
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 2: Streams & waterfalls
Combining knowledge and control?

Inter-leave user control & rules

1. User sketch
   - Slope consistency control
     Terrain lowered if needed
2. Consistent flow computations

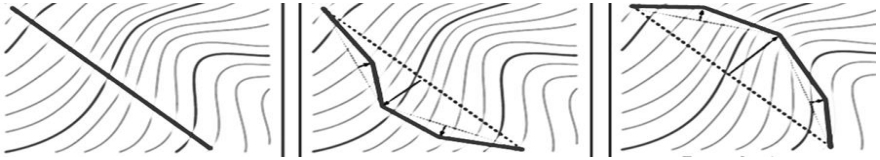


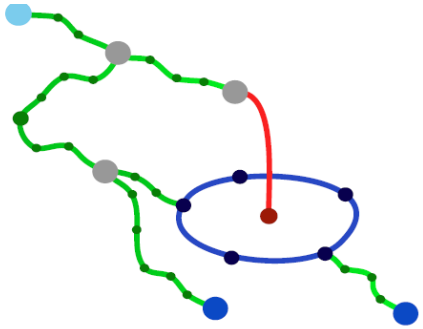


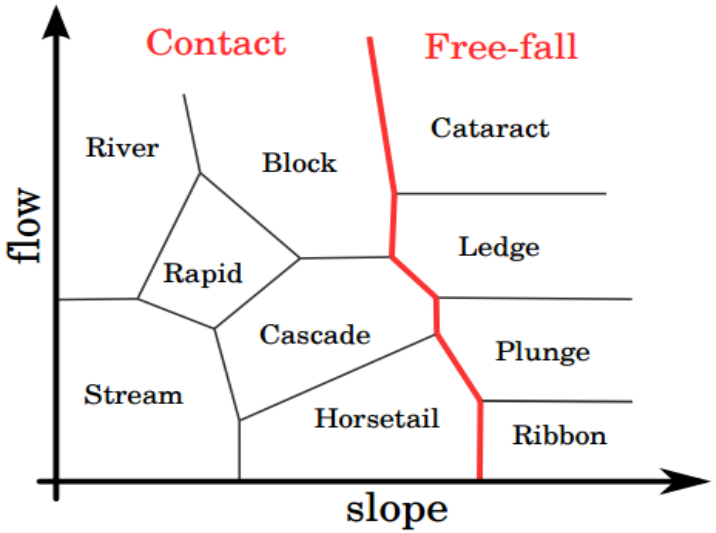
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 2: Streams & waterfalls
Combining knowledge and control?

3. User selects trajectory refinement
   - Flow-based or terrain-based
4. Consistent fall-type computed





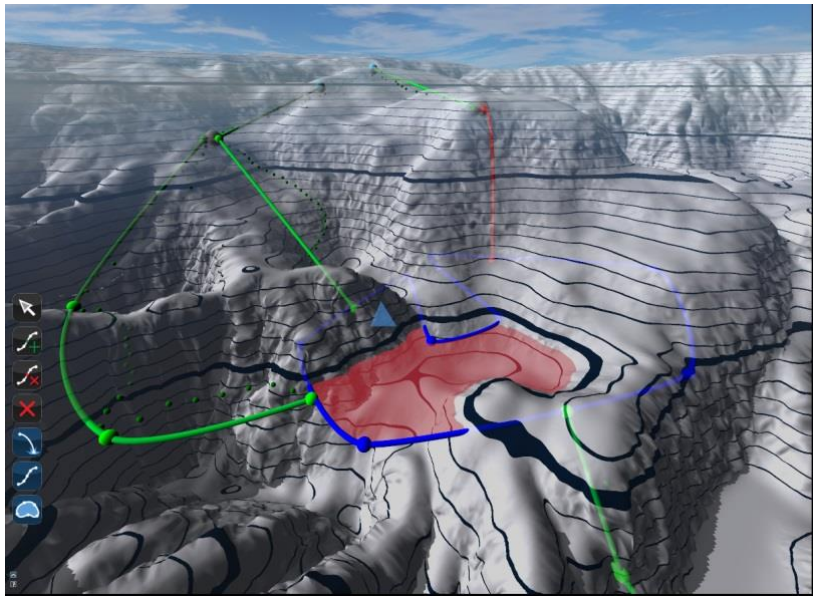


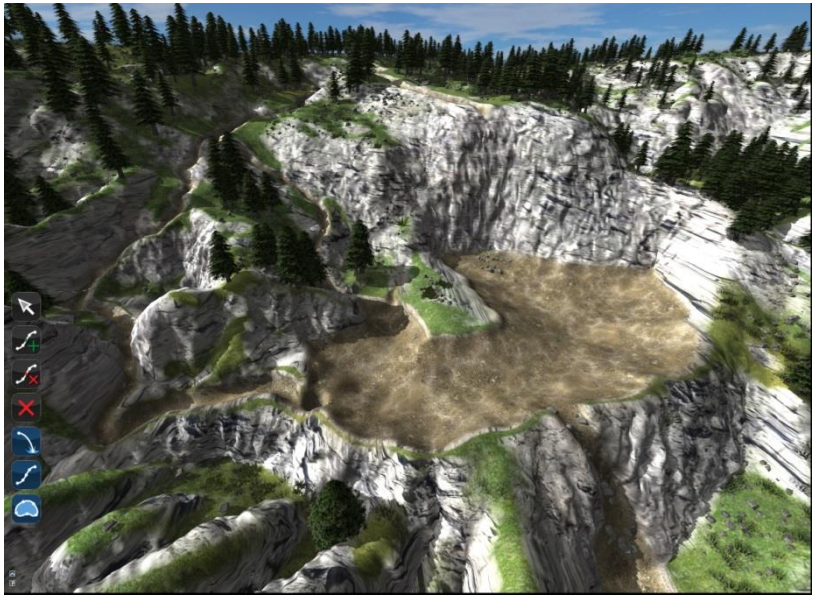
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 2: Streams & waterfalls
Combining knowledge and control?

The waterfall « sculpts » the terrain

- Displacement constraints are propagated
- Procedural details are added (rocks, trees, 2D flows, etc)

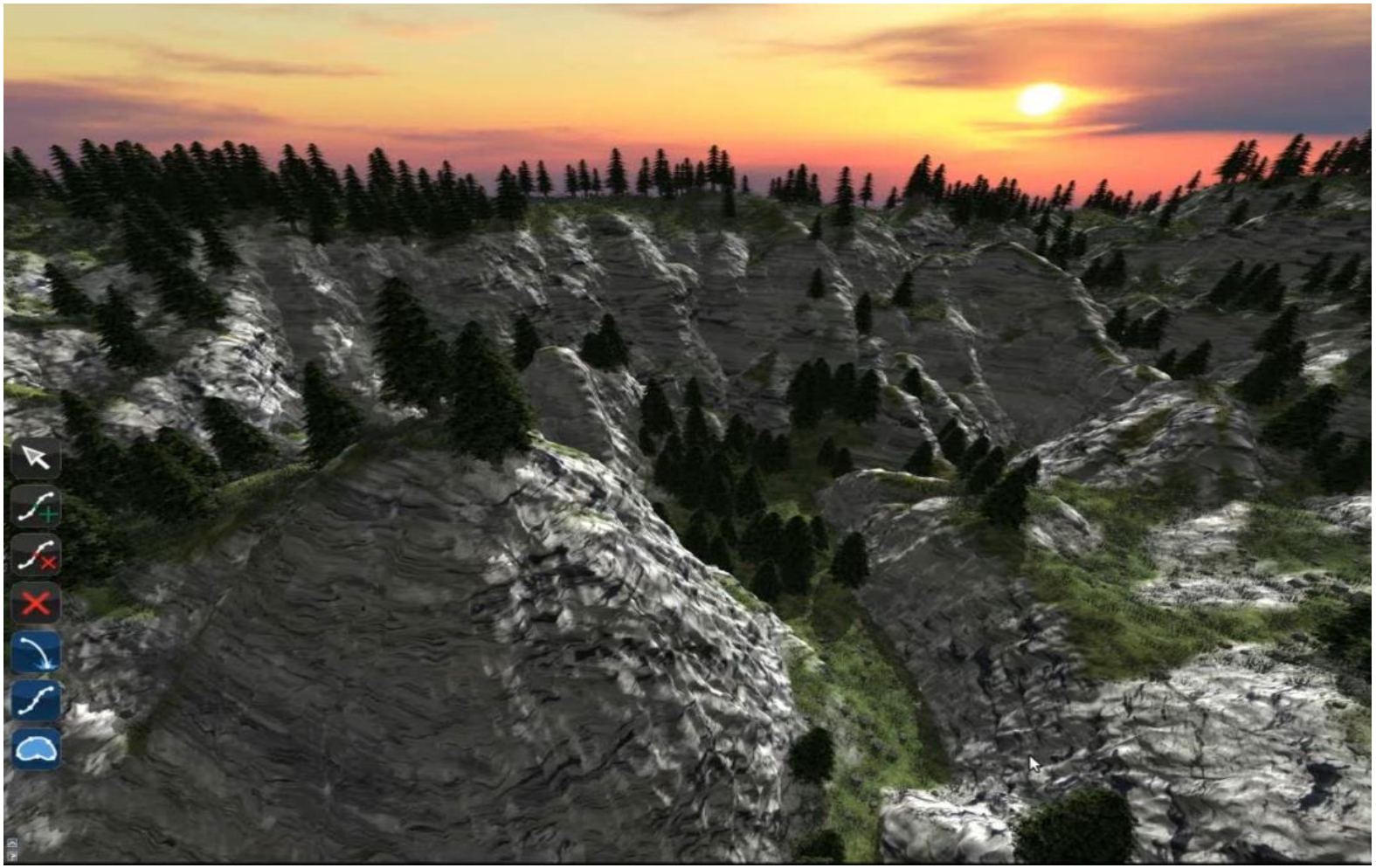




A. Procedural modeling
B. Layered animation
C. Expressive design

Case 2: Streams & waterfalls Results

[Emilien 2015]



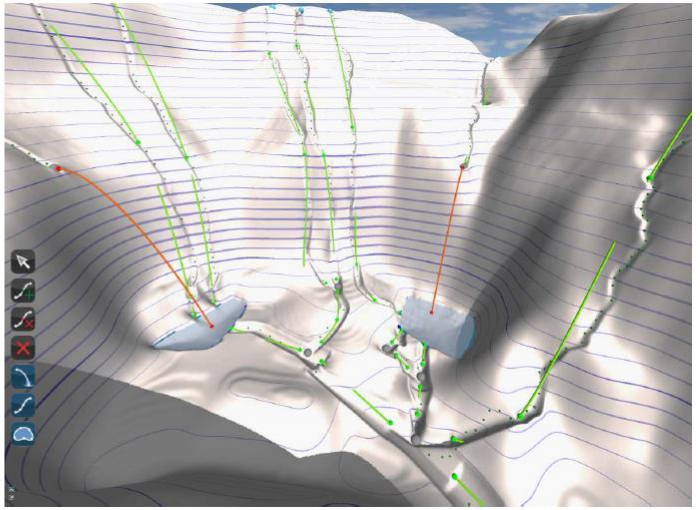
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 2: Streams & waterfalls Validation

Creation on a real waterfall: The Iron Hole (La Réunion)

- Modeling time < 10 min
- Generation time < 1 sec

Photo @Serge Gélabert



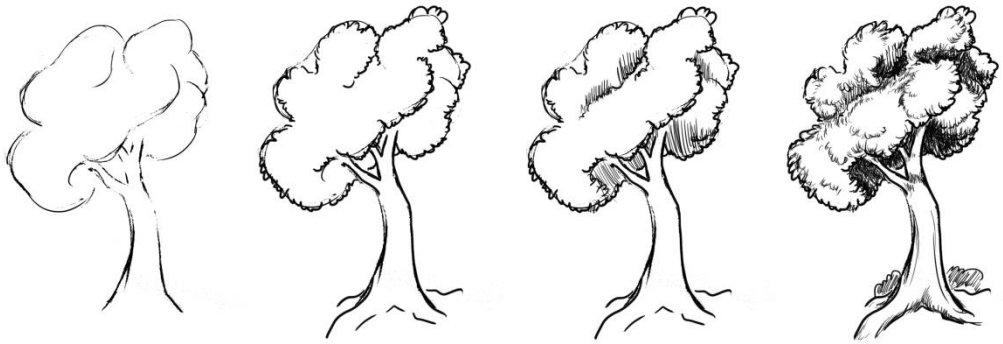
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Sketch-based modeling of a tree

Challenges

- Need to control a specific shape
- Too many branches for interactive modelling!
- Distributions matching laws from biology

Inspiration



Idea

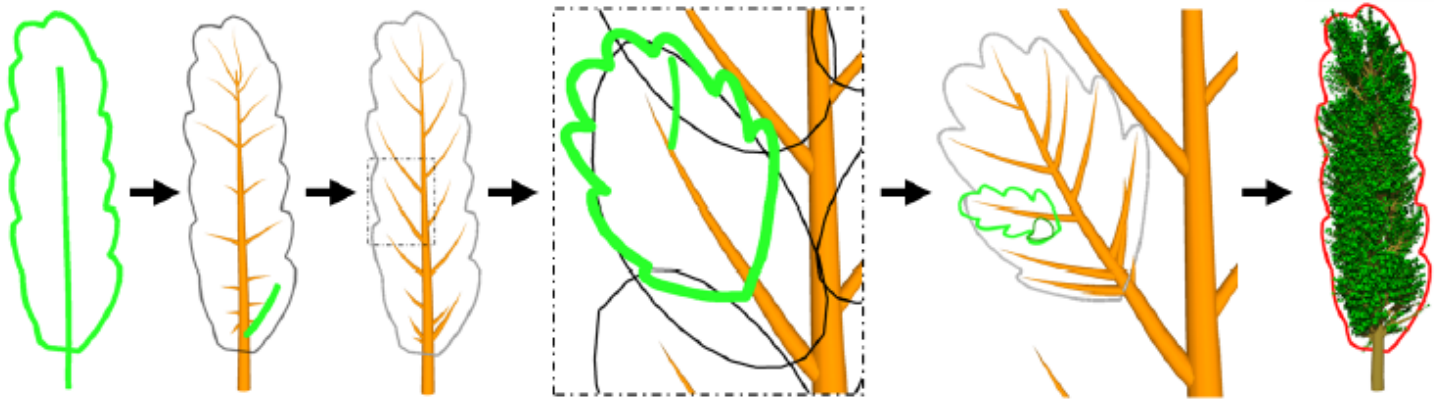
Combine multi-resolution sketches with procedural generation!

A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Sketch-based modeling of a tree

Idea of solution [Wither 2009]

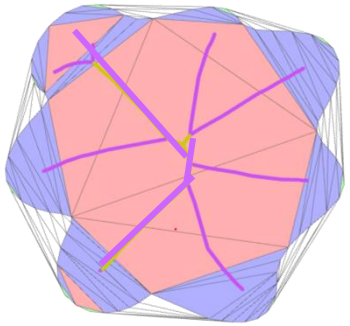
- Structure from silhouette!
- Use rules from botanic, statistics, perception to:
  - Infer sub-structures
  - Adapt branching style
  - Extend branches to 3D

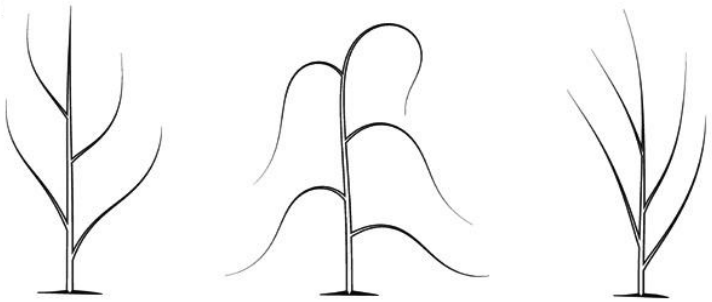


A. Procedural modeling
B. Layered animation
C. Expressive design

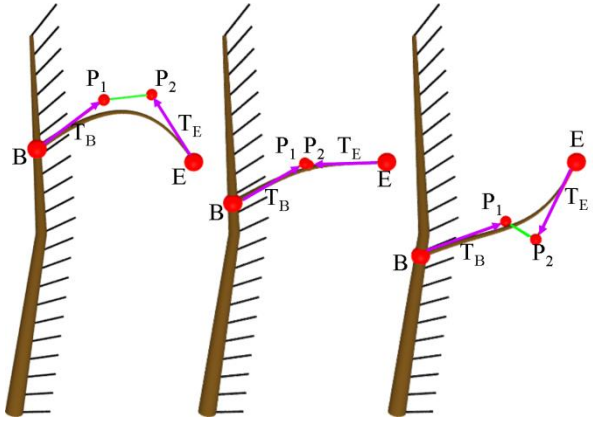
Case 3: Vegetation
Sketch-based modeling of a tree

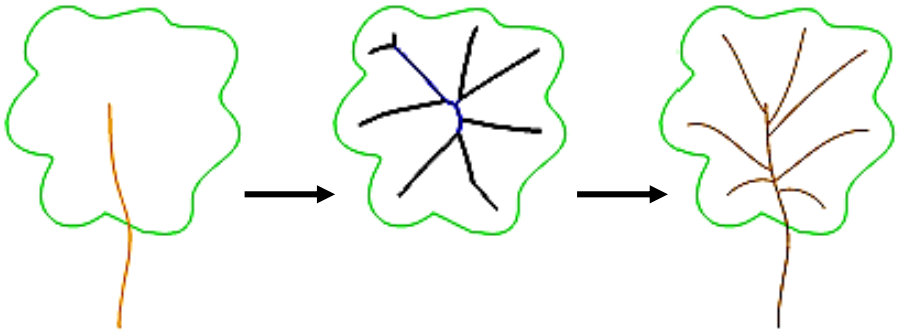
- Silhouette analysis
  - Medial axis?
  - Add knowledge on branching arrangements
  - Find shortest branch





Knowledge on branching rules

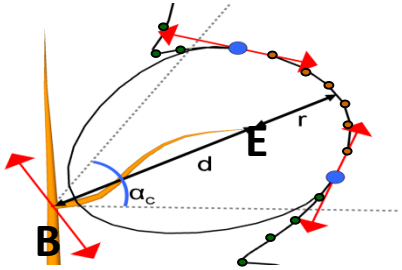


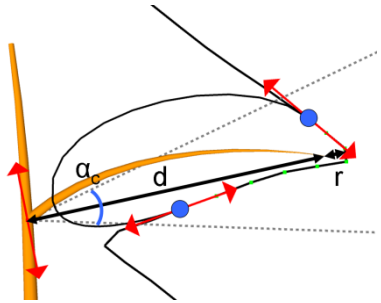


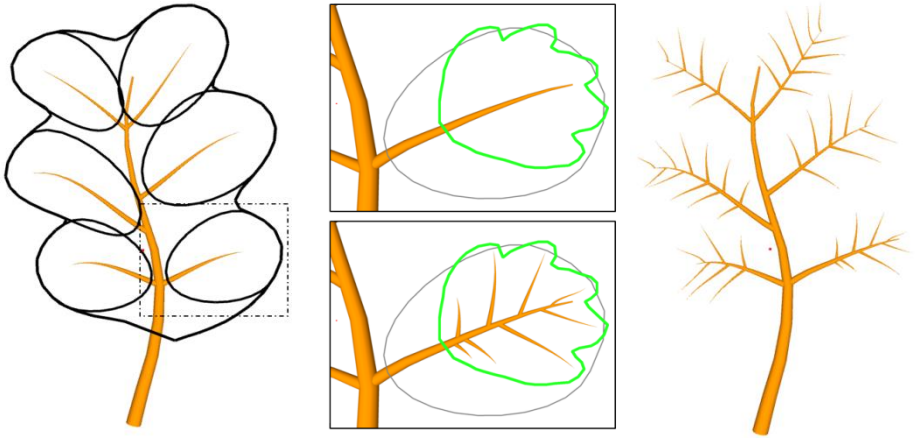
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Sketch-based modeling of a tree

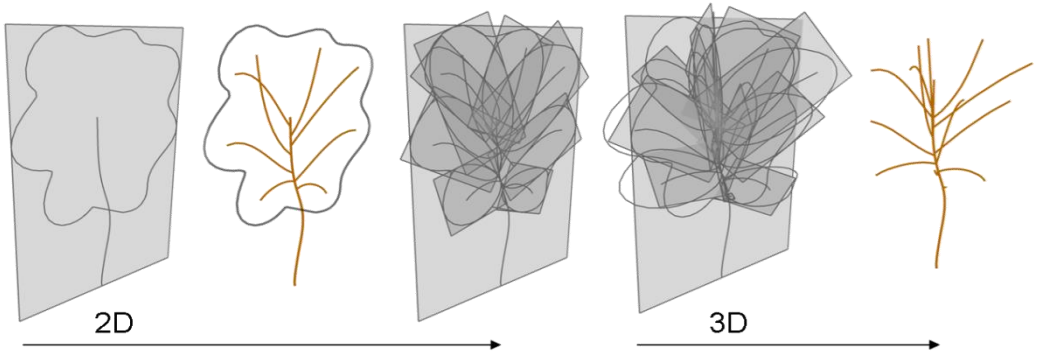
- Inferring substructures

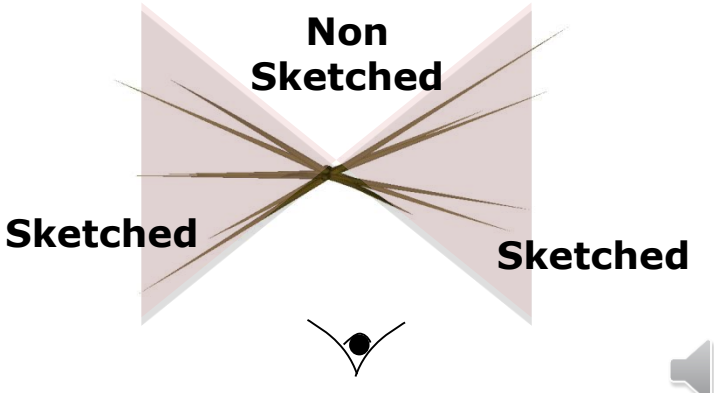






- Inferring 3D branch distribution



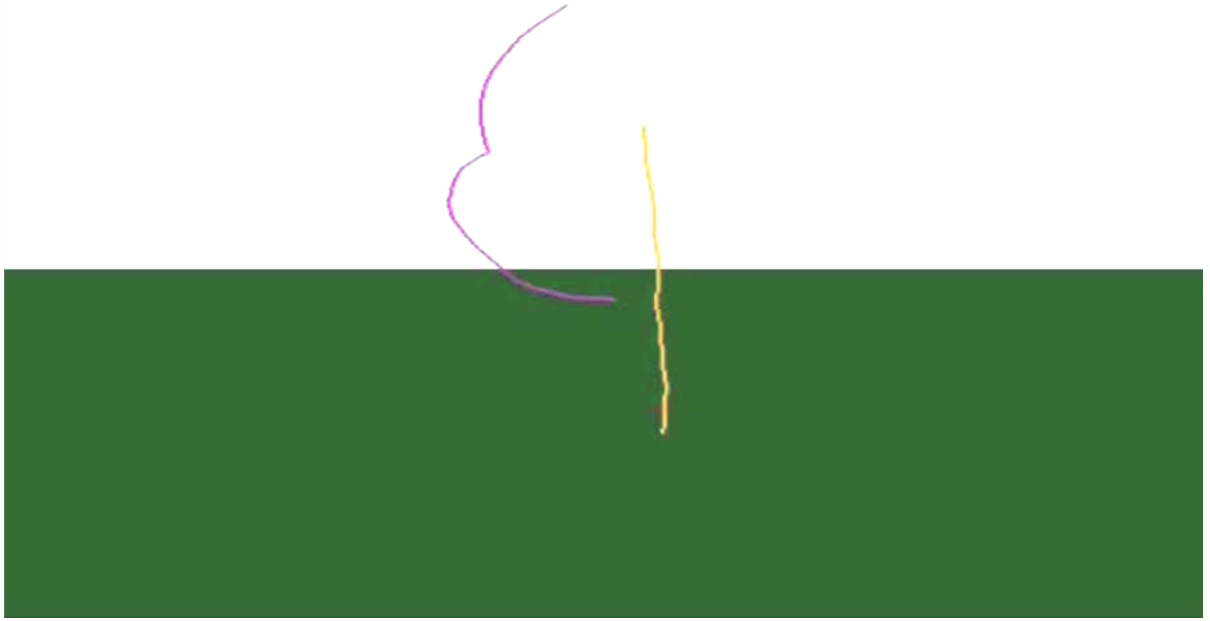


A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Sketch-based modeling of a tree

Eucalyptus

[Wither 2009]



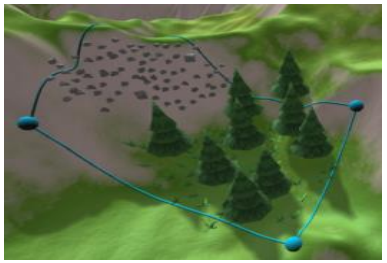
A. Procedural modeling
B. Layered animation
C. Expressive design

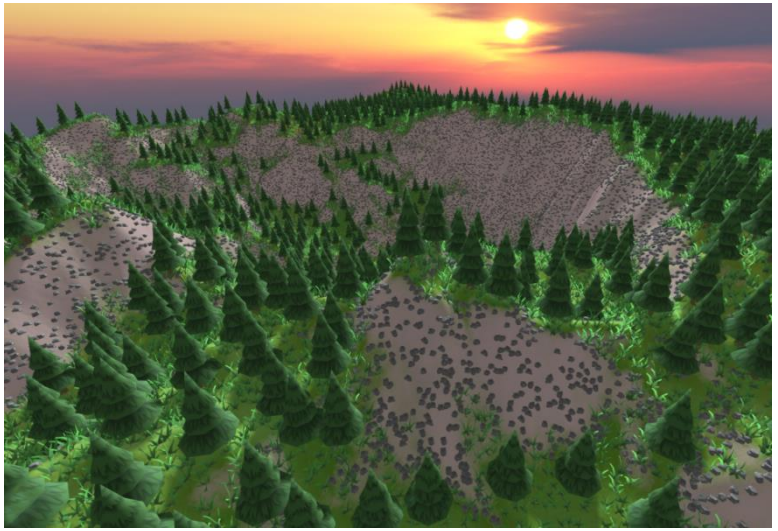
Case 3: Vegetation
Populating virtual worlds with distributions

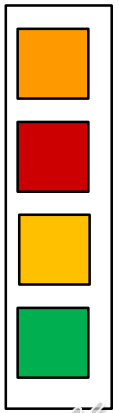
Color = {Statistics on distributions} (trees, stones …)

- ✓ Learnt from examples
- ✓ Correlated with terrain slope
- ✓ Stored in a « palette »

User-designed exemplar →







A variety of tools

- Pipette (learn new “color”)
- Copy or Brush (transfer!)
- Gradient (blend colors)
- Move & deform content

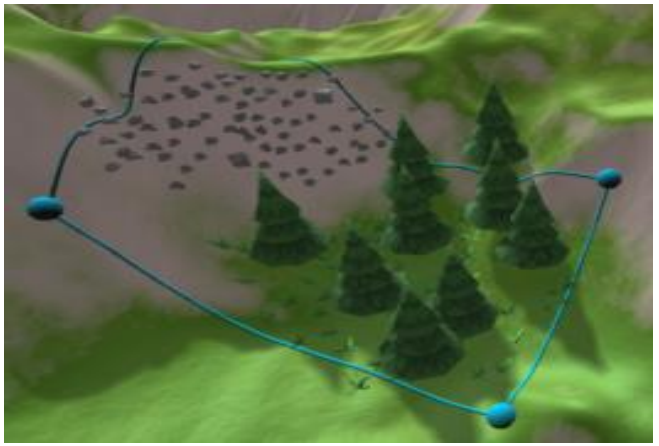
A. Procedural modeling
B. Layered animation
C. Expressive design

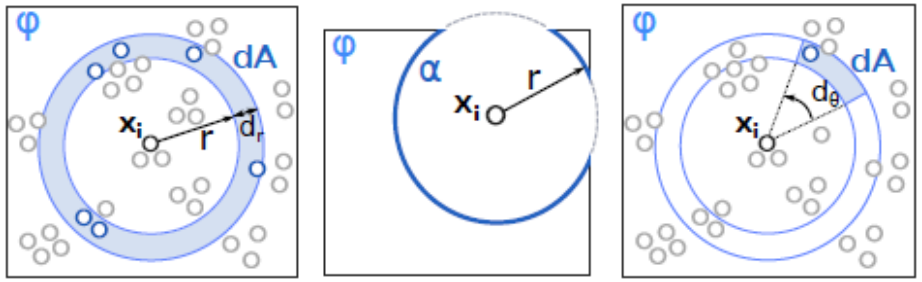
Case 3: Vegetation

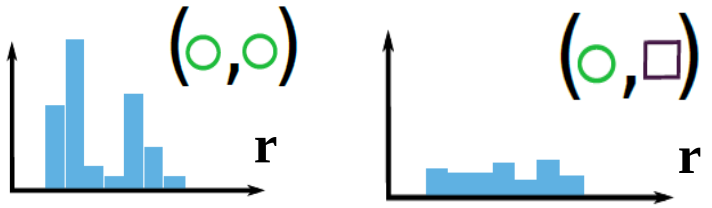
Populating virtual worlds with distributions

Learning and synthesis

- Point processes (trees, stones…)
- Improvement
  - Robustness to small samples
  - Angular histograms
  - Correlation with terrain slope





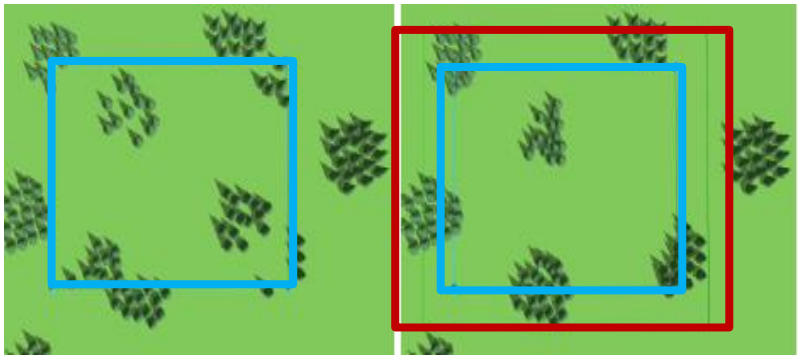


A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation

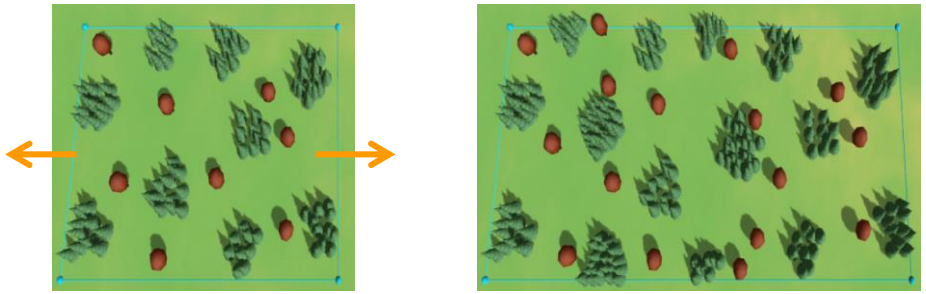
Populating virtual worlds with distributions

- Copy-paste : influence region



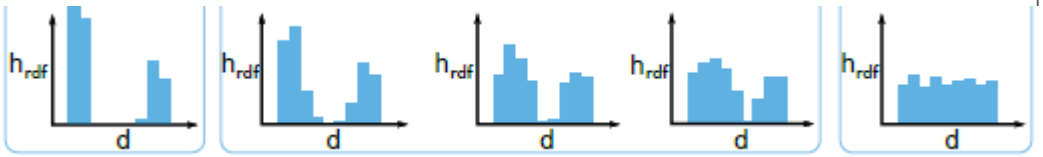
Without / With influence zone

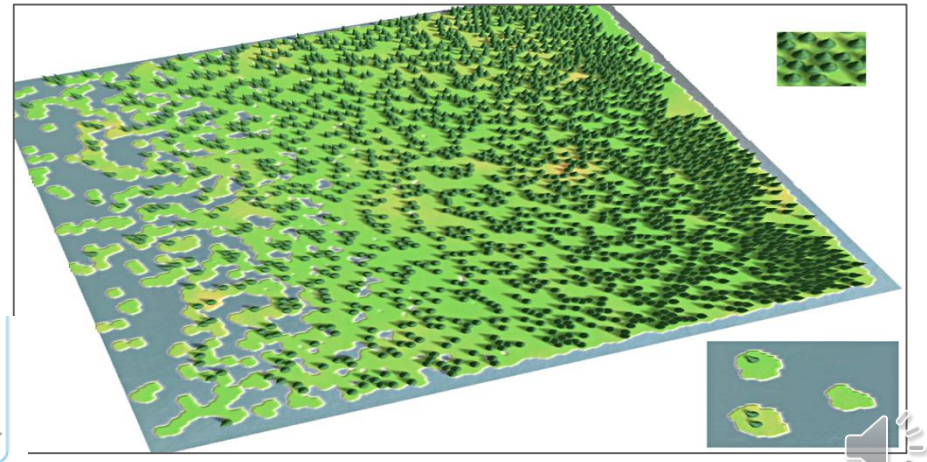
Deformation (seam carving)



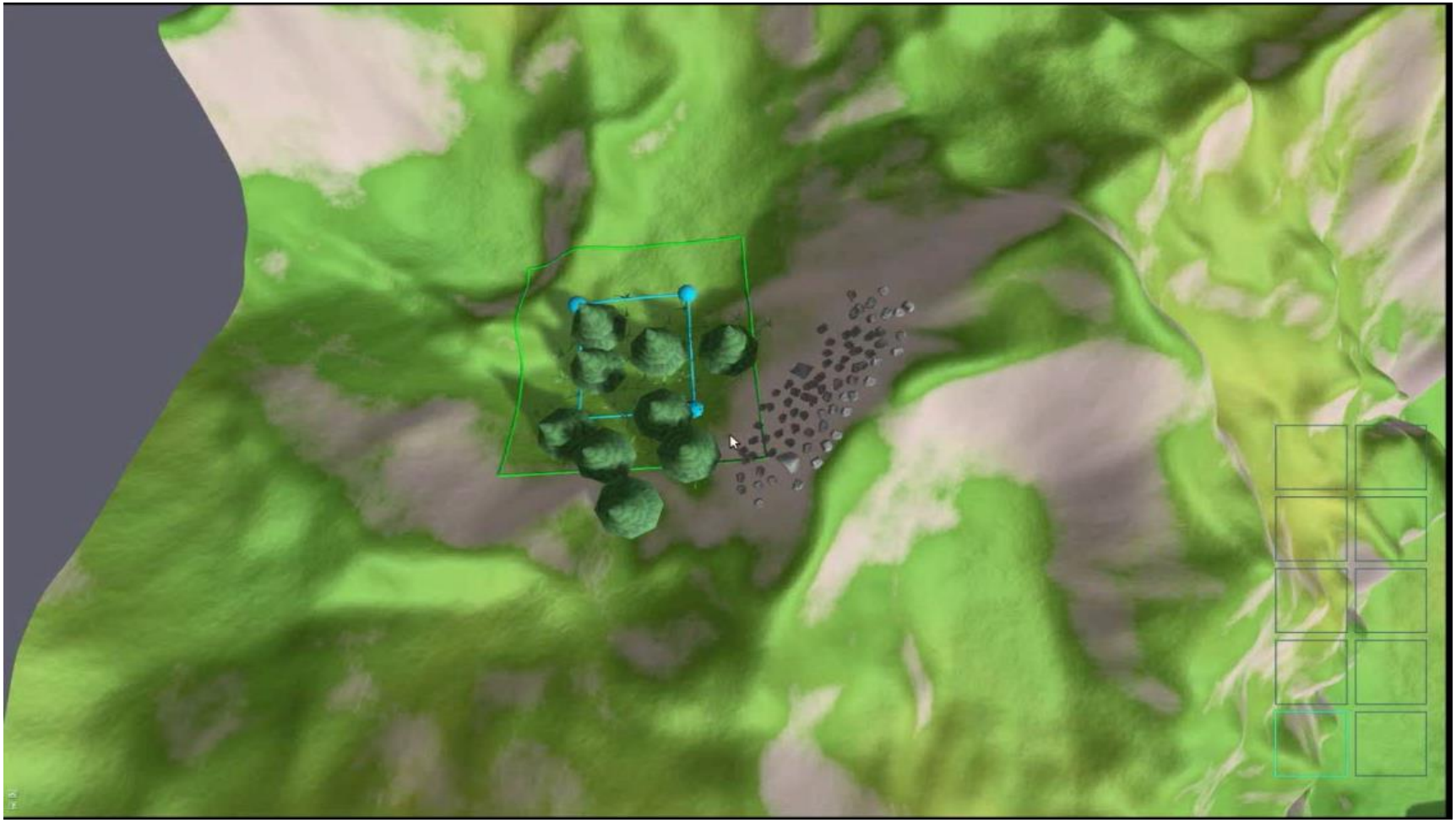
- Gradient tool

Optimal mass transport





Case 3: Vegetation
Populating virtual worlds with distributions



“World-brush” ***[****Emilien 2015]*

A. Procedural modeling
B. Layered animation
C. Expressive design

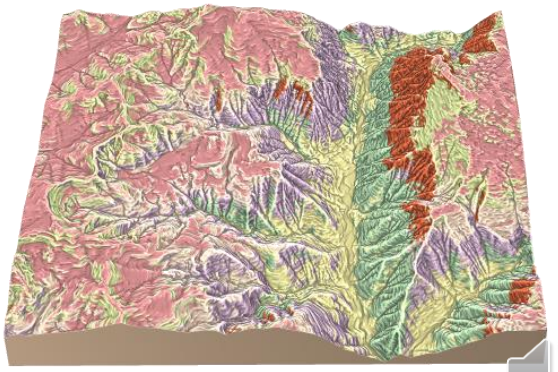
Case 3: Vegetation
Learning from Ecosystem simulation?

Challenge : Consistent vegetation + user control




Idea: Combine world-brush with simulation!

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



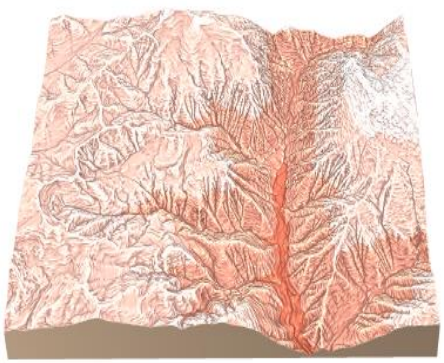
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Learning from Ecosystem simulation?

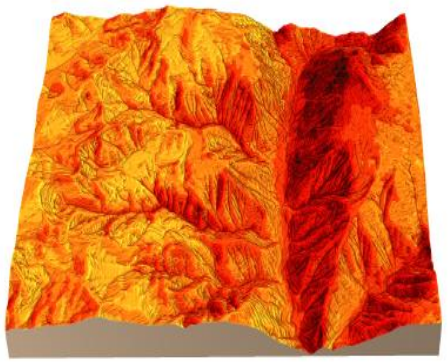
Terrain clustering

- Resource maps

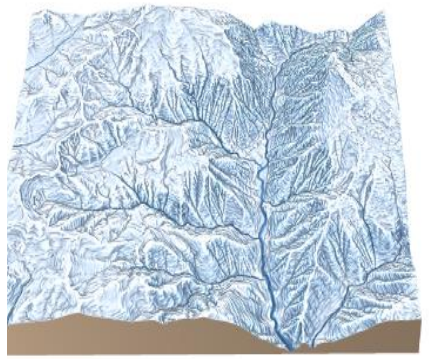
Input: DEM, altitude, latitude, precipitations…



Temperature



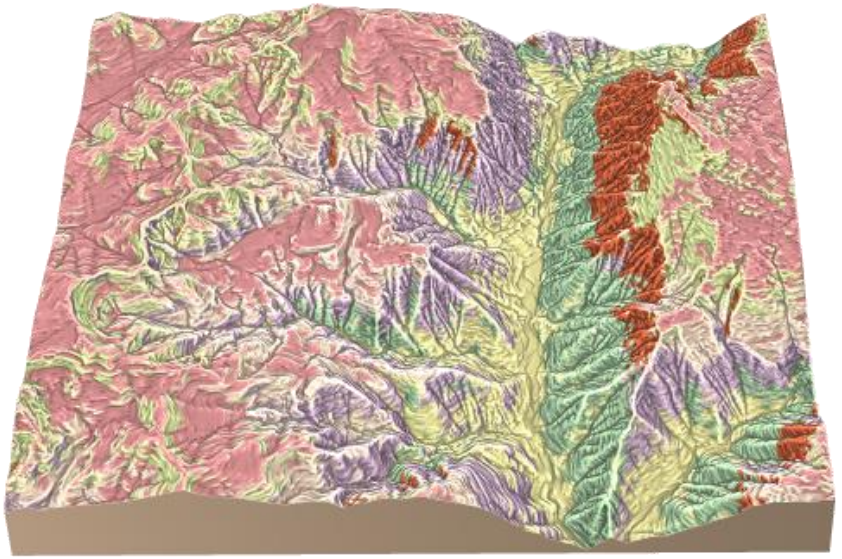
Sunlight



Moisture

- Resulting clusters

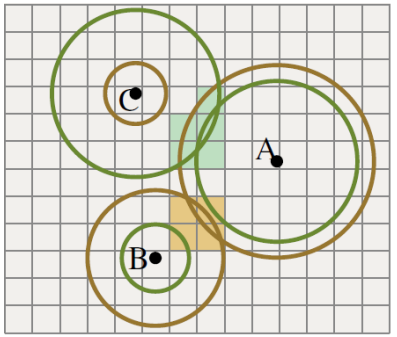
K_means clustering with 6-10 clusters



A. Procedural modeling
B. Layered animation
C. Expressive design

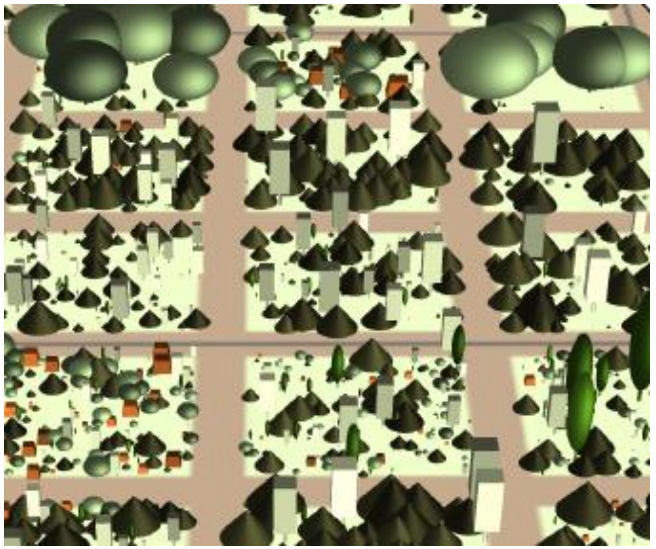
Case 3: Vegetation Learning from Ecosystem simulation?

Sand-box simulations: 100x100m per cluster



- Plants modeled as pairs of circles
  - canopy and roots
- They compete in cells where they overlap

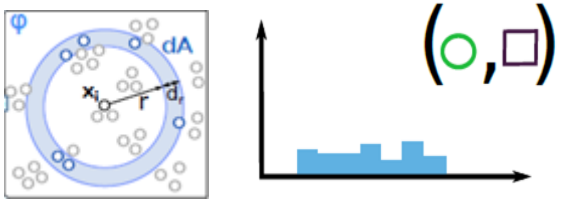
Resulting ecosystems



A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Learning from Ecosystem simulation?

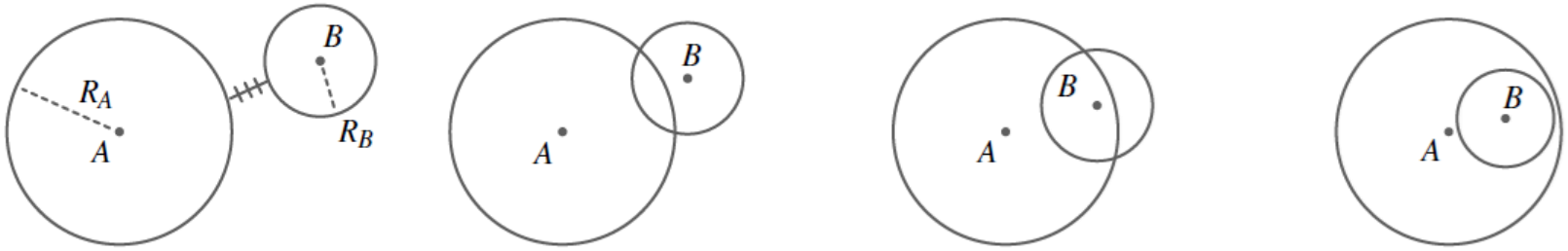
Learning statistics: Disc processes!



- Position and canopy size are correlated
- 2D histograms would be too costly

→ Analyze distributions of possibly overlapping discs

Solution: Measure distance between discs + 3 « overlap » bins



No shading lest than half more than half fully shaded

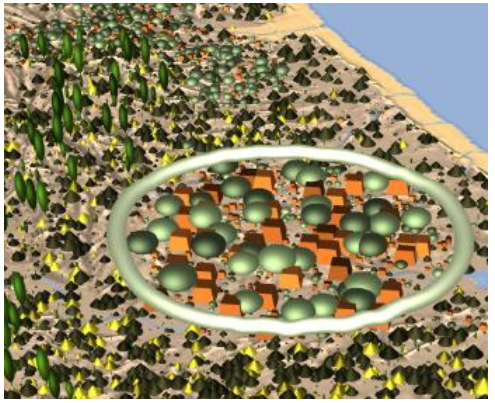
A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Interactive editing: Semantic brushes

Goal: Combining consistency and control

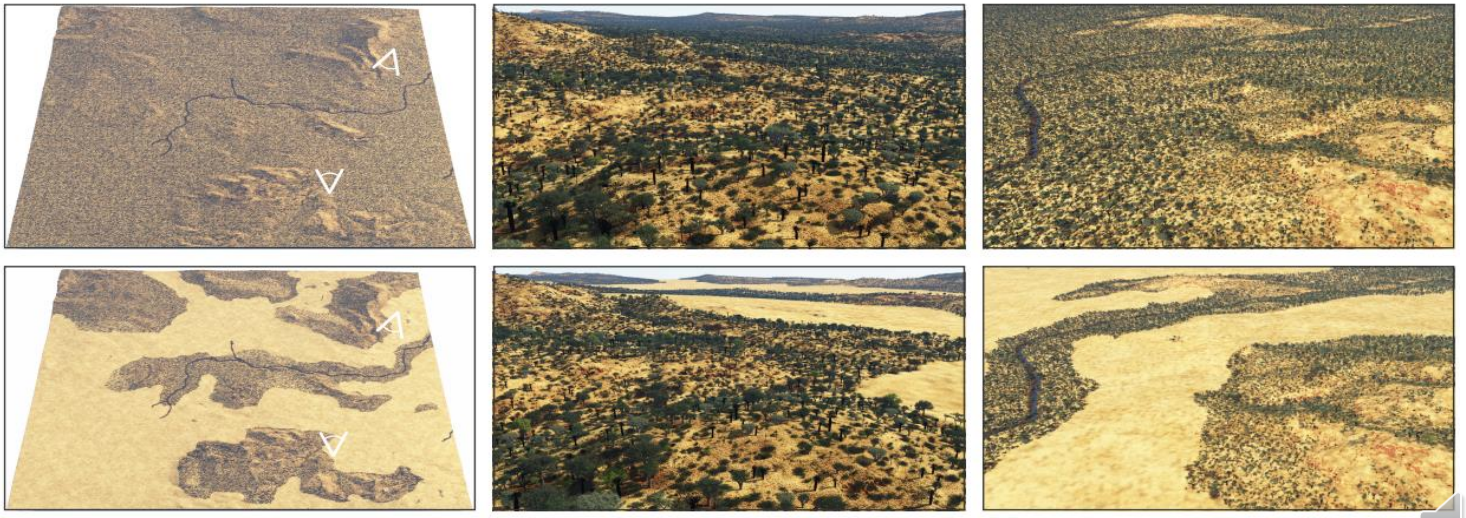
Semantic brushes

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



African savanah

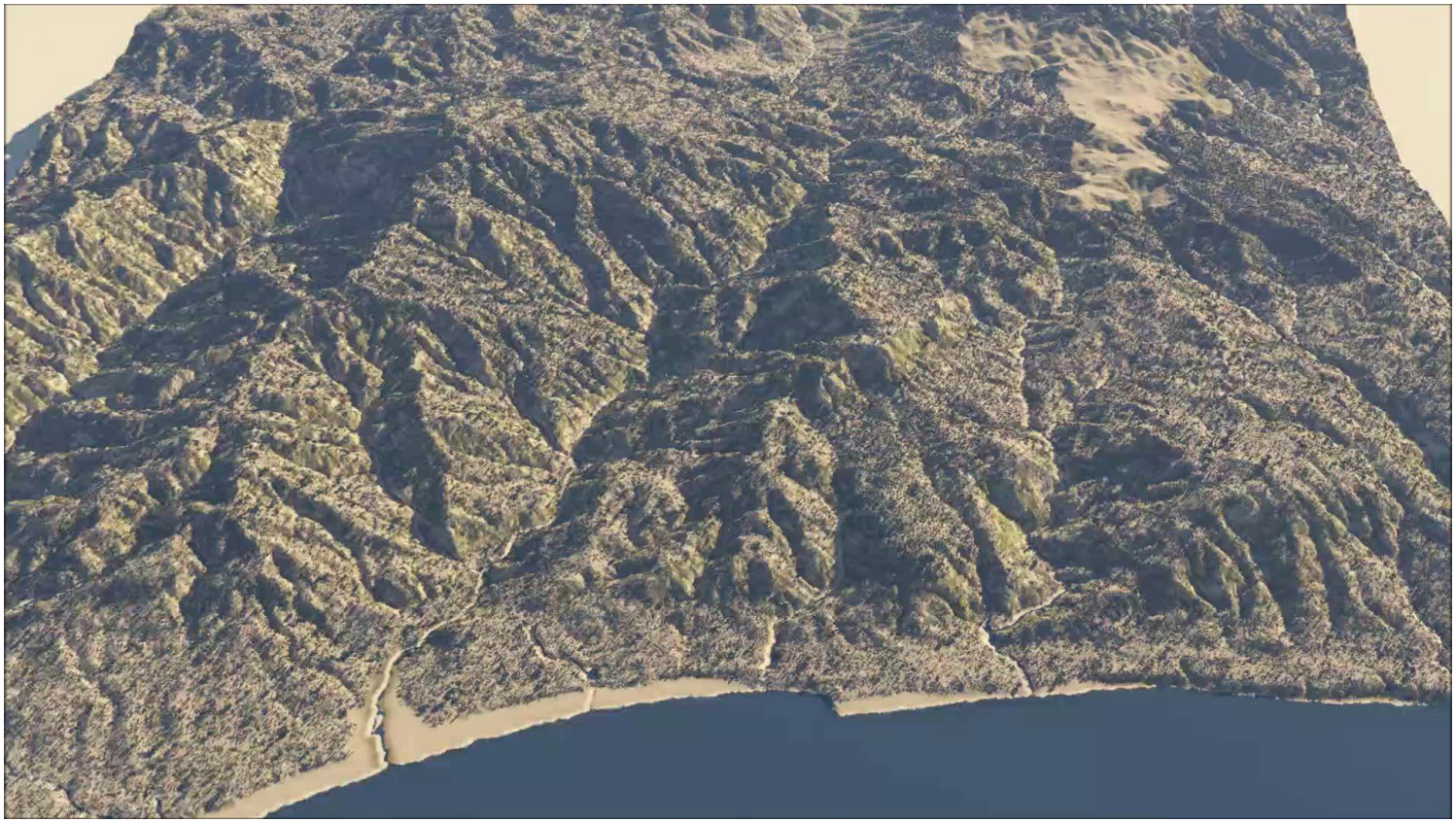
- without
- with destruction (fire & animals)



A. Procedural modeling
B. Layered animation
C. Expressive design

Case 3: Vegetation
Learning from Ecosystem simulation

EcoBrush *[Gain 2017]*



A. Procedural modeling
B. Layered animation
C. Expressive design

Pair correlation function
Continuous model for distributions

[Öztireli 2012]

Distribution represented by

- A density
- A normalized function

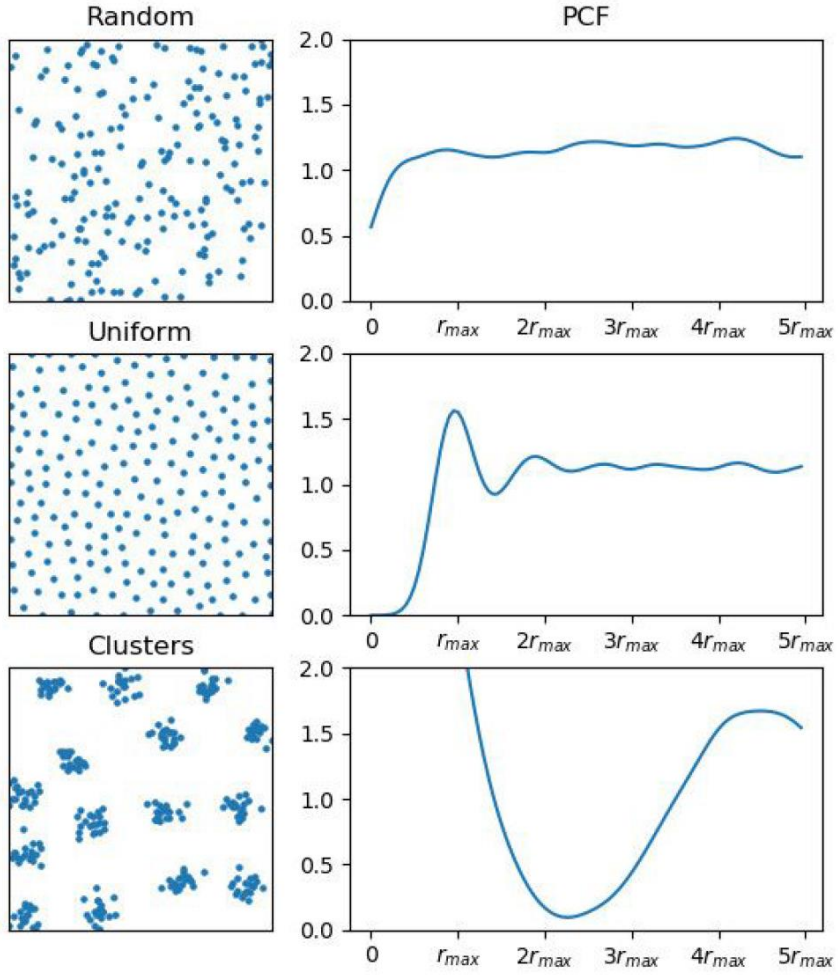
$$\mathrm{PCF}(r) = \frac{1}{A_r n^2} \sum_{i \neq j} k_\sigma(r - d_{ij})$$

Normalization

Gaussian

Area of ring at distance r
Distances normalized by r_{max}

- Easier interpretation
- Accurate synthesis thanks to gradient descent

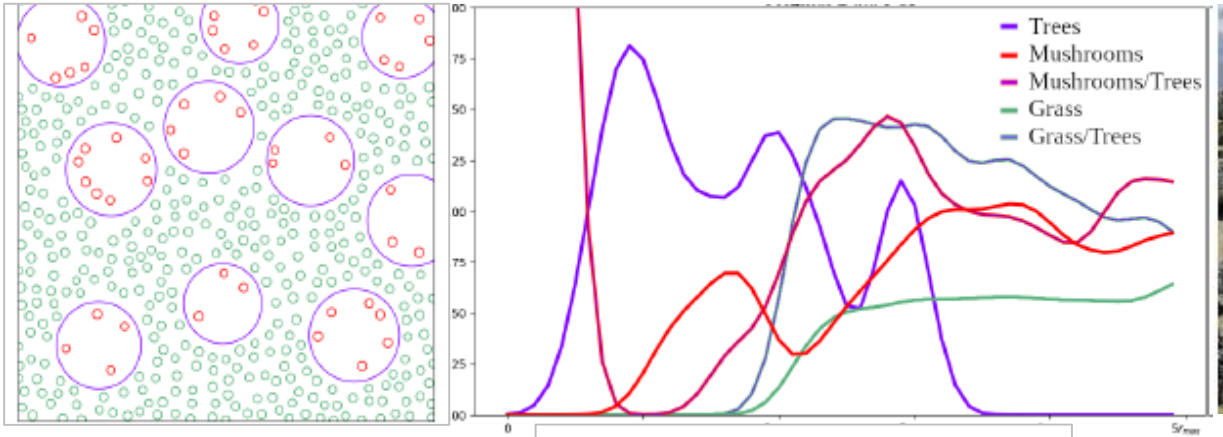


1. *Knowledge*
2. *Gesture-based control*
3. *Learning*

Challenge
Learning disc distributions!

Input

Output



Pair correlation functions

[Ecormier-Nocca, Eurographics 2019]

Conclusion
3D modeling & simulation of virtual worlds

- Specific needs: realism /consistency, user control !
- Methodology to handle complexity
  - Procedural generation (prior or learnt knowledge)
  - Layered models: Hierarchy of coupled, minimal models
- Authoring tools – “Expressive modeling”, “Creative AI”
  - Interleave user control & automatic generation of consistent details
  - User interaction : Sketching, sculpting, providing examples
- Perceptual validation + User studies for design tools

References

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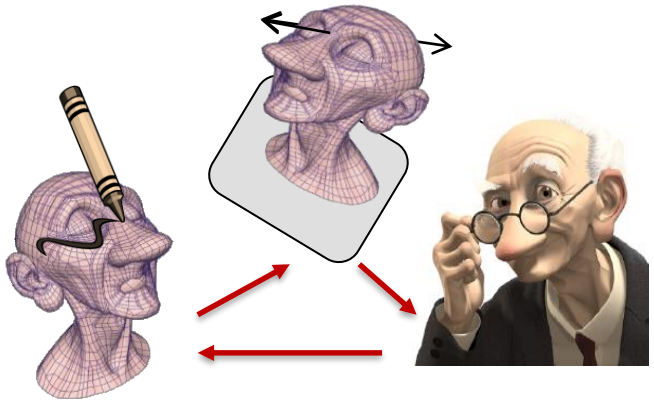
- Wither, Boudon, Cani, Godin. Structure from silhouettes: a new paradigm for fast sketch-based design of trees. Computer Graphics Forum, 28 (2) , Eurographics 2009.

Conclusion : Creative AI
Systems that help users in creative tasks

« Expressive modeling »

- Gesture-based design
- Knowledge in the models

  From priors or learnt



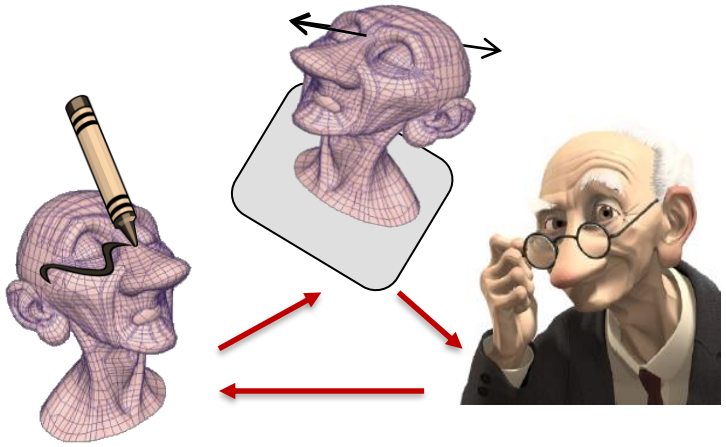
Extension to Virtual Worlds

- Control to the user
- Knowledge to the system

Specificities of AI for creative tasks

AI to ease human creation

- Control to the user
- Smart models to help
  - Interpreting user gestures
  - Maintaining constraints
  - Handling repetitive details



Different ways to use AI

- Modeling prior knowledge (rules, ontologies, expert systems)
- Learning from examples: **Small user data / Synthetic examples**
  - Advantages: Control on training data & no human slave!