Laboratoire d'Informatique
de l'Ecole Polytechnique

Recherche en Informatique Graphique au LIX

Damien Rohmer

Recherche Informatique Graphique au LIX

1) Qu’est ce que l’Informatique Graphique & applications
2) Pourquoi faire de la recherche en IG

4) Les équipes de recherche du LIX: Vista & Geomerix
5) Focus particulier – exemple de recherche

Qu’est ce que l’Informatique Graphique

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Ensemble des **sciences et techniques** permettant de

répresenter, **créer** et **interagir** avec des modèles virtuels.

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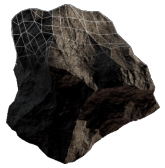
Rendu du ciel
Ex. Diffusion de Rayleigh

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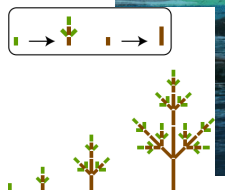
Modèle surfacique procédural



$$P(x) = \sum_{k=0}^{N} \alpha^k f(\omega^k x)$$

Végétation procédurale



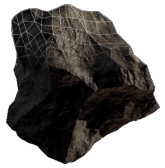




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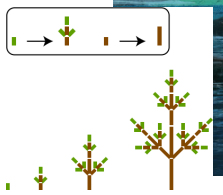
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Rendu du ciel
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Déformeurs interactifs

$$w(p) = \exp(-\|p - c\|^2/\sigma^2)$$



Animation de personnages

$$p = \left(\sum_{k=0}^{N-1} \alpha_k \, \mathrm{M}_k\right) p^0$$





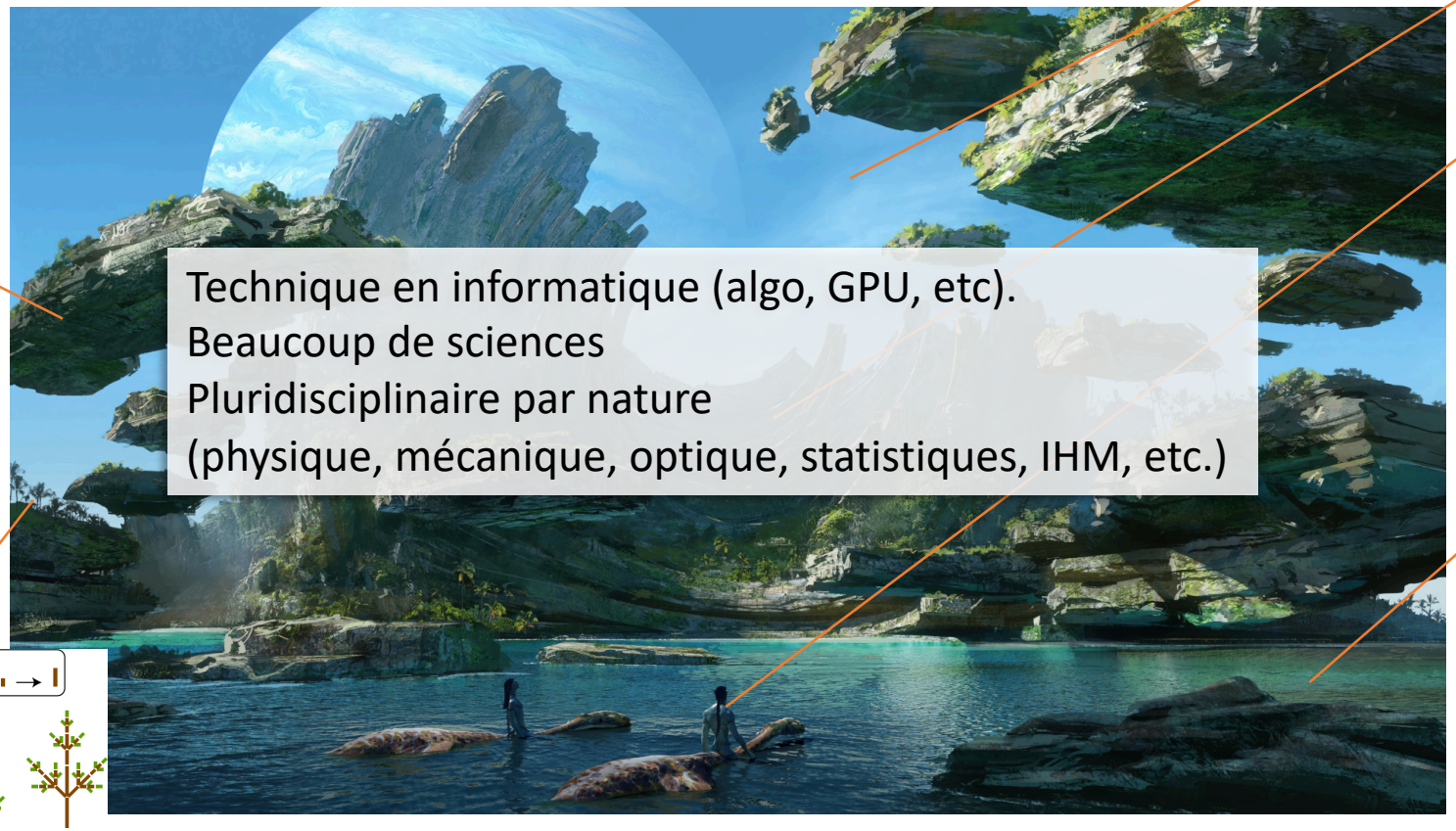
Animation/simulation de fluides



$$\begin{aligned} \nabla \cdot \mathbf{u} &= 0 \\ \frac{\partial \mathbf{u}}{\partial t} &= -(\mathbf{u} \cdot \nabla)\mathbf{u} - \frac{1}{\rho}\nabla p + \nu \nabla^2 \mathbf{u} + \mathbf{f} \end{aligned}$$

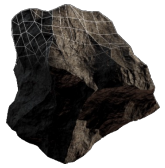
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Technique en informatique (algo, GPU, etc).
Beaucoup de sciences
Pluridisciplinaire par nature
(physique, mécanique, optique, statistiques, IHM, etc.)

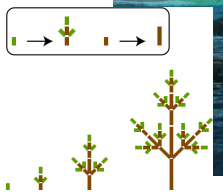
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Applications de l'Informatique Graphique

Loisir (Jeu vidéo, Cinéma, VFX), mais également applications scientifiques

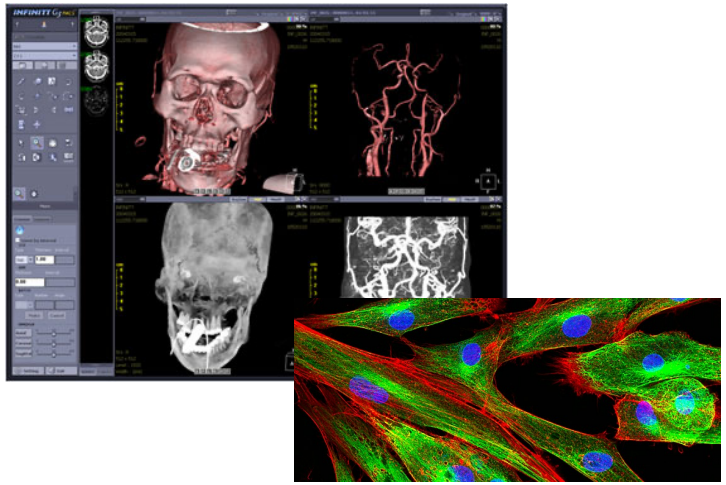
Design



Voiture autonome



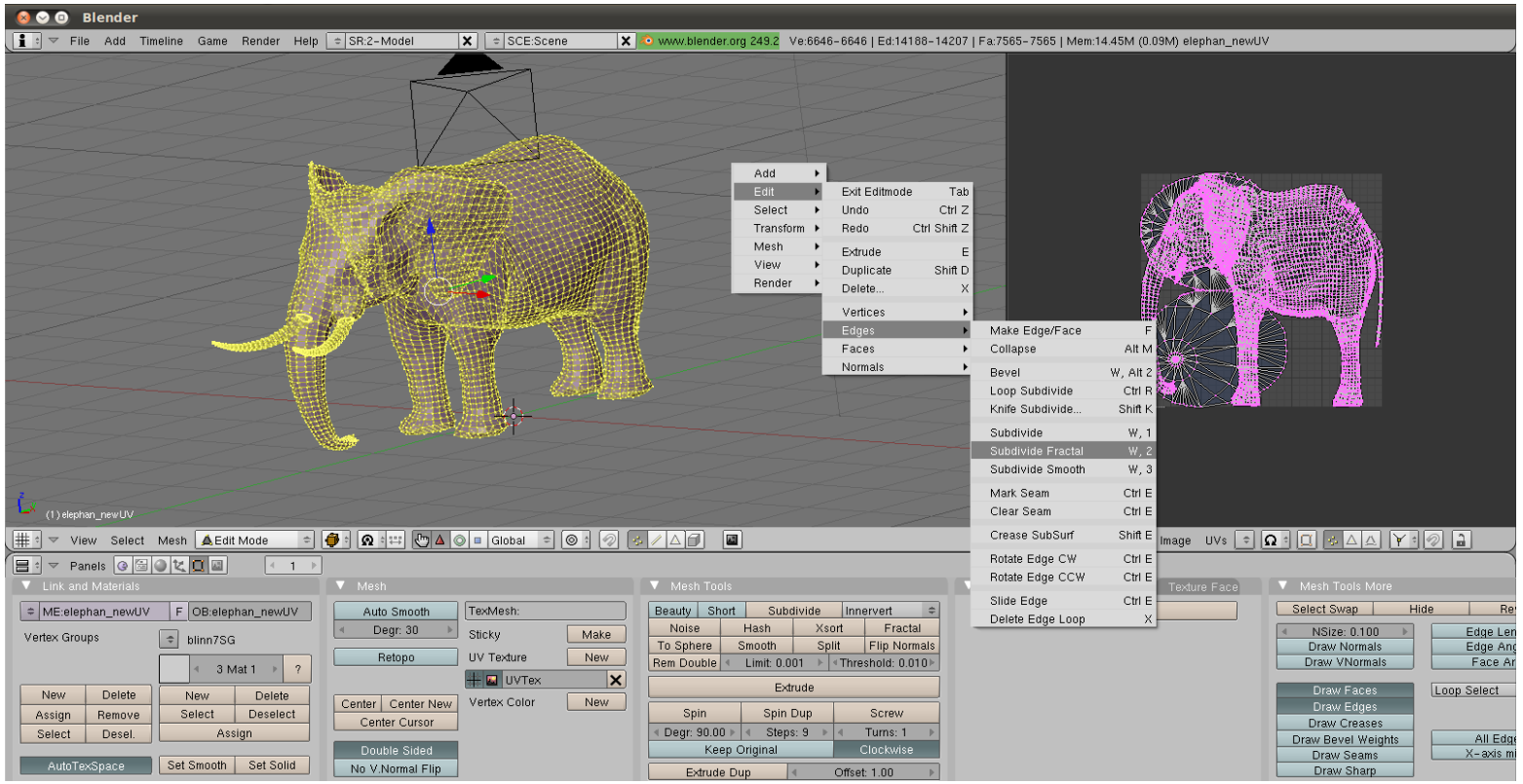
Imagerie médicale, biologique

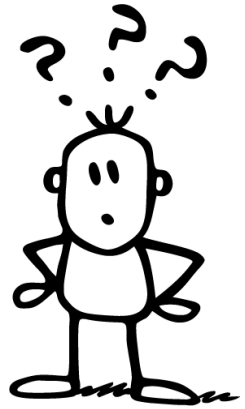


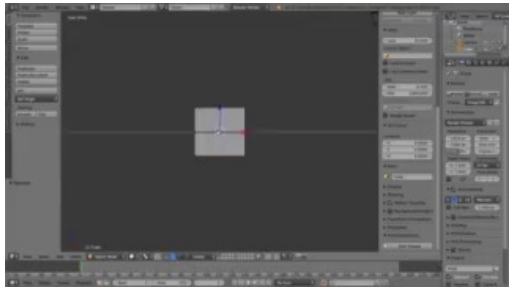
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La recherche en Informatique Graphique

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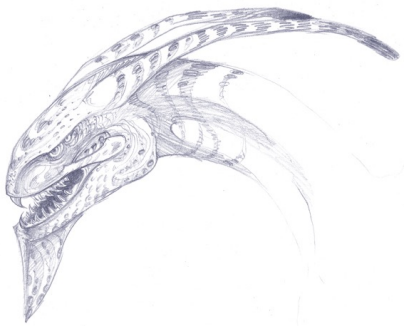
La recherche en Informatique Graphique

Cout & temps passé sur la creation 3D n'a jamais été aussi élevé

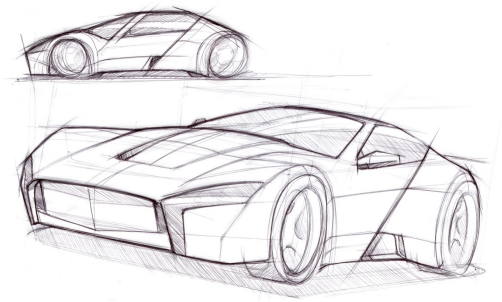
Amélioration des logiciels 3D, mais:

- Données de plus grandes tailles (BigData)
- Données plus hétérogènes (Captures, procedural, volumiques, bruit, etc)
- Besoin d'automatisation croissante (IA, modèles générateurs)
- Demande de qualité croissante constante

Rem. Dessins/sculpture (à la main) restent souvent plus efficaces pour le prototypage









La recherche en Informatique Graphique au LIX

LIX

VISTA

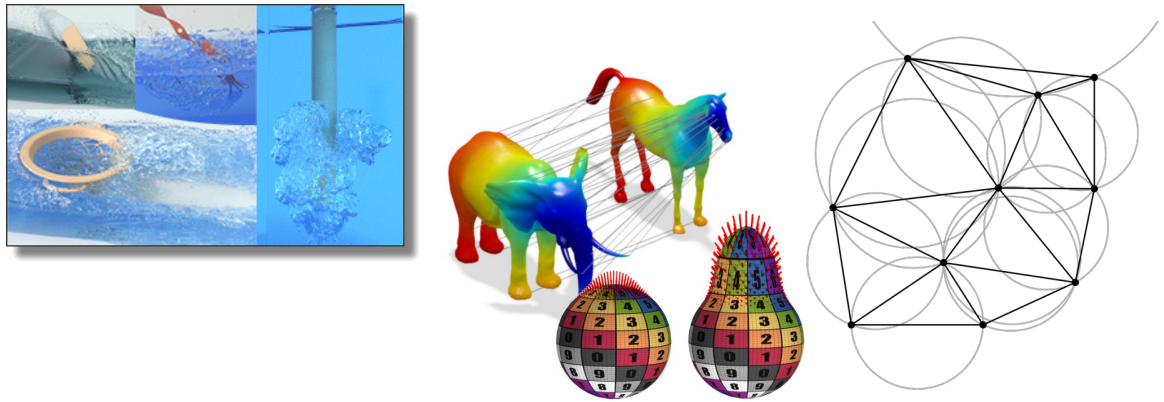
Geomerix

Création de mondes virtuels animés
Aide aux artistes/scientifiques

Analyse de géométrie
Modèles fondamentaux de géométrie



https://www.lix.polytechnique.fr/vista/



https://www.inria.fr/fr/geomerix

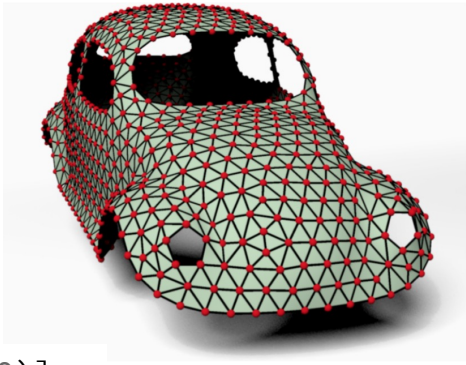
Focus: Modèle alternatif représentation des surfaces

Approche standard: Maillages triangulés

(+) Pipeline standard

(-) Pas de notion d'intérieur/extérieur

(-) Mélange/Intersection/Union complexe entre surfaces



```
geometry = [(0.0, 0.0, 0.0), (1.0, 0.0, 0.0), (0.0, 1.0, 0.0), (0.0, 0.0, 1.0)]
connectivity = [(0,1,3), (0,3,2), (0,2,1), (1,2,3)]
```

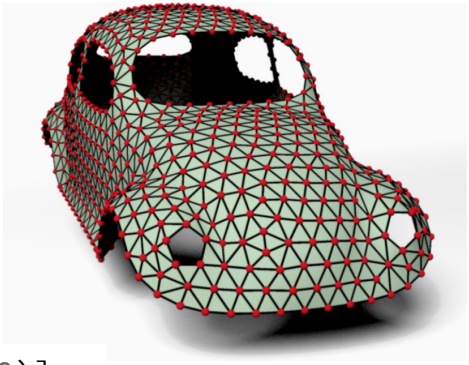
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```

Notre approche de recherche:

Développer modèles interactifs basés sur les **surfaces implicites**

$$S = \{(x, y, z) \in \mathbb{R}^3 \mid F(x, y, z) = iso\}$$

Surface Implicites

Exemple: $F(x,y,z) := R^2 - (x^2 + y^2 + z^2)$

$$F(x,y,z) = 0 \ ?$$

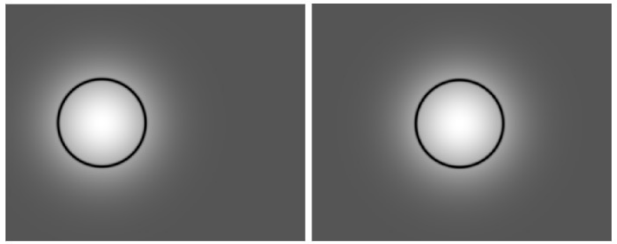
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Exemple: $F_{p_0}(p) = e^{-\|p-p_0\|^2}$

$$F_{p_0}(p) = 0.5 \ ?$$



F_{p_1} F_{p_2}

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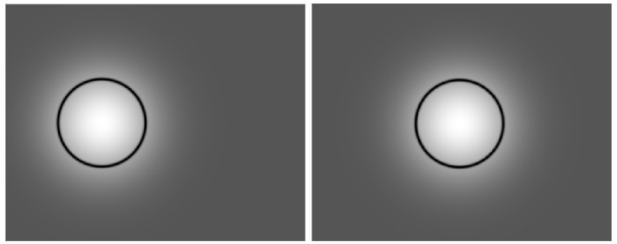
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Propriétés:

- Position p sur la surface: F(p)=0
- p est à l'intérieur: F(p)>iso
- p est à l'extérieur: F(p)<iso

$\Rightarrow$ Requête simple



F_{p_1} F_{p_2}

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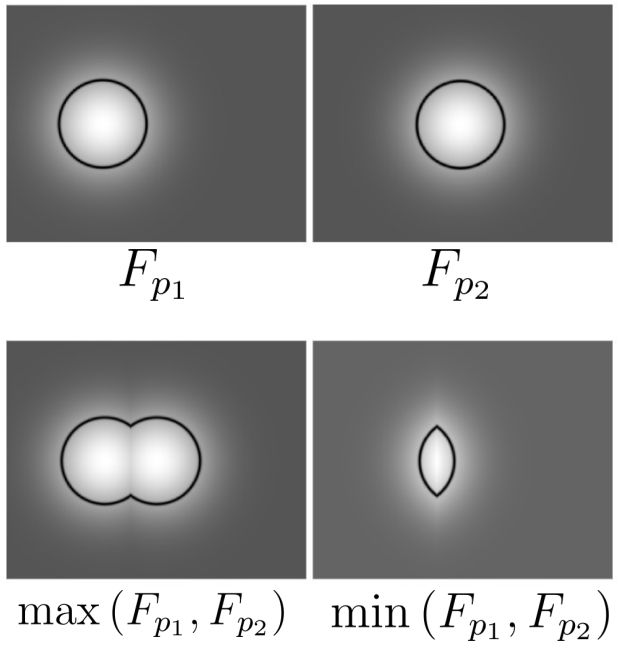
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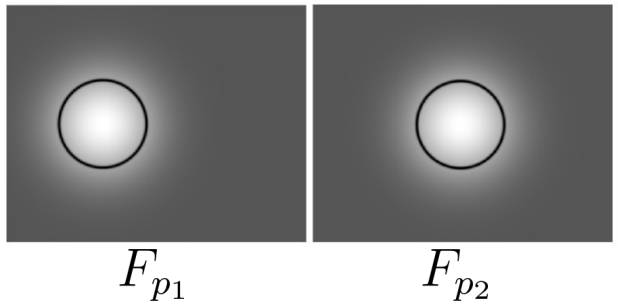
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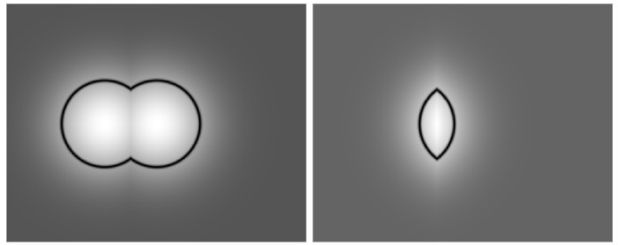
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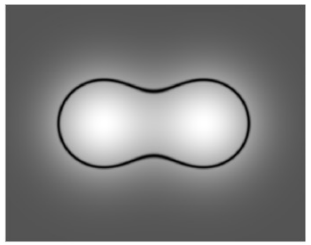


F_{p_1} F_{p_2}





$\max(F_{p_1}, F_{p_2})$ $\min(F_{p_1}, F_{p_2})$



$F_{p_1} + F_{p_2}$

Opérateurs simples (min, max, +) => opérateurs booléens/mélange de surfaces

Recherche utilisant surfaces implicites

1. Opérateurs de mélange

$$f = \mathcal{O}(f_1, f_2, \nabla f_1, \nabla f_2)$$



A Gradient-Based Implicit Blend
TOG13

Recherche utilisant surfaces implicites

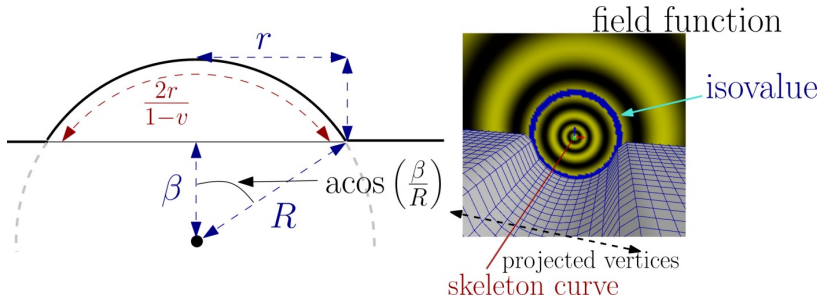
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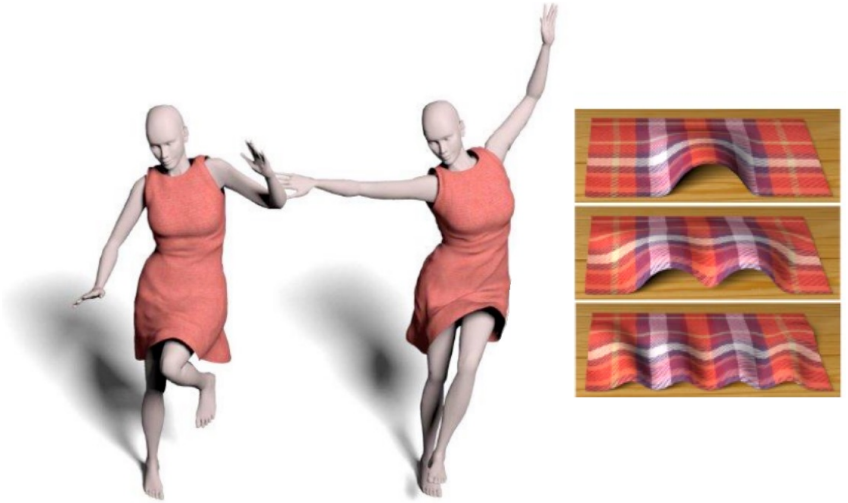
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2. Plis de vêtements





Animation Wrinkling
Siggraph Asia 10

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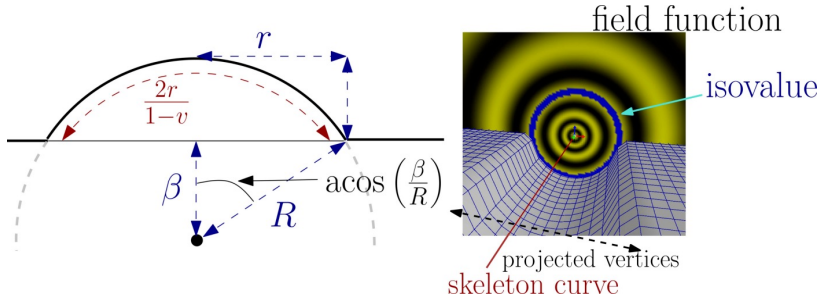
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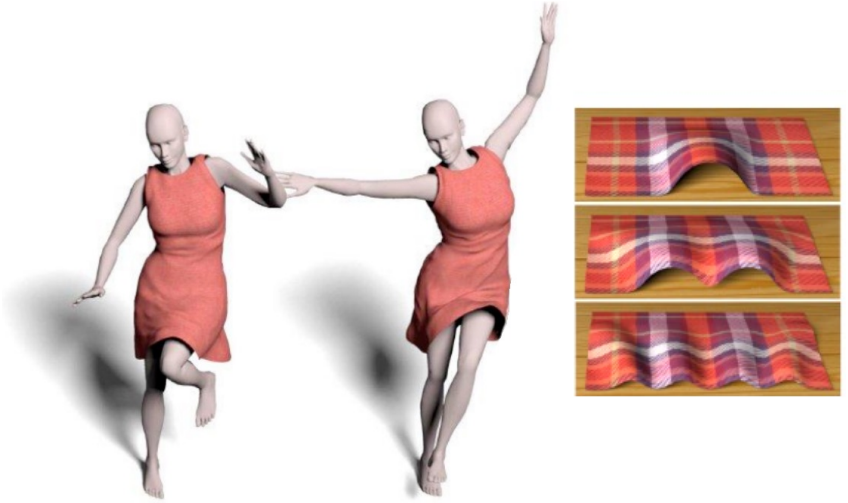
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3. Démêlage de couches de vêtements

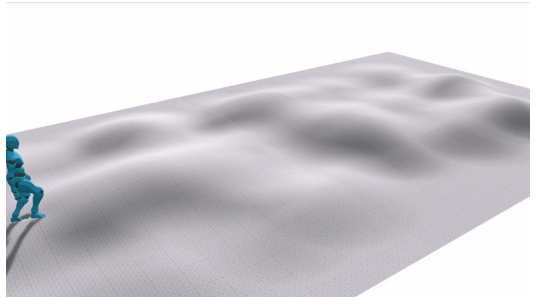
$$\forall i \in [1, N],\ \forall b \in [0, i-1],\ \forall c \in [0, N-i],$$
$$H_i^{b,c} = \left\{ f \in \mathbb{R}^N \,\middle|\, n_i^{b,c} \cdot f = 0 \ \text{ and } \ M_i^{b,c}\, f > 0 \right\}$$



Implicit Untangling
Siggraph 19

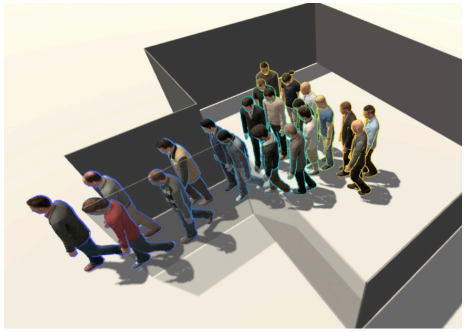
Autres thèmes en cours

Characters & environment

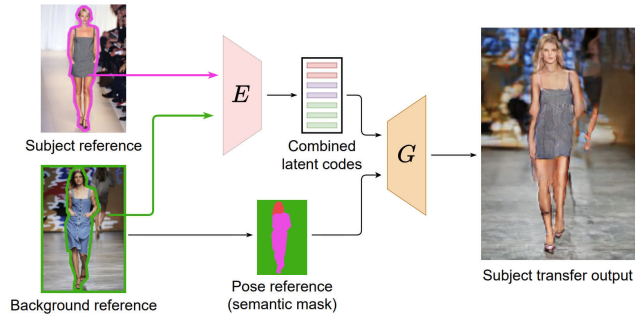


Complex terrain interaction

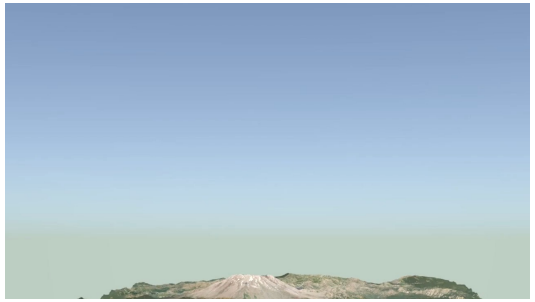




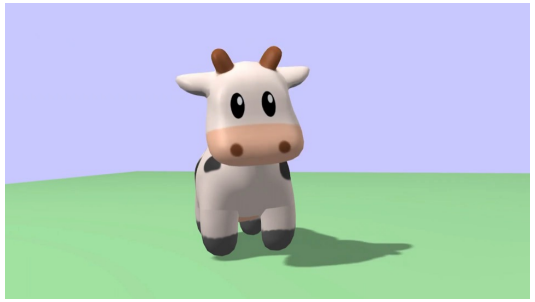
Crowd animation



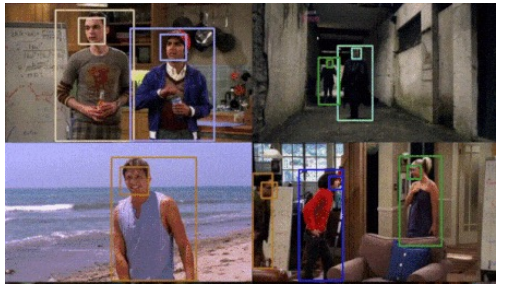
Garment transfert



Natural environment simulation

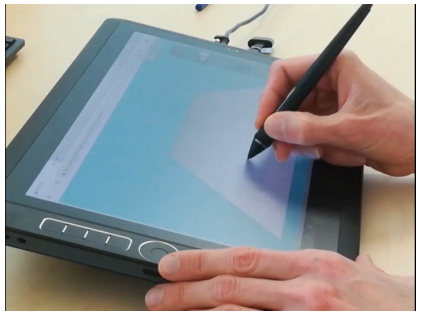


Cartoon effect



Human detection

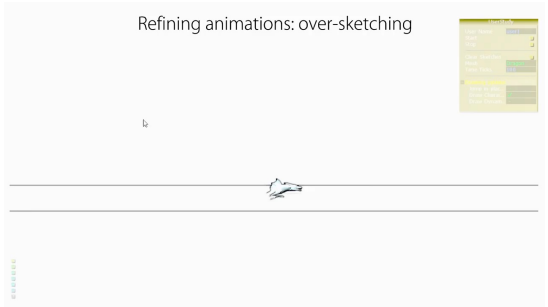
Interactive Design



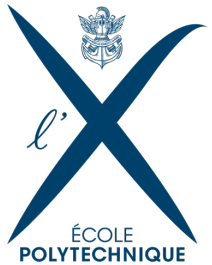
Architecture design



Bio inspired modeling



Animation sketching





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POLYTECHNIQUE
DE PARIS





Laboratoire d'Informatique
de l'Ecole Polytechnique

Merci

Virtual environment recent related Projects

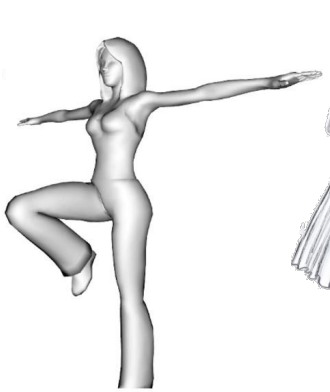
Methodology

Hybrid/Layered Models	Efficient/Alternative representation	Expressive creation

Applications

Characters

1. Skin **2. Cloth** **3. Behavior**

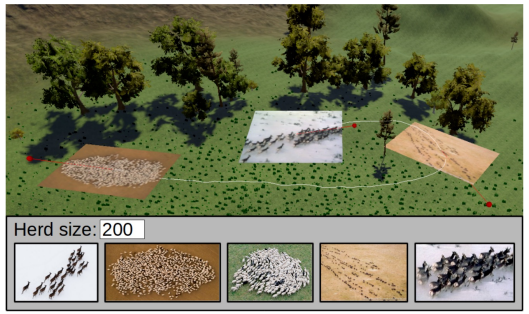






Natural environnement

4. Ecosystems **5. Terrain** **6. Atmospheric**



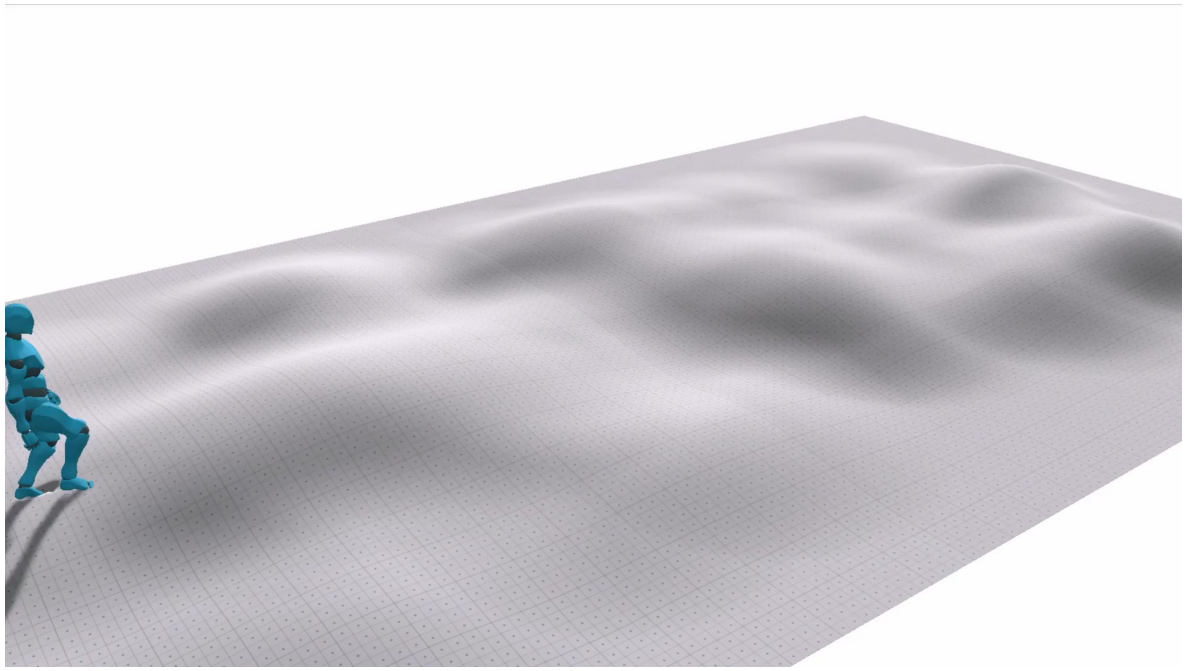




Character Behavior: Soft Walks

Bilateral interaction b/w character & environment

Hybrid Models | **Efficient Representation**



Method

- Pressure model under foot
  velocity, mass, pose
- Local terrain deformation
  visco-elastic (Hooke+Poisson ratio)
- Retroaction terrain/gait with IK

Advantages

- Coupled terrain deformation/walking gait
- Automatic adjustment of deformation to character (velocity, weight, motion)
- Fully work in game environment: Unity

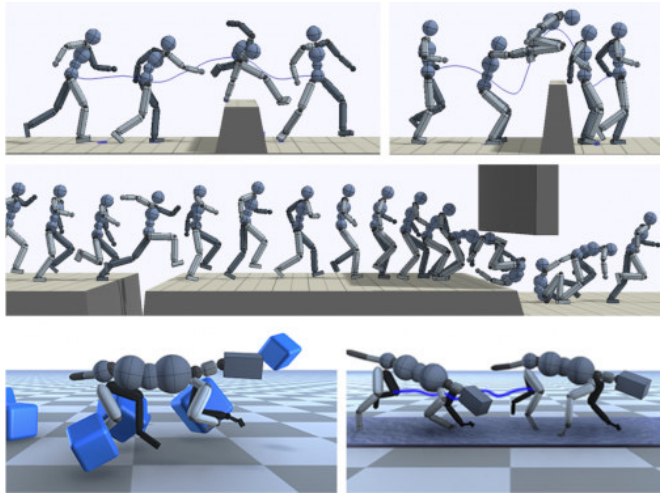




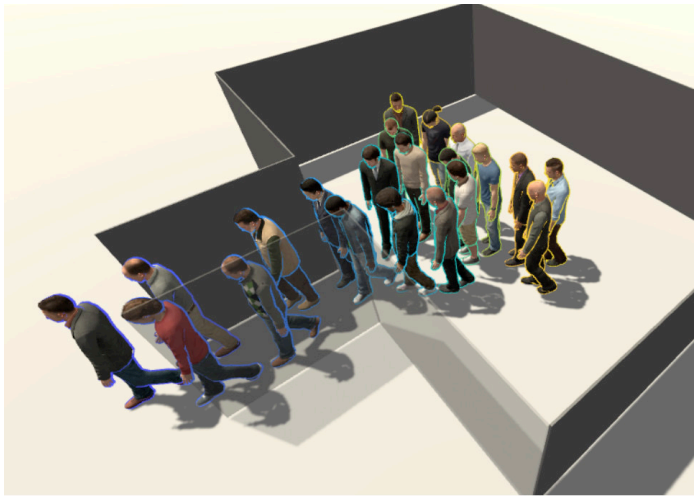
[Real-Time Locomotion on Soft Grounds with Dynamics Footprints. E. Alvarado et al. Frontiers in VR, 2022.]
[Soft Walks. C. Paliard et al., Eurographics short paper 2021]

Code: https://github.com/edualvarado/unity-footprints

Character Behavior: Crowds & interaction

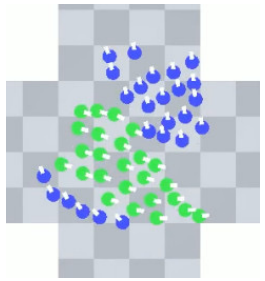


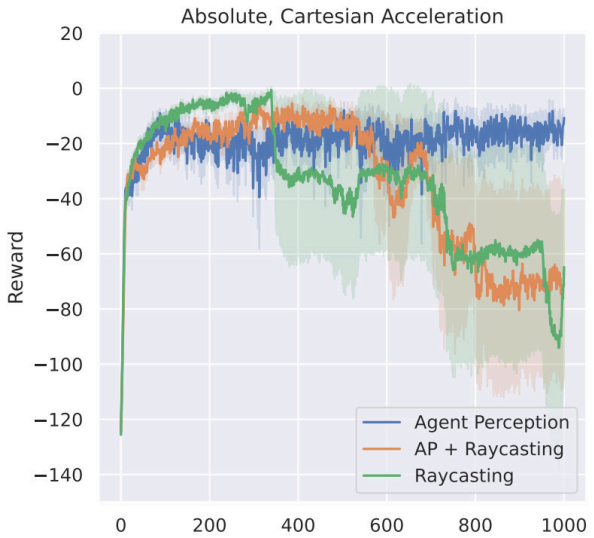
STAR EG 2022



Collab. on VR project
(TVCG 2022)

Hybrid Models





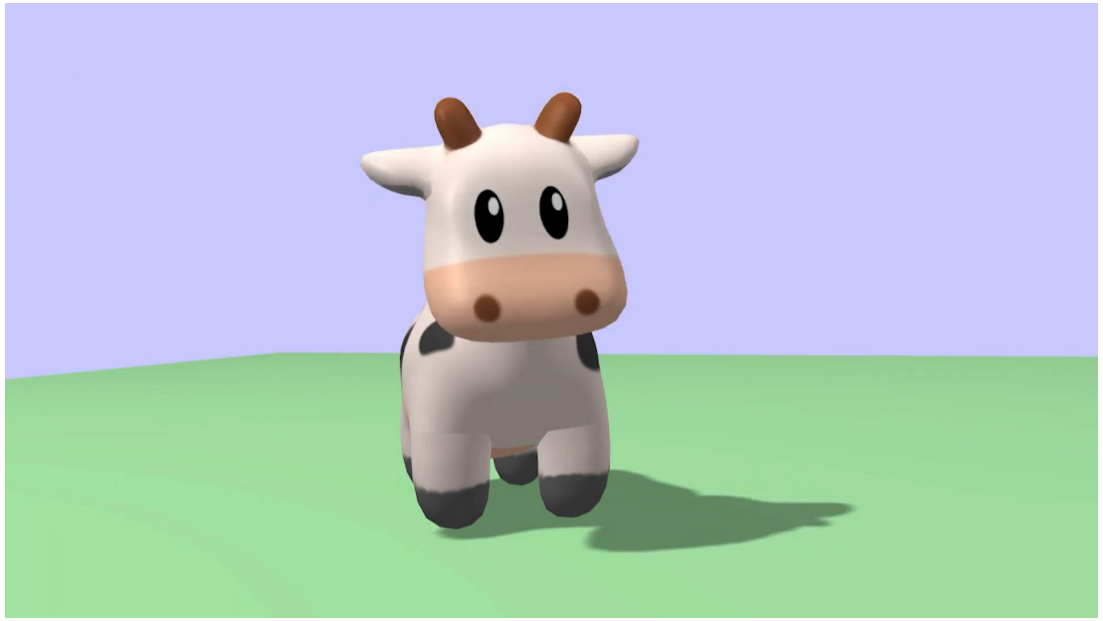
Understanding reinforcement learned crowds
MIG 2022

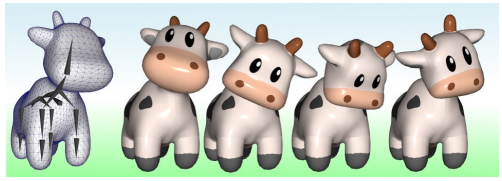
Character Skin: Velocity Skinning

Cartoon deformation with Skinning + velocity based deformers

Effect drag, stretch, follow-through

Efficient representation | **Expressive creation**





https://**velocityskinning.com**

Method

Derive a velocity-based skinning

$$v(p) = \sum_{joints\ j} \widetilde{w_j}\ v_j$$

Convert velocity to per-vertex deformation

Advantages

Extremely efficient
- *No iterations (no physics)*
- *Run on single pass Vertex Shader*

Work "out-of-the-box"
- *Only rely on skinning weights + skeleton*
- *Compatible Pipeline Animation*
  - *Developed with Art Master (Clemson)*

Super simple to implement (*demos)

[Velocity Skinning, Rohmer et al., Eurographics 2021]
[Acceleration Skinning, Kalyanasundaram et al., Graphics Interface 2022]

Character Cloth: Implicit Untangling

Convert colliding surface layers => Contact layers

Alternative representation

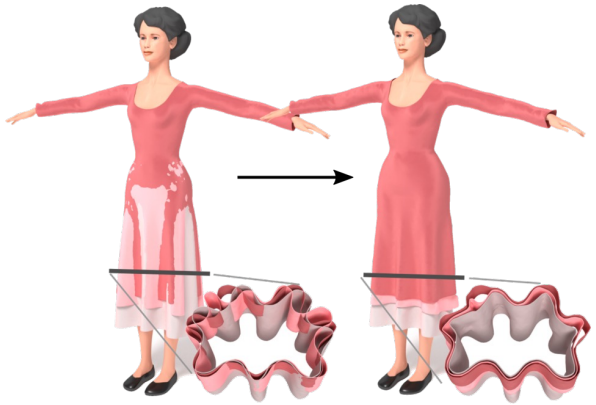


Method

- Extend Implicit representation for cloth
  (well defined interior/exterior)
- Create operators on fields values
  "pushing" iso-set on contact surface

Advantages

- No Simulation/iteration
  Closed-form solution
  Ensure collision free state
- No need of past collision-free state

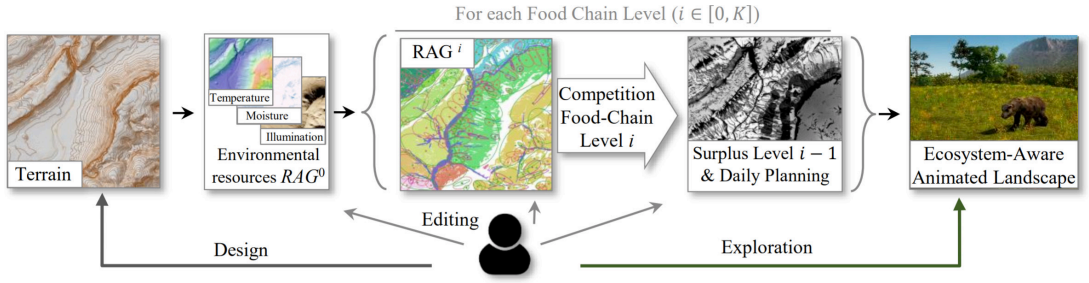


[Implicit Untangling, Buffet et al., SIGGRAPH 2019]

Code: https://gitlab.com/TBuffet/implicit-untangling

Natural Ecosystem: Authoring Landscapes

Landscape Design, Editing, Simulation & Exploration with Flora & Fauna





[Authoring Consistent Landscapes with Flora and Fauna, P. Ecormier-Nocca et al., SIGGRAPH 2021]

Layered Models

Method

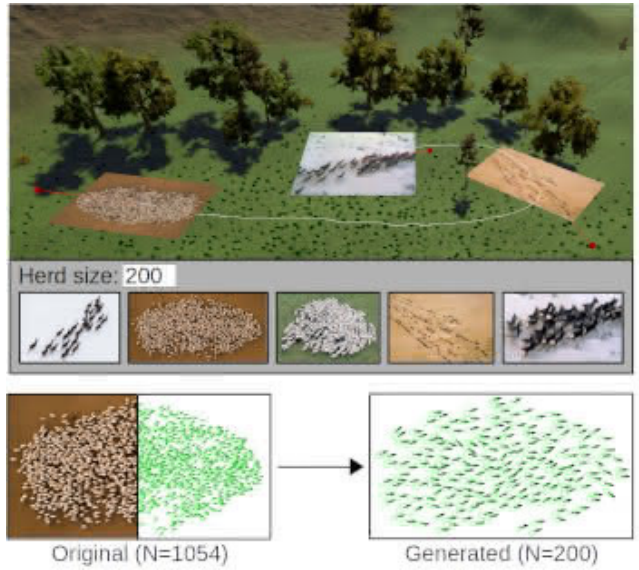
- Interaction of species in food chain + terrain
  Resource Access Graph
- Fast equilibrium state
  Procedural competition algorithm

Advantages

- On-the-Fly Instancing of plants and animals
  (works in Unity)
- Handle real data
  Validated animals' daily paths
  Collab. Paleonthologists (Tautavel)

Natural Ecosystem: Authoring crowds

Layered Models



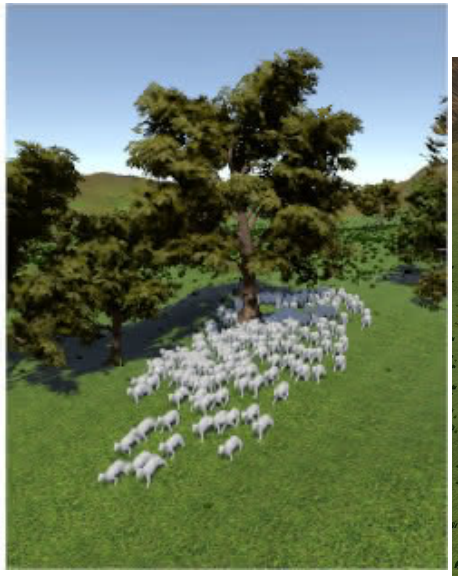
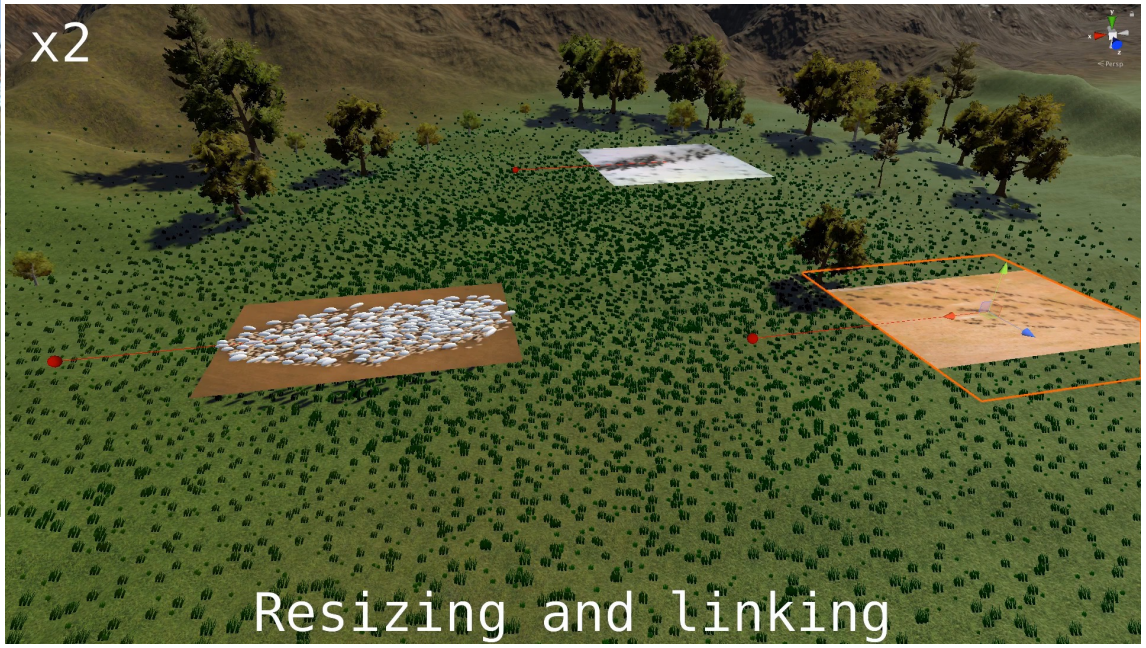


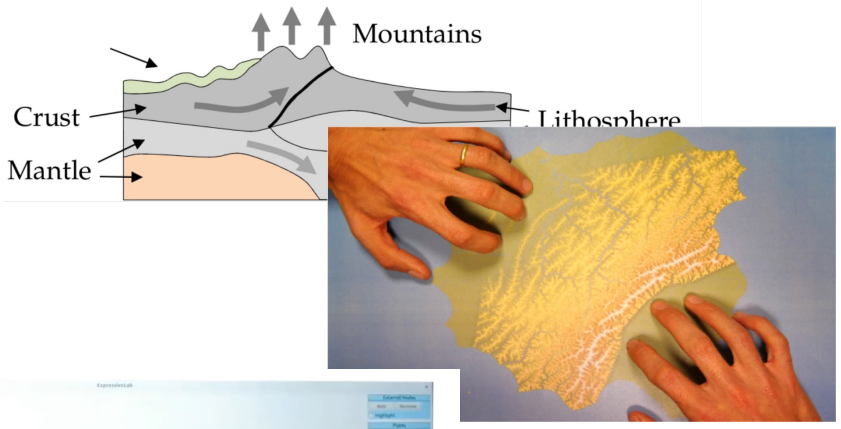
Image-based authoring of heard animations
Ecormier et al. CAVW 2019

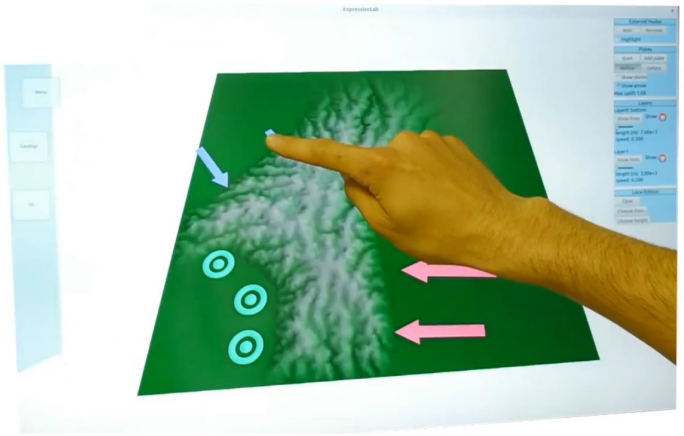


Natural Terrain: Sculpting Mountains

Interactive design of plausible terrain with plate tectonics simulation

Layered Models | **Expressive creation**



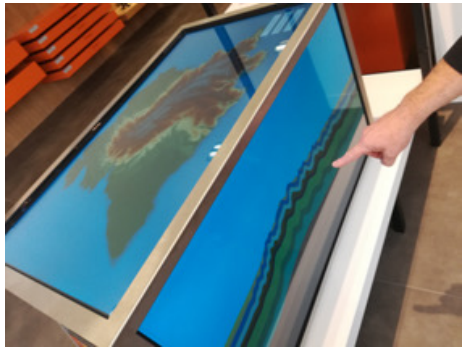


Method

- Lightweight simulation of sub-layers
  viscous material
- Procedural uplift from compressed regions
- Fast erosion simulation

Advantages

- Valid terrain shape guaranteed
- Allow game-like user interaction
  (demo at musX)

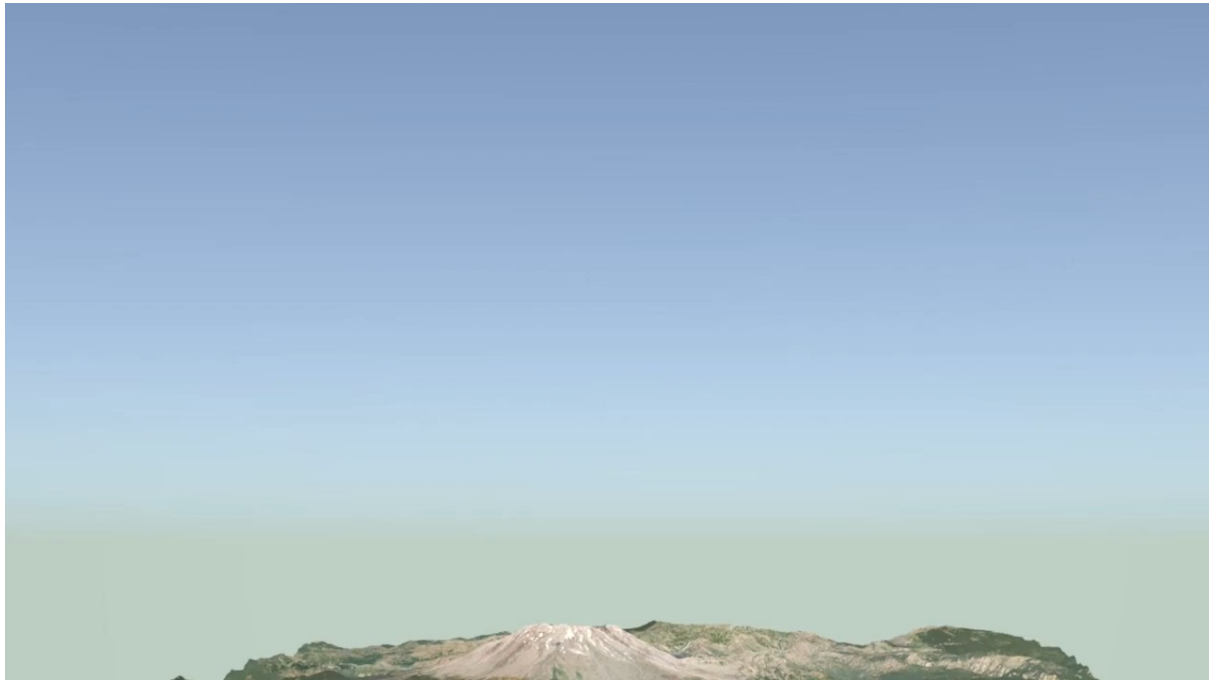


[Sculpting Mountains: Interactive Terrain Modeling Based on Subsurface Geology. G. Cordonnier et al., IEEE TVCG, 2018]

Atmospheric model: Volcanic ejections

Visual simulation of volcanic plume and pyroclastic flow

Layered Models | **Efficient Representation**



Method

- Large scale: Fast Lagrangian plume simulation
  - *Cylindrical slices shape*
  - *Buoyancy, heat/density, surrounding air*
- Low scale: multi-res. procedural spheres+noise

Advantages

- Large scale physically coherent simulation
  - *Uprising plume velocity, altitude, wind*
  - *Automatic pyroclastic flow detection*
- Rich visual details at low scale
- Interactive simulation modification

[Interactive simulation of plume and pyroclastic volcanic ejections. M. Lastic et al., I3D 2022]

Code: https://gitlab.com/mlastic/volcanicplume

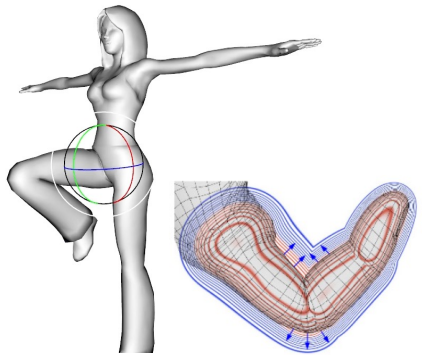
Other projects

More on

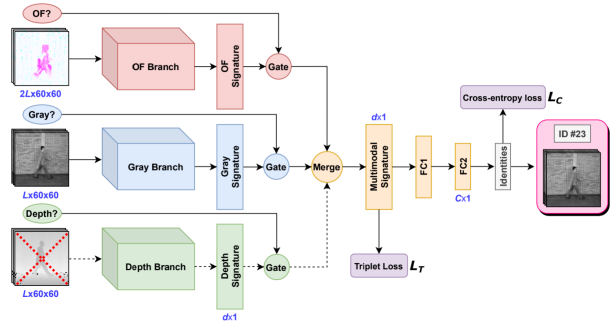
Characters & Cloth



Sketch to 3D

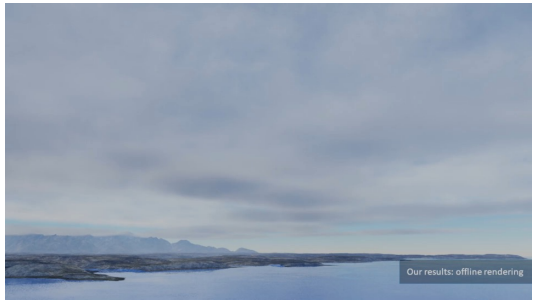


Implicit Skinning



Multimodal Gait Detection

Natural Phenomena & Simulation



Clouds

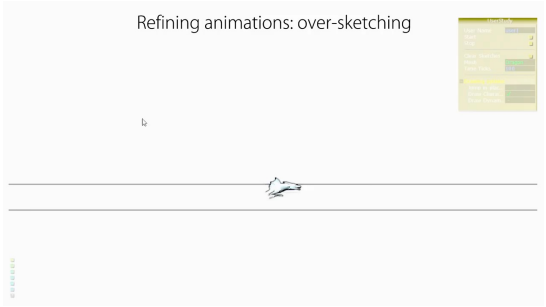


Waterfall

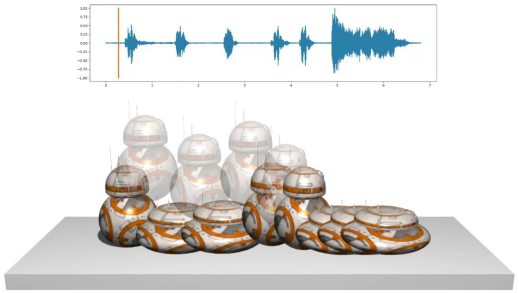


Bioinspired Shapes

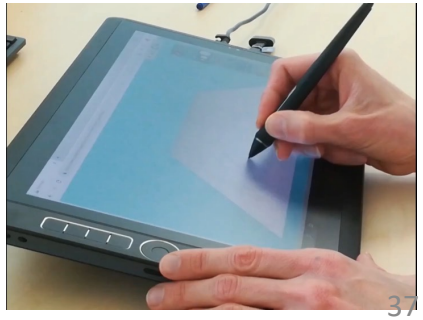
Design & Authoring



Sketching Animation



Voice to Animation

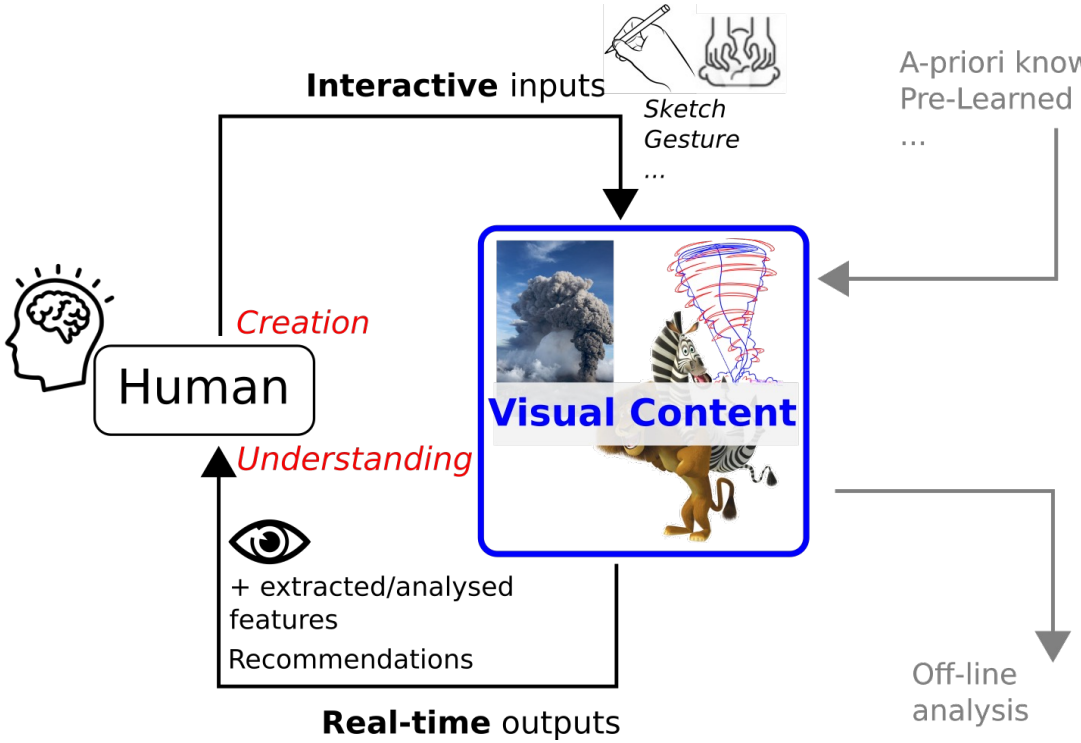


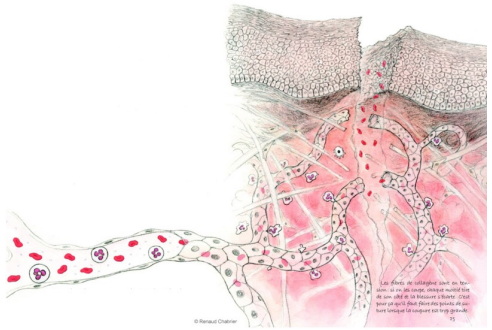
Sketching Hierarchies

Starting project(s) - CreativeAI

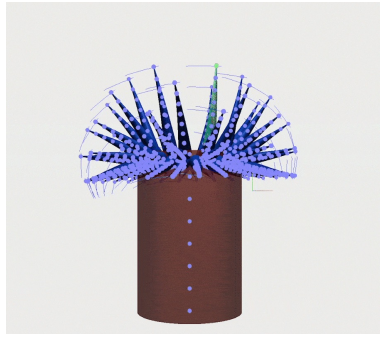
Enabling scientists to sketch & refine their mental image

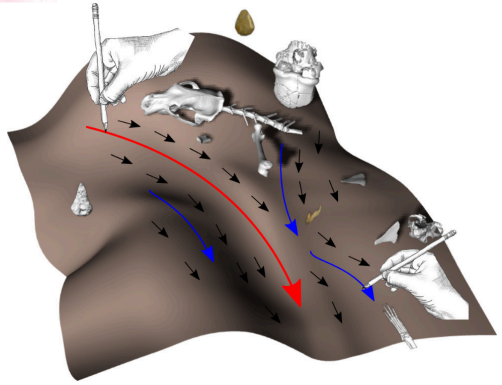
Enhance lightweight learning for graphics



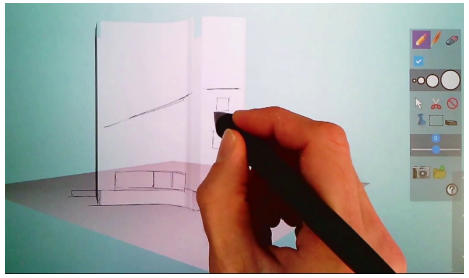
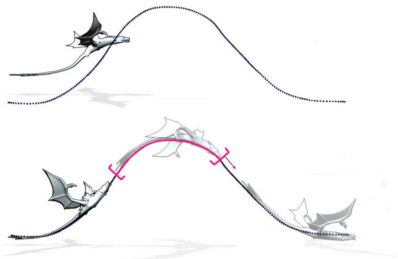


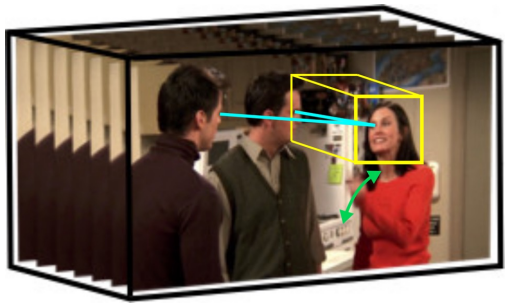
+ AR/VR





Thank you !

Main ongoing academic & industrial projects

Main Academic projects

- **CLIPE -** EU H2020 Innovative Training Network (2xPhD)
  Creating Lively Interactive Populated Environments
- **CREATIVE AI** - Hi! Paris Advanced Fellowships (1xPhD + Invited Prof.)
  Enhance lightweight learning for graphics with application to other scientists

Industrial partners

- **Dassault Systèmes** (1xPhD CIFRE) [BioInspired]
- **Adobe** (support with Donation)
- **Ubisoft** (via CLIPE) [Character Anim]

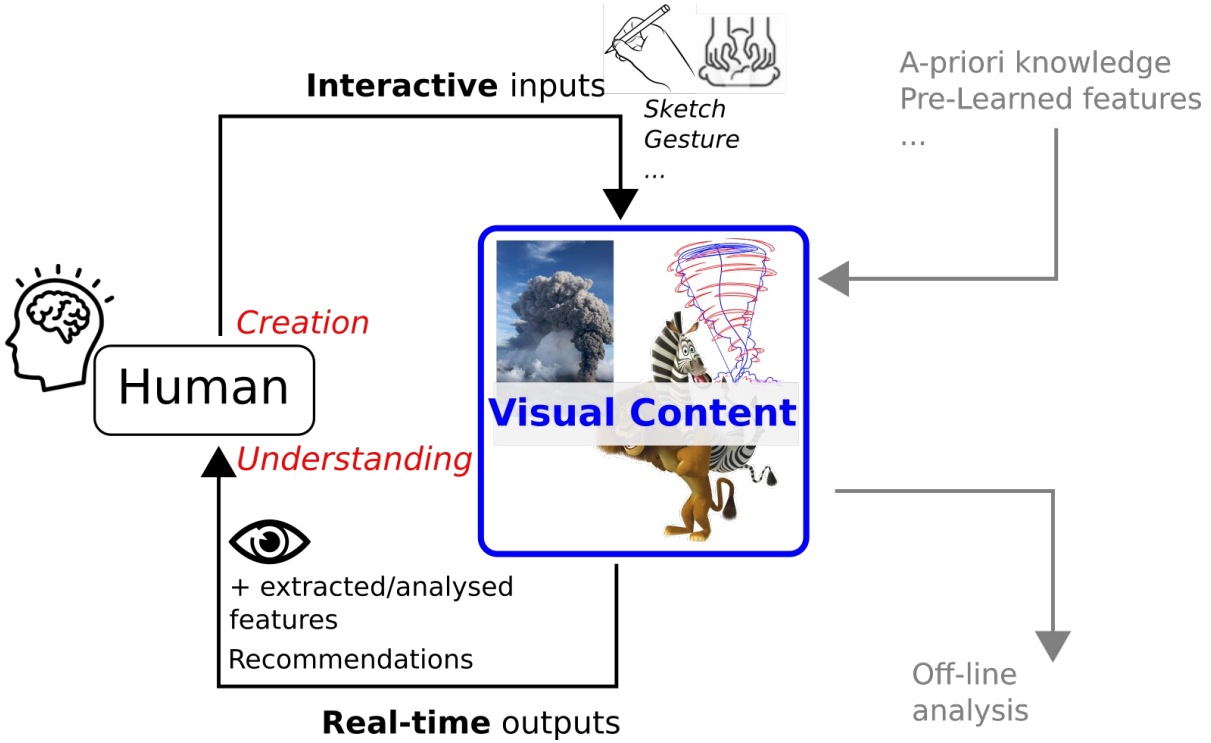
Ongoing Discussion: Kinetix, Dada Animation!, LVMH, ModaLive, Homiwoo

Prev. Partners: Google, Uber, TeamTo, Mercenaries Engineering, Vuitton.

Starting project: CreativeAI

Enabling scientists to sketch & refine their mental image

Enhance lightweight learning for graphics

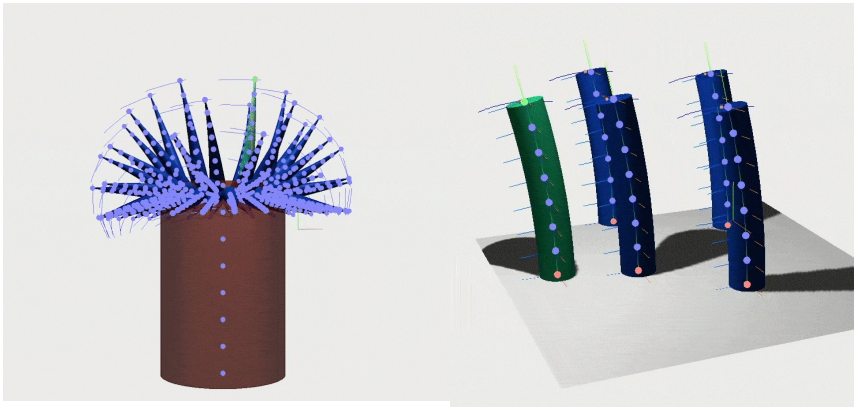


2 masters:

Infinite Details Modeling



Sketching animation of hierarchies



+ 1 PHD to start

Formation (in CG & Vision)

Masters:

Engineers X (2A+M1/3A)
Image, Vision, Learning

Master IP Paris IGD
Interaction, Graphics & Design

MSc&T AI-ViC
AI & adv. Visual Computing

Unique mix:
Advanced Math/Learning + Real CS

Courses

Graphics
- Graphique 3D (2A – 130 students)
- Computer Animation (M1/3A – 40 students)
- Advanced 3D Graphics (M2 – 20 students)

Vision
- DL in Computer Vision (2A – 40 students)
- Adv. Computer Vision (M2 – 20 students)

+ Dev. Jeu video; Shape analysis; Image Synthesis; Real-time AI in Video Game; Image Processing; ML and autonomous agents Shape analysis; Reinforcement Learning; Soft Robots; Socio-emotional conversational agents; VR/AR and 3D Interactions.mage Synthesis; Real-time AI in Video Game; Image Processing; ML and autonomous agents

Environment

DesignLab

HCI/Design @Telecom (DIVA)

Virtual Models @VISTA

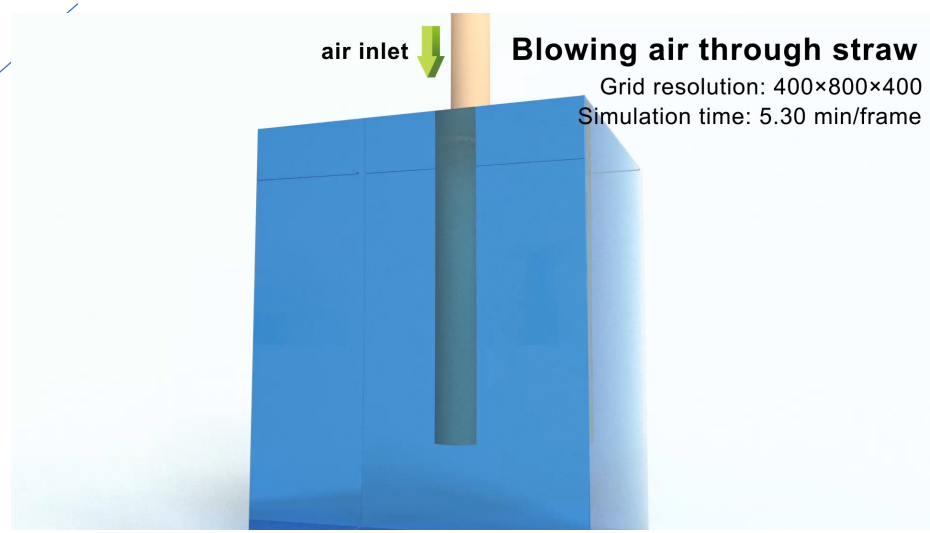
+ *GeomeriX*
+ *CG@Telecom*

Interaction

Applications

VirtualLab

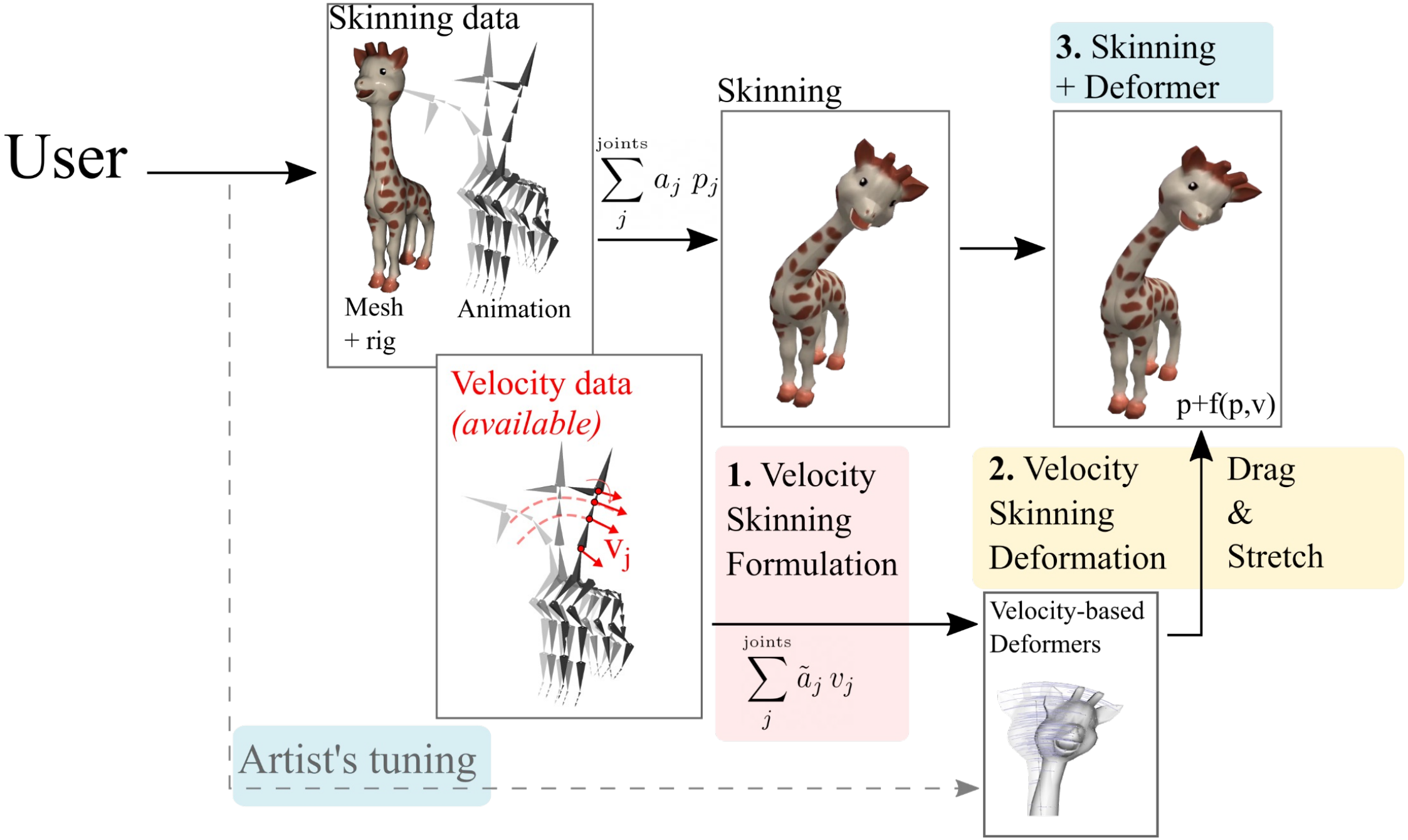
GameLab



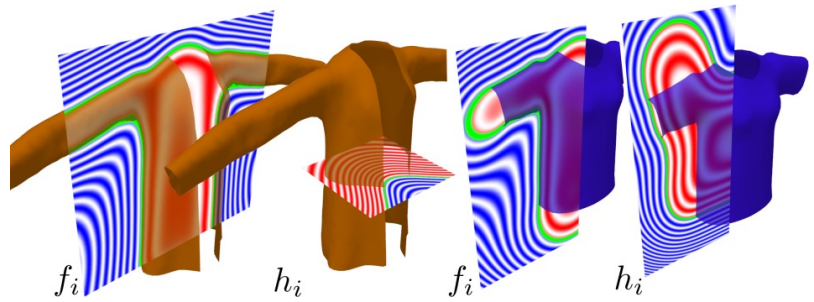
Wei et al., SIGGRAPH 2022



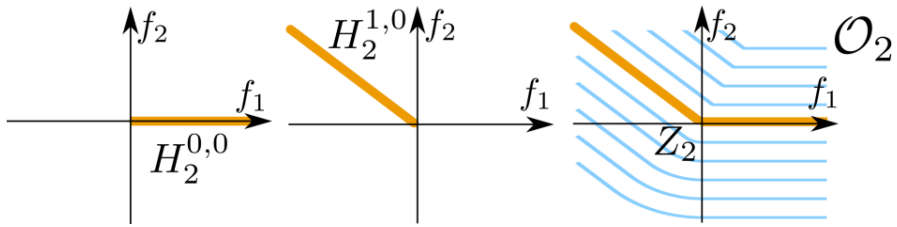
Parrakat et al., VCIBA 2022

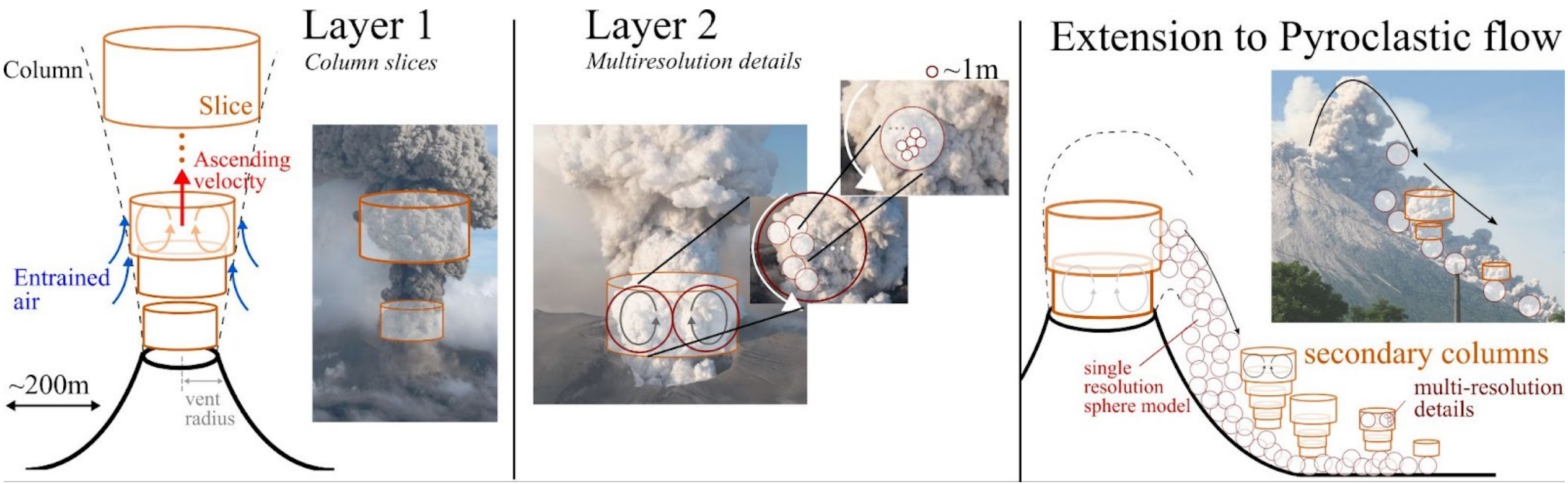

User
Skinning data
Mesh
+ rig
Animation
joints
$\sum_j a_j\ p_j$
Skinning
3. Skinning
+ Deformer
p+f(p,v)
Velocity data
(available)
v_j
1. Velocity
Skinning
Formulation
joints
$\sum_j \tilde{a}_j\ v_j$
2. Velocity
Skinning
Deformation
Drag
&
Stretch
Velocity-based
Deformers
Artist's tuning





$$H_i^{b,c} = \left\{ f \in \mathbb{R}^N \,\middle|\, n_i^{b,c} \cdot f = 0 \text{ and } M_i^{b,c} f > 0 \right\}$$




Layer 1
Column slices
Column
Slice
Ascending velocity
Entrained air
~200m
vent radius
Layer 2
Multiresolution details
~1m
Extension to Pyroclastic flow
secondary columns
single resolution sphere model
multi-resolution details