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Sparse representation of terrains for procedural modeling

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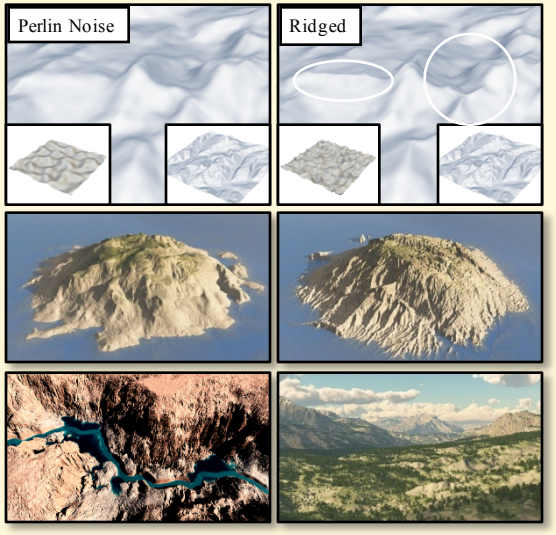
Introduction

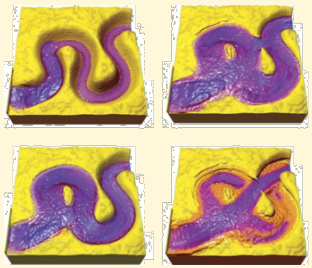
Motivations

- Sparse modeling applied to terrain
- Many applications
  - Inverse procedural modeling
  - Compact representation
  - Terrain synthesis
  - Terrain amplification

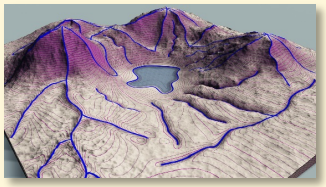


Related work

	Simulation		Sketching and editing		Procedural	
	Erosion	Uplift	Interactive editing	Example based	Function	Sparse
Scalable	-	-	-	-	+	+
Fast	-	+	-	-	+	+
Control	-	+	+	+	-	+
Geology	+	+	-	-	-	-



[Benes 2006]

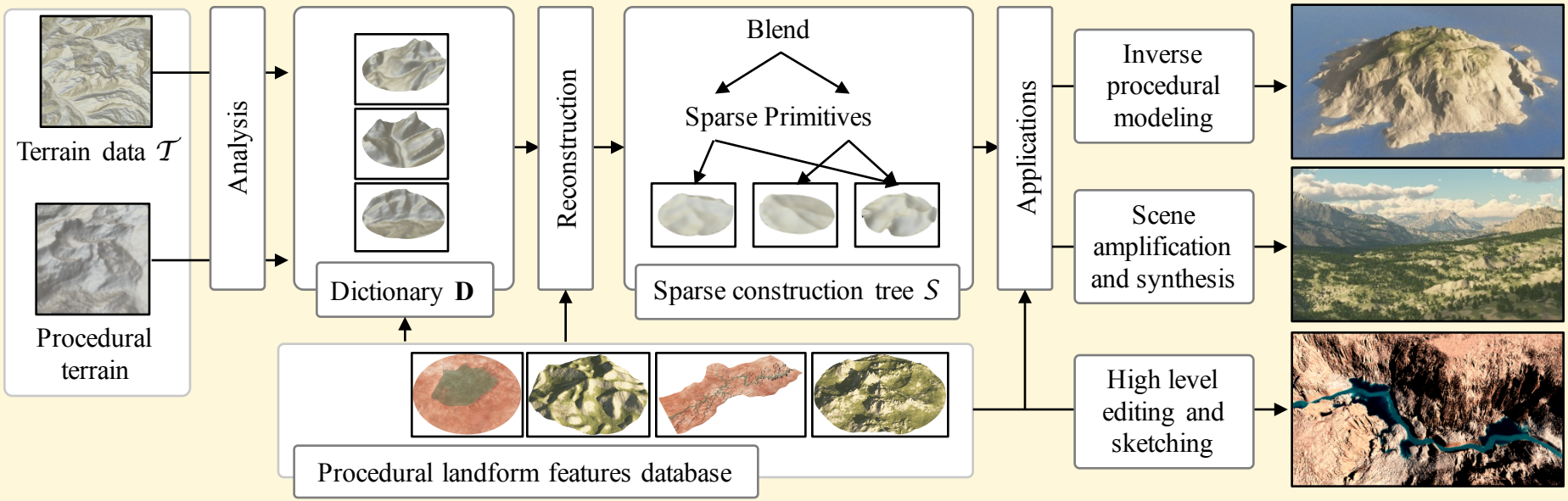


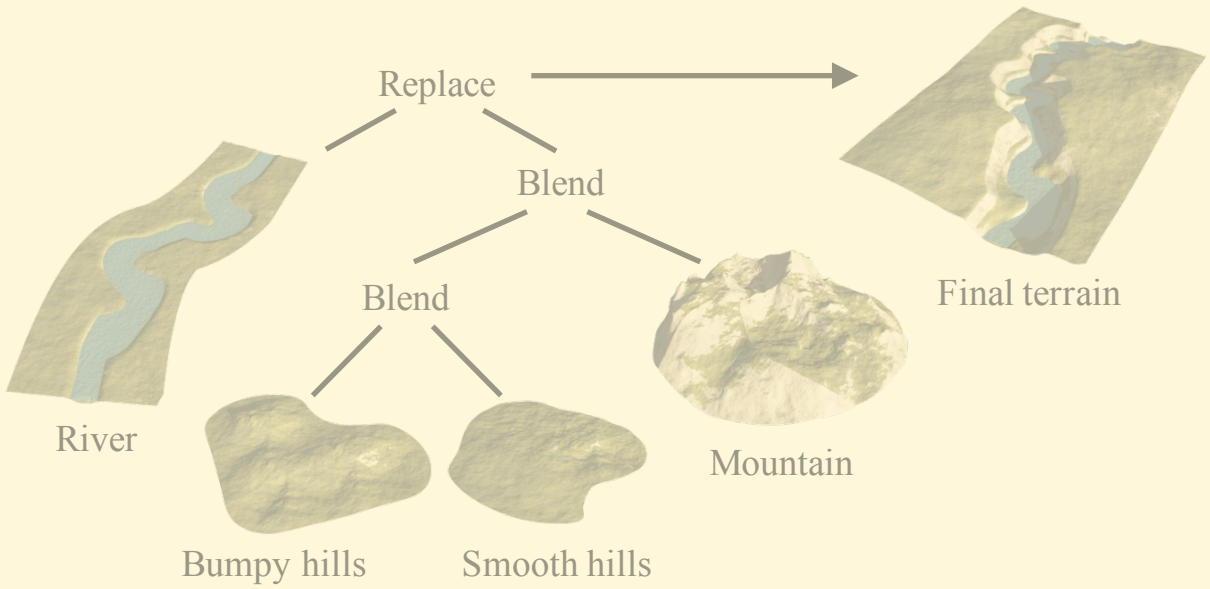
[Hnaidi 2010]

[Zhou 2007]

[Génevaux 2013]

Overview

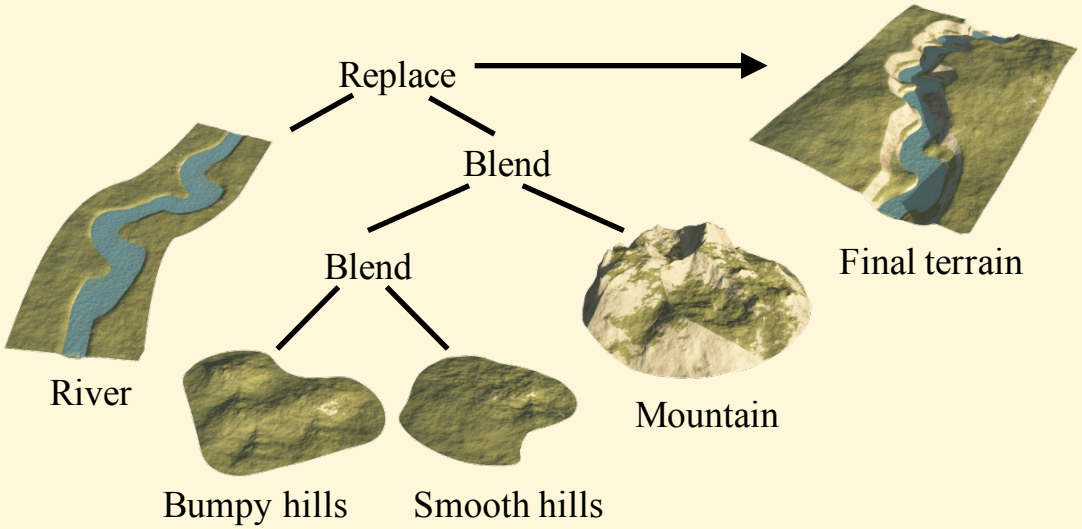

Terrain data $\mathcal{T}$
Procedural terrain
Analysis
Dictionary **D**
Reconstruction
Blend
Sparse Primitives
Sparse construction tree S
Procedural landform features database
Applications
Inverse procedural modeling
Scene amplification and synthesis
High level editing and sketching



Terrain model

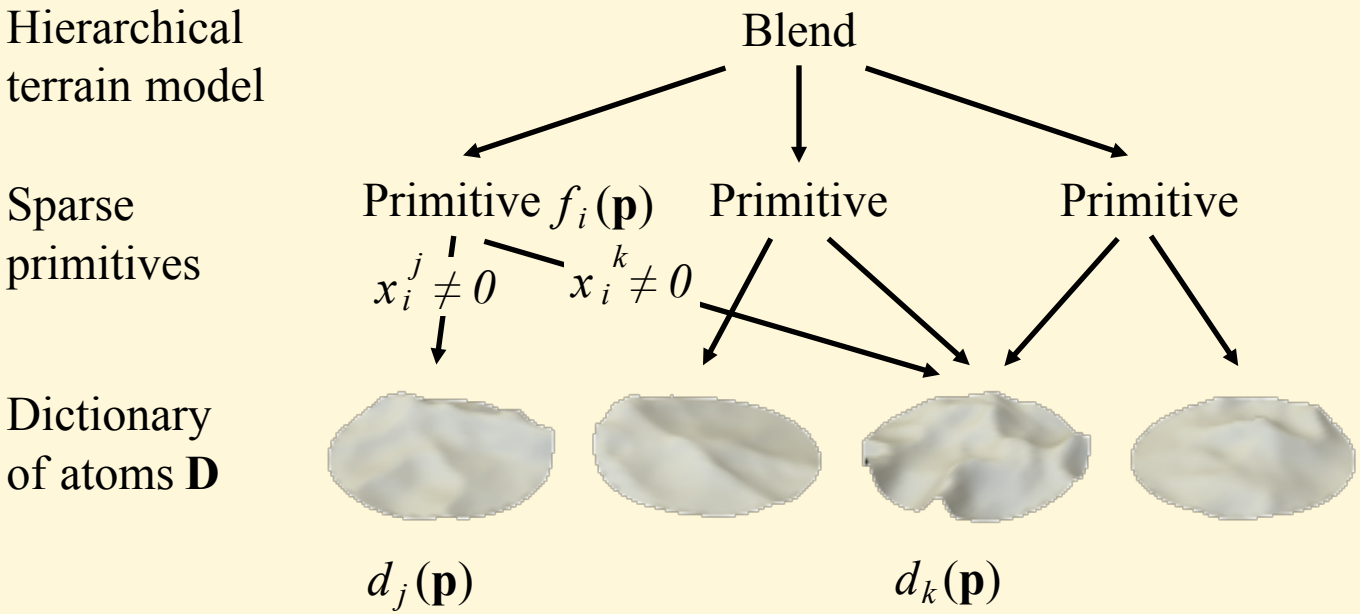
Sparse construction tree

- Extends [Génevaux15] « *Terrain modelling from feature Primitives* »
- Hierarchical and functional model
- Combination of primitives and sub-trees

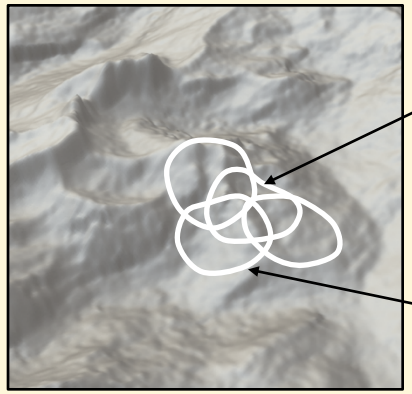


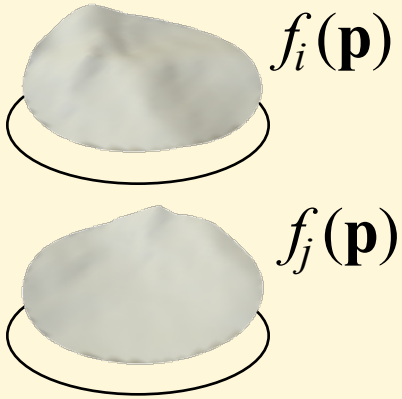
Sparse construction tree (2)

- Atoms of a dictionary are linearly combined to form sparse primitives



Example





Terrain model $\mathcal{T}$

Sparse Primitives

$$f(\mathbf{p}) = \sum_{i=0}^{n-1} f_i(\mathbf{p})\alpha_i(\mathbf{p}) / \sum_{i=0}^{n-1} \alpha_i(\mathbf{p})$$

$$f_i(\mathbf{p}) = z_i + \sum_{j=0}^{N-1} x_i^j d_j(\mathbf{p} - \mathbf{c}_i)$$

About the sparsity

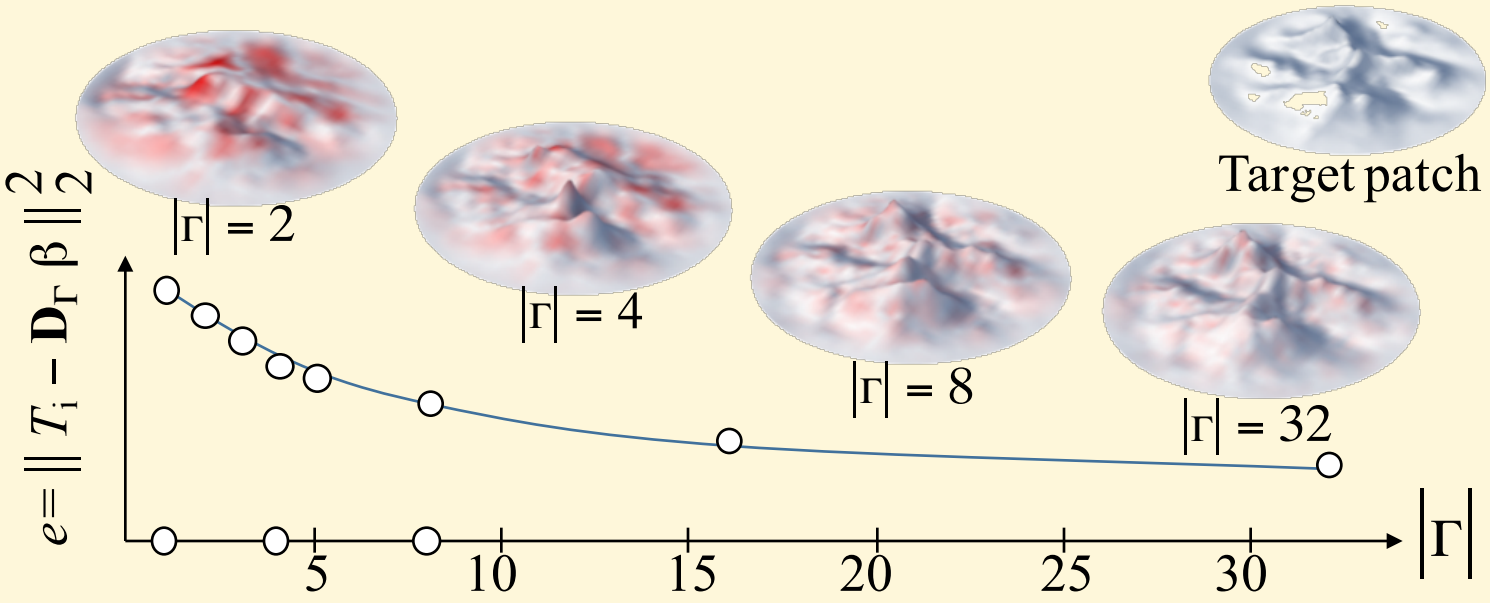
- $\mathbf{X}_i = \{x_i^j\}$ represents the linear coefficients needed to reconstruct a primitive
- $||\mathbf{X}_i||_0$ represents the number of nonzero coefficients, denoted s
- s has to be much smaller than N

Sparse decomposition (OMP)

1. $$(\hat{k}, \hat{\beta}) = \underset{k \in \bar{\Gamma}, \beta \in \mathbb{R}^{|\Gamma|+1}}{\operatorname{argmin}} \left\| T_i - \mathbf{D}_{\Gamma \cup \{k\}} \beta \right\|_2^2$$

2. $$\Gamma = \Gamma \cup \{\hat{k}\} \qquad \mathbf{X}_i^{\Gamma} = \hat{\beta}$$

[Mallat93]



Dictionary learning

- Minimization problem
- Given a set of primitives $\mathbf{F}$ to represent and a sparsity s, find the dictionary $\mathbf{D}$ that minimizes the reconstruction error

$$\min_{\mathbf{D}\in\mathbb{R}^{K,N},\mathbf{X}\in\mathbb{R}^{N,n}} \|\mathbf{F}-\mathbf{D}\cdot\mathbf{X}\|_F^2$$

$$\text{such that } \forall i=1,\ldots,n, ||\mathbf{X}_i||_0 \leq s$$

Dictionary learning (2)

- K-SVD resolution [Aharon2006]
- In practice, we sometimes want to keep the original patches of the terrain intact

$$\min_{\mathbf{D}\in\mathbb{R}^{K,N},\mathbf{X}\in\mathbb{R}^{N,n}} \|\mathbf{F}-\mathbf{D}\cdot\mathbf{X}\|_F^2$$

$$\text{such that } \forall i=1,\ldots,n, ||\mathbf{X}_i||_0 \leq s$$

$$\forall j \in \{1,\ldots,N\}, \exists l \in \{1,\ldots,n\}, d_j = f_l$$

Applications

Compact terrain representation

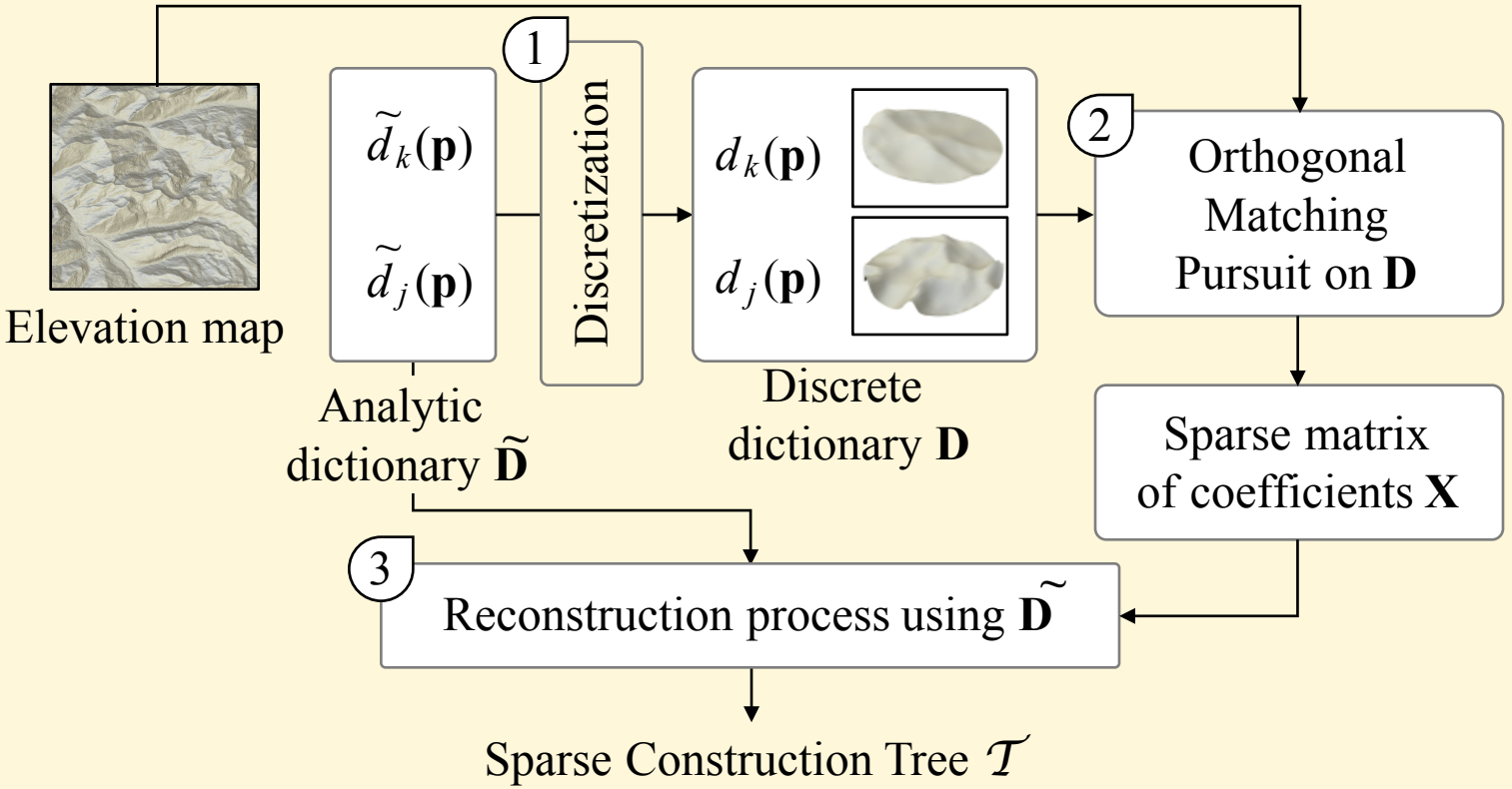
- Input : a terrain $\mathcal{T}$
- Extract patches
- Optimize dictionary
- Store only $\mathbf{D}$ and $\mathbf{X}$ (sparse matrix) + mean altitudes of the patches

Compact terrain representation (2)

- Results (dictionary size 128 atoms)

Terrain	Size t_0	Sparsity s	Ratio ρ	PSNR
Alpes (512×512)	$0.26M$	1	14.9 %	23.7
		2	20.0 %	26.4
		8	50.9 %	21.1
Italy (3600×3600)	$12.96M$	1	4.9%	31.7
		2	9.7 %	34.2
		8	38.0 %	39.2

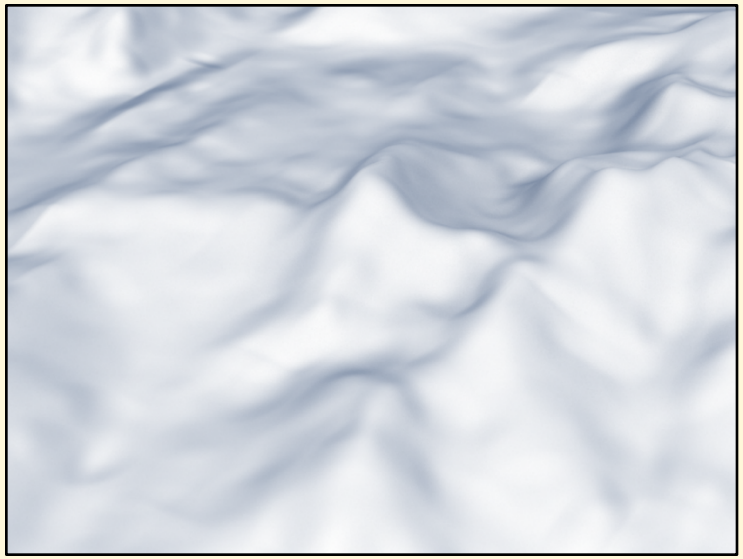
Inverse procedural modeling

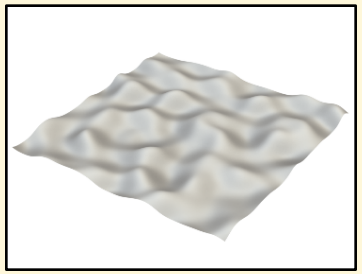


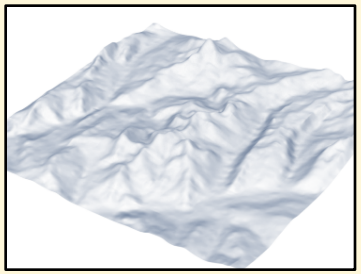
Inverse procedural modeling (2)

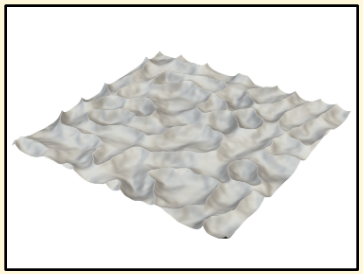
Perlin Noise

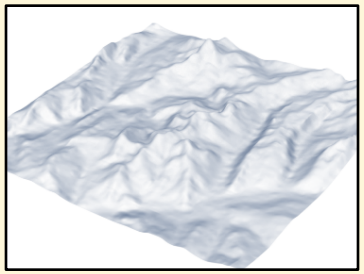
Ridged



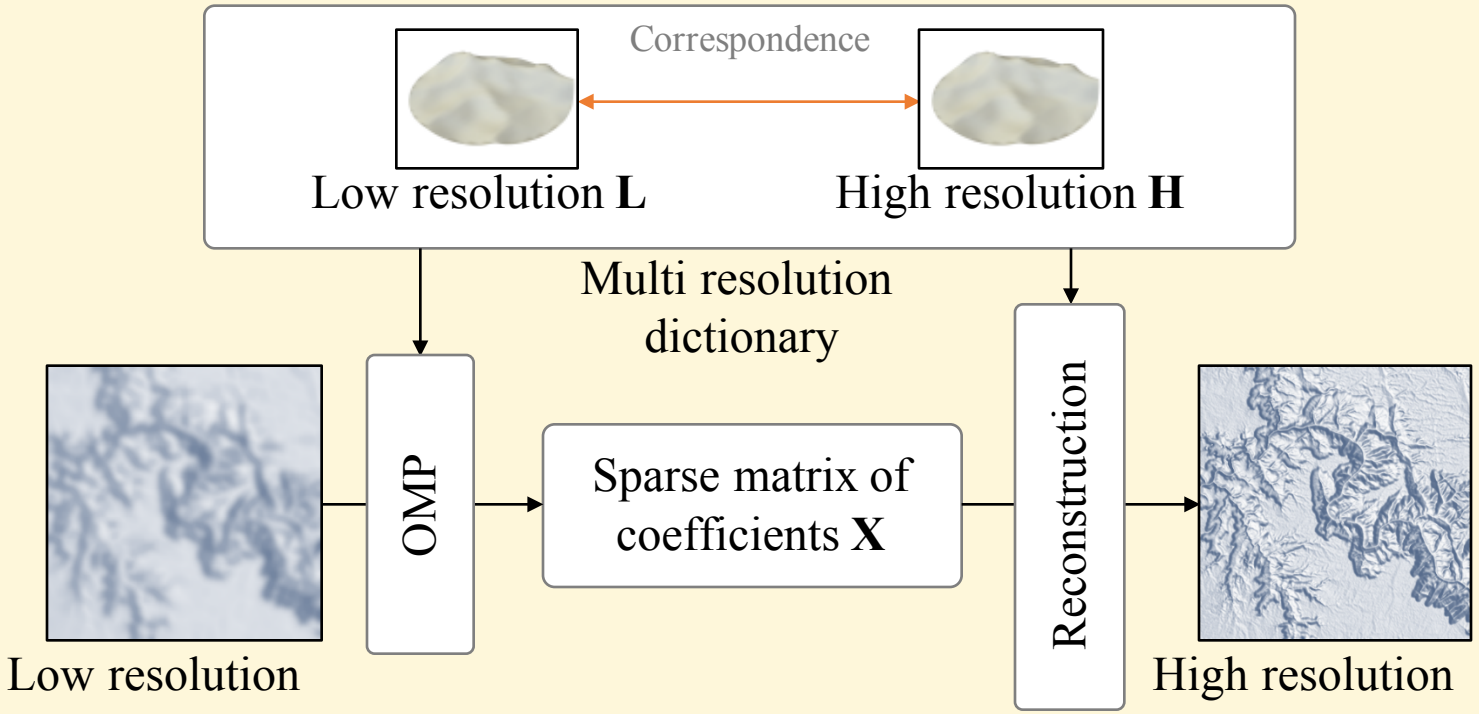








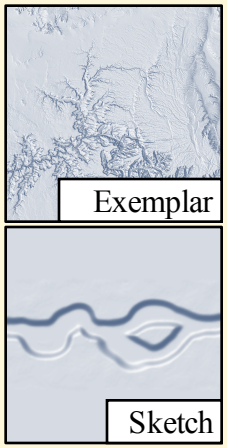
Terrain synthesis and amplification

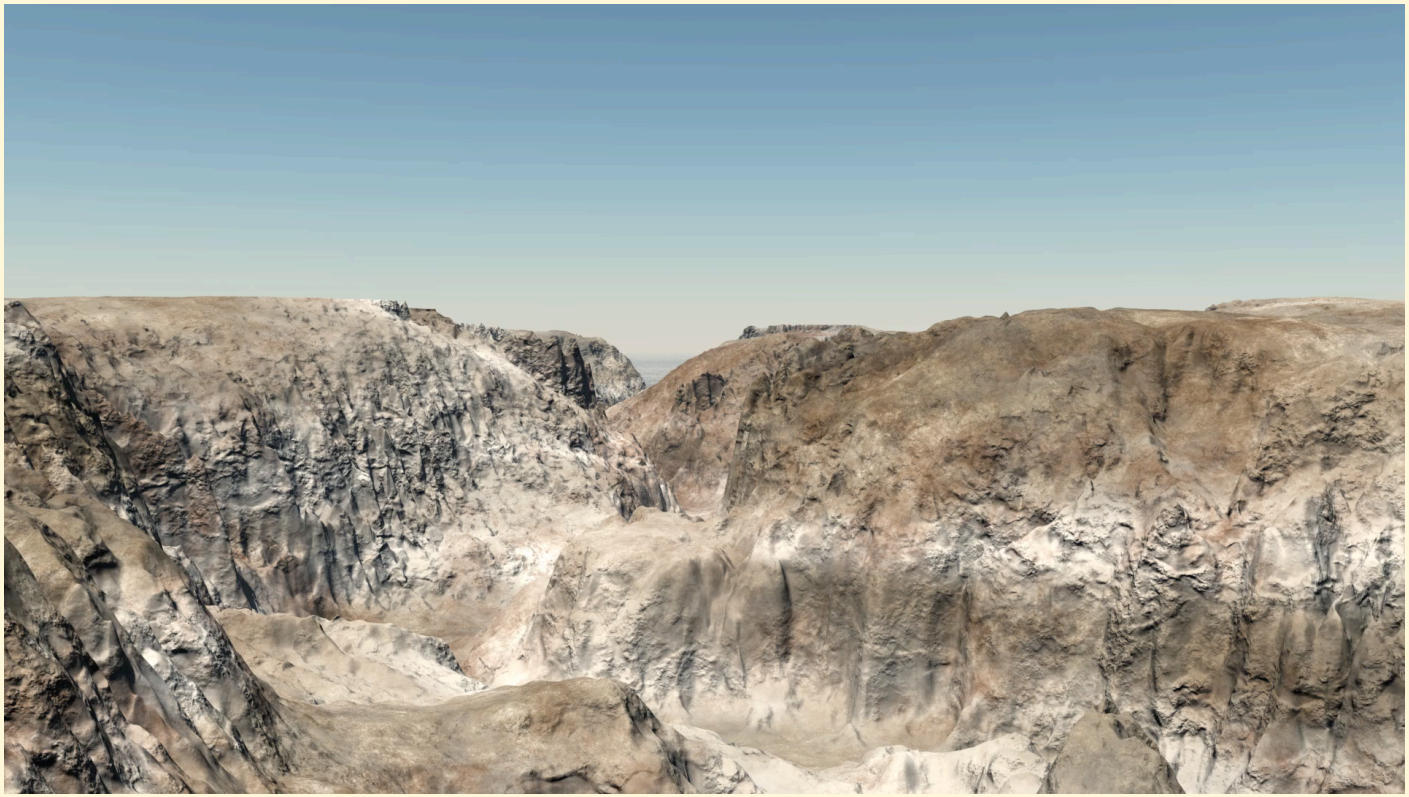


Terrain amplification

- Introduction
- Terrain model
- Applications
- Conclusion

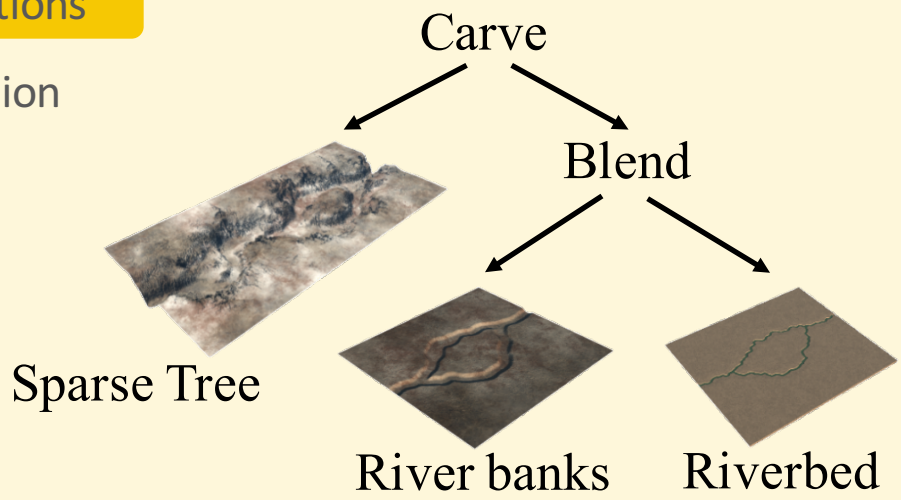
Terrain synthesis - Canyon

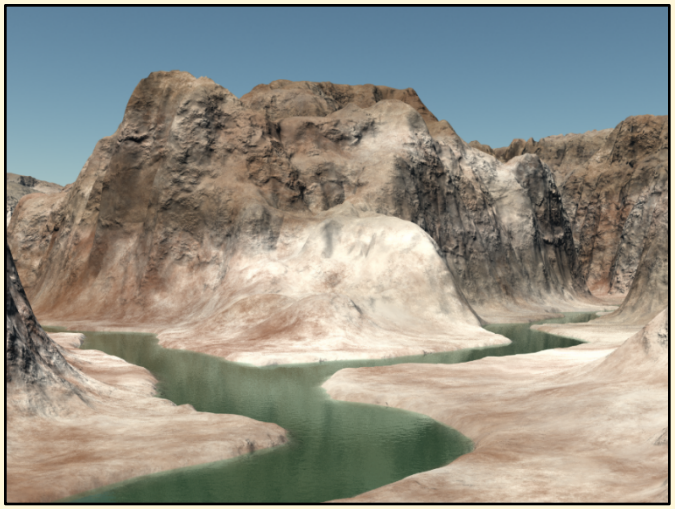




Control

- Complete the tree with additional nodes





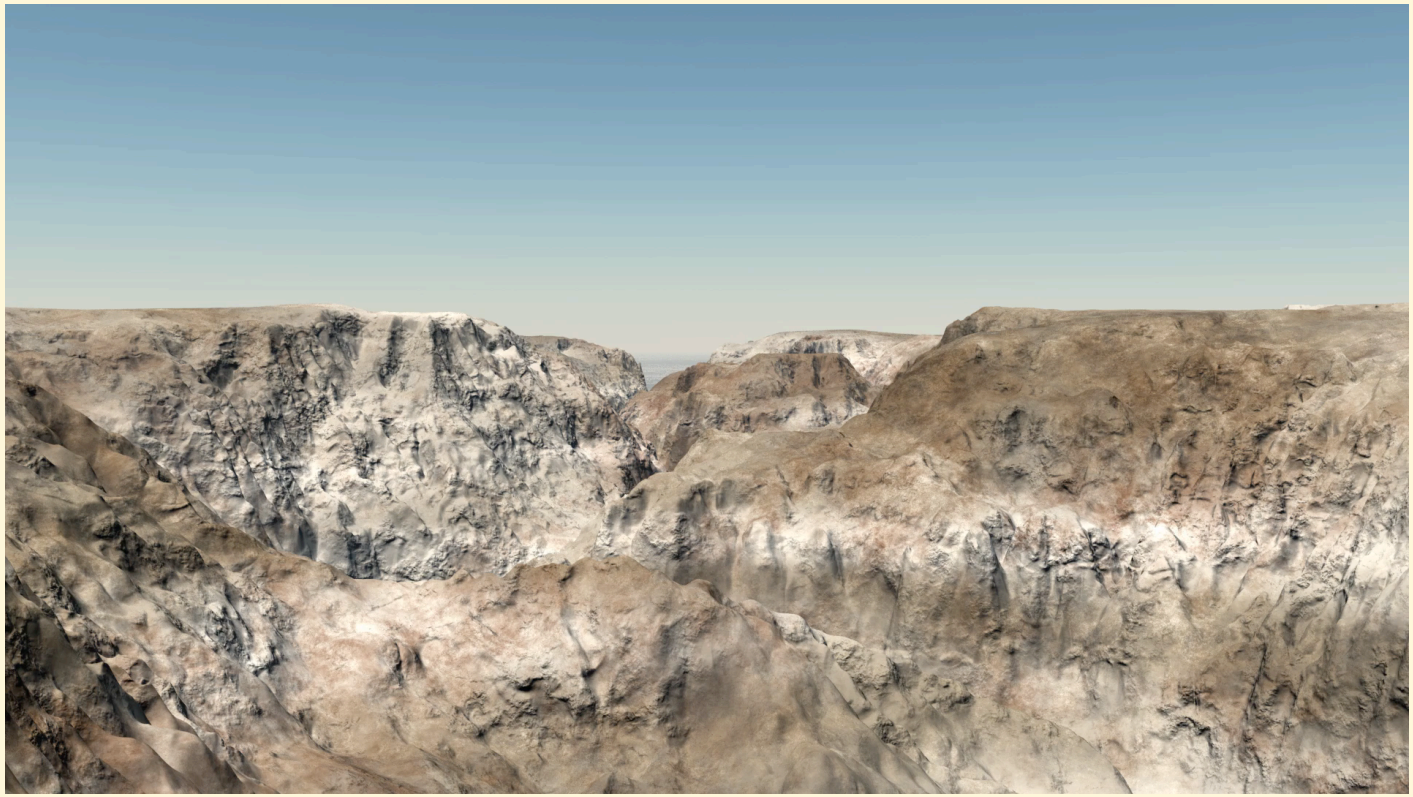
Canyon with river

Introduction

Terrain model

Applications

Conclusion

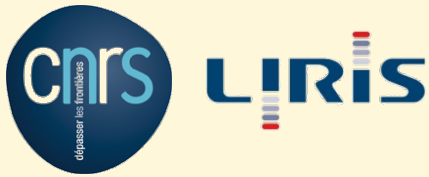


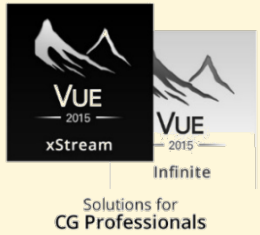
Conclusion

Conclusion

- Versatile model for terrain modeling
- Many perspectives
  - Terrain stylization
  - Include other data (color, vegetation, *etc.*)
  - Volumetric data

Thank you!





Papaya Project