STRUCTURE TENSOR BASED SYNTHESIS OF DIRECTIONAL TEXTURES FOR VIRTUAL MATERIAL DESIGN

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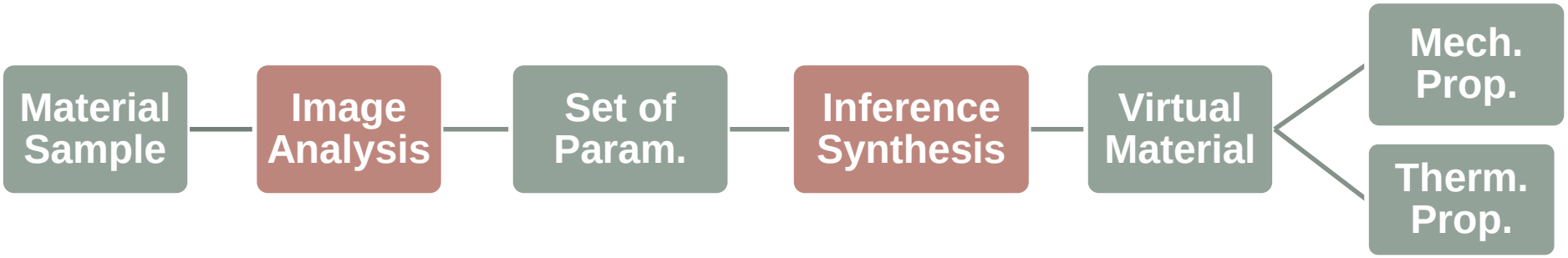
Virtual Material Design

Motivation:

To produce “in silico material” from parameters extracted from image analysis of real material samples.



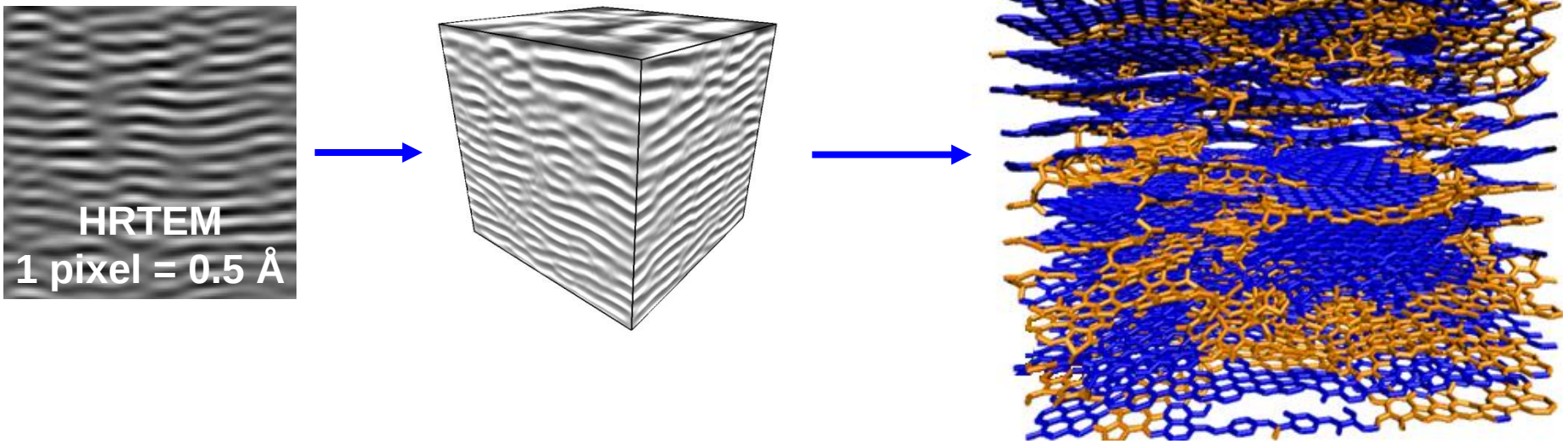
Virtual Material Design

Pyrocarbon at atomic scale :

- Image Guided Atomistic Reconstruction
- High Resolution Transmission Electronic Microscope (HRTEM)

HRTEM Image Analysis
3D Image Synthesis

Image guided simulated annealing

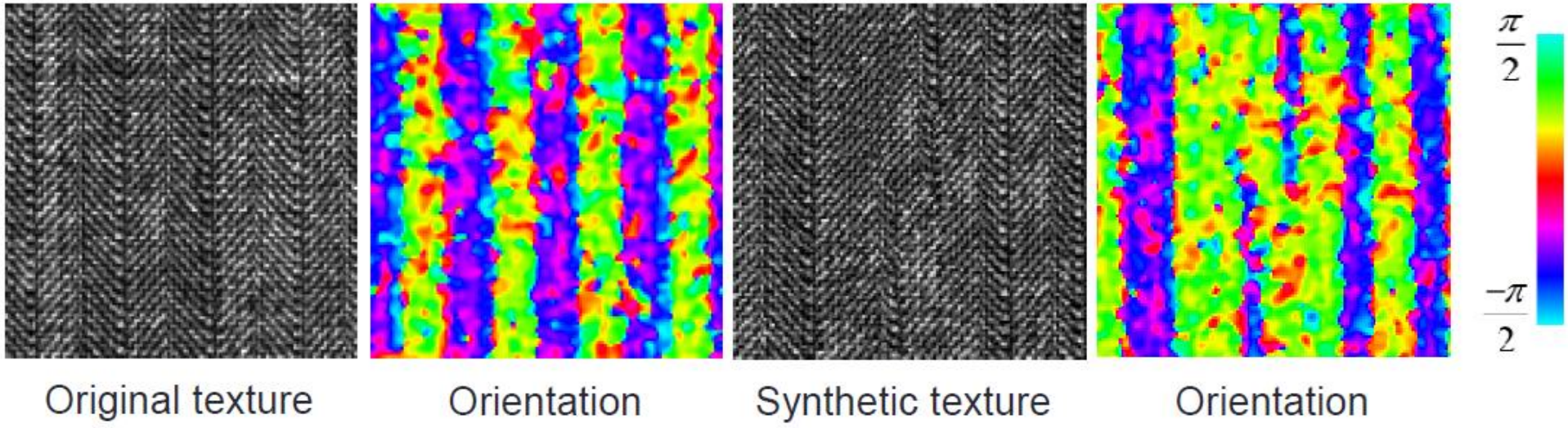


[1] Applied Physics Letters, (2009), “An image-guided atomistic reconstruction of pyrolitic carbons”,

Previous works

Structured anisotropic textures synthesis:

- Non parametric approaches [2] tend to produce more regular textures than the exemplar
- Parametric approaches [3] produce unexpected artifacts
- Both fail on highly structured and non homogeneous textures



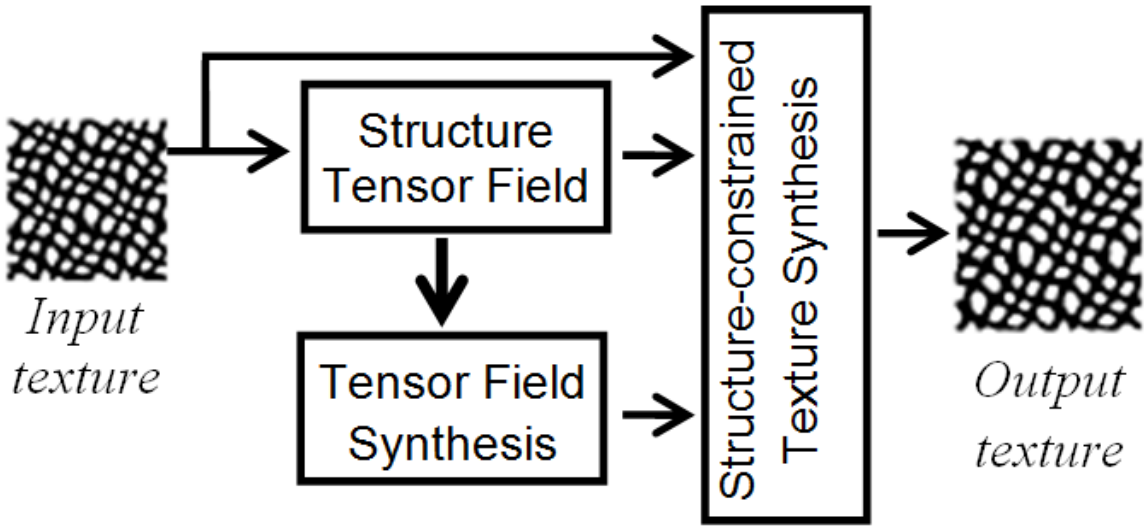
(2] L.-Y. Wei and M. Levoy, "Fast texture synthesis using tree-structured vector quantization," Proc. of ACM SIGGRAPH 2000.
[3] J. Portilla and E. P. Simoncelli, "A Parametric Texture Model based on Joint Statistics of Complex Wavelet Coefficients". Int'l Journal of Computer Vision. 2000

Proposed approach

As in [4], we take into account a “geometric layer”

Our approach combines :

- A prior synthesis of a geometric layer (structure tensor)
- A non parametric synthesis algorithm guided by the geometric layer (derived from [2])

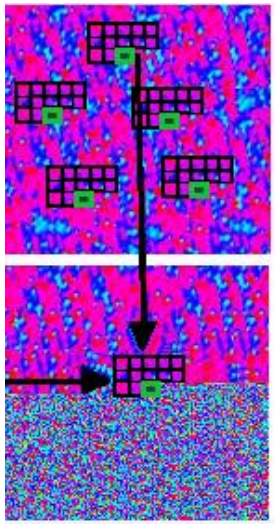


(2] L.-Y. Wei and M. Levoy, "Fast texture synthesis using tree-structured vector quantization," Proc. of ACM SIGGRAPH 2000.
[4] G. Peyré, "Texture Synthesis with grouplets". IEEE Trans. on Pattern Analysis and Machine Intelligence, 32(4):733-746, 2009.

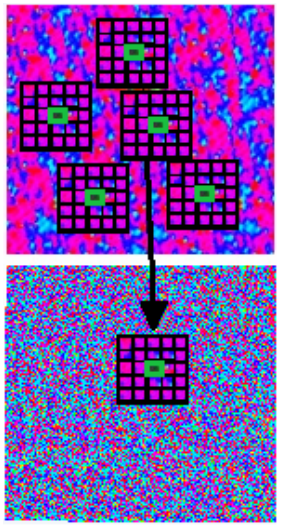
Texture tensor field synthesis

Based on Wei and Levoy algorithm [2]
Adapted to the specificities of tensor-valued images
=> Synthesis of a tensor field similar to the exemplar's:

Causal neighborhood with a lexicographical scan



Square non-causal neighborhood with a random walk



(2] L.-Y. Wei and M. Levoy, "Fast texture synthesis using tree-structured vector quantization," Proc. of ACM SIGGRAPH 2000, pp. 479-488, 2000.

Texture tensor field synthesis

Structure tensor field $S = G_\sigma * (\nabla I . \nabla I^t)$

$$S(x,y) = \begin{bmatrix} S_{xx}(x,y) & S_{xy}(x,y) \\ S_{xy}(x,y) & S_{yy}(x,y) \end{bmatrix}$$

Coherence $C(S)$ is computed from the eigenvalues λ_i

$$C(S) = \left(\lambda_1(S) - \lambda_2(S)\right) / \left(\lambda_1(S) + \lambda_2(S)\right)$$

Orientation $O(S)$ is obtained from the 1st eigenvector $[e_x, e_y]$:

$$O(S) = tan^{-1}\left(e_y / e_x\right)$$

Texture tensor field synthesis

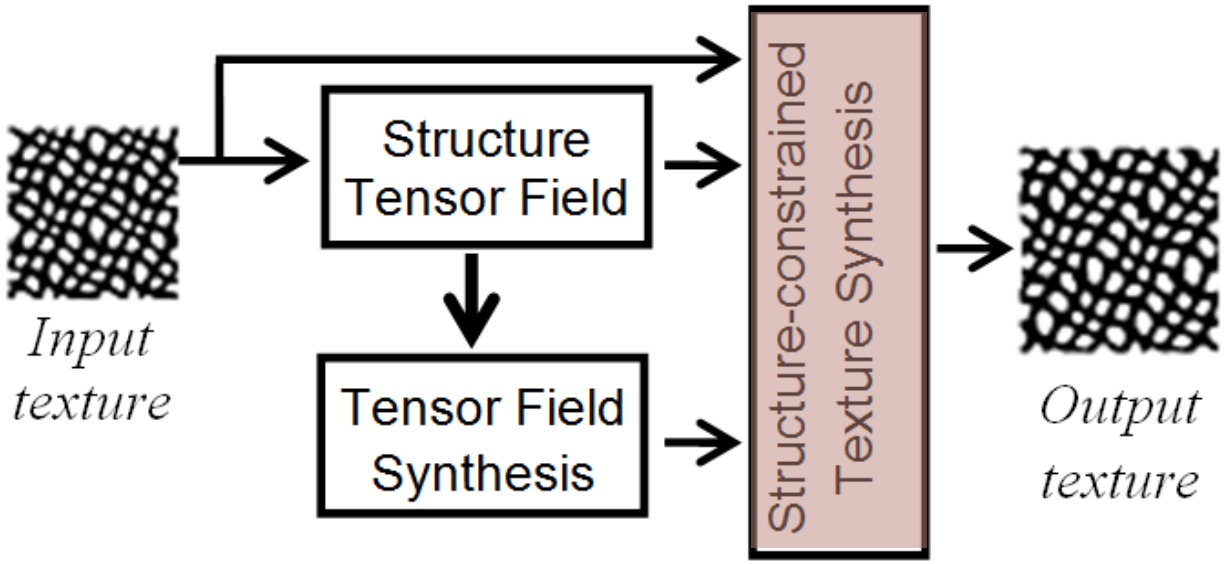
Tensor neighborhoods are compared:
using the sum of their tensor dissimilarities

$$STD(F_1, F_2) = \sum_{n=1}^{N} M_i\left(F_1(n), F_2(n)\right); \quad i \in \{1,2,3,4\},$$

Four tensor-space metrics M_i are considered:

- Euclidean distance M_1
- Shape-Orientation metric: M_2
- Frobenius norm M_3
- Log-Euclidean metric M_4

The structure/texture approach



Combining Tensor domain and Pixel domain

$$D = p \cdot SSD\left(G_{in}, G_{out}\right) + \left(1 - p\right) \cdot STD\left(F_{in}, F_{out}\right)$$

Pixel domain: SSD (Sum Square Distance)
Tensor domain: STD (Sum of Tensor Dissimilarity)
p: weight assigned to each domain

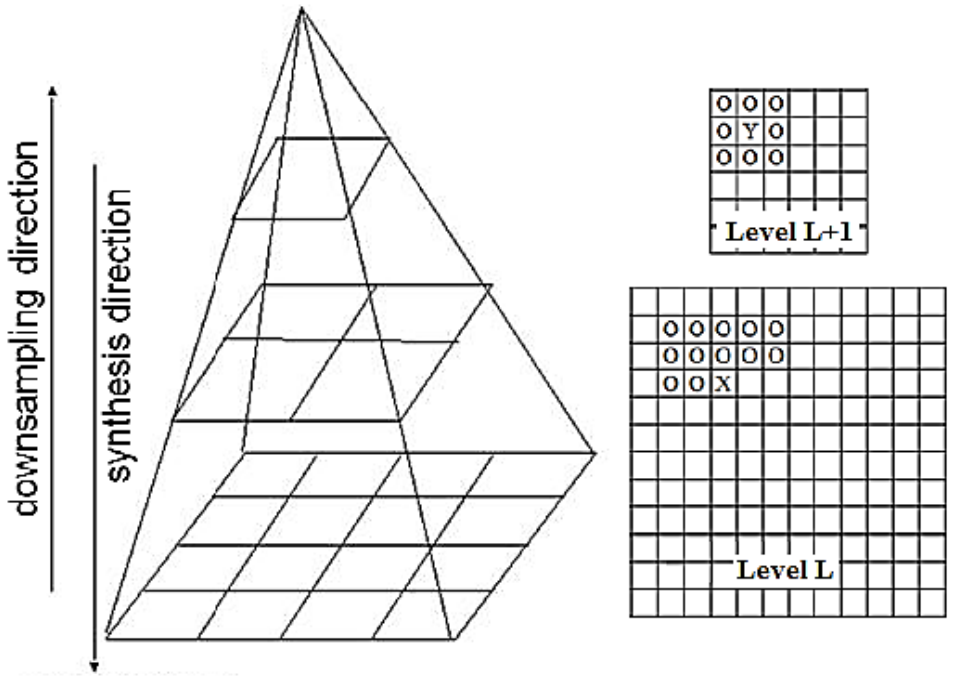
Texture tensor field synthesis

Multi-resolution pyramids : avoid the use of large neighborhoods

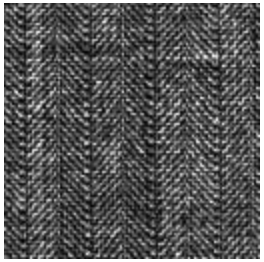
- Smoothing the tensor field with a Gaussian kernel
- Down-sampling with a 2:1 factor for each additional scale

Multi-resolution neighborhood of the tensor at level *L:*

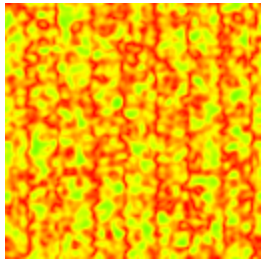
Level L neighborhood
+
Neighborhood of the tensor at level L+1



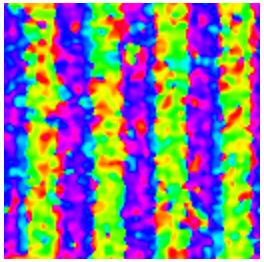
Results



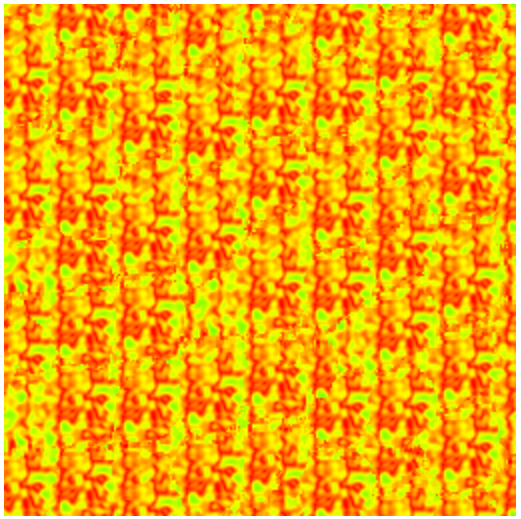
Input texture



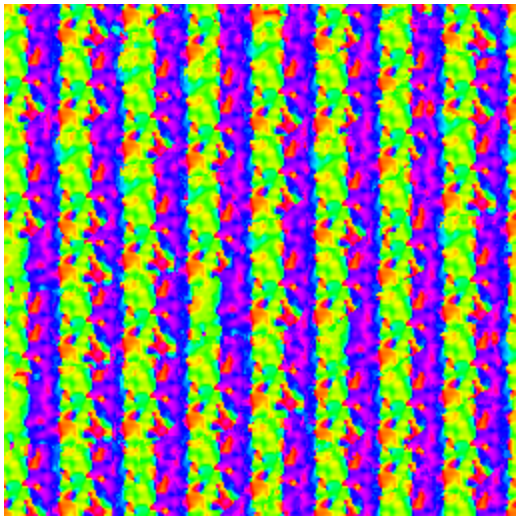
Coherence



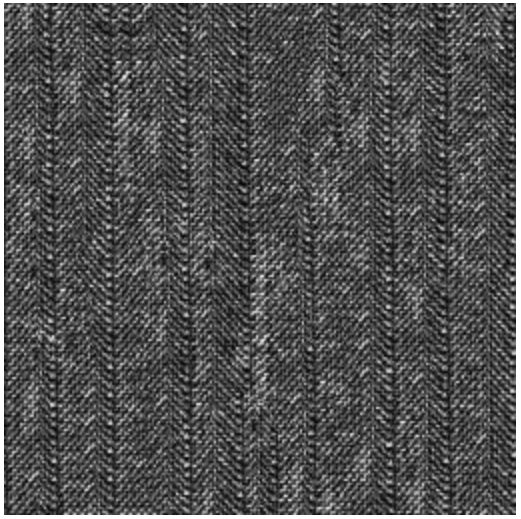
Orientation



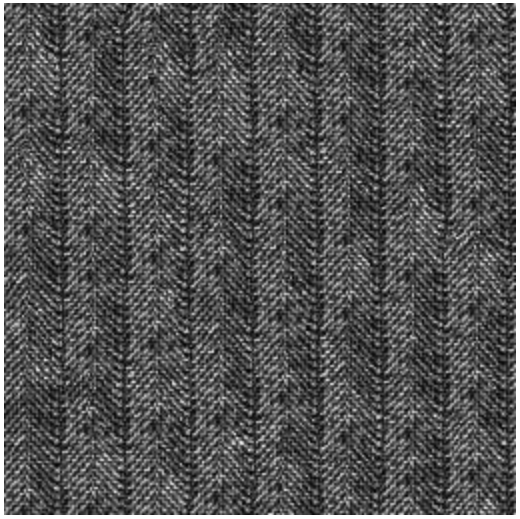
Synthetic coherence image



Synthetic orientation image

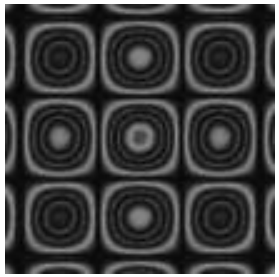


Synthetic texture by W&L

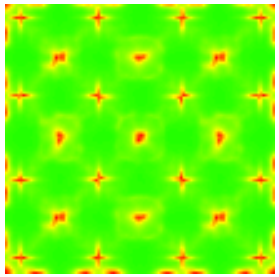


Synthetic texture by the proposed approach

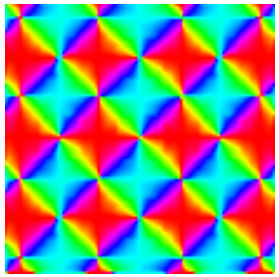
Results



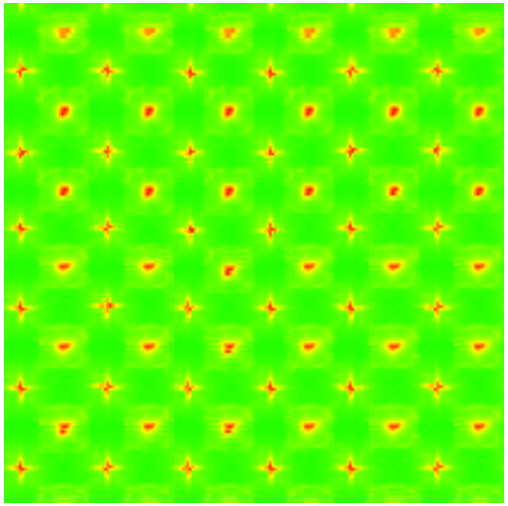
Input texture



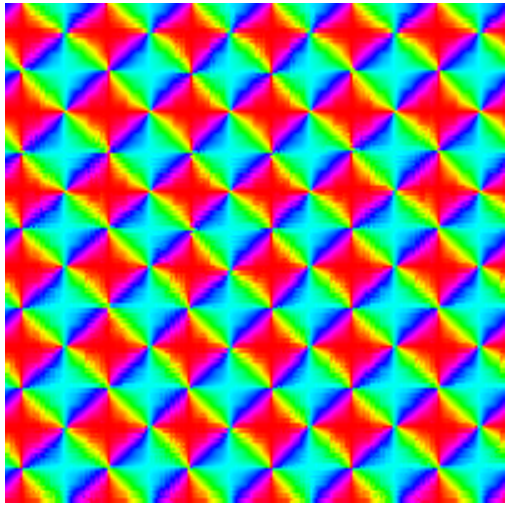
Coherence



Orientation

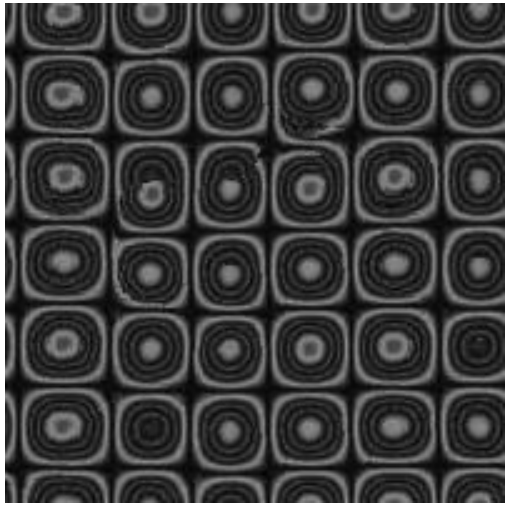


Synthetic coherence image



Synthetic orientation image

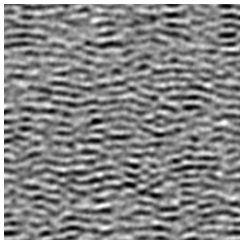
Synthetic texture by W&L



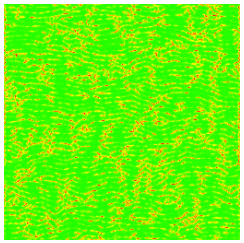
Synthetic texture by the proposed approach

Results for virtual material

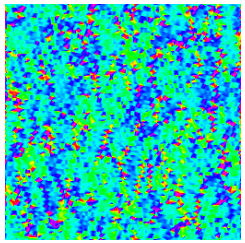
Preliminary results on pyrocarbon HRTEM images (2D)



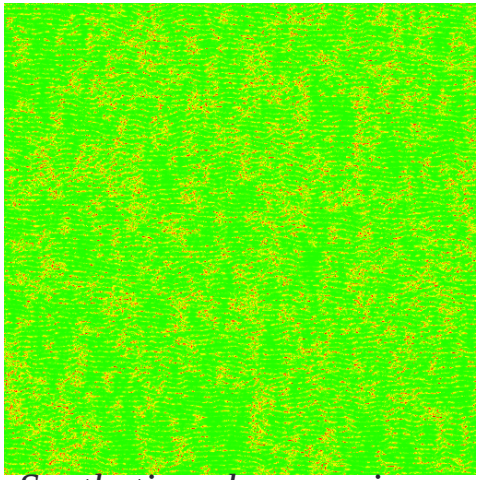
Input texture



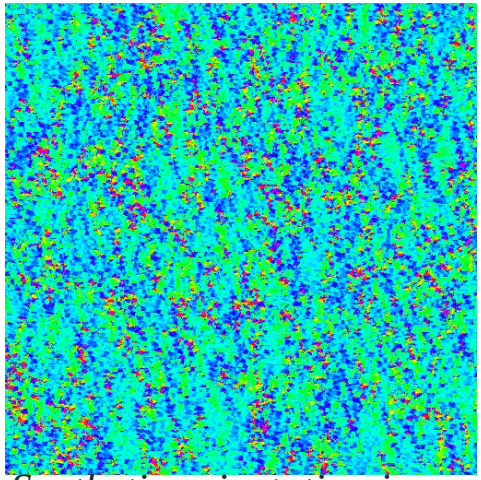
Coherence



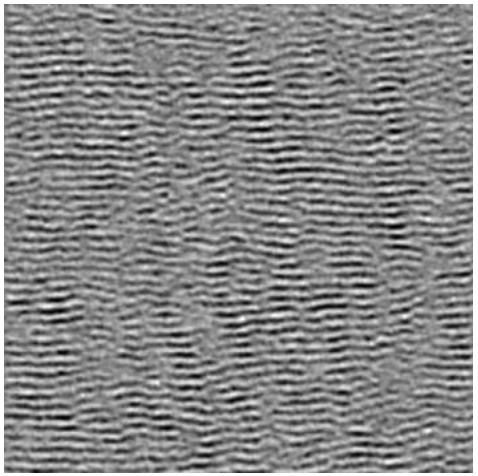
Orientation



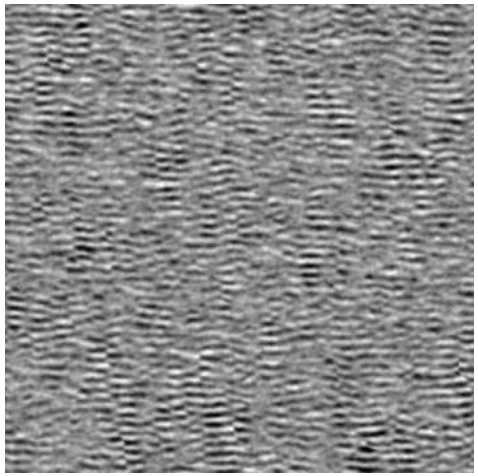
Synthetic coherence image



Synthetic orientation image



Synthetic texture by W&L



Synthetic texture by the proposed approach

Conclusions & Prospects

Non-parametric methods

- Tend to produce textures more regular than wanted

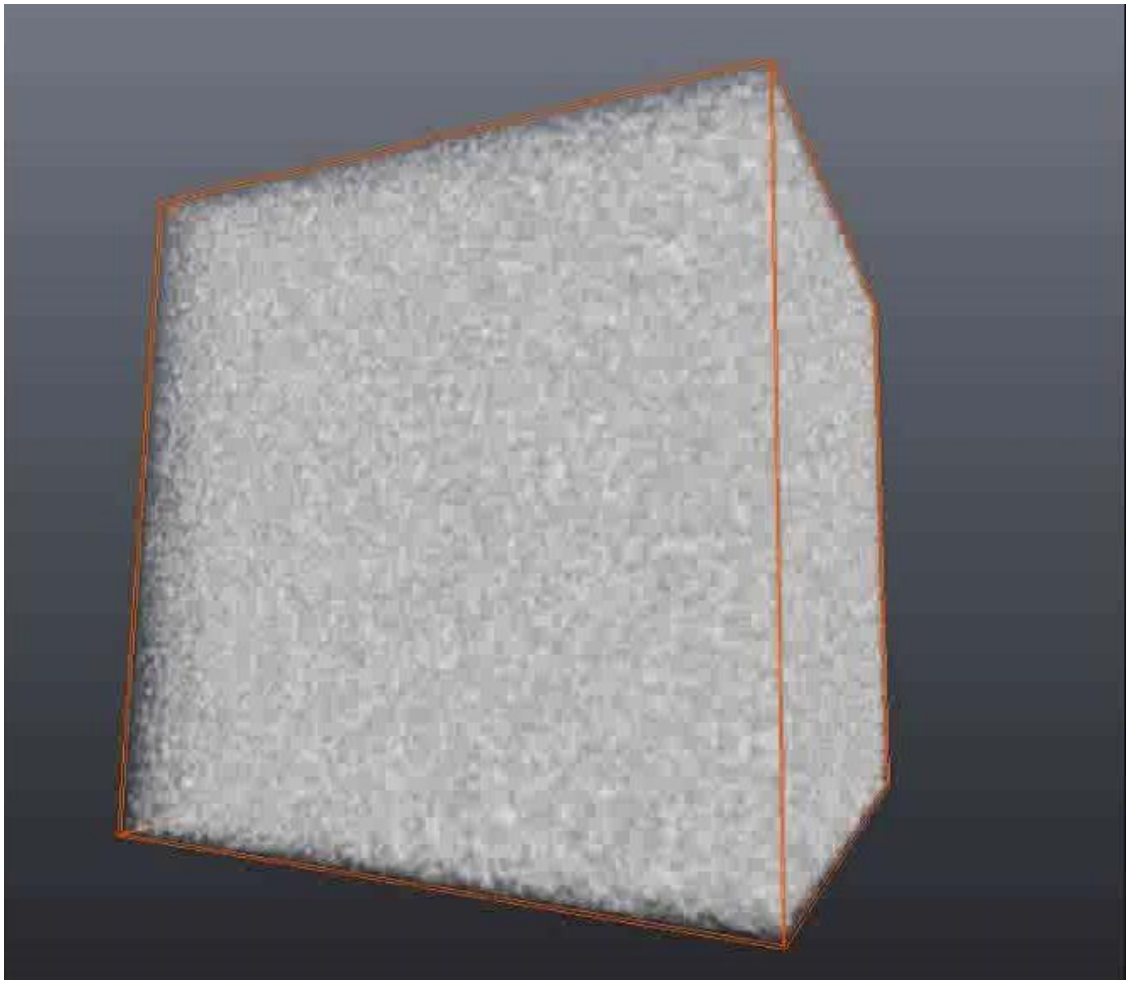
The proposed approach

- multi-stage structure/texture synthesis
- Accurately reproduces the exemplar's variations of orientation

Prospects

- Objective measures for evaluation
- Synthesis of non-stationary textures
- 3D extension
- Synthesis of material samples showing laminar structures

Thank you! Any questions ?



ANR Project « PyroMaN »: http://www.pyroman.cnrs.fr/pyroman/