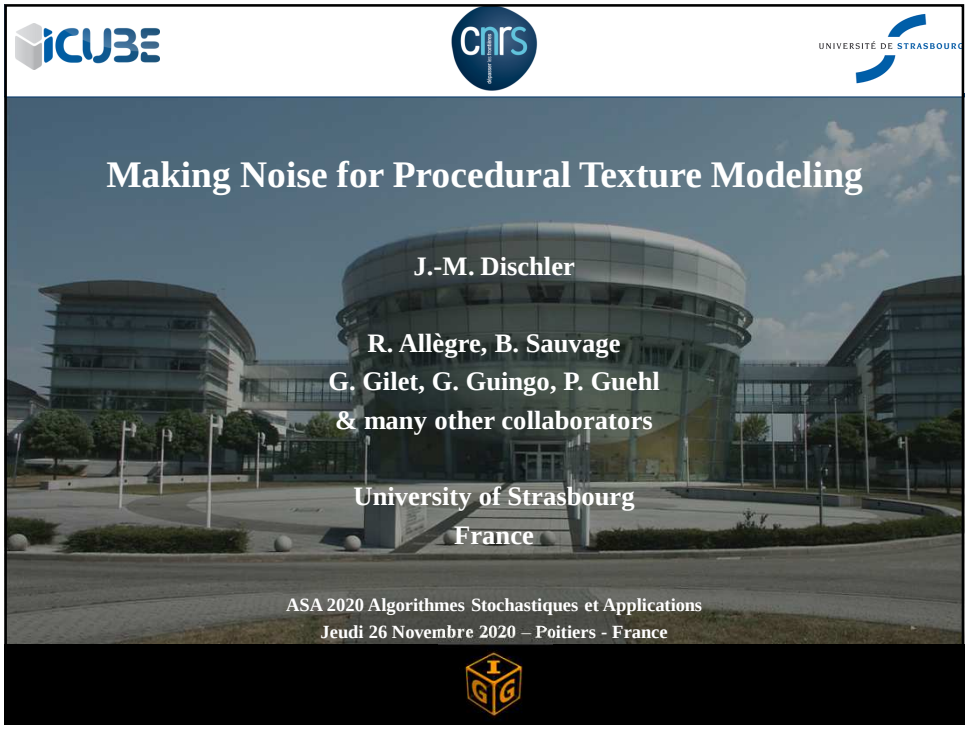
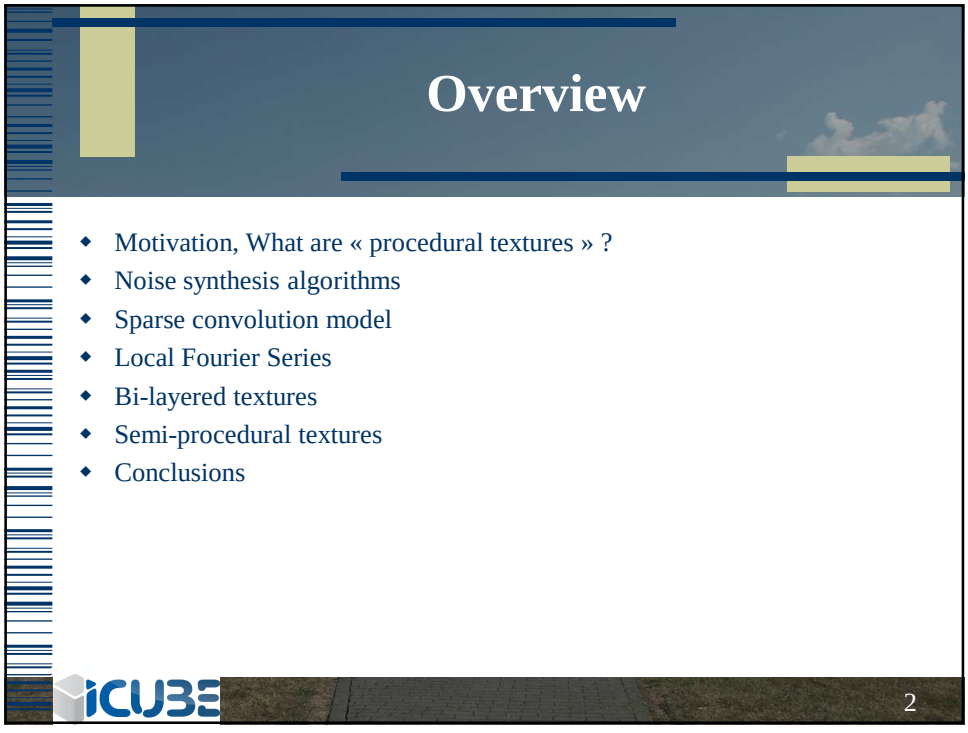

Making Noise for Procedural Texture Modeling
J.-M. Dischler
R. Allègre, B. Sauvage
G. Gilet, G. Guingo, P. Guehl
& many other collaborators
University of Strasbourg
France
ASA 2020 Algorithmes Stochastiques et Applications
Jeudi 26 Novembre 2020 – Poitiers - France

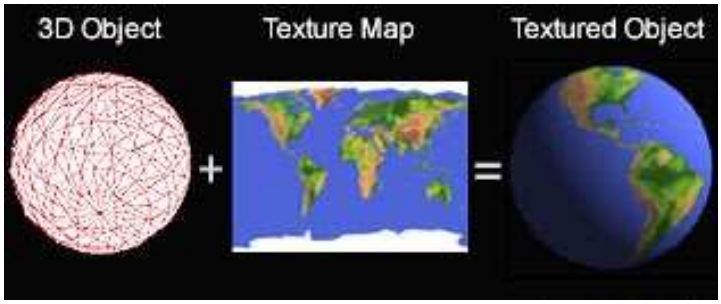
1


Overview
Motivation, What are « procedural textures » ?
Noise synthesis algorithms
Sparse convolution model
Local Fourier Series
Bi-layered textures
Semi-procedural textures
Conclusions
2

2

Historical

Ed Catmull, 1974: texture = image « mapped » on surface using parameterization



3

Why texture synthesis ?

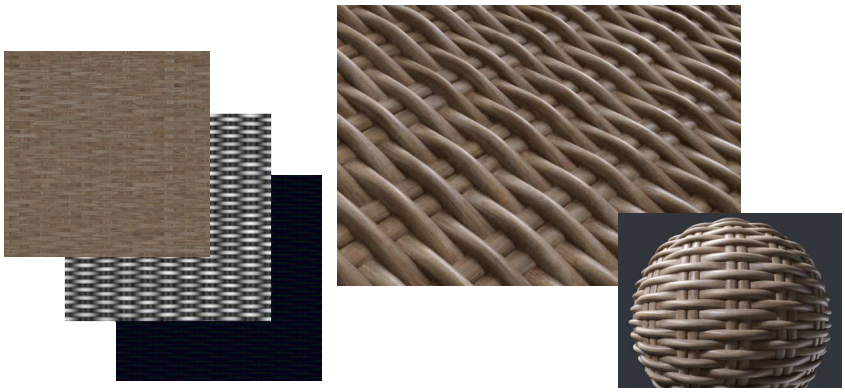
Textures give virtual objects a « material » appearance.

But using images raises many issues…

not realistic

4

Materials: layered images



Source: https://www.textures.com/

5

Why texture synthesis ?

We need **algorithms** to create virtual materials, that have given properties…

more realistic

6

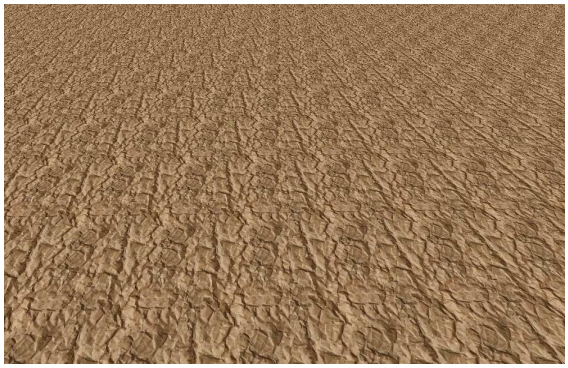
Desired Texture Properties

- *Unbound*
- *Fine details*
- *Fast*
- *Pixel-parallel*
- *Compact*
- *Continuous*
- *Antialising*

7

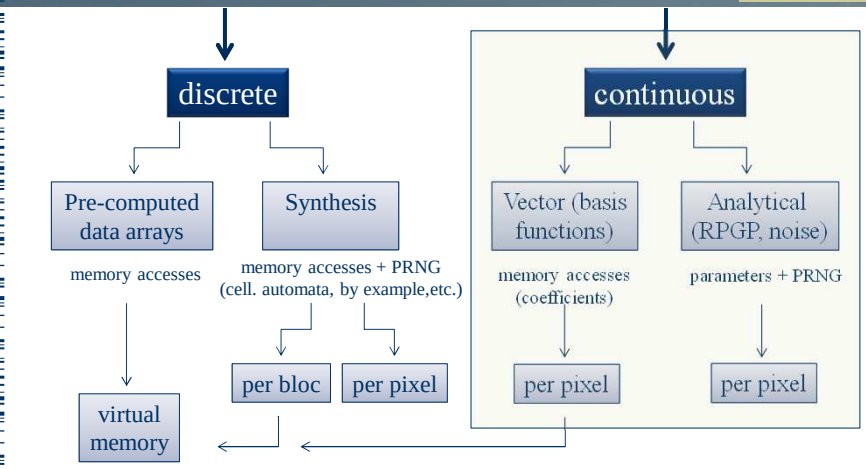
Images have limitations…

- *Not unbound*
- *No fine details*
- *Fast*
- *Pixel-parallel*
- *Not compact*
- *Not continuous*
- *Antialising*



8

Digital texture representations

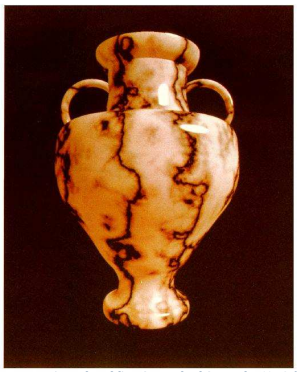


9

Procedural texturing

- **Unbound**
- **Fine details**
- ***Not fast***
- **Pixel-parallel**
- **Compact**
- **Continuous**
- *Antialiasing*

Procedural texture models [Ebert et al.]

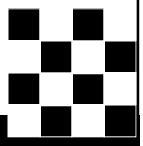


Ebert, David S. and Musgrave, F. Kenton and Peachey, Darwyn and Perlin, Ken and Worley, Steven, **Texturing and Modeling: A Procedural Approach**, 2002, 3rd dition, Morgan Kaufmann Publishers Inc.

10

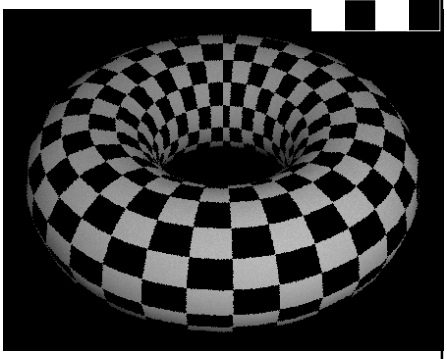
Procedural texturing

Idea: define a texture directly with a program (a function, « **shader** »)



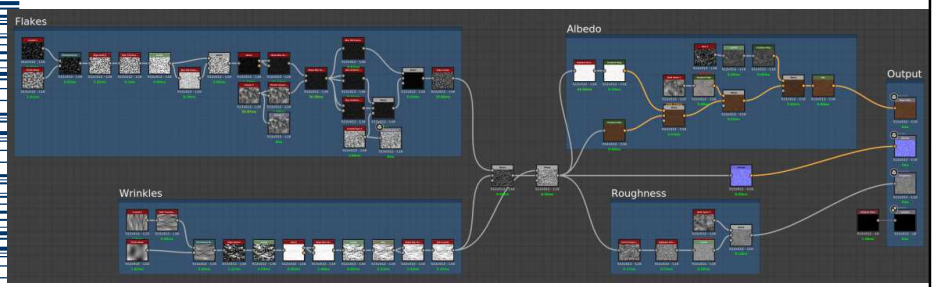
Example : checkerboard

```
Def checker (u,v):
    u=frac(u);
    v=frac(v);
    if (u<0.5 and v<0.5) or
      (u>0.5 and v>0.5):
                return WHITE
    else:
                return BLACK
```



Material Graphs

- **Programming “shaders” is not a trivial task,**
- Shaders are authored by connecting nodes and thereby building a graph;
- Important need: **random functions (stochastic processes)**



https://www.substance3d.com/substance/

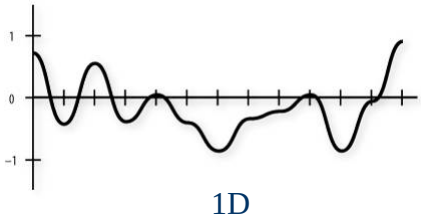
Pseudo Random Number Generation

```
uint seed;

void seeding(uint x, uint y) {
  seed=HASH(x+HASH(y));
}

float next() {
  seed *= uint(1103515245);
  seed=(seed+uint(12345))%(uint(1)<<uint(30));
  seed &= uint(0x3fffffff);
  float res=(float(seed)/float(0x3fffffff))*2.0-1.0;
  return res; // pseudo random value in [-1,1]
}
```

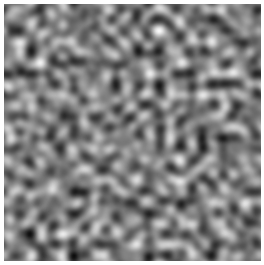

Noise-Functions

Perlin noise, 1985:

Low-pass filtered noise: function $\mathcal{N}$ that returns for a given t a real value in [-1, 1] according to a normal probability distribution.



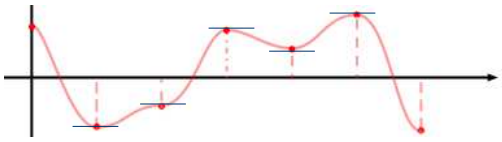
1D



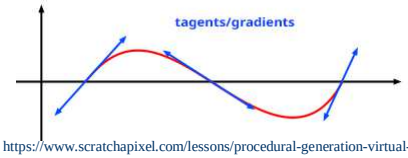
2D

Grid-based noise

Value noise:



Gradient noise:



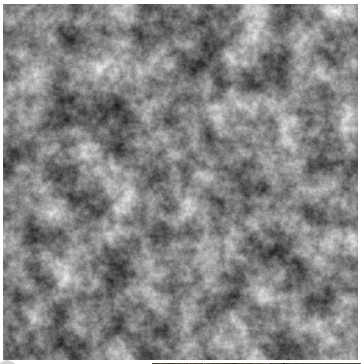
https://www.scratchapixel.com/lessons/procedural-generation-virtual-worlds/procedural-patterns-noise-part-1/simple-pattern-examples

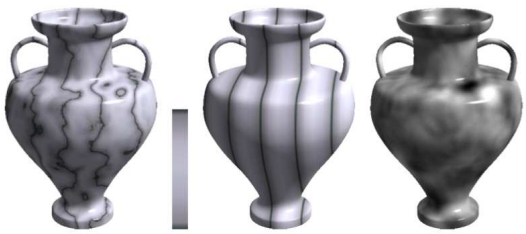
15

Fractal noise

$$turb(t) = \sum_{i=0}^{n} \frac{abs(Bruit(2^i t))}{2^i}$$

$$Marbre(x,y,z) = \sin^p\left(x + a \cdot turb(b \cdot x, b \cdot y, b \cdot z)\right)$$





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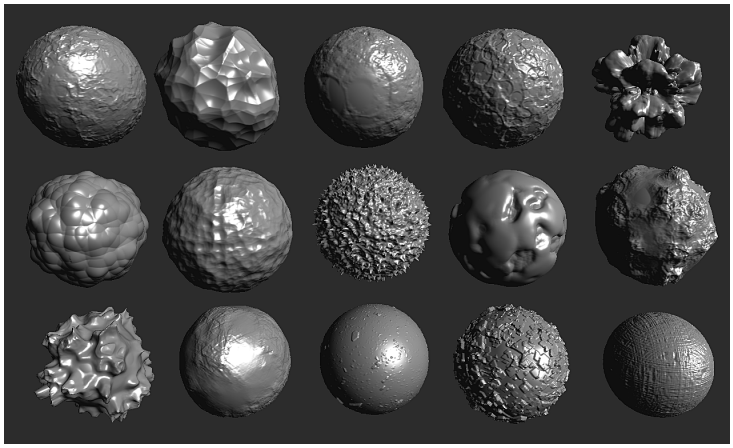
Examples of using different noises for texture modeling



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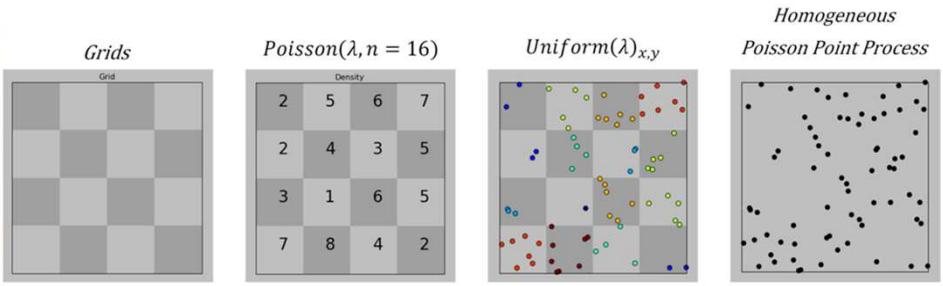
Sparse Convolution Noise

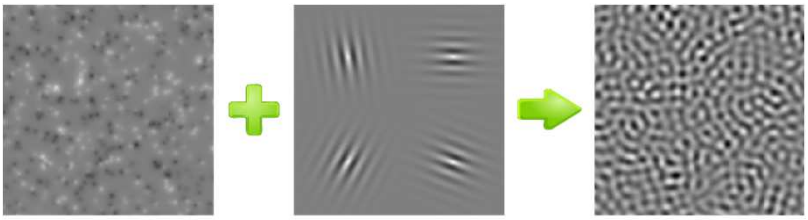
Poisson point process: use an integer lattice and jittering with PRNG to distribute points in space



18

Gabor sparse convolution noise

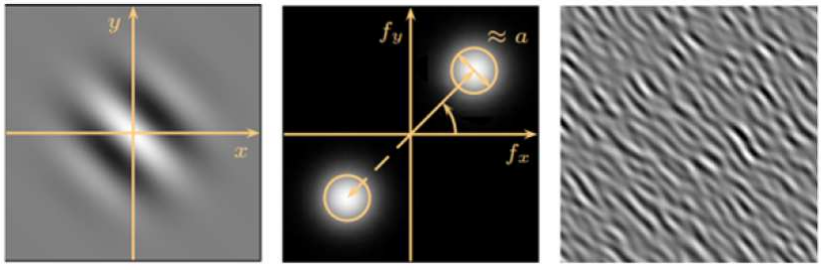
Gabor kernel unifies spatial and spectral properties:



Ares Lagae, Sylvain Lefebvre, George Drettakis, and Philip Dutré. 2009.
Procedural noise using sparse Gabor convolution. ACM Trans. Graph. 28, 3, Article 54 (August 2009)

19

Gabor sparse convolution noise



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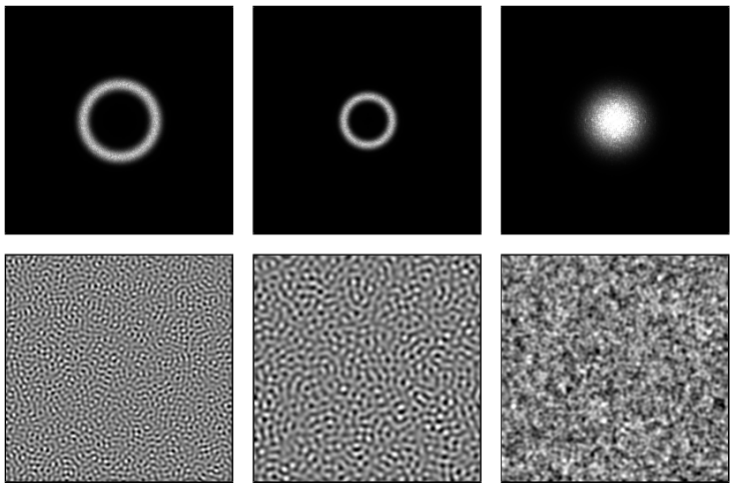
Gabor sparse convolution noise



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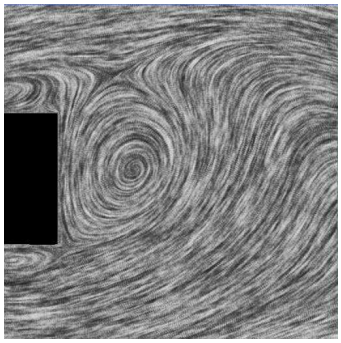
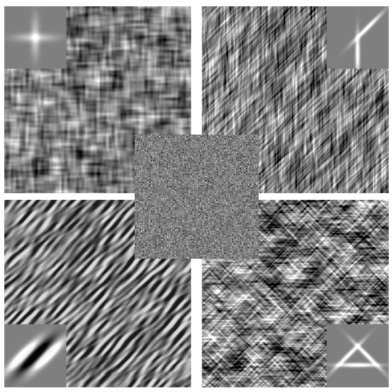
Spot noise (van Wijk, 91)





Arthur Cavalier, Guillaume Gilet, Djamchid Ghazanfarpour: **Local spot noise for procedural surface details synthesis**. Computers and Graphics 85: 92-99 (2019)

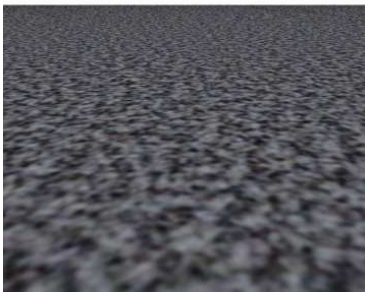
22

Noise « by example »

Noise is hard to use: try to fit parameters of noise using an **example**.

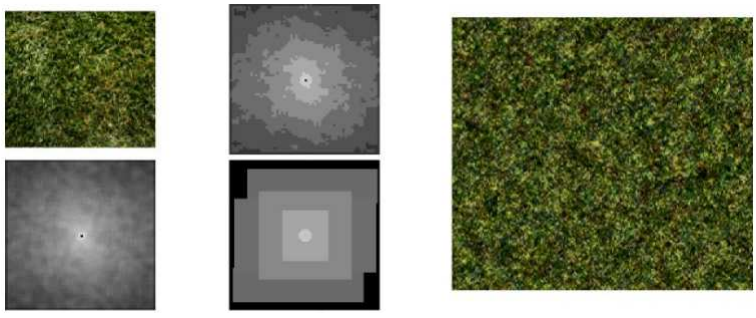
Define a noise that matches: Power Spectral Density & Histogramm of exemplar

Parmeters:
Amplitudes + Frequencies
of noises (PSD)



G Gilet, JM Dischler, L Soler , **Procedural descriptions of anisotropic noisy textures by example**, - Eurographics 2010, Short paper

Noise-Textures by example



Multiple Kernels Noise for Improved Procedural Texturing
Guillaume Gilet, Jean-Michel Dischler, Djamchid Ghazanfarpour
The Visual Computer, 2012

But only noise, no structure…

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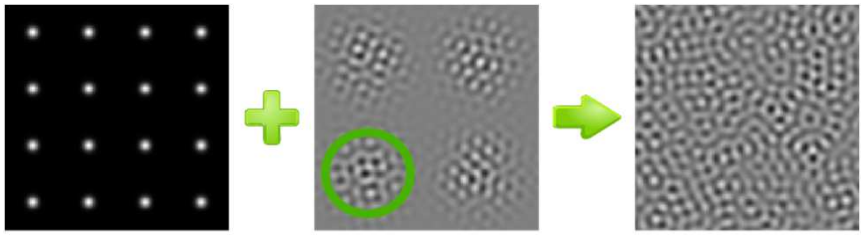
Local Random-Phase Noise

$$\sum_i w(x - x_i) \times \sum_j (A_{ij} \times cos(f_{ij} \times x + \varphi_{ij}))$$



Sum of cosines

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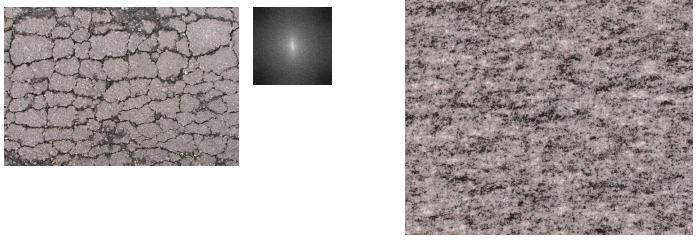
Local Random-Phase Noise « by example »

Define noise by local Fourier series.

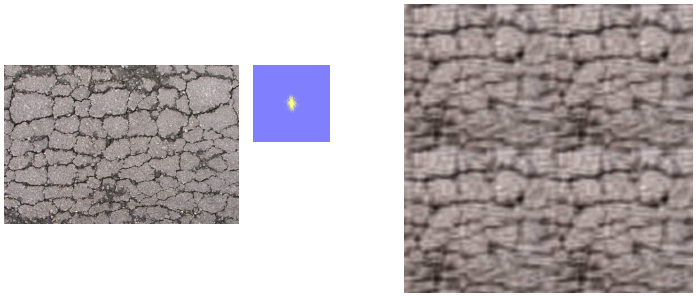


Guillaume Gilet, Basile Sauvage, Kenneth Vanhoey, Jean-Michel Dischler, and Djamchid Ghazanfarpour. 2014. **Local random-phase noise for procedural texturing**. ACM Trans. Graph. 33, 6, (November 2014)

27

Local Random-Phase Noise « by example »

Define noise by local Fourier series.



Guillaume Gilet, Basile Sauvage, Kenneth Vanhoey, Jean-Michel Dischler, and Djamchid Ghazanfarpour. 2014. **Local random-phase noise for procedural texturing**. ACM Trans. Graph. 33, 6, (November 2014)

28

Local Random-Phase Noise « by example »

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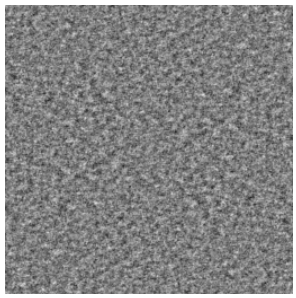

Guillaume Gilet, Basile Sauvage, Kenneth Vanhoey, Jean-Michel Dischler, and Djamchid Ghazanfarpour. 2014. **Local random-phase noise for procedural texturing**. ACM Trans. Graph. 33, 6, (November 2014)

29

Local Random-Phase Noise « by example »

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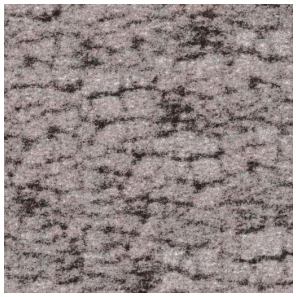

Guillaume Gilet, Basile Sauvage, Kenneth Vanhoey, Jean-Michel Dischler, and Djamchid Ghazanfarpour. 2014. **Local random-phase noise for procedural texturing**. ACM Trans. Graph. 33, 6, (November 2014)

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Local Random-Phase Noise « by example »

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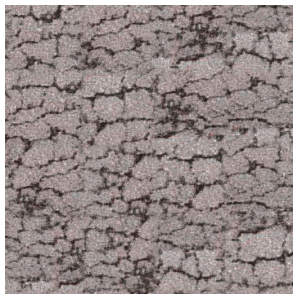

Guillaume Gilet, Basile Sauvage, Kenneth Vanhoey, Jean-Michel Dischler, and Djamchid Ghazanfarpour. 2014. **Local random-phase noise for procedural texturing**. ACM Trans. Graph. 33, 6, (November 2014)

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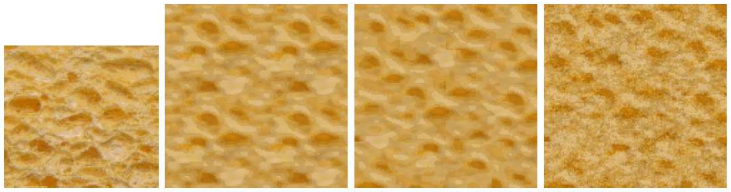
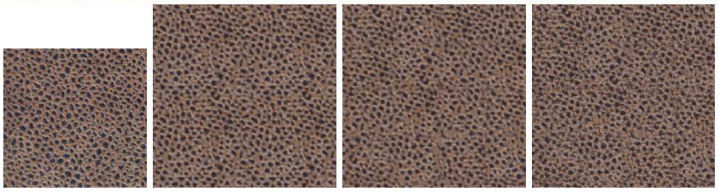
Local Random-Phase Noise « by example »

Blending between fast “patch” based texture synthesis (coarse scale) + noise (fine scale).



$J = 50,\ r = 20\%$



$J = 40,\ r = 35\%$

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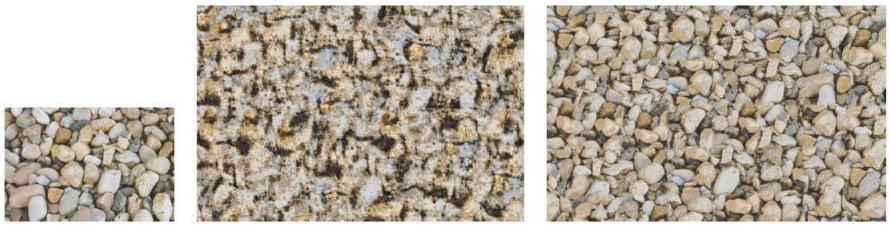
Lack of correlation: « Structure » versus Noise

Un-correlated noise
Too much repetition when fixing too much phases (no real synthesis)



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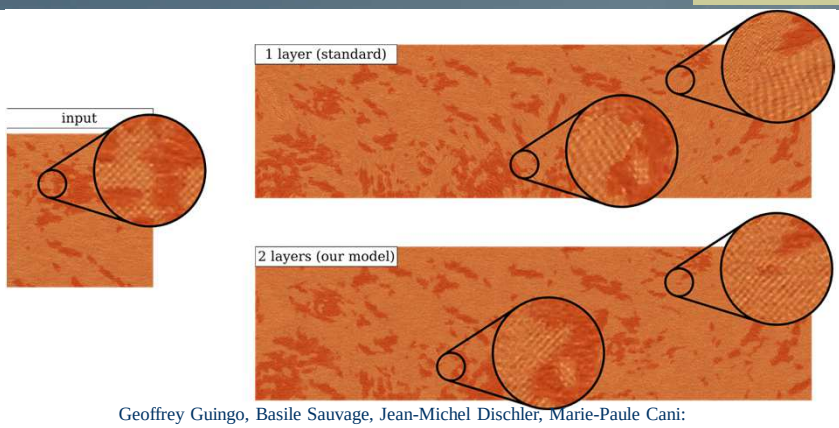
Add visual variety with spatial distorsions



Geoffrey Guingo, Basile Sauvage, Jean-Michel Dischler, Marie-Paule Cani:
Bi-Layer textures: a Model for Synthesis and Deformation of Composite Textures. Comput. Graph. Forum 36(4): 111-122 (2017)

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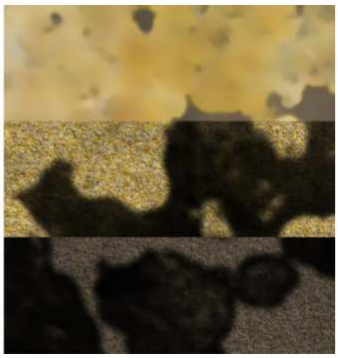
Bi-layered Texture synthesis



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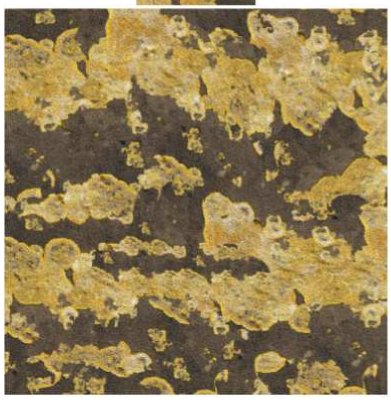
Bi-layered Texture synthesis



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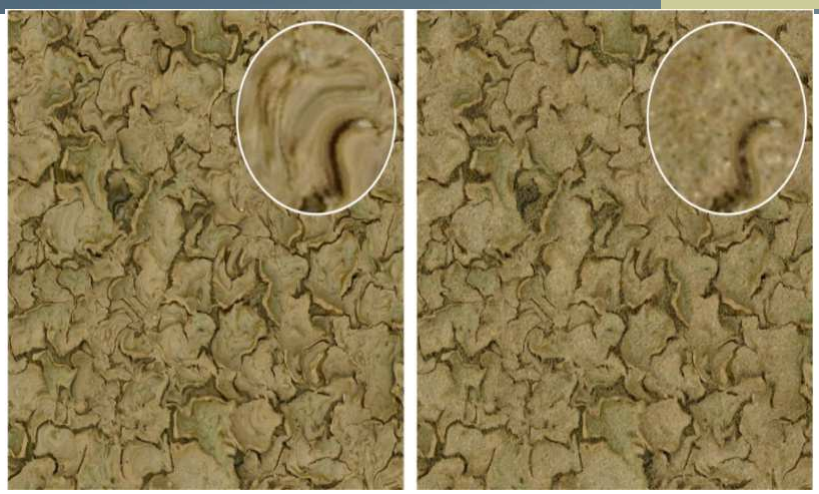
Bi-layered Texture synthesis



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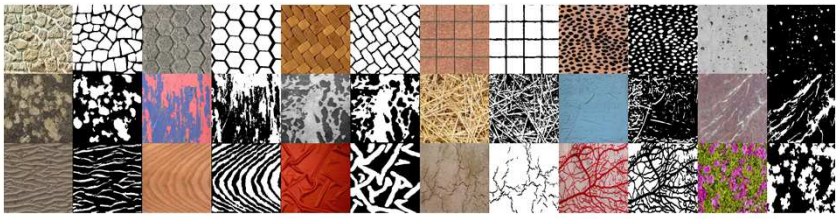
Structure versus Noise



Many natural textures embed *spatial stochastic structures* such as cells, cracks, grains, scratches, spots, stains or waves.

They can be characterized by *binary images*

Three characteristics:

1. Distribution
2. Mutual interaction
3. Local visual shape

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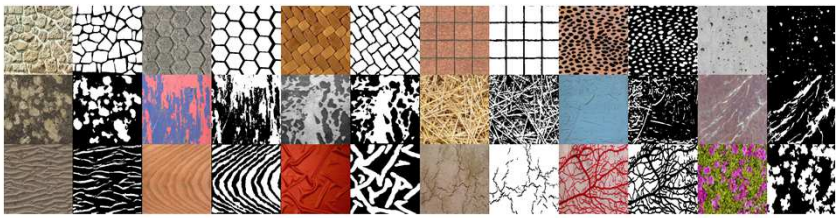
Structure versus Noise



$$Structure(\vec{x}) = P * (W \ F)(\vec{x})$$

(1) (2) (3)

Three characteristics:

1. Distribution
2. Mutual interaction
3. Local visual shape

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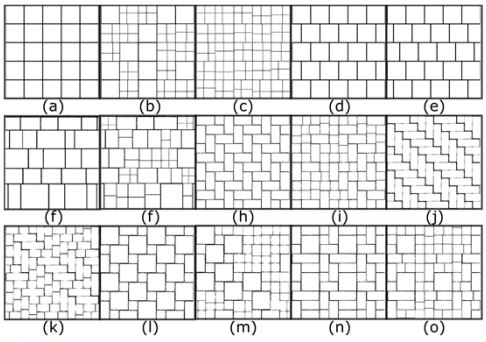
Non-Uniform Point Distributions

POINT PROCESS

$$P(\vec{x}) = \sum_i \delta(\vec{x} - \vec{x}_i)$$



Poisson point process

approximations : square cells with constant area

Cox point process

random tessellations, cells consist of rectangles Ri of varying sizes

Gibbs point process

approximation : (iterative) Lloyd algorithm

Near-regular / regular

Jittering amplitude controls randomness
low value can model near-regular distributions

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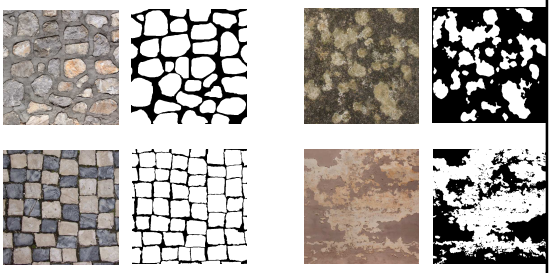
Window Function

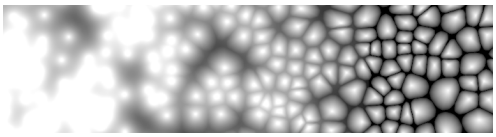
$$w(\mathbf{x}) = \sum_{j=1}^{n_w} \frac{\omega_j}{\mathrm{N}_j} w_j(\mathbf{x})$$

$$w_j = \lfloor e^{-\sigma_j D_j(\mathbf{x}-\vec{x_i})} \rfloor_{d_j}$$

weighted sum of collections of basis windows with Gaussian profile



overlapping and *non-overlapping*



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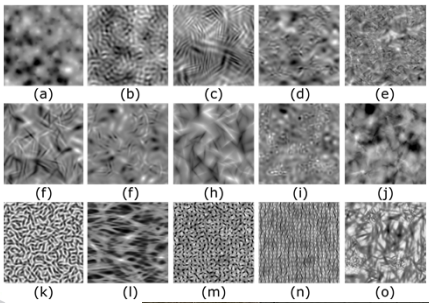
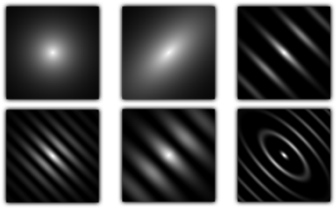
Feature Function

$$f(\mathbf{x}) = \sum_{j=1}^{J} \omega_j(\mathbf{x}) \tilde{G}_j(\mathbf{x}),$$

$$\tilde{G}_j(\mathbf{x}) = A_j \left(e^{-\sigma_{j|i} \left\| \Xi(\vec{x} - \vec{\mu_{j|i}}) \right\|_f} \right) \left(.5 + .5 \cos \left(\phi \left\| \Xi(\vec{x} - \vec{\mu_{j|i}}) \right\|_f \right) \right)^{\tau}.$$

Anisotropy, *thickness* and *curliness* allow more efficient modeling of anisotropic features like grains, stripes and folds.





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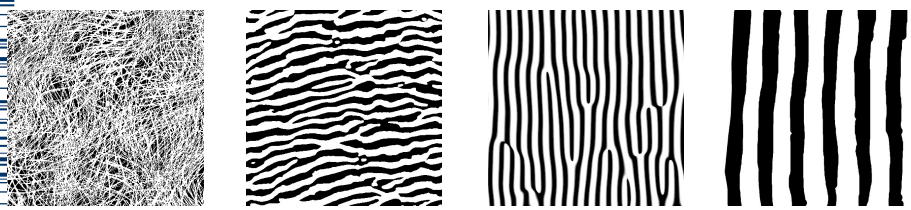
Correlating Window and Feature Function

No correlation

adding little correlations helps spatial organization

adding more correlations

strong correlation



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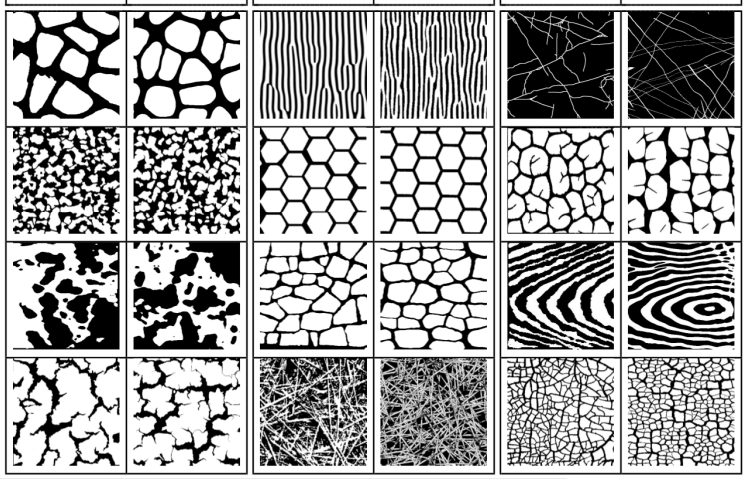
Evaluation of visual « span »

Input binary structure	Procedural structure	Input binary structure	Procedural structure	Input binary structure	Procedural structure



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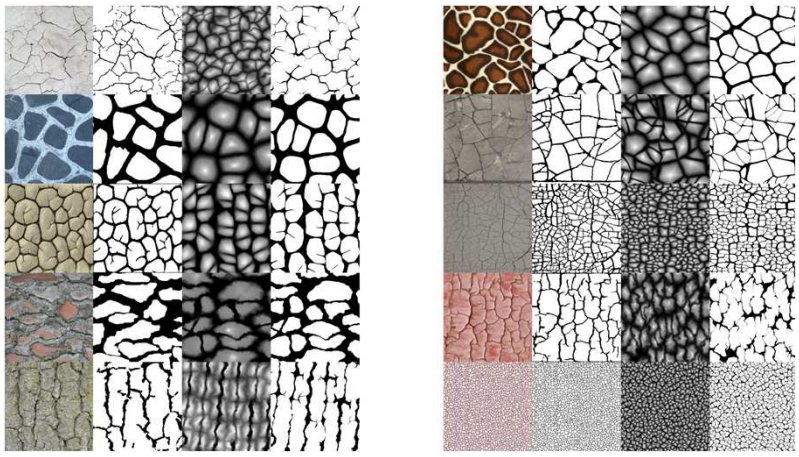
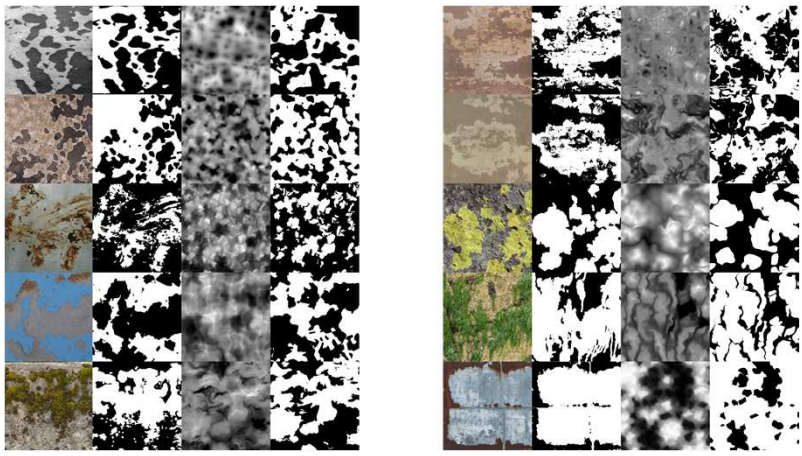
Structure classes: cells, grains, lines, waves, stains, piles, dots, tilings



45

Structure classes: cells, grains, lines, waves, stains, piles, dots, tilings



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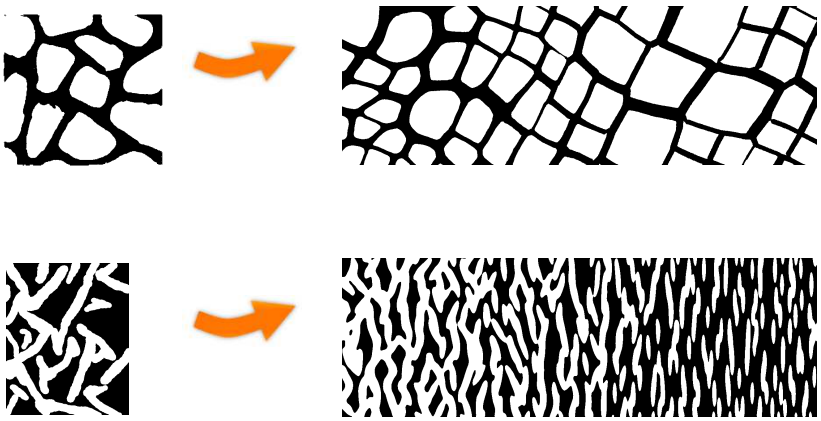
Edition + Control



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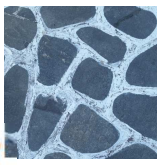
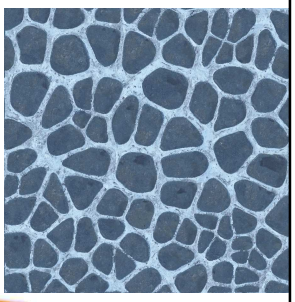
Semi-procedural texture

Input exemplar

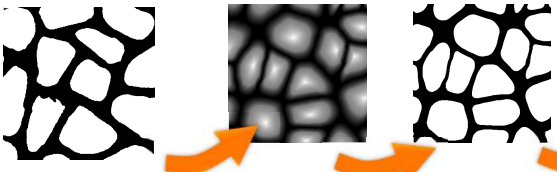


Synthesized output
(semi-procedural texture)



Procedural structure *(PPTBF)*

Segmented input (user provided)



Color transfer

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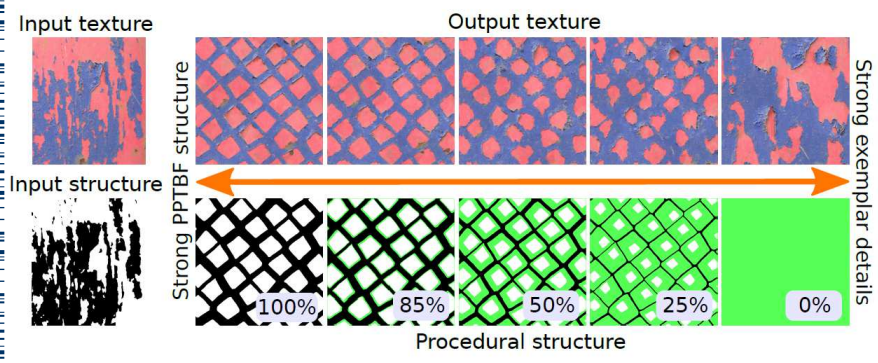
Procedural Structure versus Exemplar



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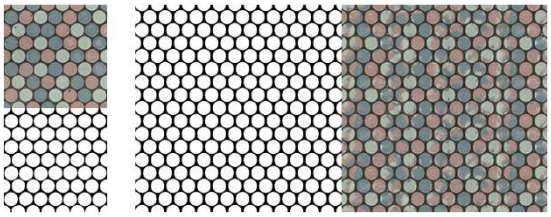
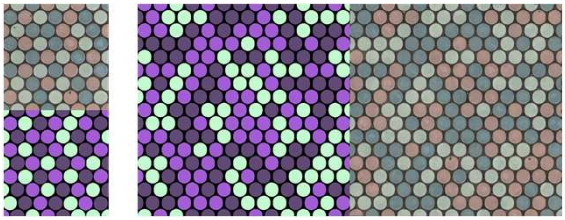
Label-maps

NO label map



mix of colors

WITH label map



no more mix

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Synthesis Results

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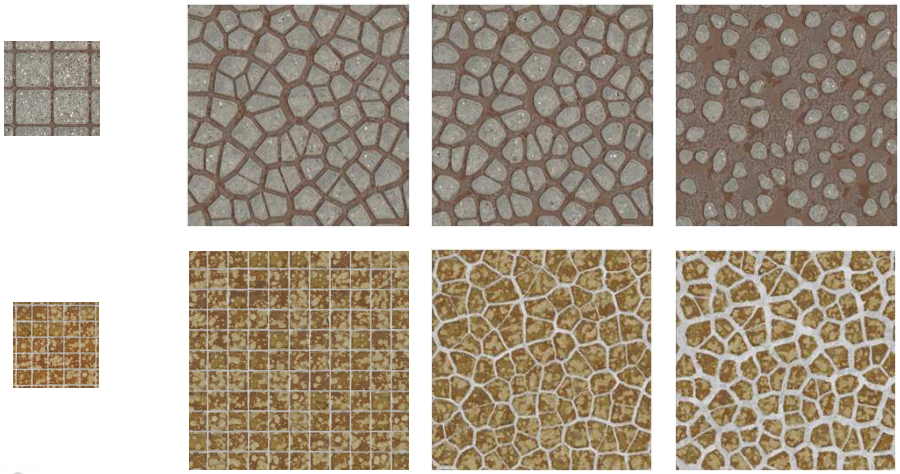
Modify structure



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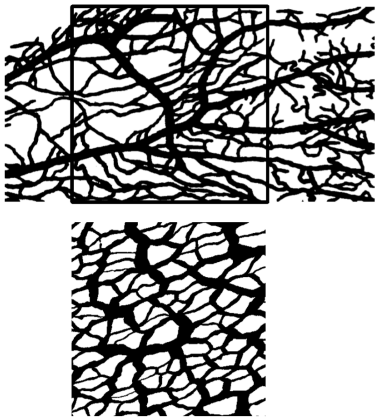
Limitations



Conclusion

Contributions

- Local Fourier Series Noise
- Procedural stochastic structure model
- Semi-procedural texture synthesis
- Database of segmented exemplars
- Database of synthesis results
- Source code available

Future work

- Explore more “non-Gaussian” stochastic processes
- Using machine learning for parameter estimation