

Texture Characterization via Joint Statistics of Wavelet Coefficient Magnitudes

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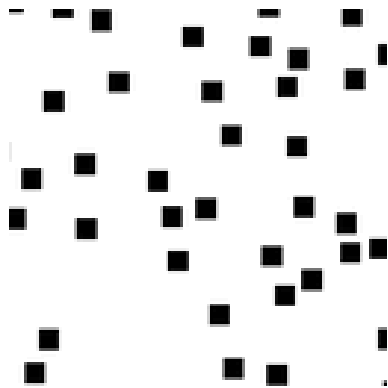
Center for Neural Science, and
Courant Institute of Mathematical Sciences
New York University

Javier Portilla

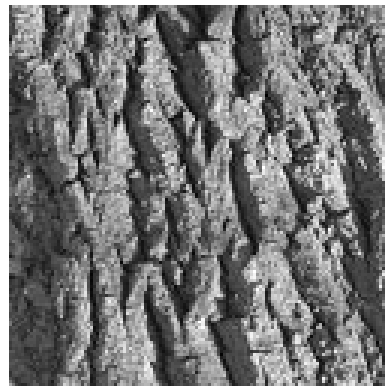
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Example Texture Types

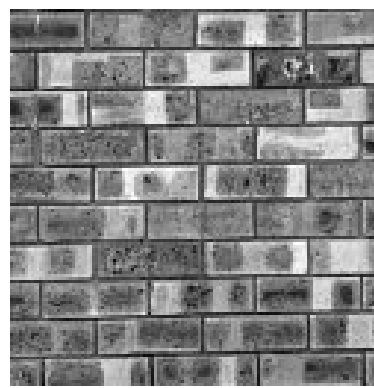
structured



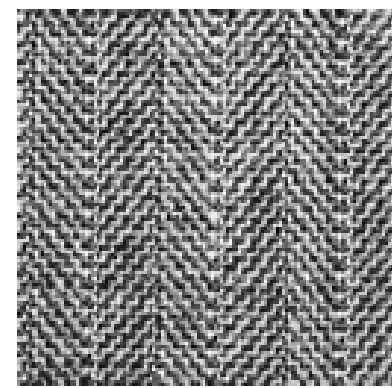
random



periodic

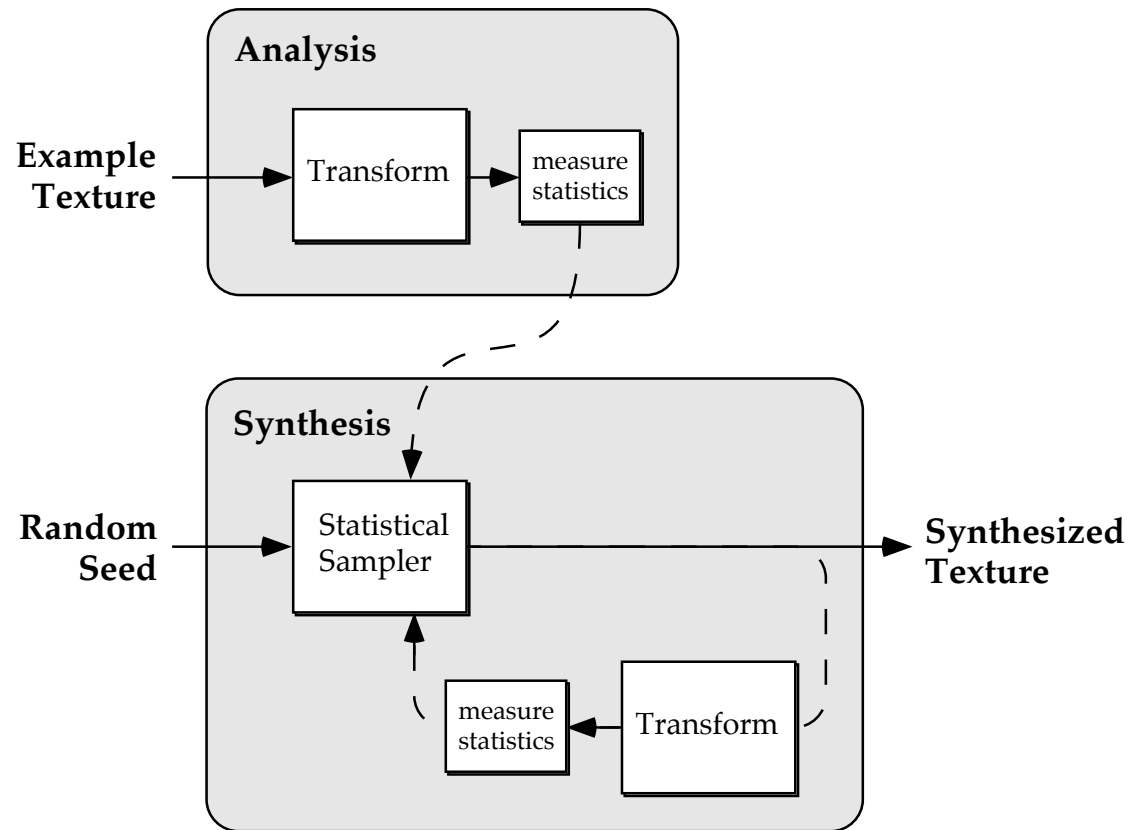


2nd-order



Can we derive a statistical model (and sampling technique) to represent all of these?

Synthesis-by-Analysis

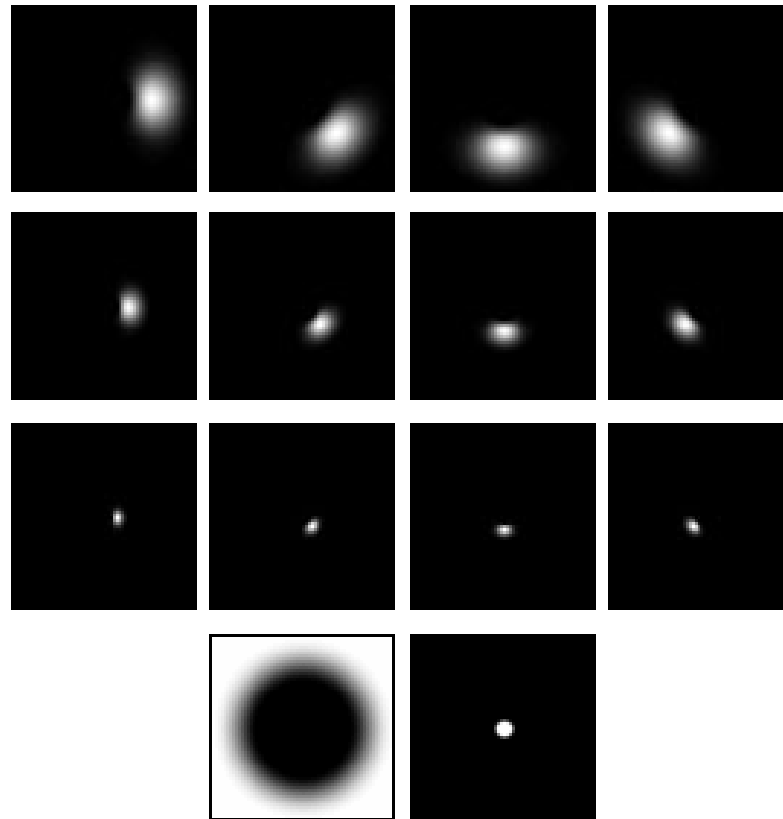


- Choice of statistical measurements crucial
- Proper transform can simplify statistics
- Most algorithms are iterative

Recent Inspirational Approaches

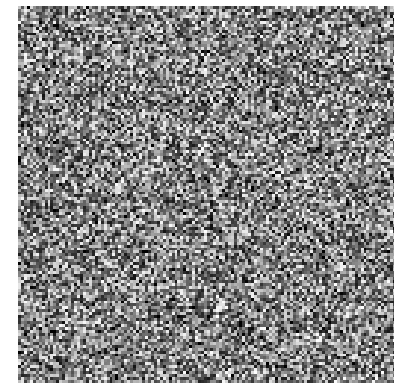
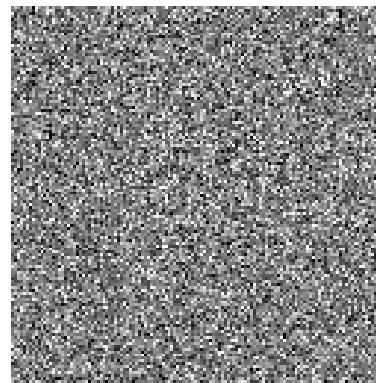
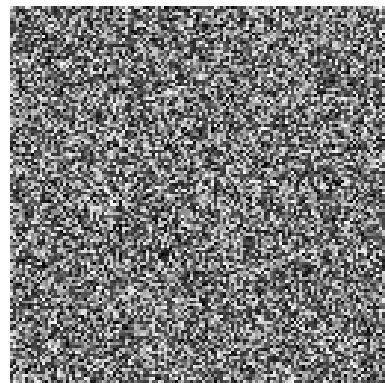
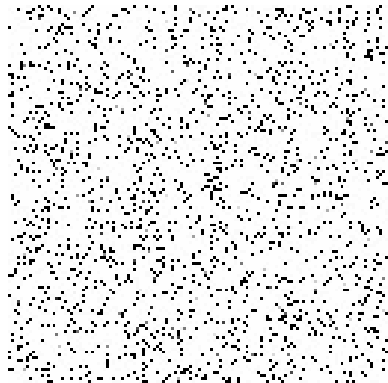
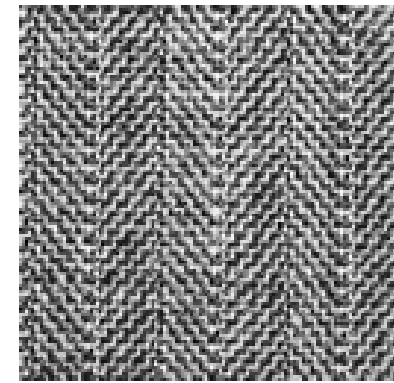
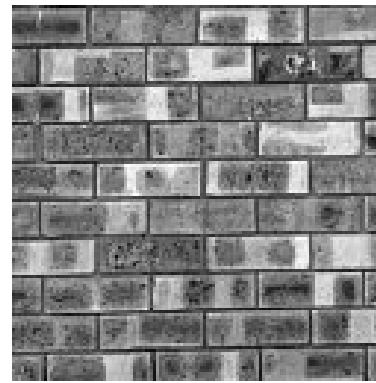
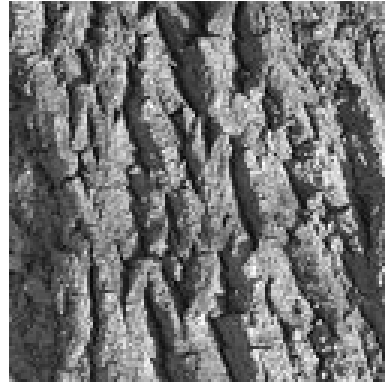
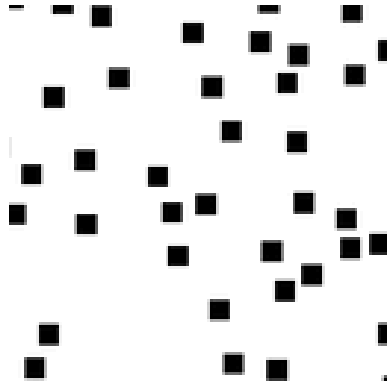
- Portilla et. al. (1996): Adaptive Gabor transform, constrained subband auto-correlation. Weakness: structures.
- Heeger & Bergen (1995): Steerable pyramid, constrained subband marginals (histograms). Weakness: periodicity, extended structures.
- Zhu, Wu & Mumford (1996): Small set of filters, constrained subband marginals, Gibbs sampling (maximal entropy). Weakness: extended structures, efficiency.
- DeBonet & Viola (1997): Laplacian pyramid, coarse-to-fine bootstrap sampling from the scale-conditional empirical neighborhood statistics. Weakness: random textures, no parameterization.

Complex Steerable Pyramid Representation

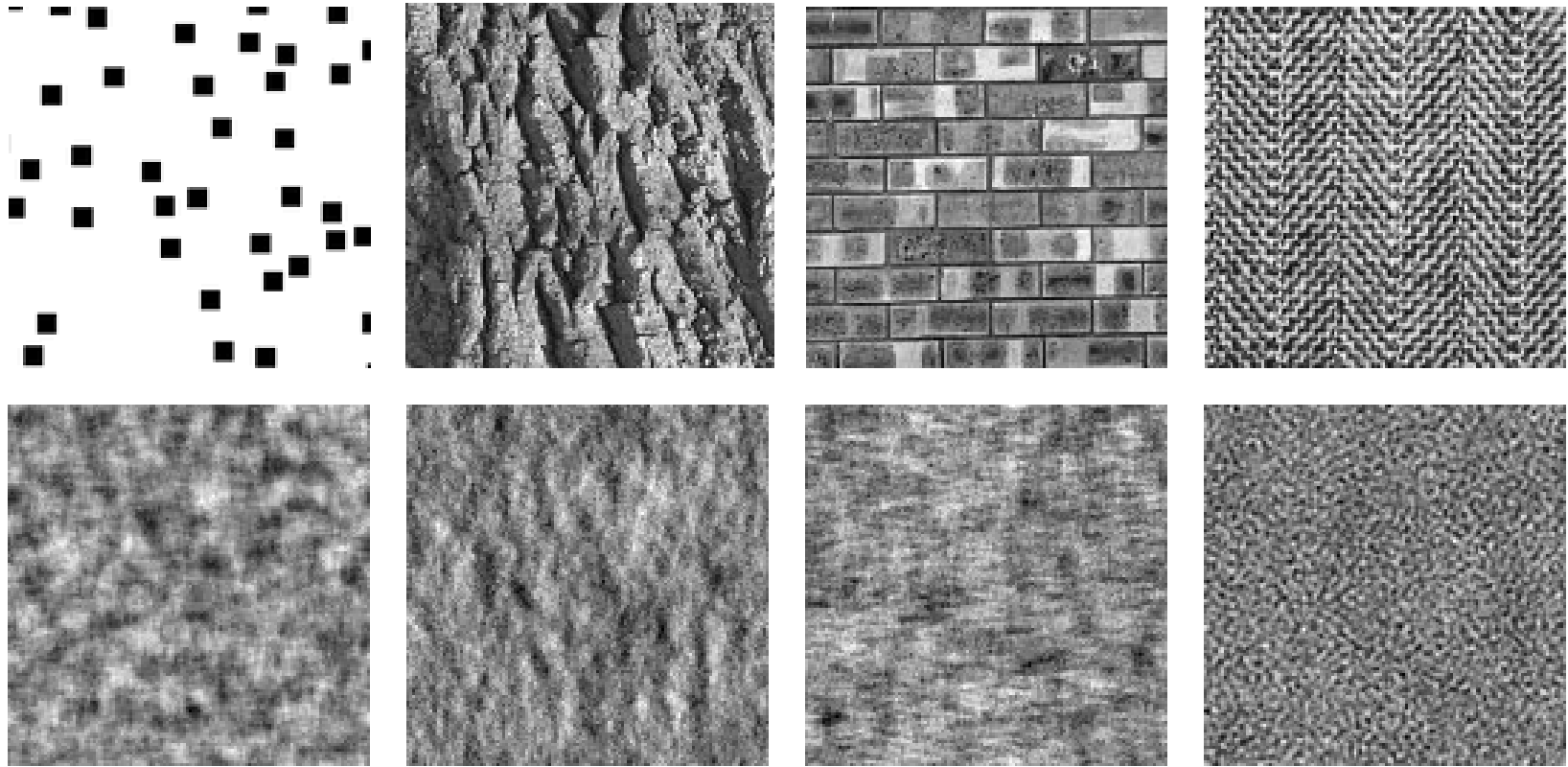


Fourier spectra of 4-orientation 3-scale complex analytic Steerable pyramid.

Matched Pixel Marginals

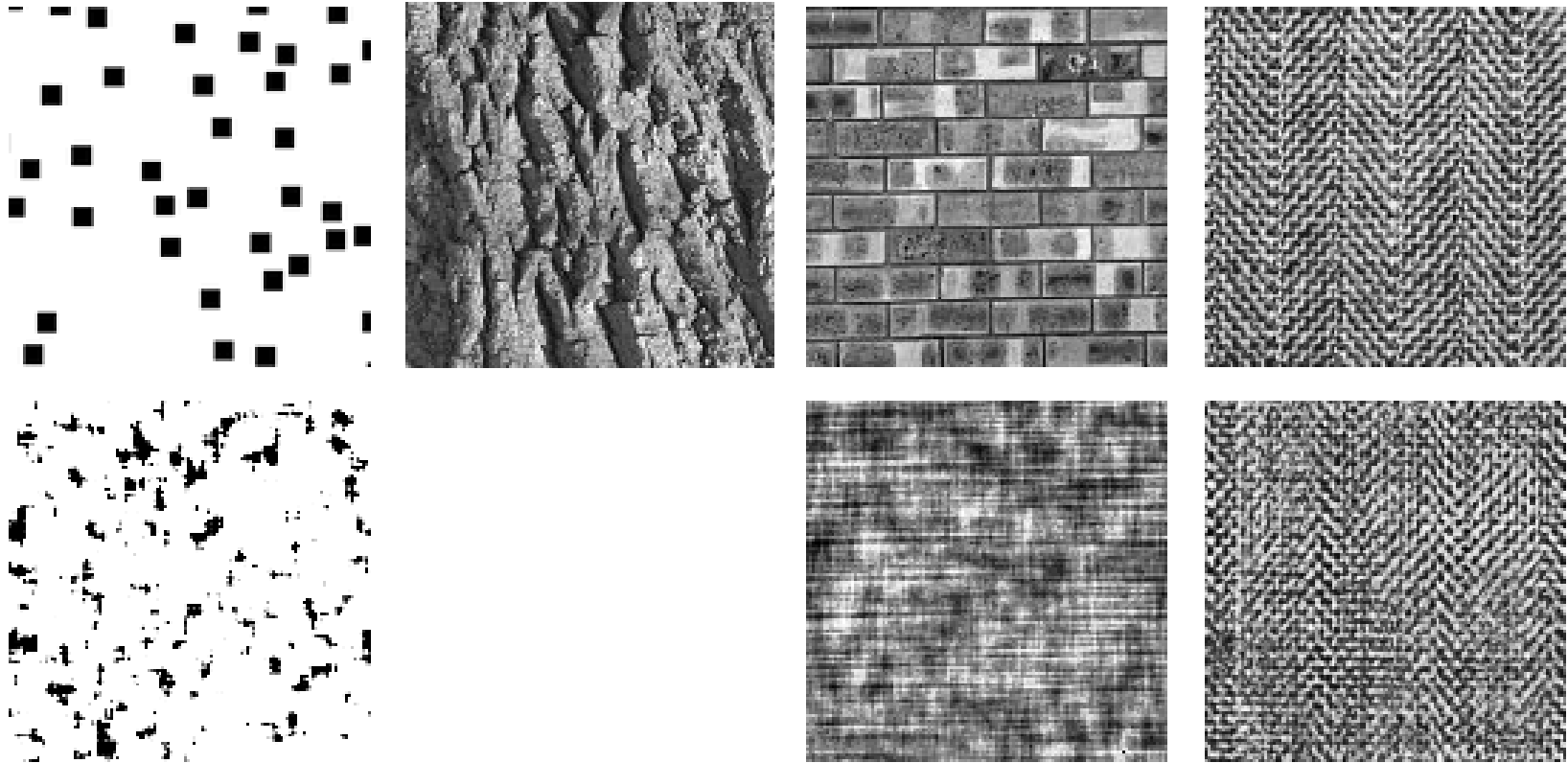


Matched Subband Variances



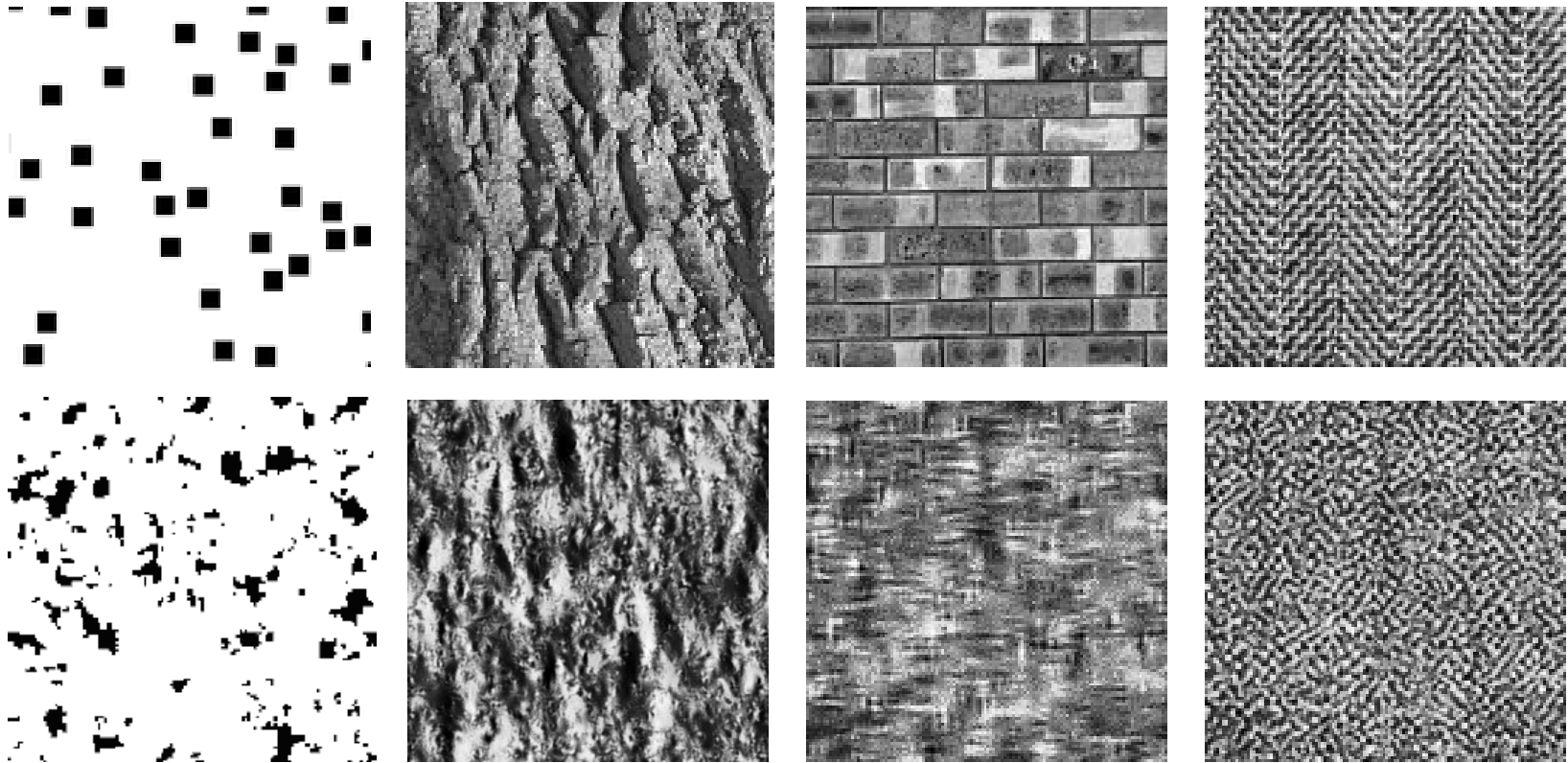
Captures smoothed distribution of energy in frequency domain.

Matched Subband Autocorrelation



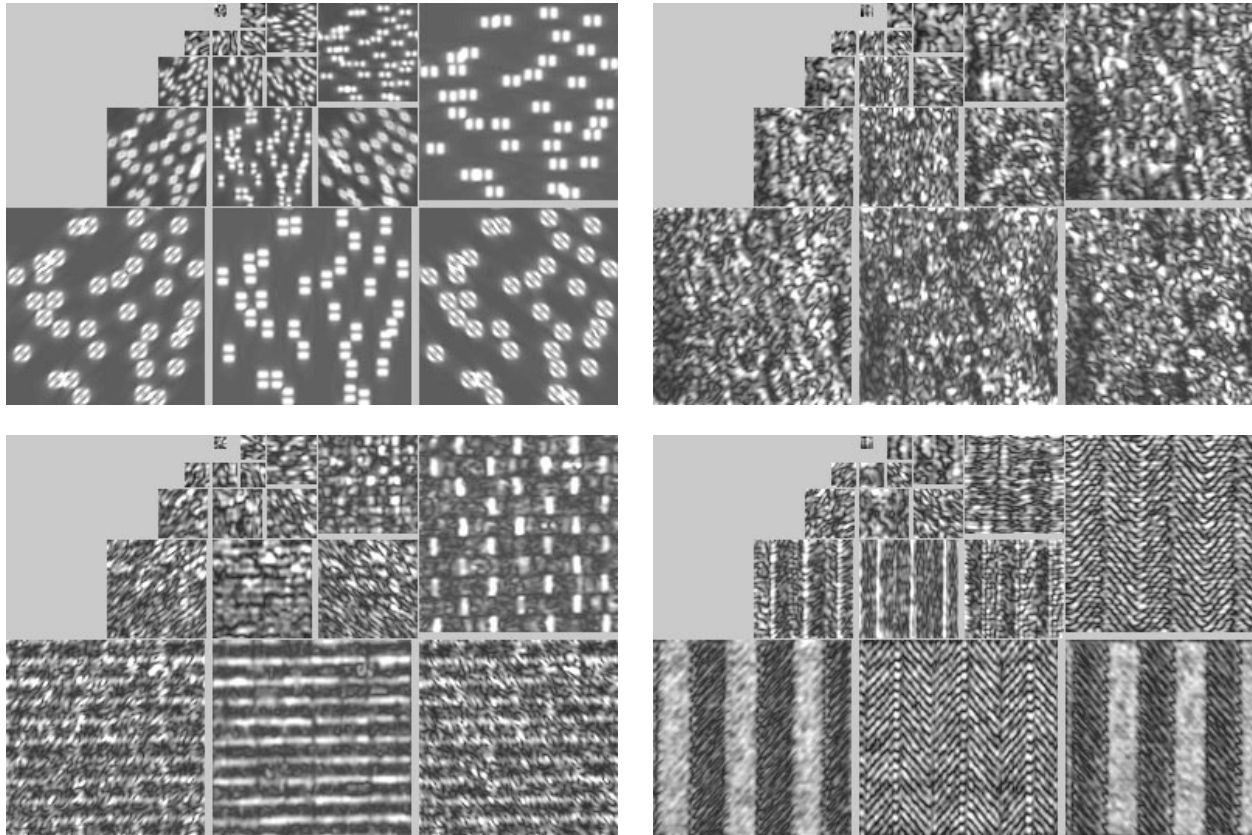
Captures periodicity.

Matched Subband Marginals



Captures some local structure.

Subband Magnitudes



Correlated or anti-correlated magnitudes capture important structure.

Texture Model Parameters

- Coefficient magnitude correlations:

$$\mathcal{E}(|c_i| \cdot |c_j|)$$

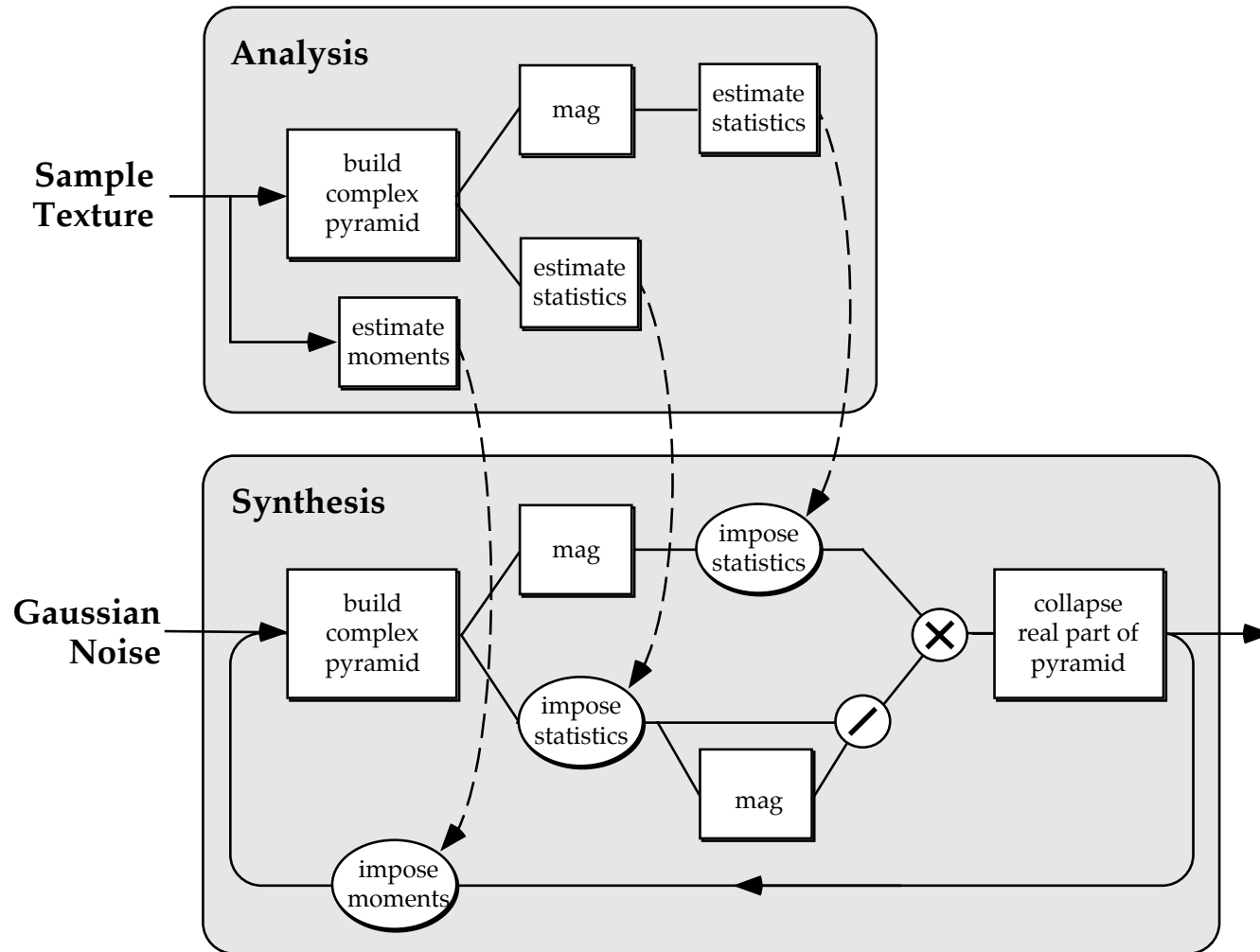
- Raw coefficient auto-correlation:

$$\mathcal{E}(c_x \cdot c_{x-\Delta})$$

- Pixel statistics: mean, variance, skew, kurtosis, min, max.

$$\left. \begin{array}{l} 7 \times 7 \text{ neighborhoods} \\ 4 \text{ orientations} \\ 4 \text{ scales} \end{array} \right\} \Rightarrow \sim 870 \text{ parameters}$$

Texture Synthesis System



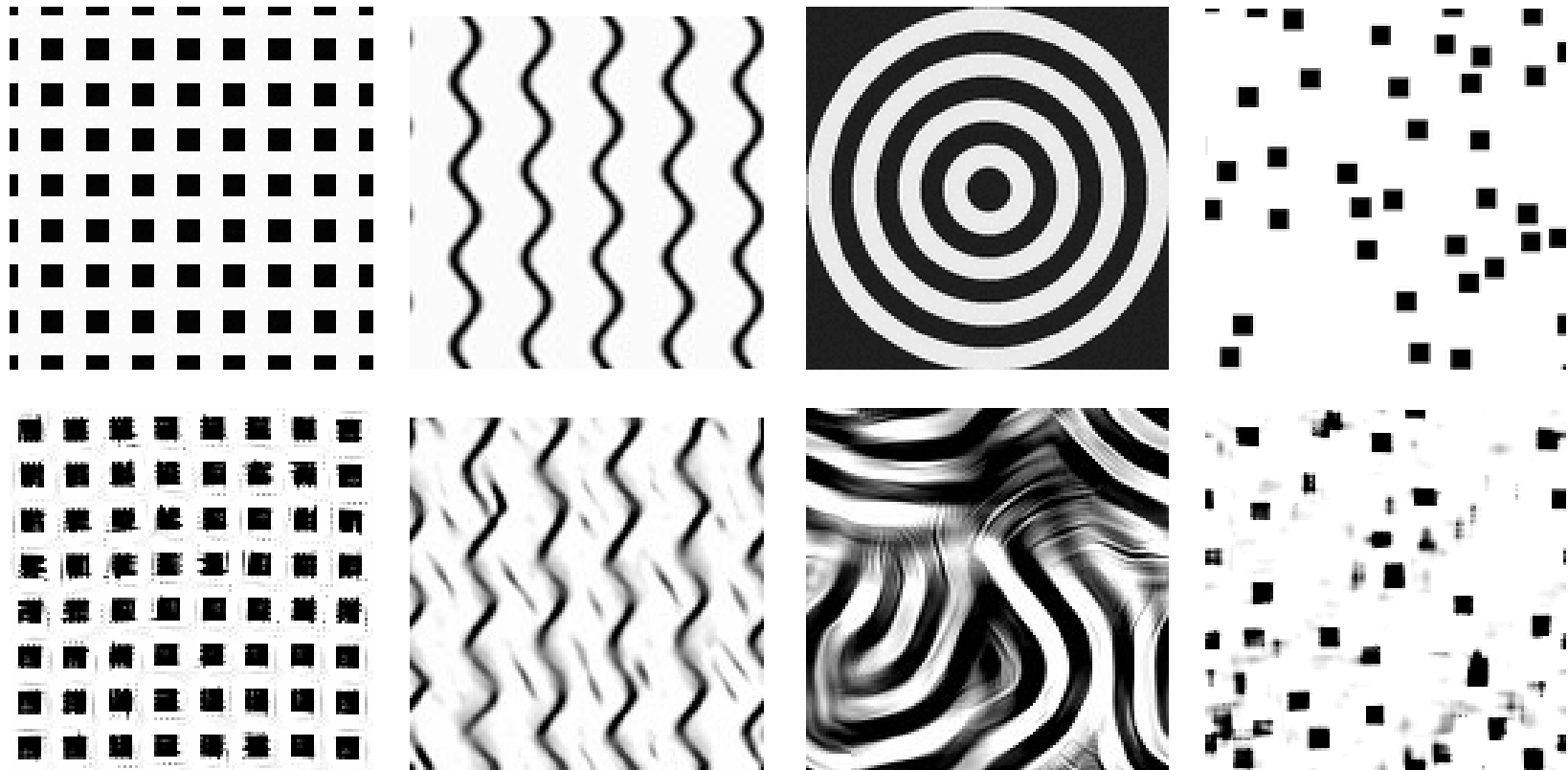
Projection onto Constraint Surfaces

- Joint magnitudes*: match correlation of local (spatial position, orientation, scale) *magnitudes*. Find linear transformation A

minimizing: $\mathcal{E}(\|\vec{Q} - A\vec{Q}\|^2)$

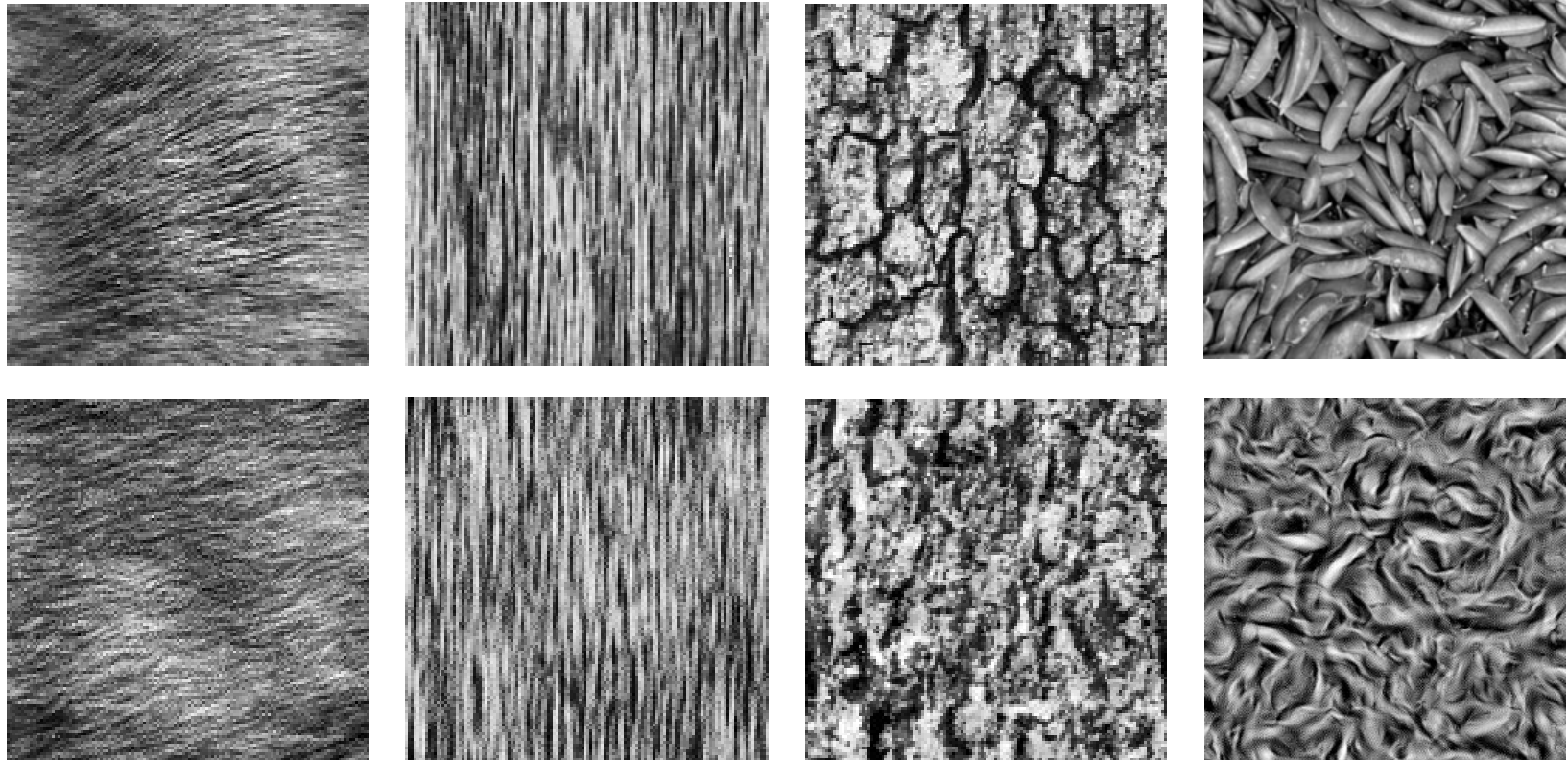
subject to: $\mathcal{E}(A\vec{Q}\vec{Q}^T A^T) = \mathcal{E}(\vec{Q}_0\vec{Q}_0^T)$.

Synthesis Results



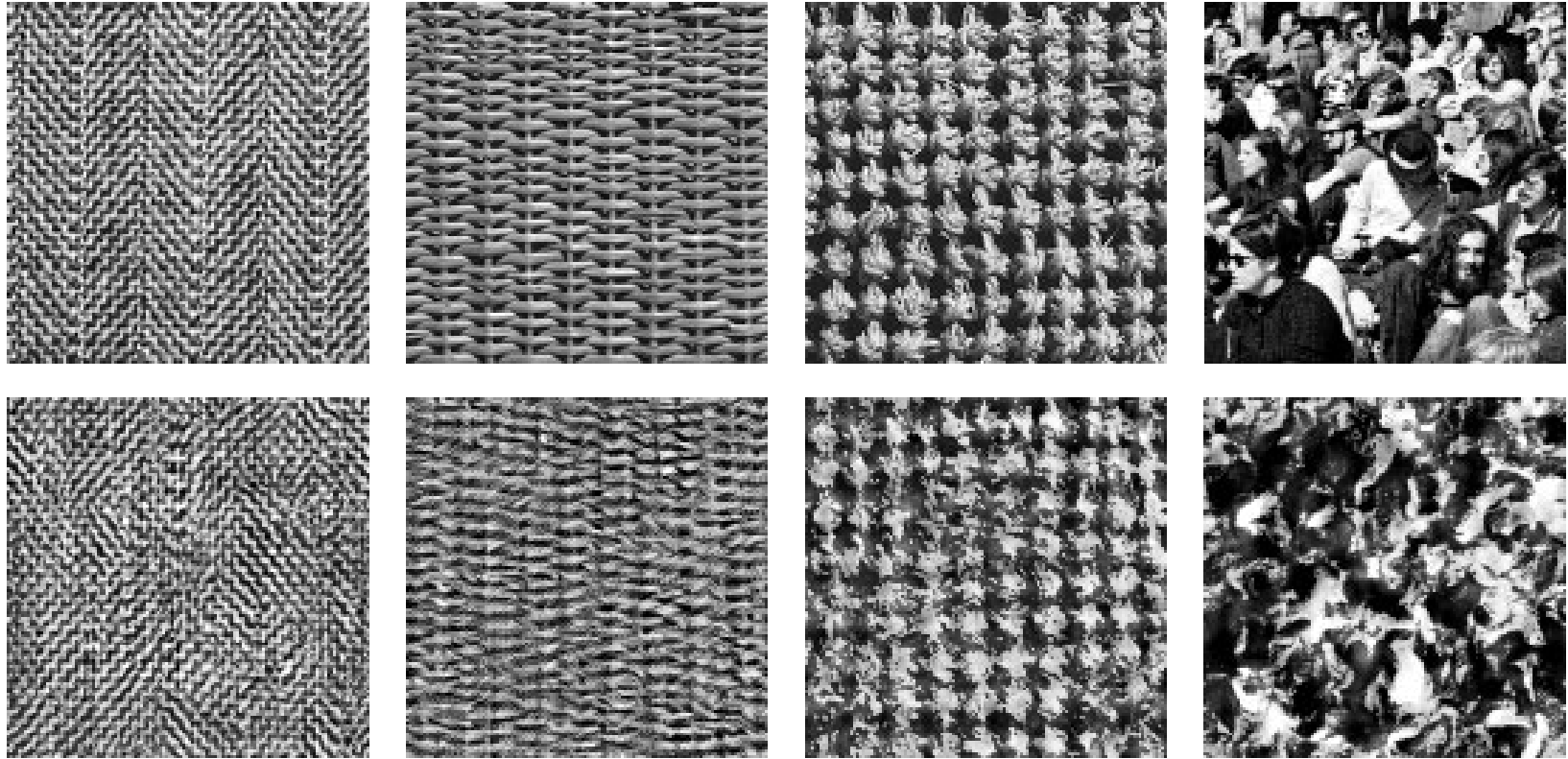
Artificial textures.

Synthesis Results



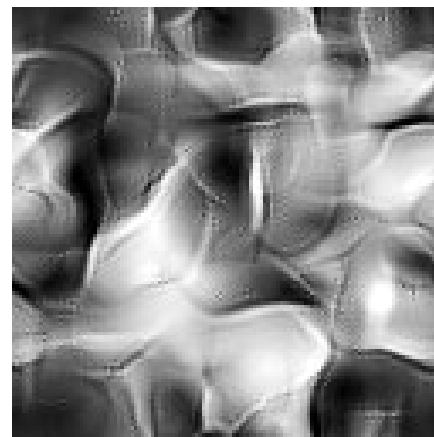
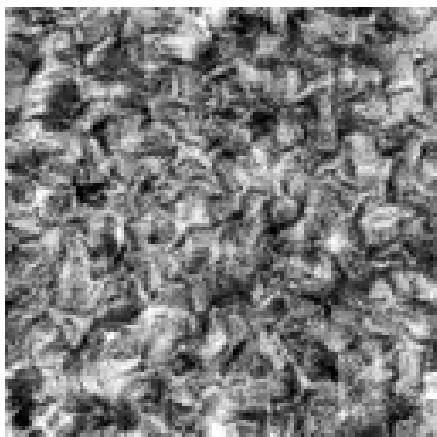
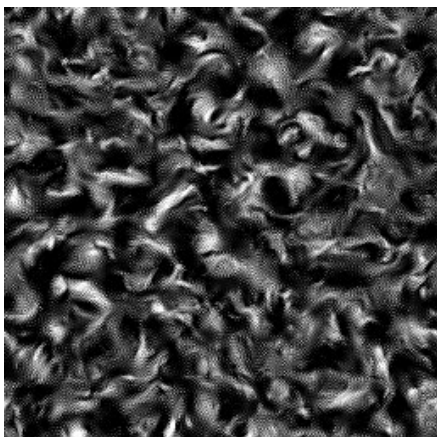
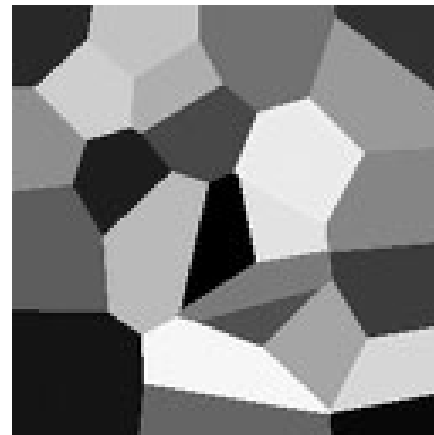
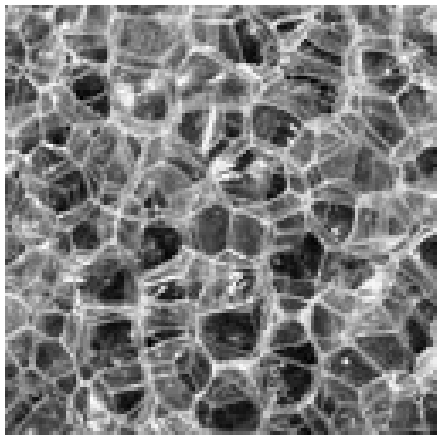
Natural textures, random.

Synthesis Results

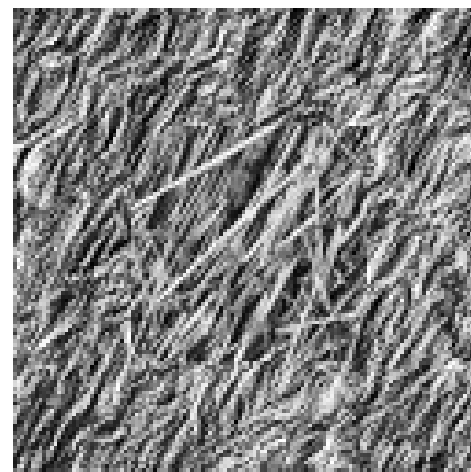
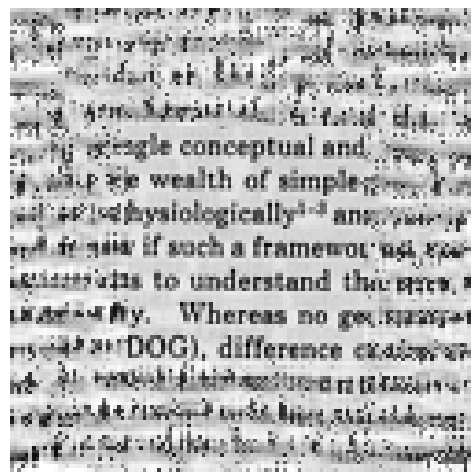
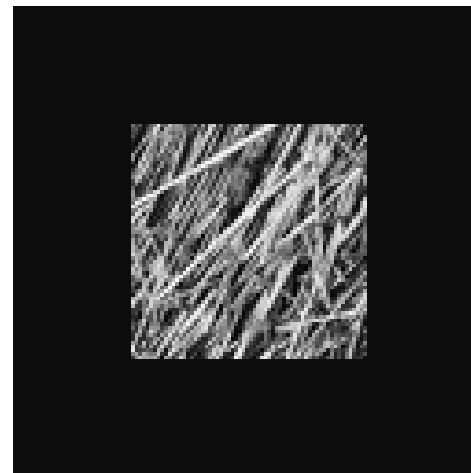
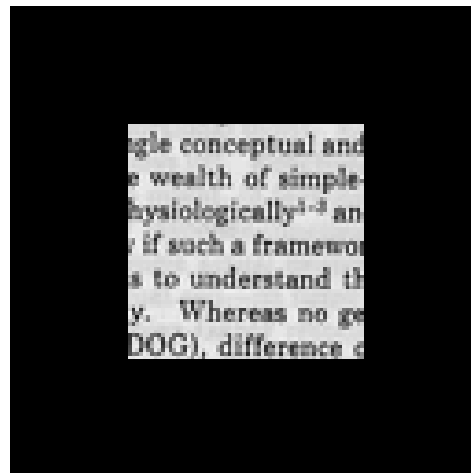


Natural textures, structured.

Synthesis Failures



Spatial Extrapolation



Scale Extrapolation

