BACON: Band-limited Coordinate Networks for Multiscale Scene Representation

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Abstract

Coordinate-based networks have emerged as a powerful tool for 3D representation and scene reconstruction.
However,

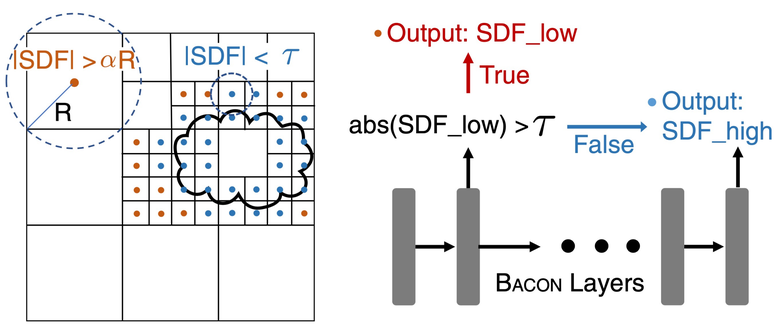
- Current architectures are black boxes:
  - Spectral characteristics are difficult to analyze.
  - Unsupervised behavior is difficult to predict.
- Naive down/up-sampling often results in artifacts.

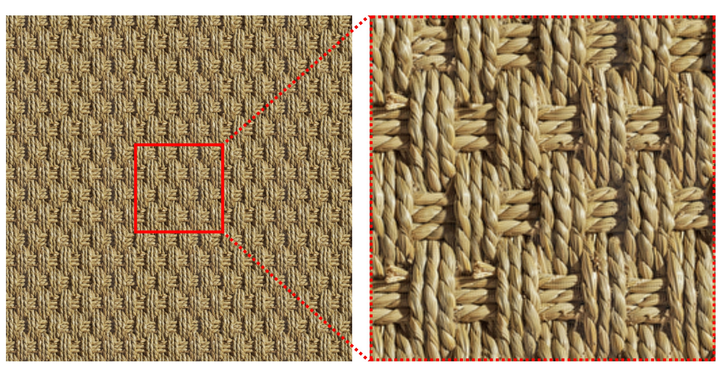
We introduce band-limited coordinate networks (BACON), an architecture with an analytical Fourier spectrum.
Features:

- Predictable behavior at unsupervised points
- Design according to the spectral characteristics of the represented signal
- Multi-scale representation without explicit supervision

Network Properties

Adaptive-frequency multiscale SDF evaluation for 80x faster mesh extraction (**top**). Periodic extrapolation (**bottom**).



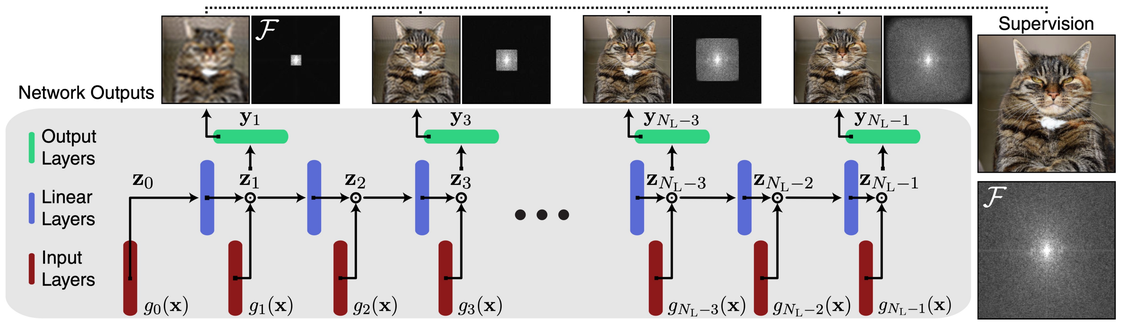


Band-limited Coordinate Networks

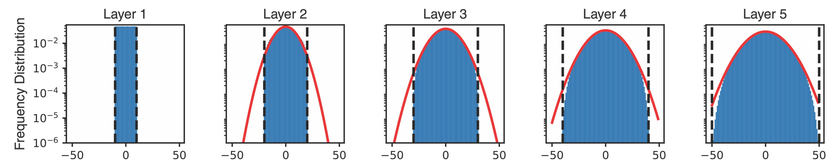
Let $g_i(\mathbf{x}) = \sin(\boldsymbol{\omega}_i \mathbf{x} + \boldsymbol{\phi}_i)$
Then extract the i[th] layer via:

$$\mathbf{z}_0 = g_0(\mathbf{x})$$
$$\mathbf{z}_i = g_i(\mathbf{x}) \circ (\mathbf{W}_i \mathbf{z}_{i-1} + \mathbf{b}_i), \quad 0 \leq i < N_\mathrm{L}$$
$$\mathbf{y}_i = \mathbf{W}_i^\mathrm{out} \mathbf{z}_i + \mathbf{b}_i^\mathrm{out},$$

a formulation which bypasses the compositional structure of standard coordinate networks, e.g.[1].

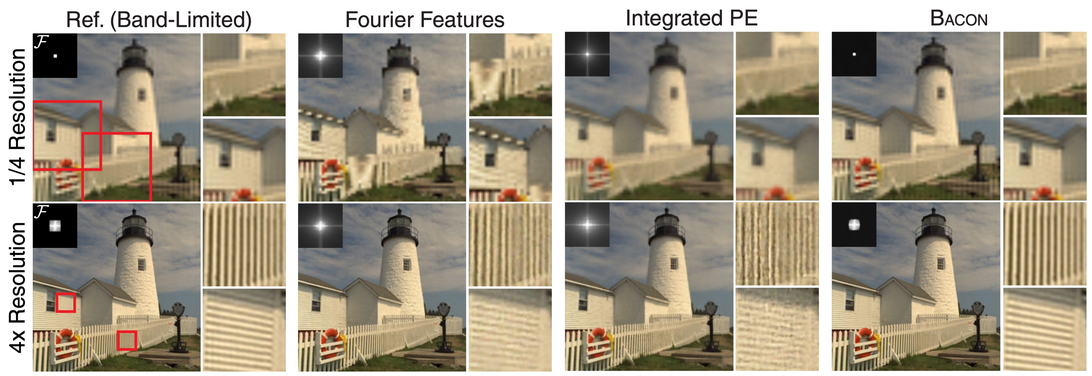


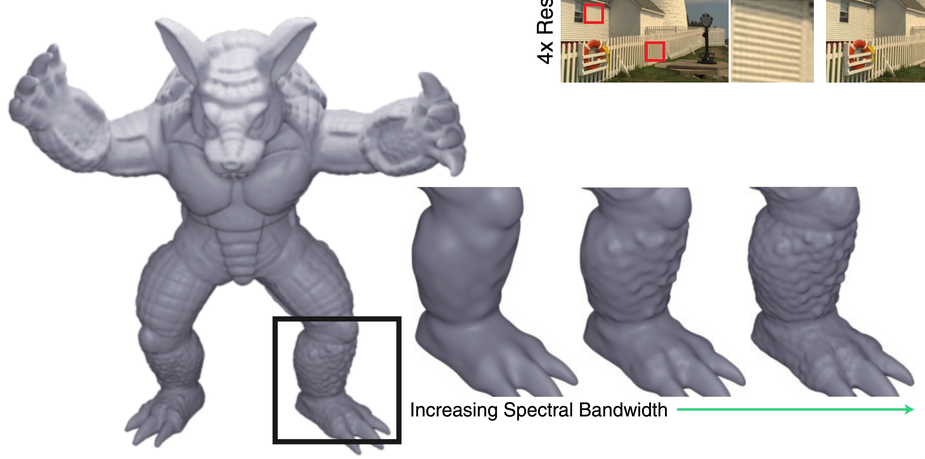
Hence the entire network can be expressed as a sum of sines. The distribution of frequencies (**right**: empirical, theoretical) shows increasing bandwidth in later layers.

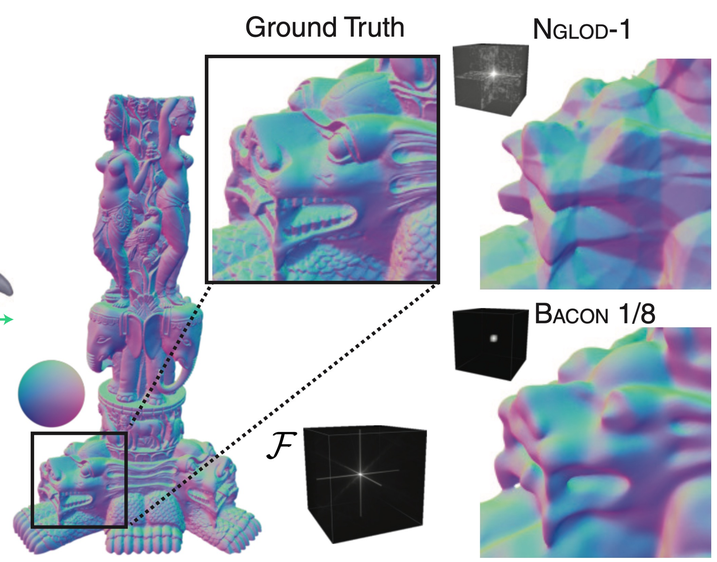


Results

Contrasted with other methods, BACON permits down/up-sampling without aliasing or artifacts (**top right**) as well as smooth, band-limited shape [2] decomposition (**bottom**) requiring fewer parameters than other multiscale methods, e.g. NGLOD [3].







	FF	SIREN	NGLOD-4	NGLOD-5	BACON 1×
# Params.	527K	528K	1.35M	10.1M	531K
Chamfer↓	**2.166e-6**	2.780e-6	8.358e-6	2.422e-6	2.198e-6
IOU ↑	**9.841e-1**	9.751e-1	9.479e-1	9.811e-1	9.833e-1

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References: [1] Sitzmann et. al., Implicit Neural Representations with Periodic Activation Functions, *Proc. NeurIPS*, 2020.
[2] Stanford 3D Scanning Repository [3] Takikawa et al., Neural Geometric Level of Detail, *Proc. CVPR*, 2021.

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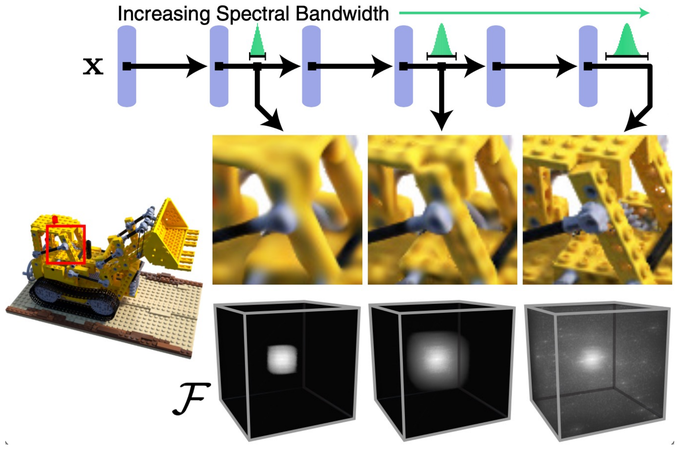
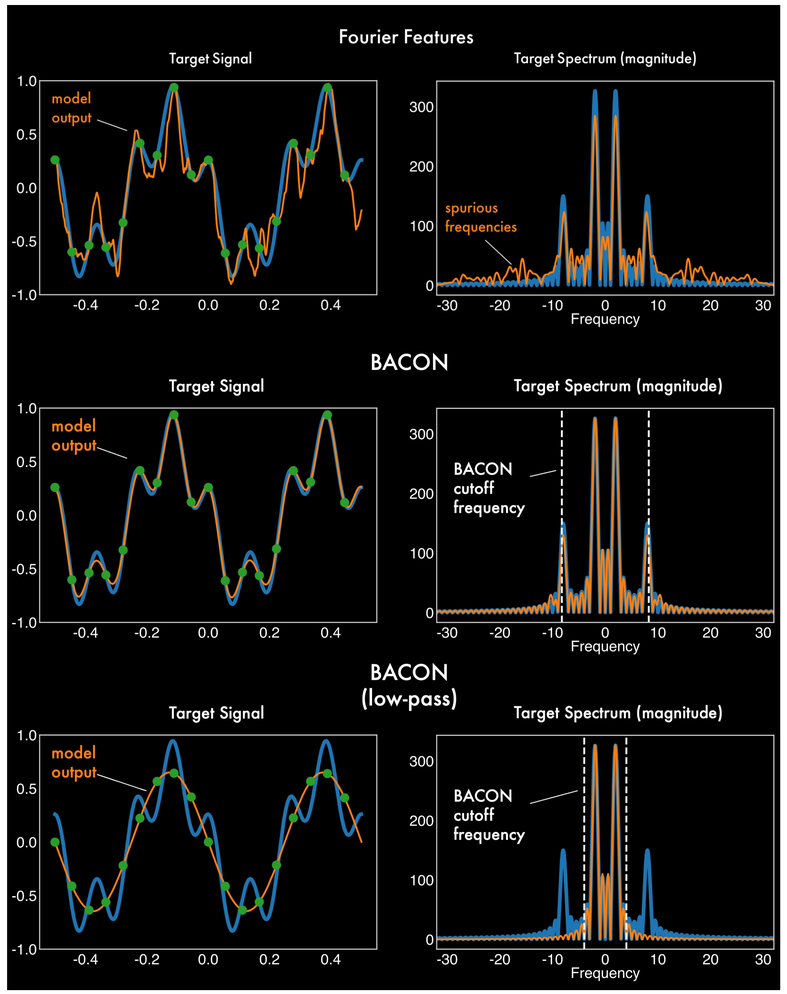
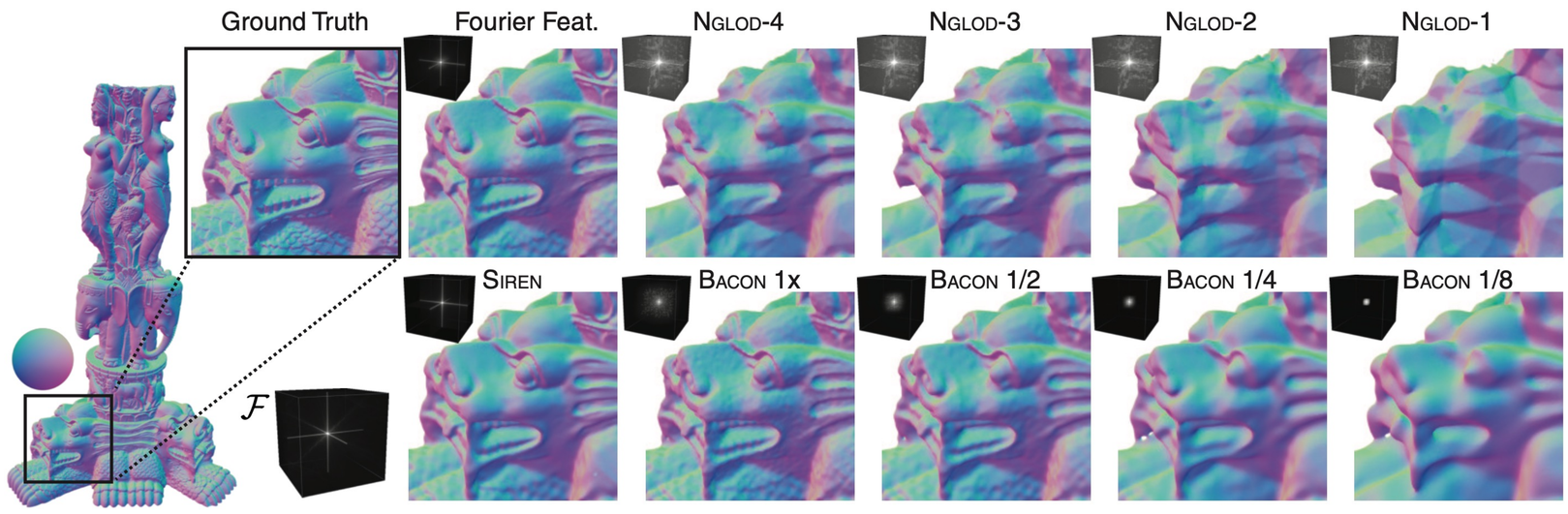
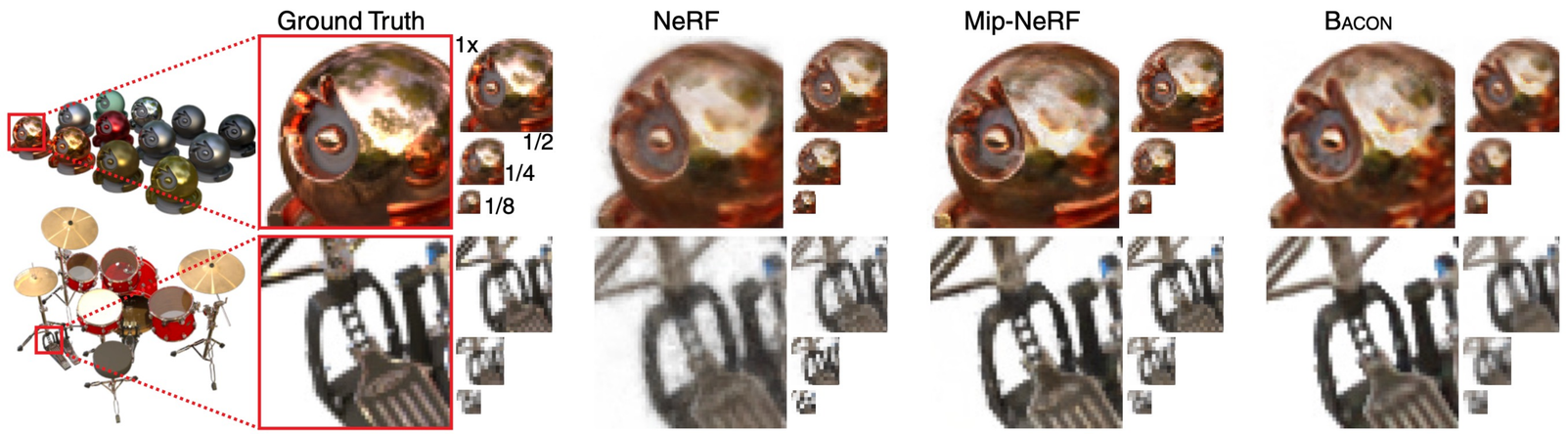
Supplemental Intuition





Supplemental Results: 3D shapes and neural rendering





	PSNR ↑					# Params.			
	1×	1/2	1/4	1/8	Avg.	1×	1/2	1/4	1/8
NeRF	26.734	28.941	29.297	26.464	27.859	511K			
Mip-NeRF	29.874	31.307	32.093	32.832	**31.526**	511K			
BACON	27.430	28.066	28.520	28.475	<u>28.123</u>	531K	398K	266K	133K

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