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Learning Generative Models for Rendering Specular Microgeometry

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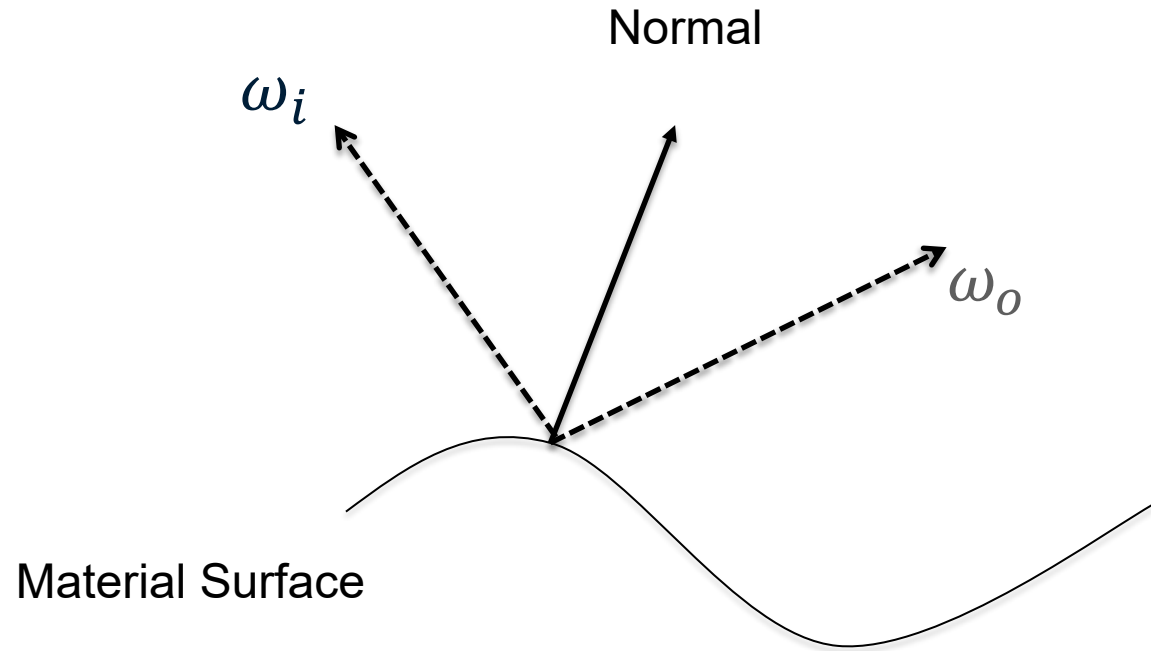
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Reflectance (BRDF)

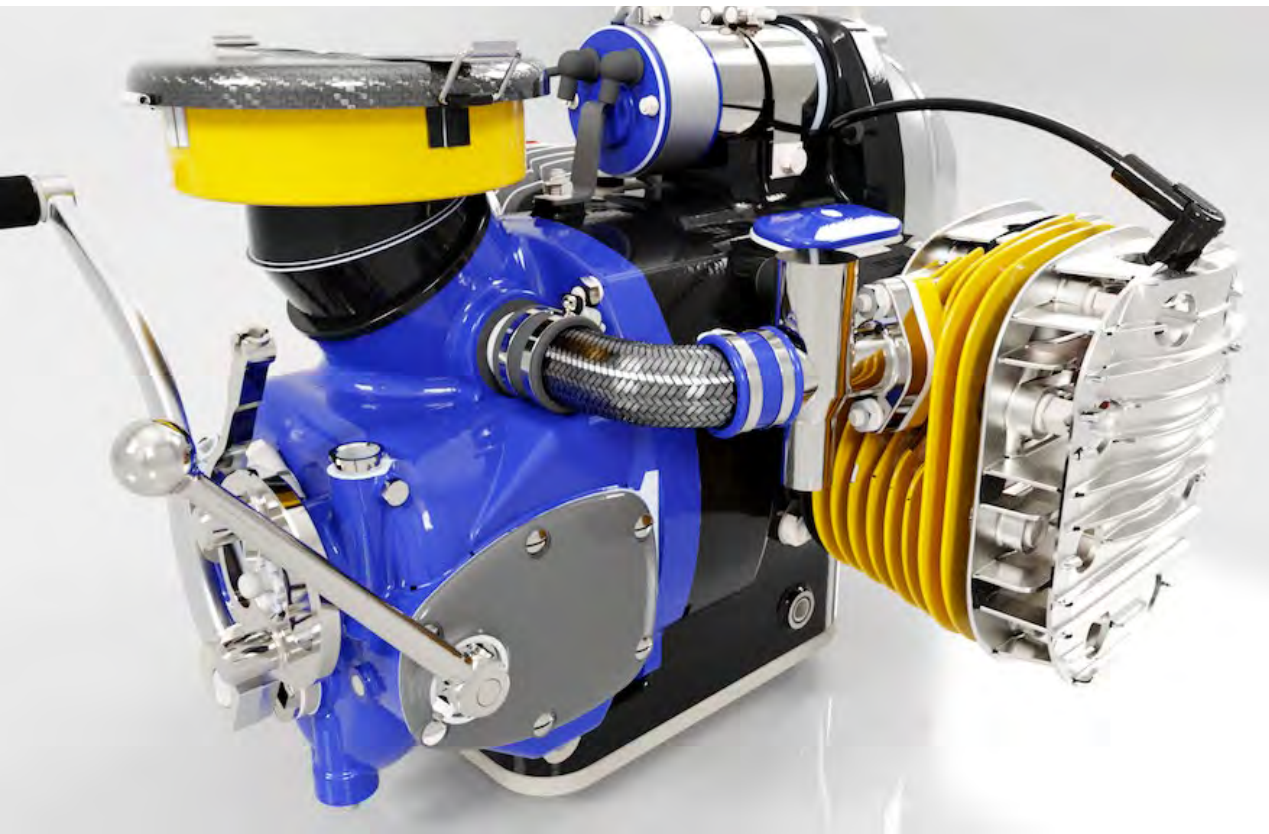




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Microfacet BRDF

- Standard material model
- Microfacet BRDFs Fails to capture imperfections



Real World Specular Surfaces

A close-up photograph of a brushed metal surface. The surface is dark and has a fine, linear texture. A bright, elongated highlight is visible, reflecting light from the upper left.

Brushed Metal

A close-up photograph of a fabric surface. The fabric is a deep magenta or red color and is heavily wrinkled and folded, creating a complex, non-uniform texture.

Fabric

A close-up photograph of a sandblasted metal surface. The surface is dark and has a fine, granular texture. A bright, elongated highlight is visible, reflecting light from the upper left.

Sandblasted Finish

A close-up photograph of a dual brushed metal surface. The surface is dark and has a fine, linear texture. A bright, elongated highlight is visible, reflecting light from the upper left.

Dual Brushed Metal

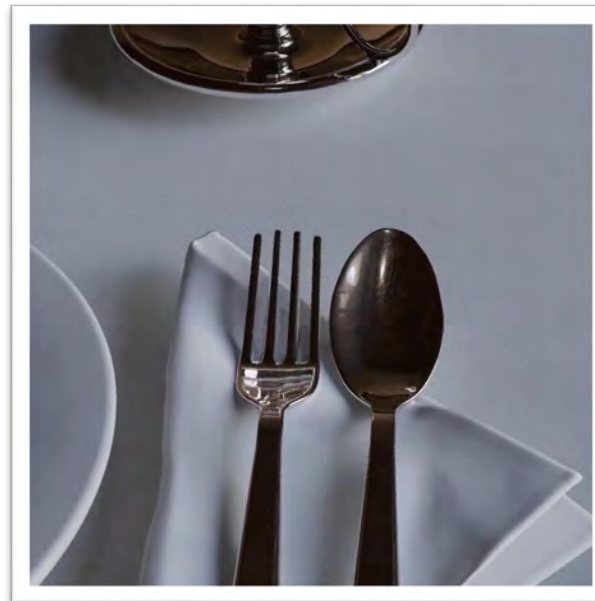


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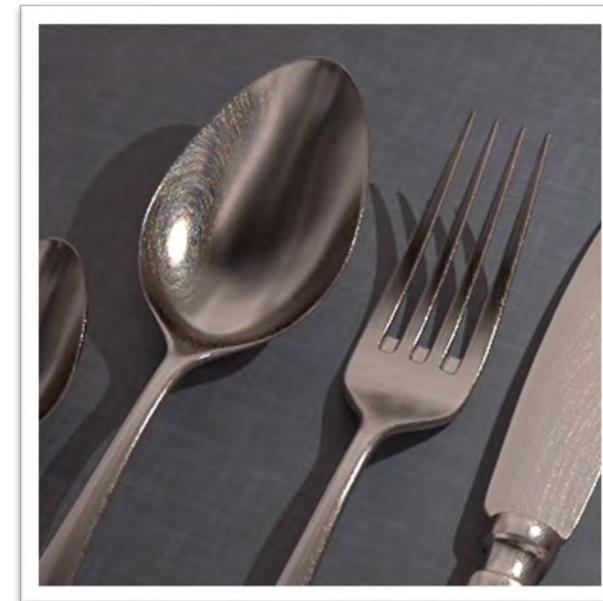
Specular Microgeometry Works



Rendering Glints on High-Resolution Normal-Mapped Specular Surfaces
by Yan et al. 2014



Scratch Iridescence: Wave-Optical Rendering of Diffractive Surface Structure
by Werner et al. 2017

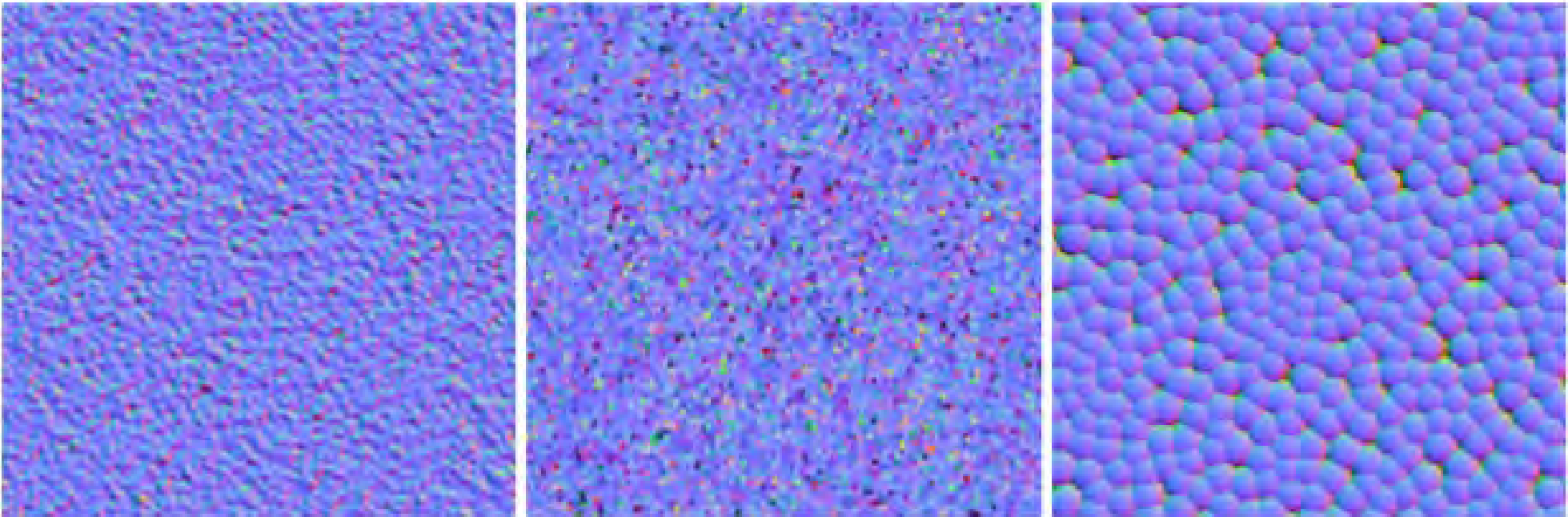


Rendering Specular Microgeometry with Wave Optics
by Yan et al. 2018



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NDF for rendering



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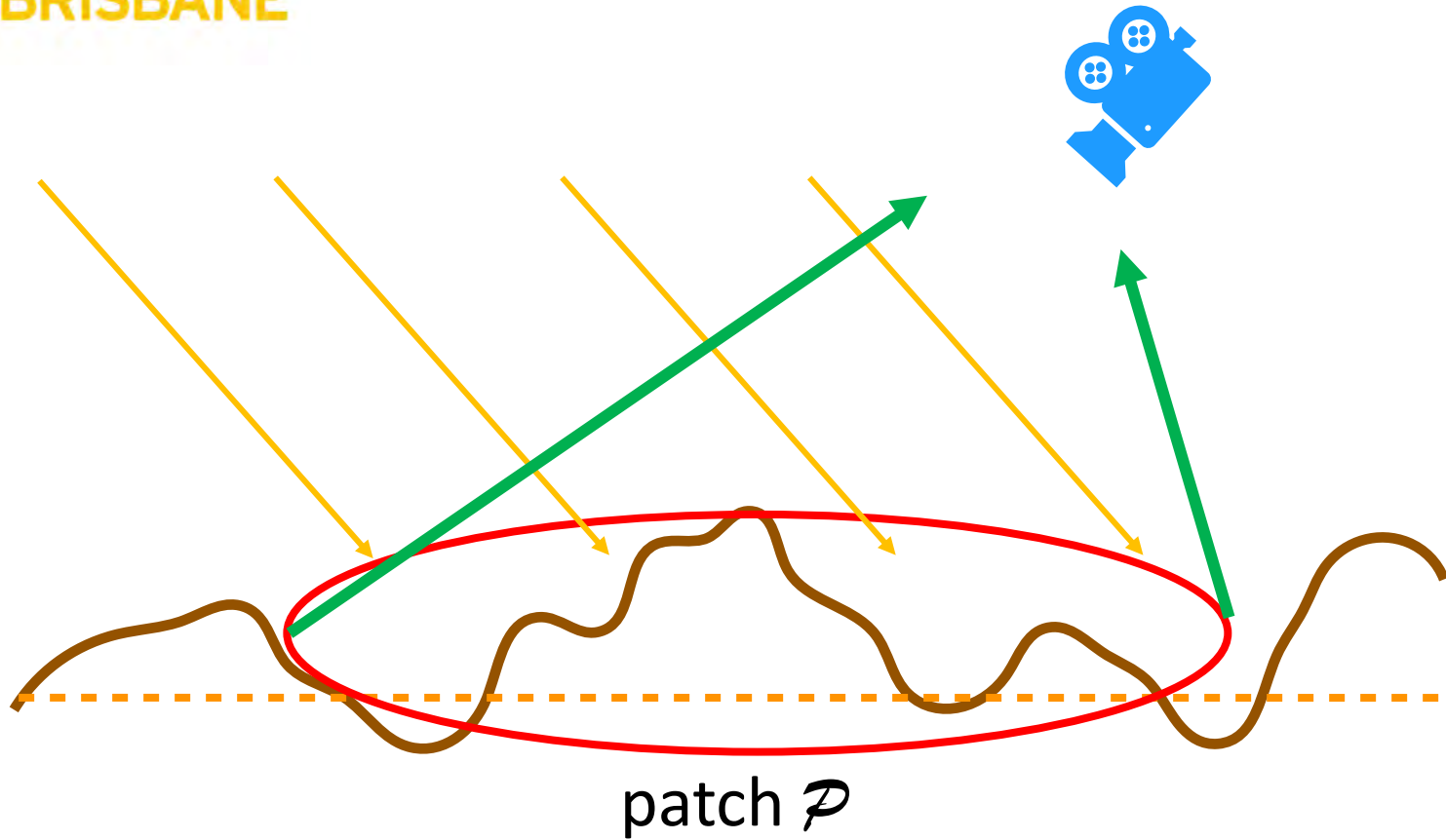
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NDF for rendering



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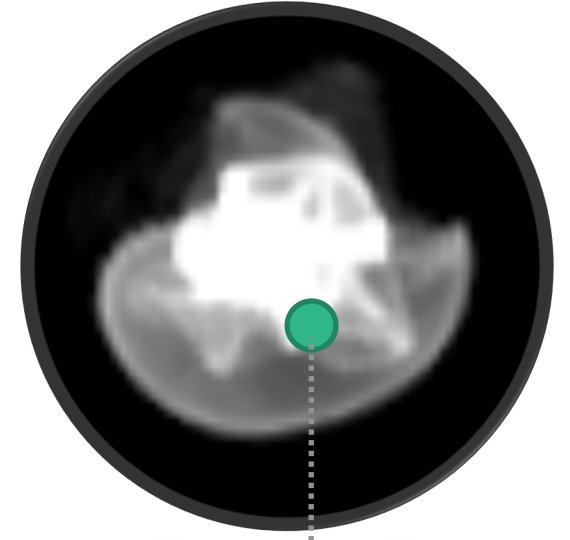
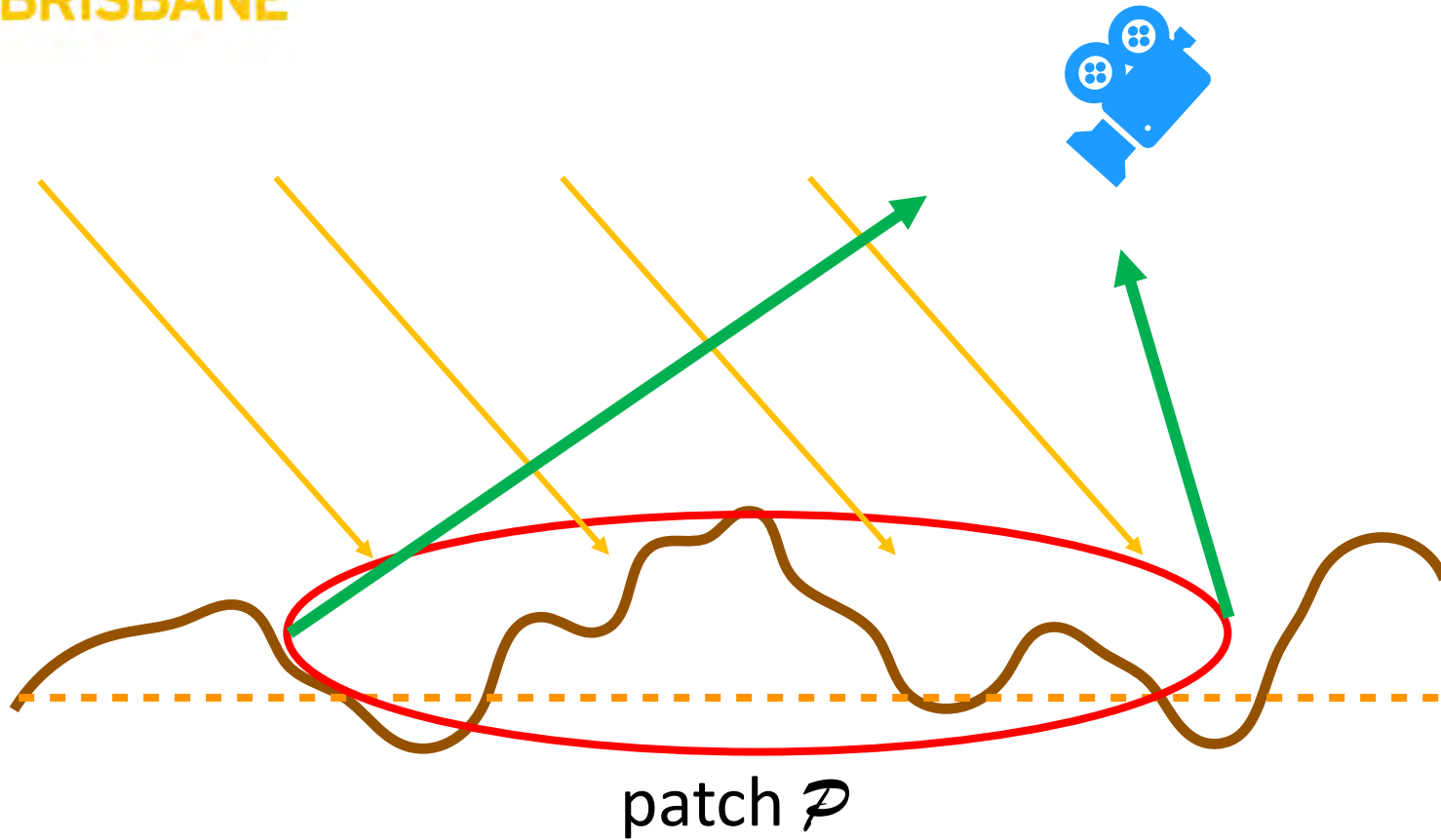
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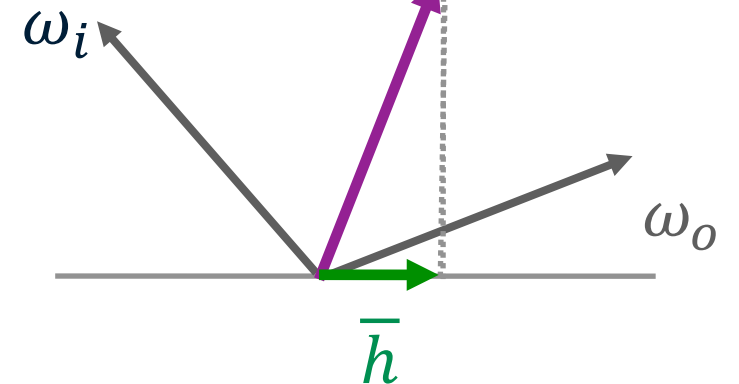
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NDF for rendering



NDF

$$h = \frac{\psi}{\|\psi\|} = \frac{i + o}{|i + o|}$$





Limitations of Previous Works

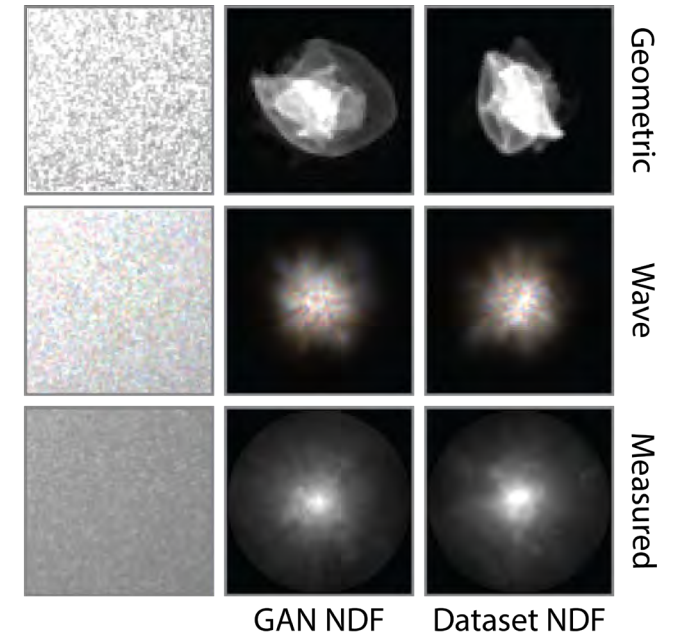
- Requires explicit heightfield
 - Explicit scratches
 - Hard to acquire
 - Memory Intensive
- Complexity of material
- Limited to simulations
 - No fabric
 - No captured materials



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Main Contributions

- First to use GAN to render
 - Performance is independent of material complexity
 - Synthesize infinite surfaces
 - Measured data
 - Small storage requirement
- Unify different methods
- Partial Evaluation of CNN
 - 50x faster





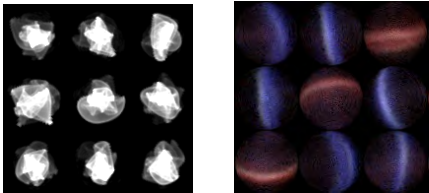
Our Pipeline

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Data Acquisition

Simulation

- Geometric
- Wave
- Fabric Capture



Stochastic

GAN

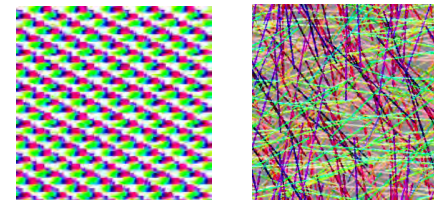
Training

Spatial Correlation

CGAN

Feature Vector
Texture

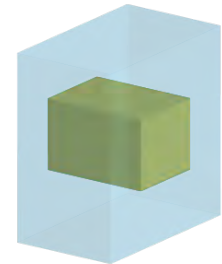
Texture Synthesis



Rendering

Partial Evaluation
of CNN

partial
4 x 4 x 64

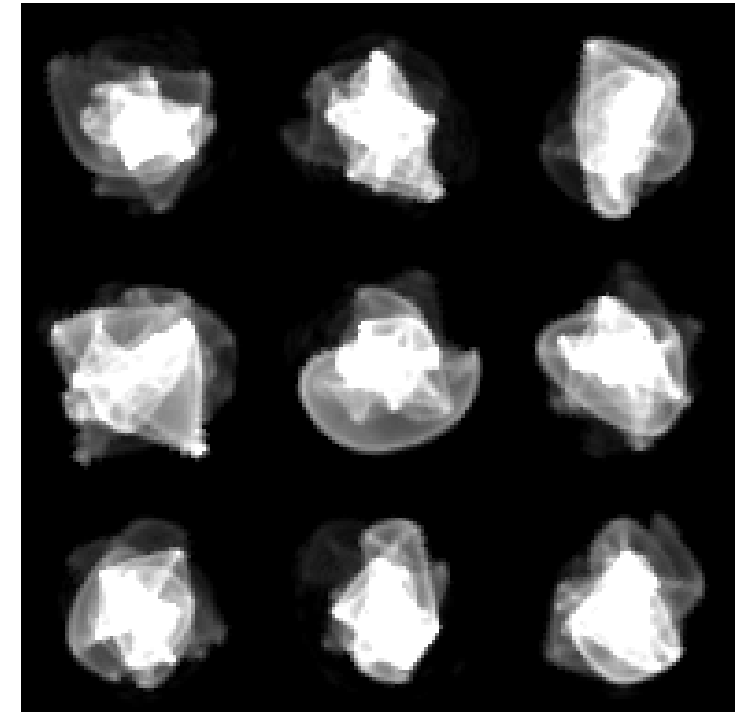
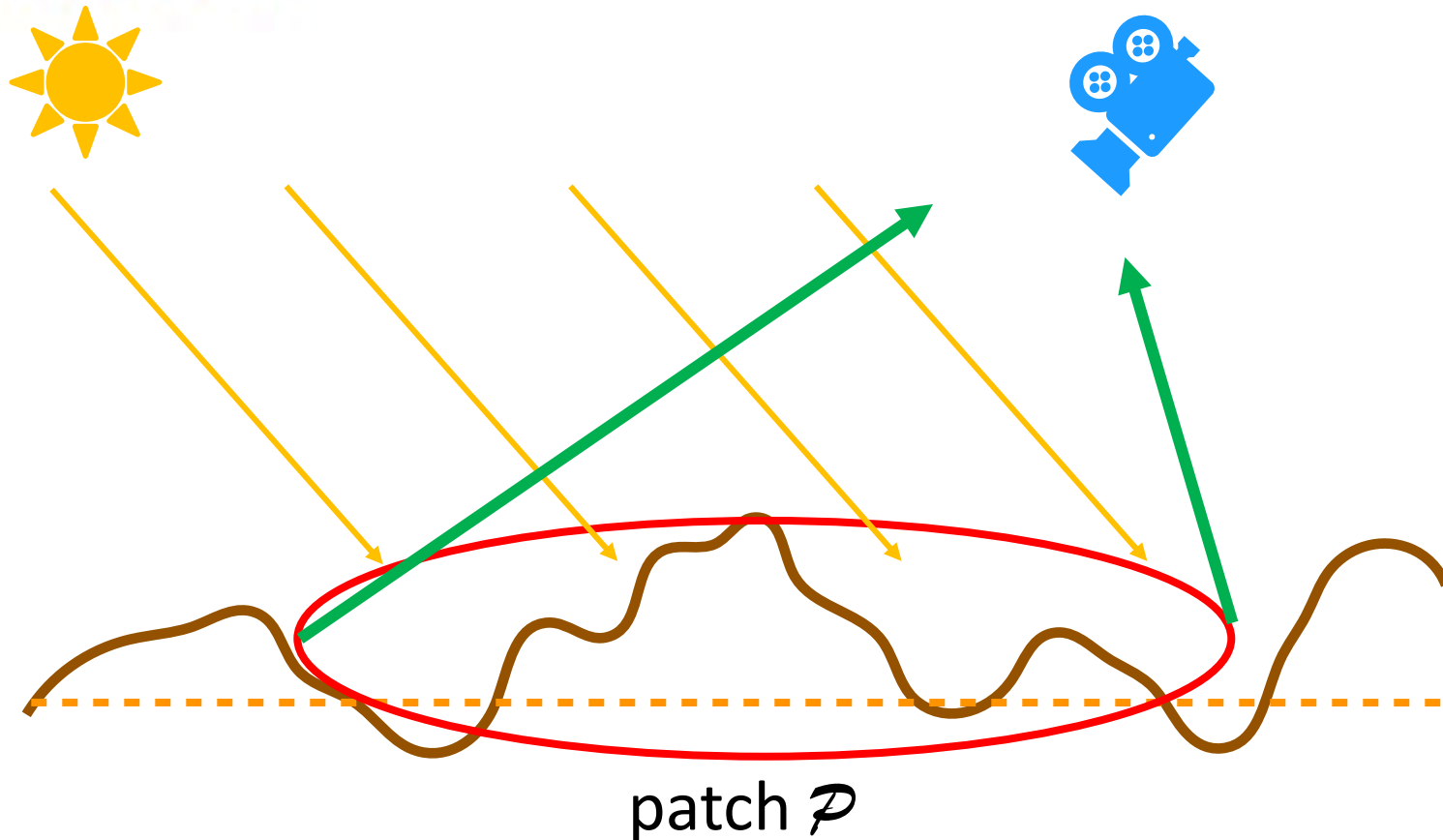




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Geometric Optic NDFs

- Contribution from patch \mathcal{P}

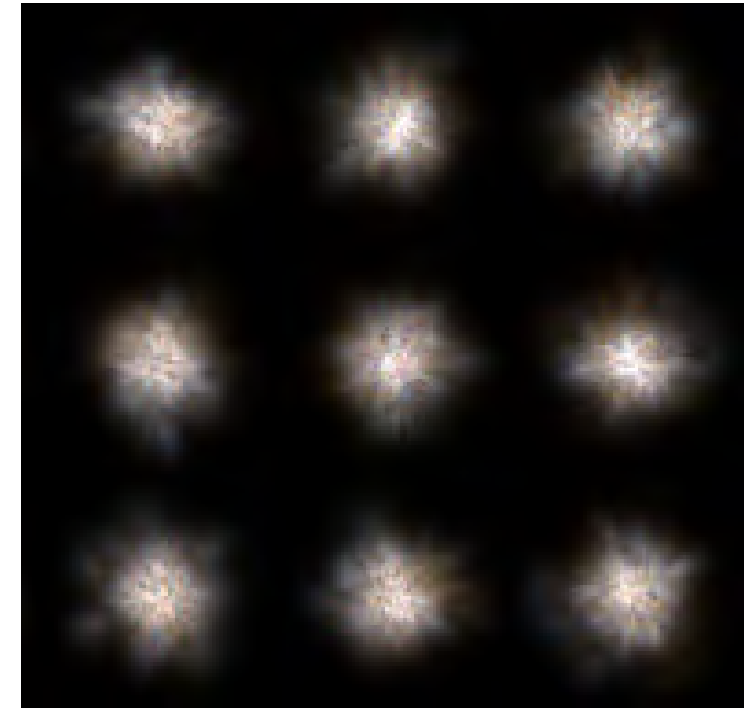
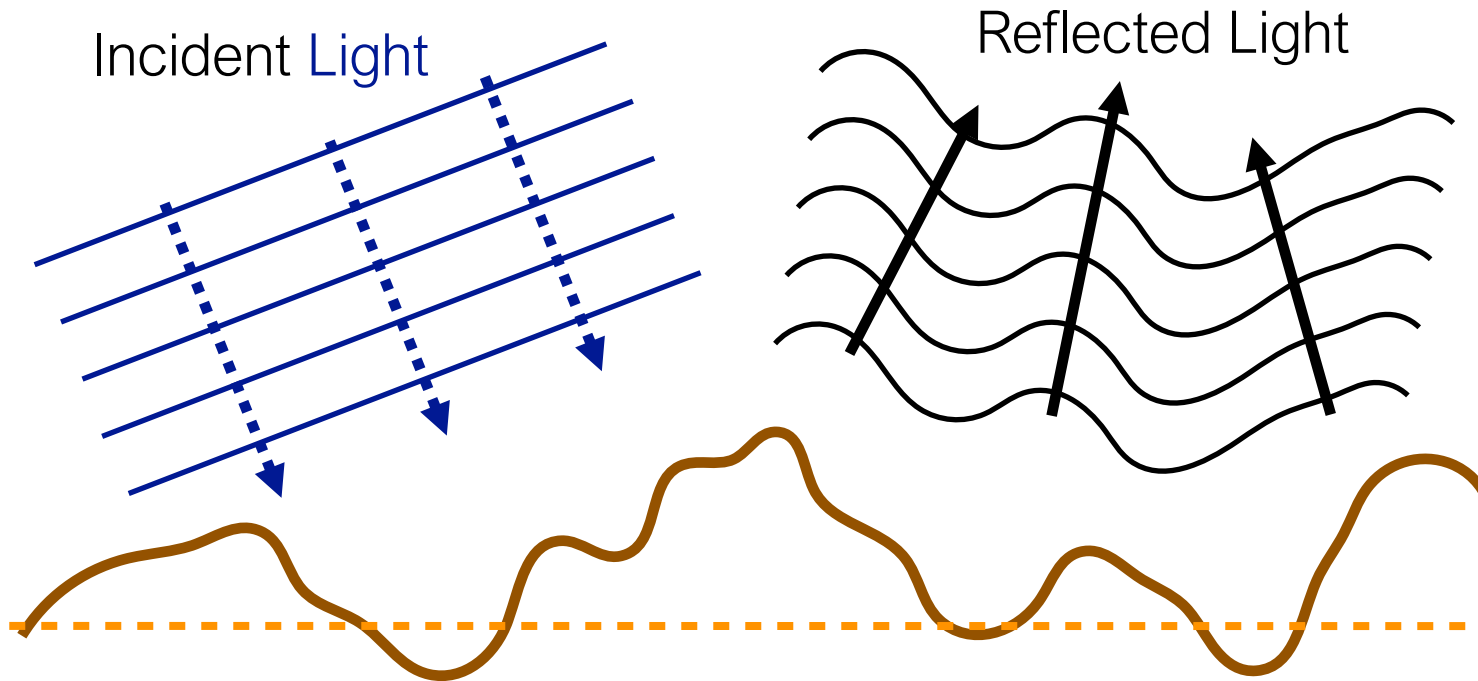




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Wave Optic NDFs

- Light is modeled as waves

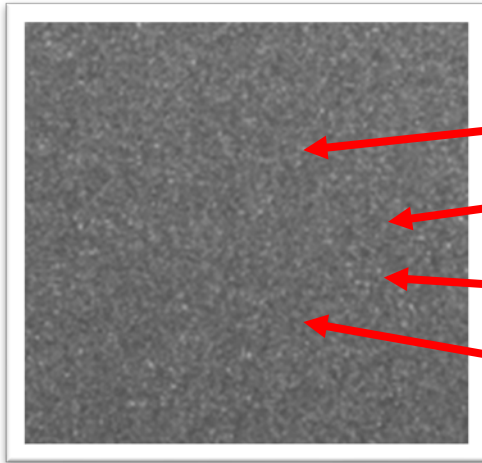




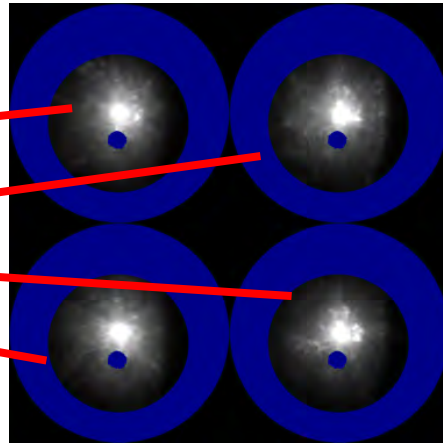
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Measurement of NDFs

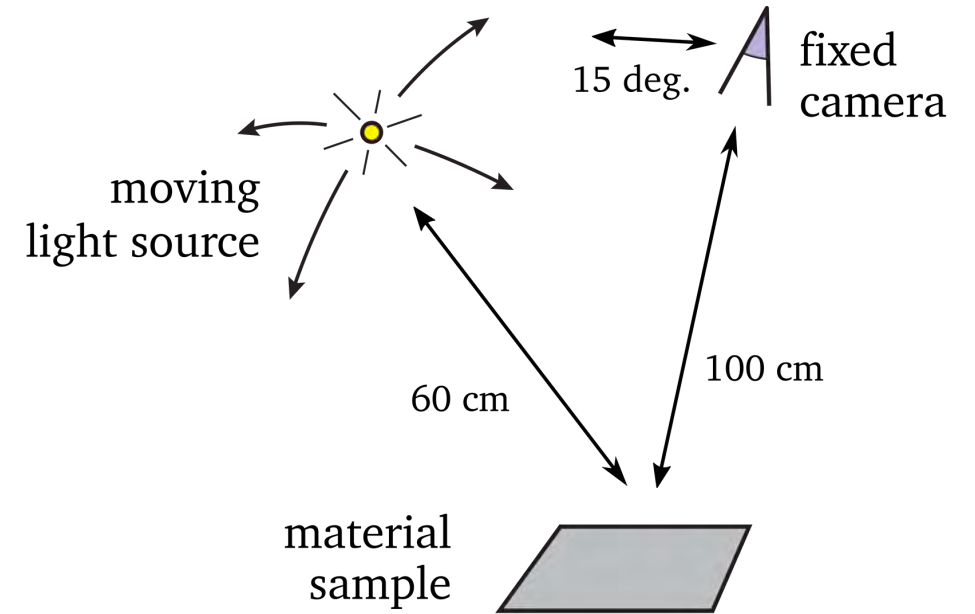
- Fixed camera
- Moving Light Source
- Blind Spots



Material Photo



Captured NDF

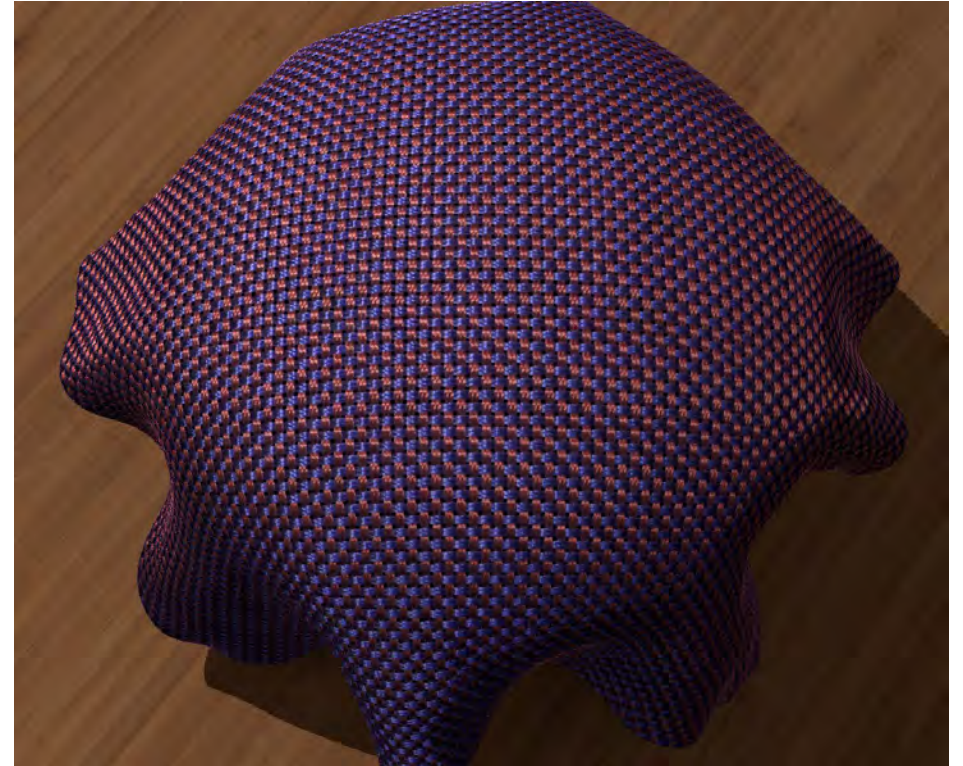
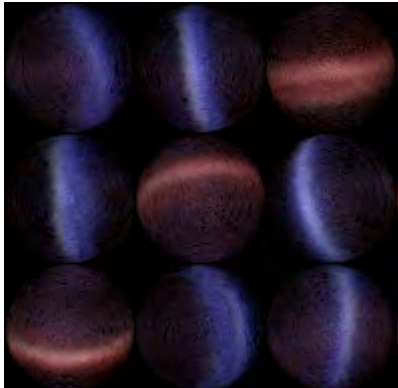




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Fabric NDFs

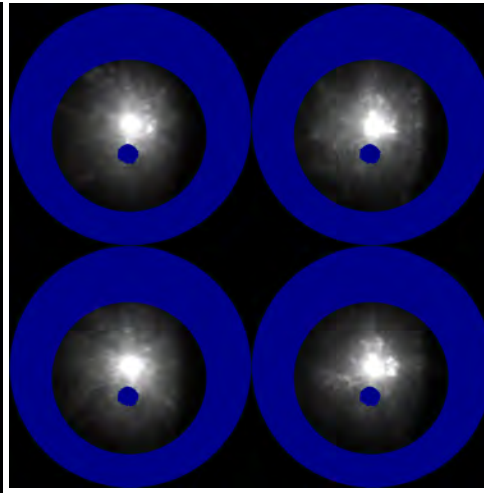
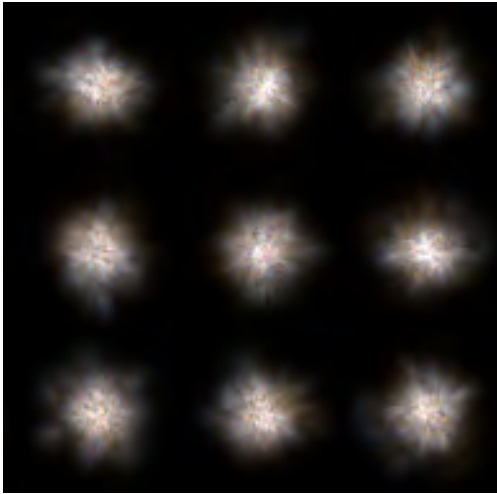
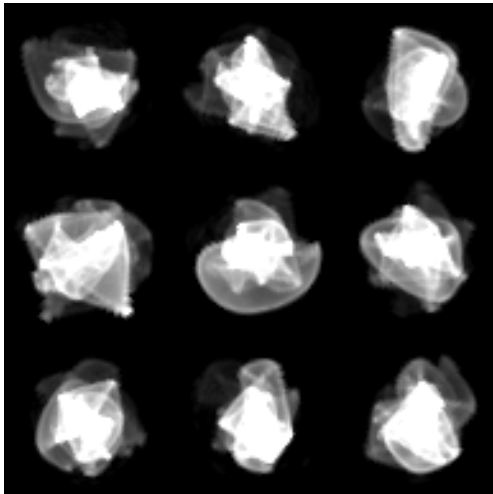
- Use fiber models
- Render NDFs with hair BSDF
- Use half-vector
 - Ignore difference vector





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NDFs



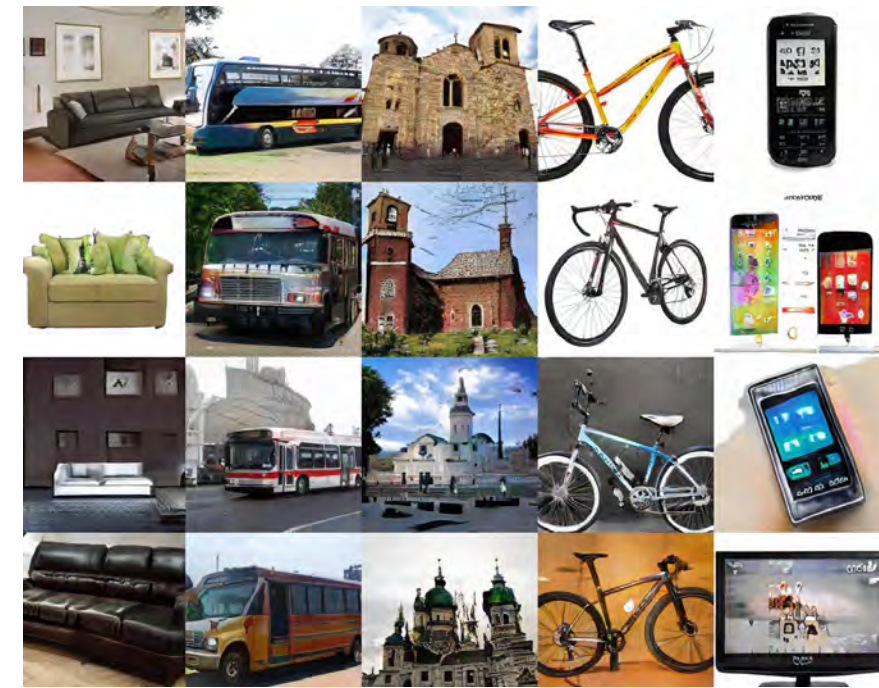
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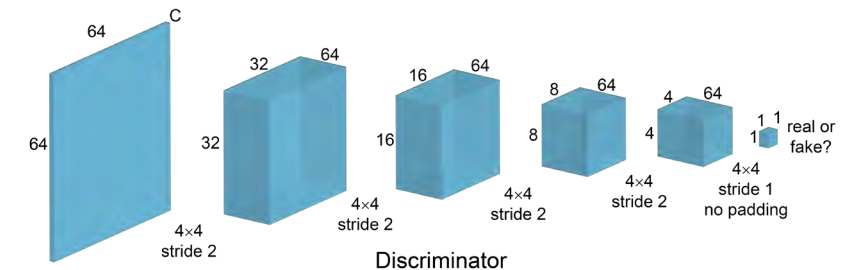
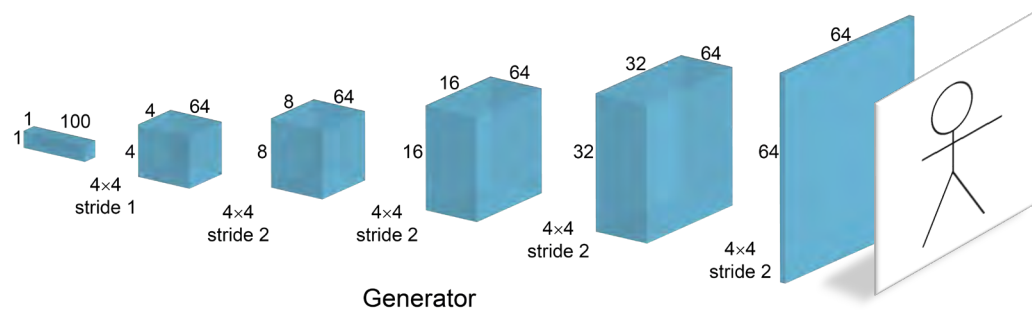


GAN Overview

- Generator
 - Generates fake data
 - Noise vector as an input
- Discriminator
 - distinguish between the real data



Images generated by GAN

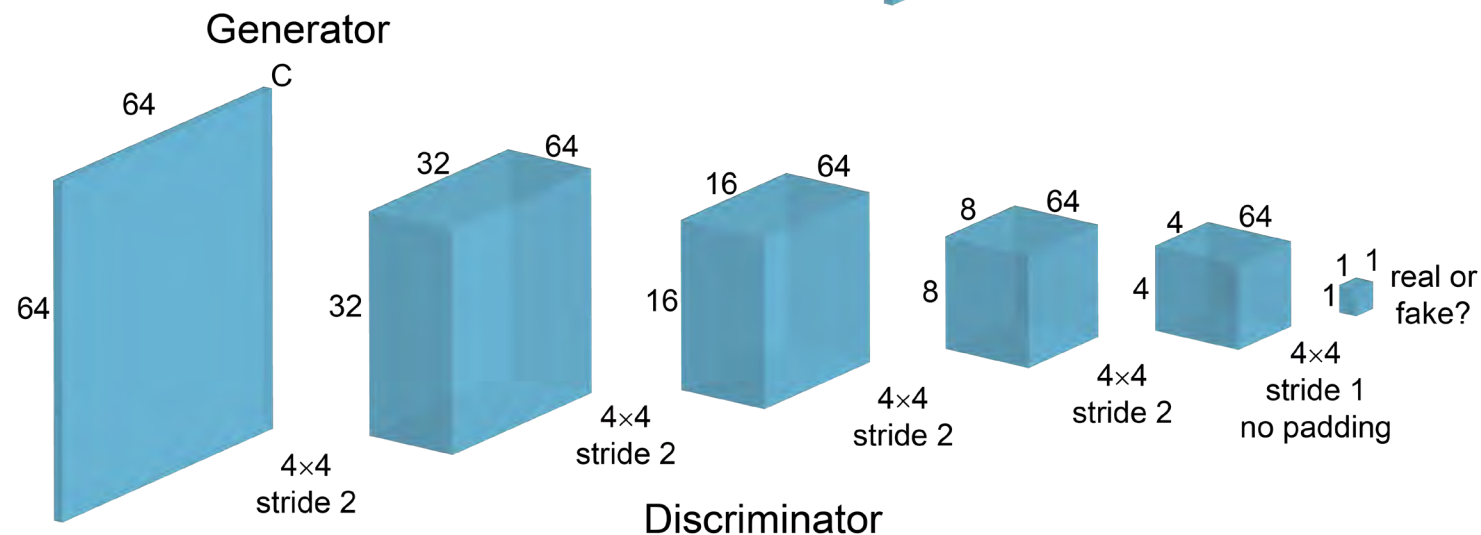
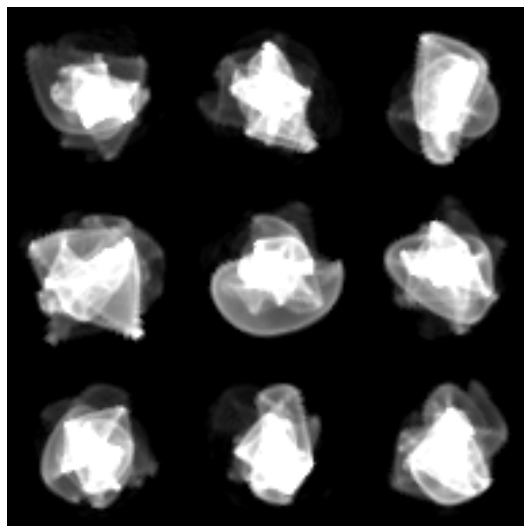
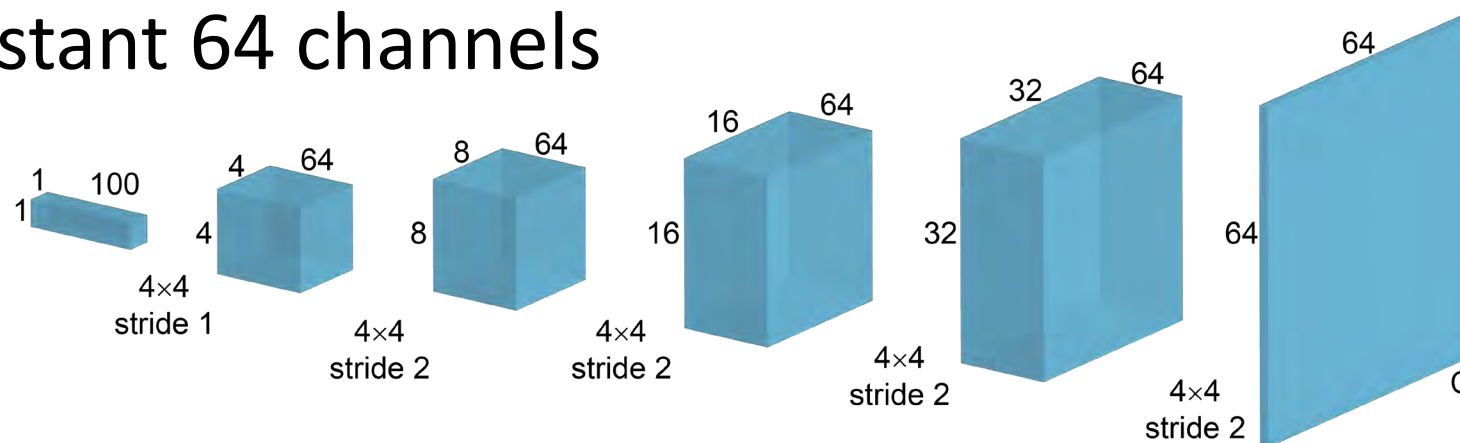




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Architecture

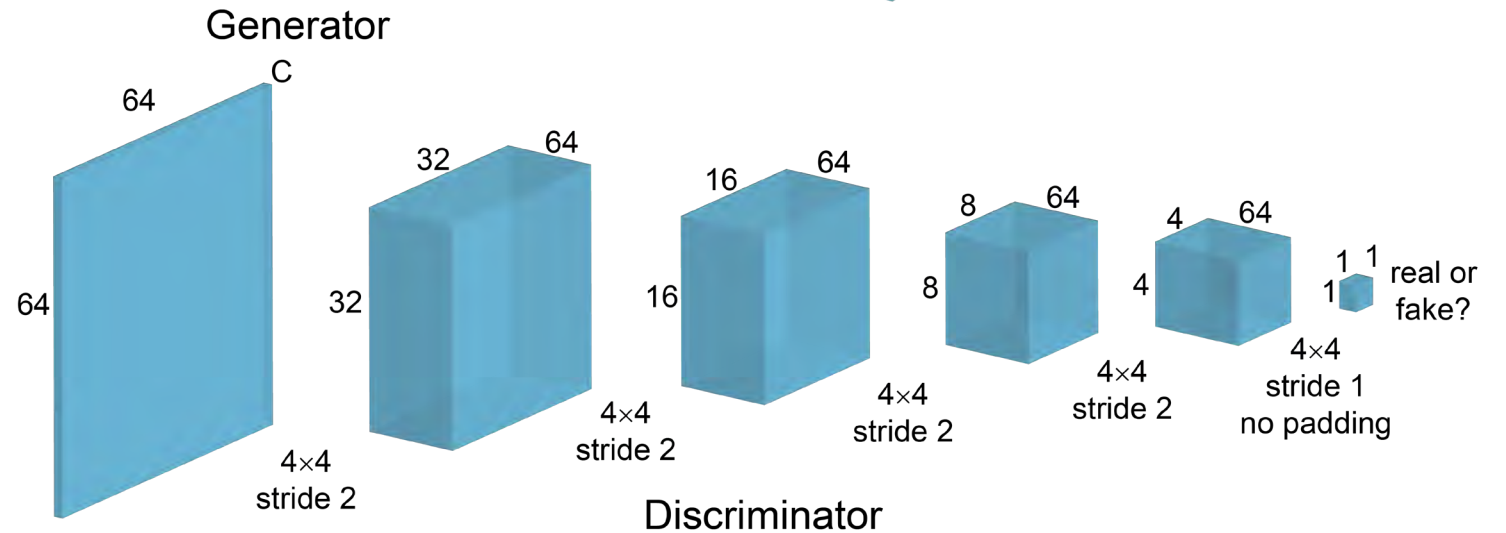
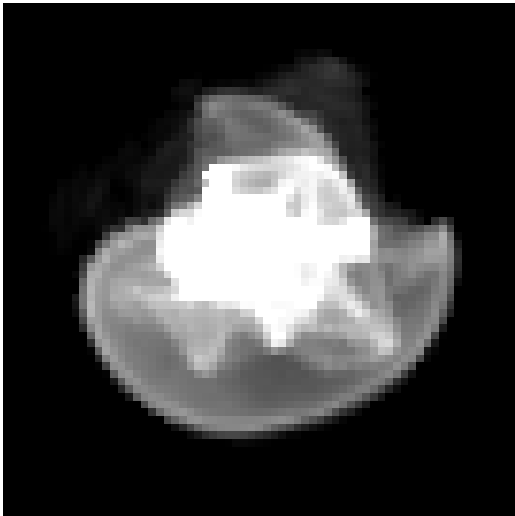
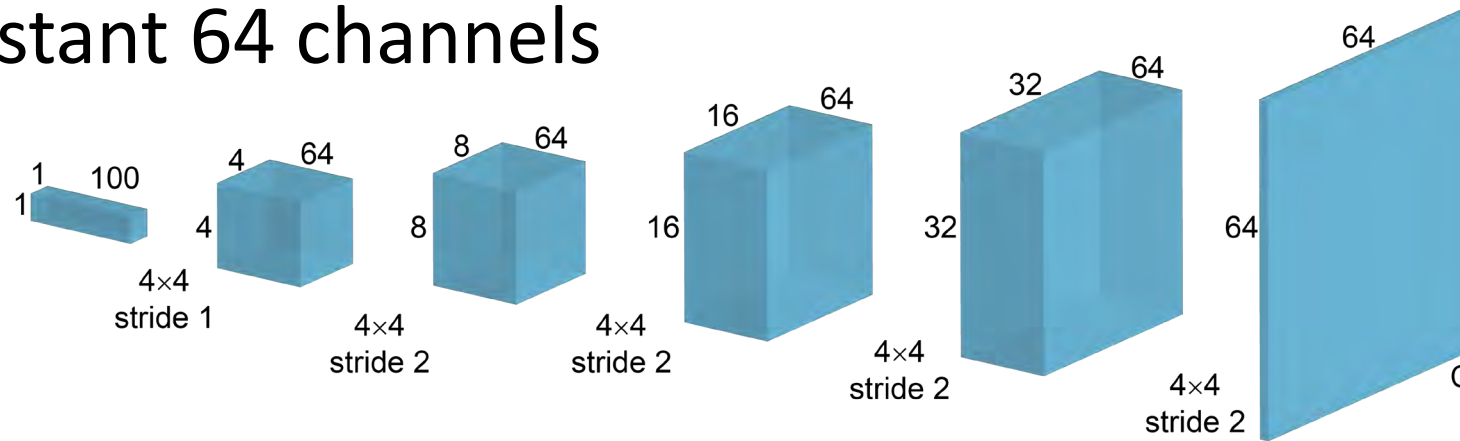
- Constant 64 channels





Architecture

- Constant 64 channels

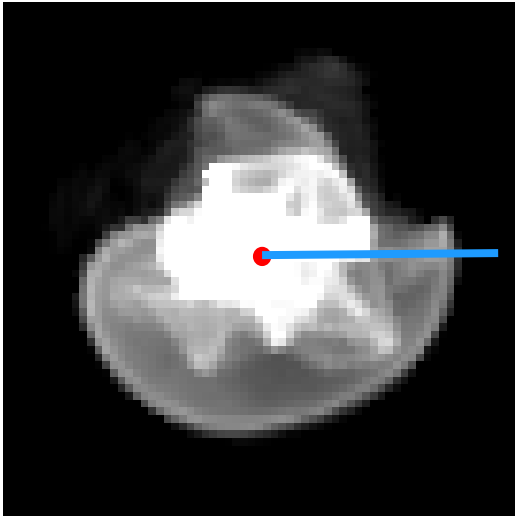




Architecture

- Constant 64 channels

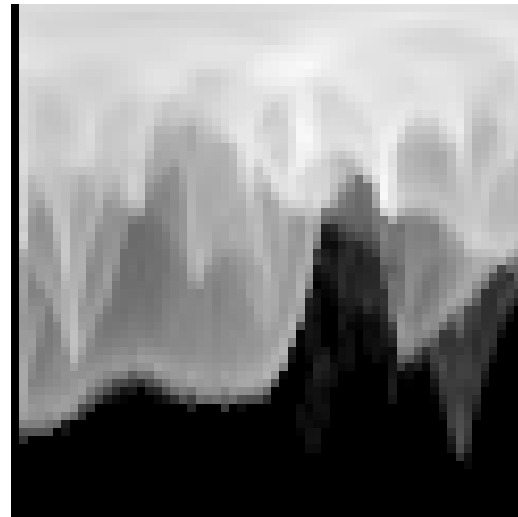
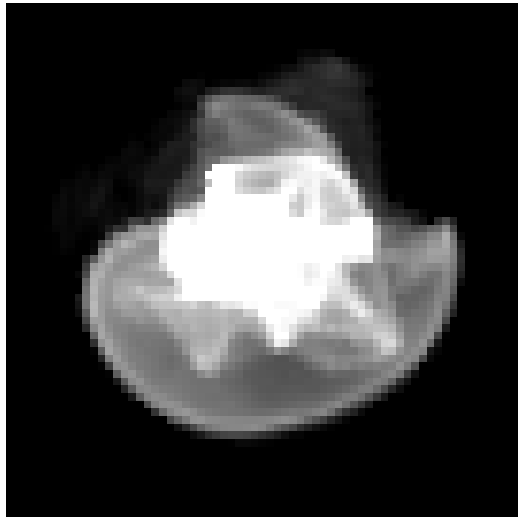
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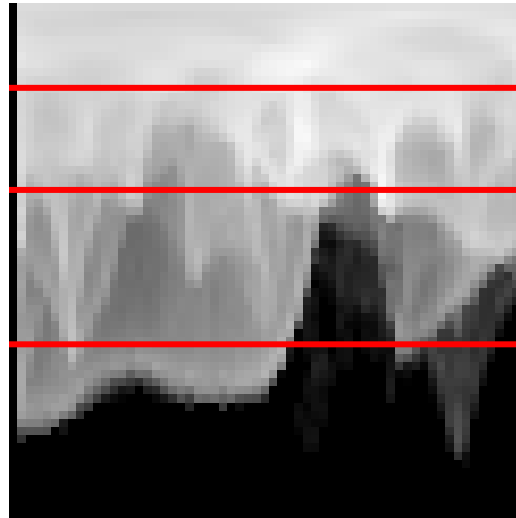
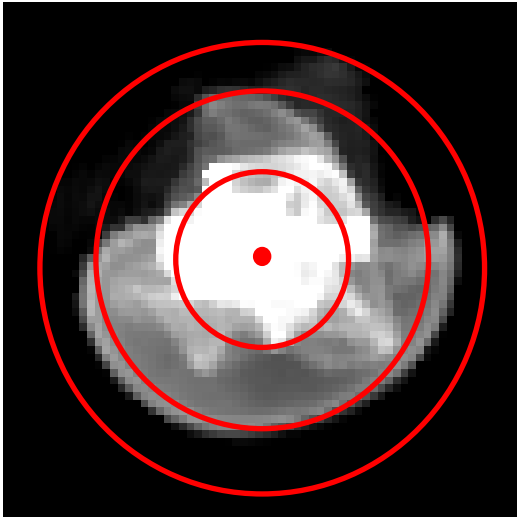
Architecture

- Constant 64 channels



Architecture

- Constant 64 channels

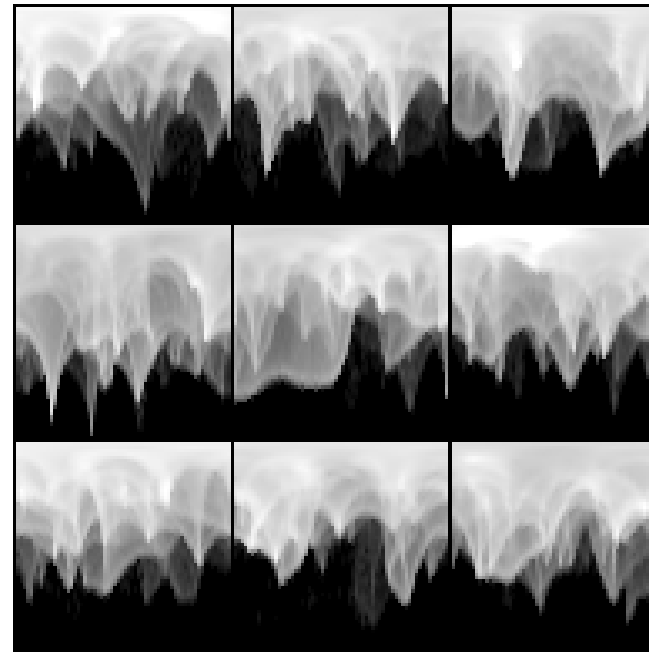
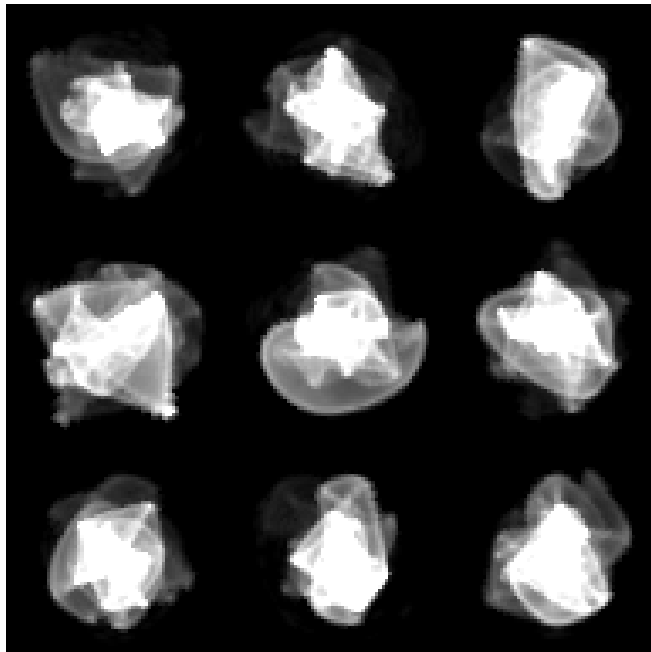




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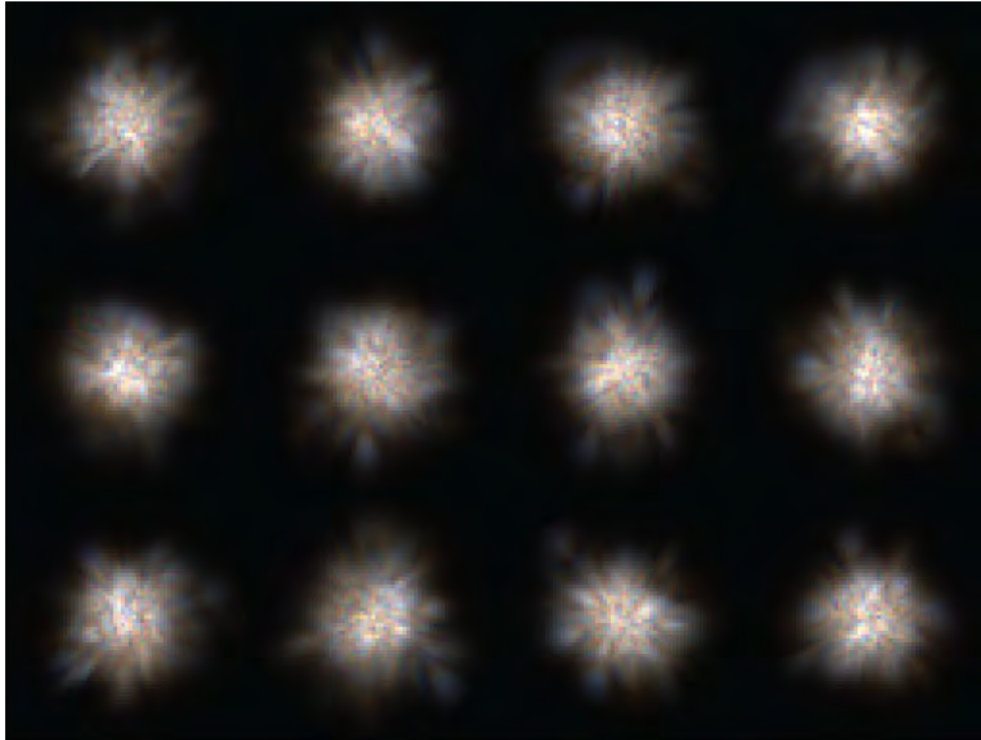
Polar Transformation

- Circular Structure
- Convolution reuses features
- Horizontal wrapping

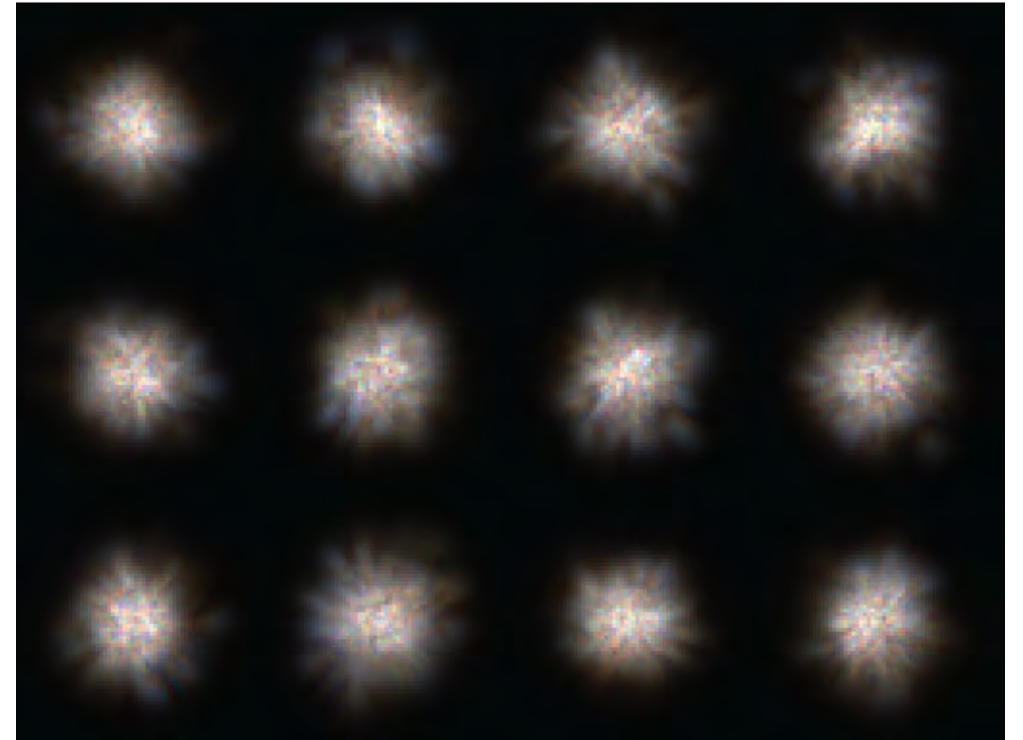


Comparison of NDFs

Wave Optics



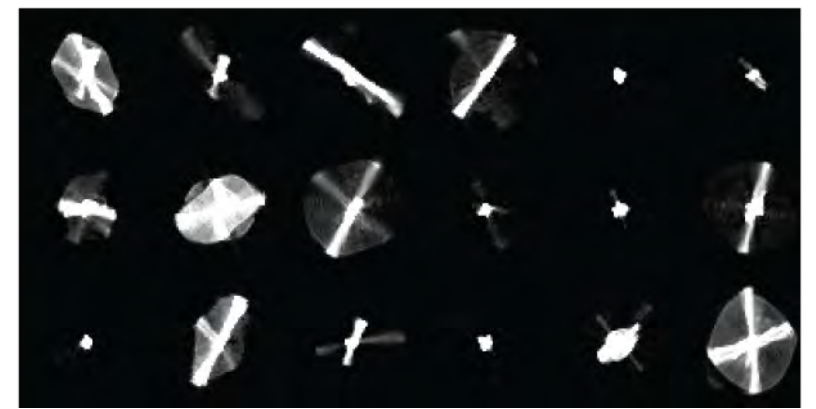
NDFs in training set



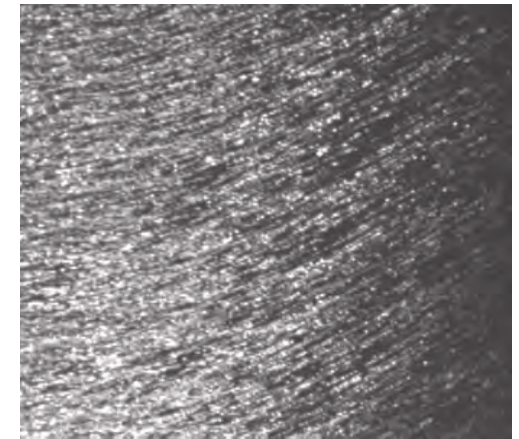
Our generated NDFs

cGAN and Feature Vectors

- Large Scale Texture Variation
 - Scratched/brushed metal
 - Fabric
- Train autoencoder
 - Low dimensional feature vector
 - Blurry lack of details
- Use this feature vector as condition for training cGAN



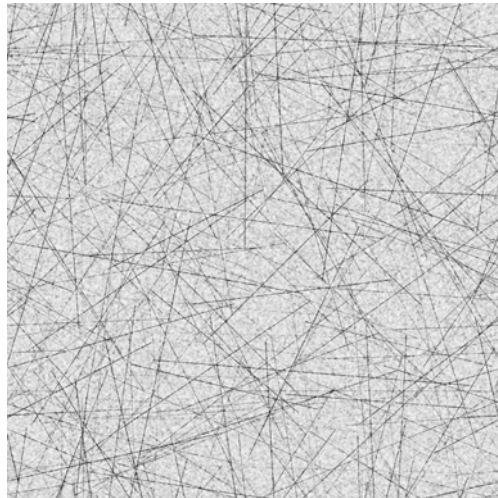
NDFs of scratched metal



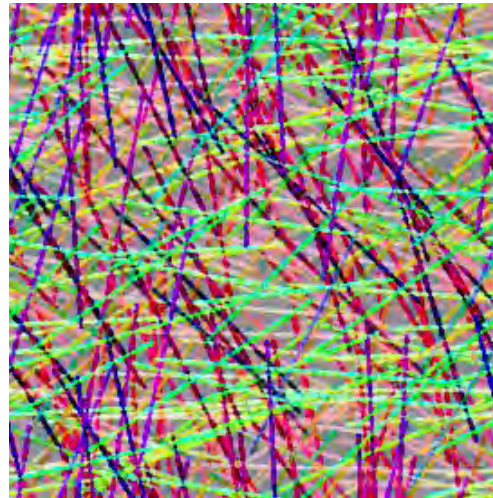
Scratched metal

cGAN and Feature Vectors

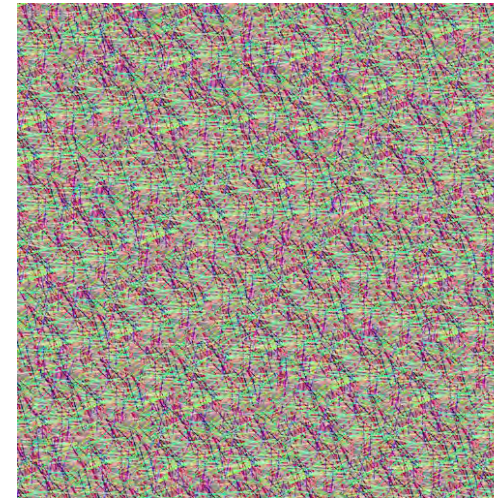
- Convert real NDFs into 2D grid of feature vectors
 - 256x256
- Use corresponding feature vector when rendering
- Use texture synthesis to increase size



Heightfield



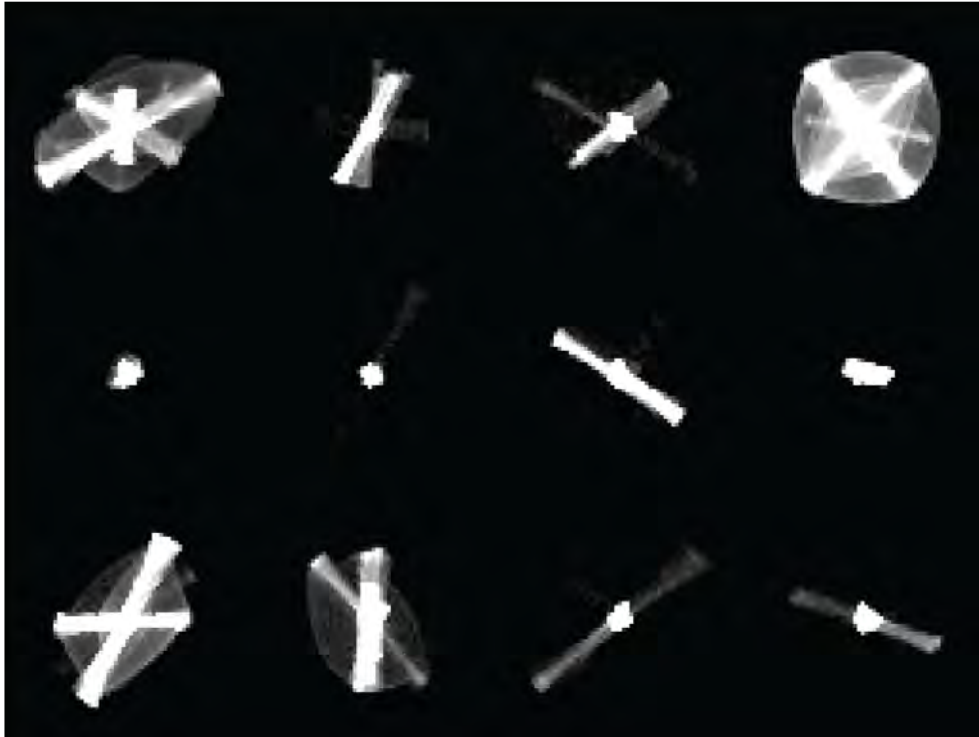
Feature Texture



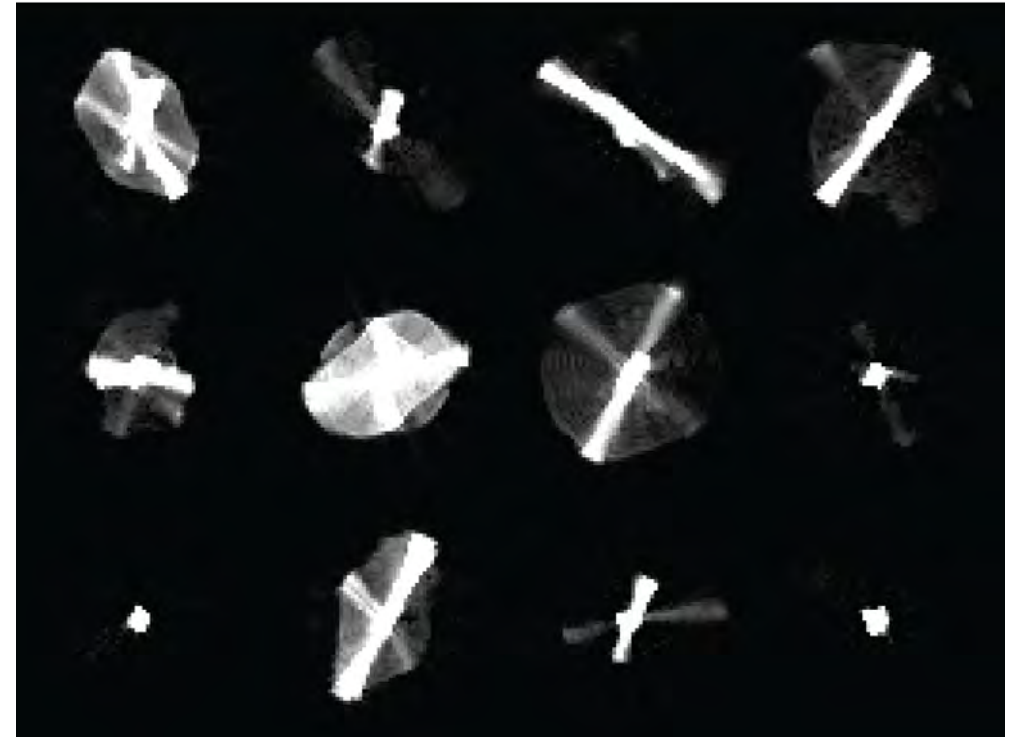
Texture Synthesis

Comparison of NDFs

Scratched metal



NDFs in training set

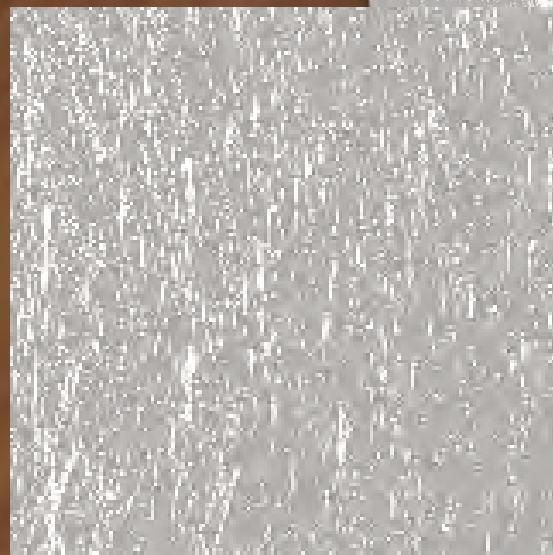


Our generated NDFs



No texture synthesis





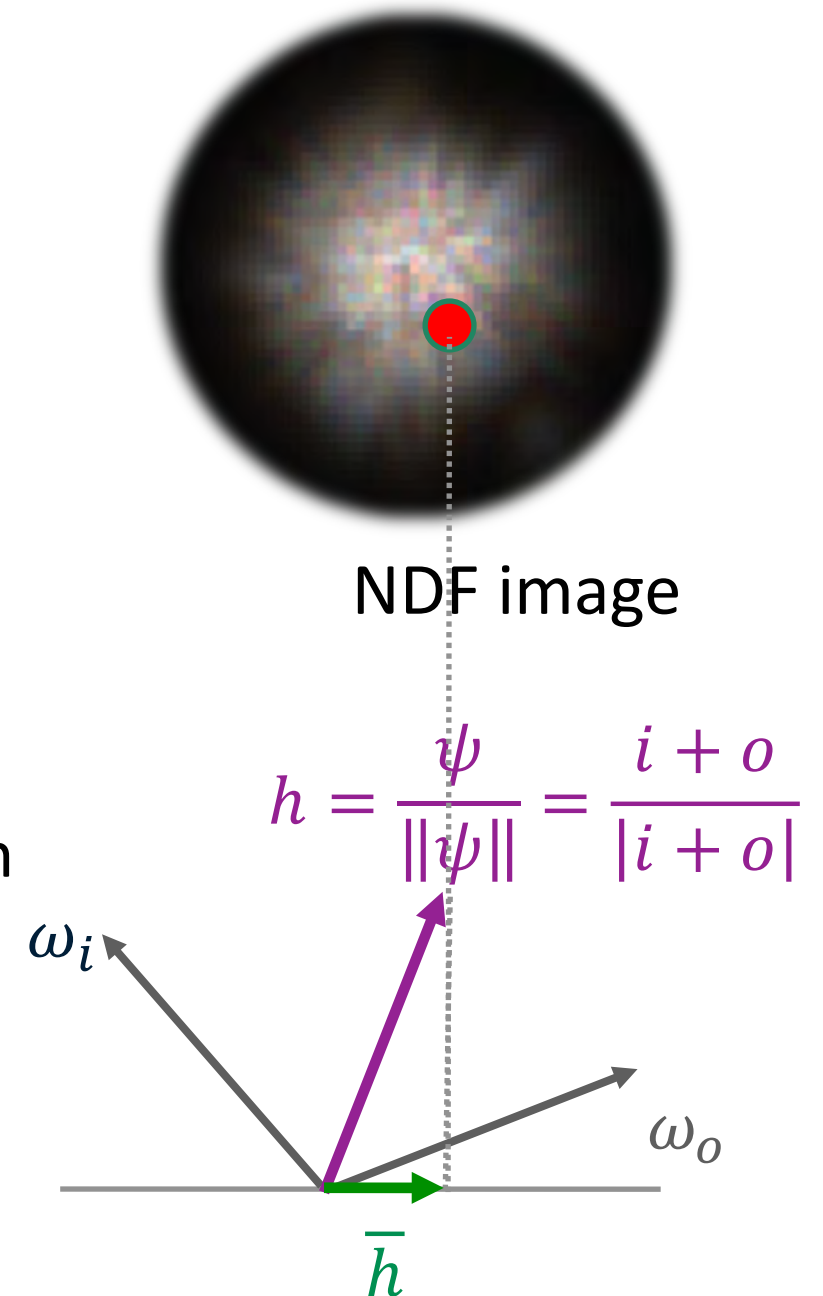
Texture synthesis





Rendering

- Each intersection
- Calculate half-vector h
 - Light source and camera directions
- Project h to unit circle
- Look up value from the image
 - 2x2 image region if bilinear interpolation

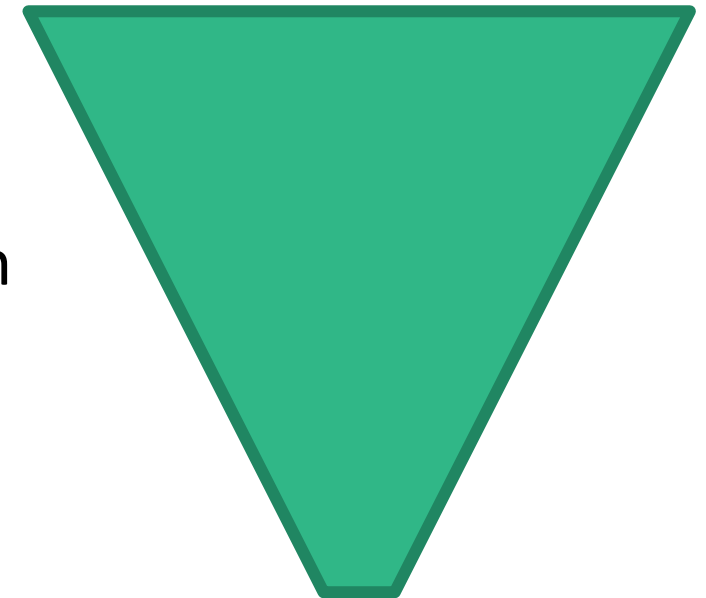
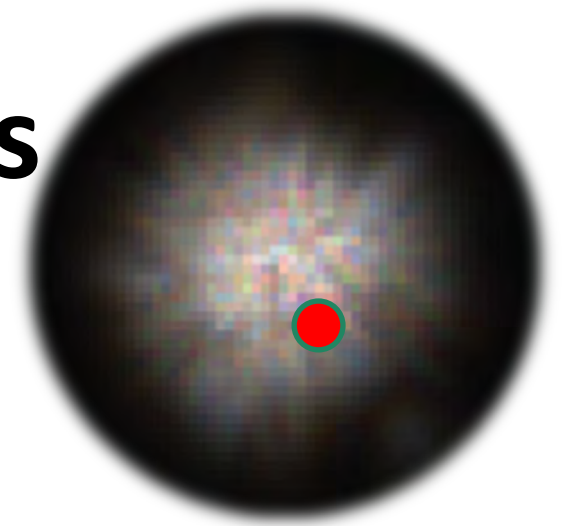




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Partial Evaluation in Details

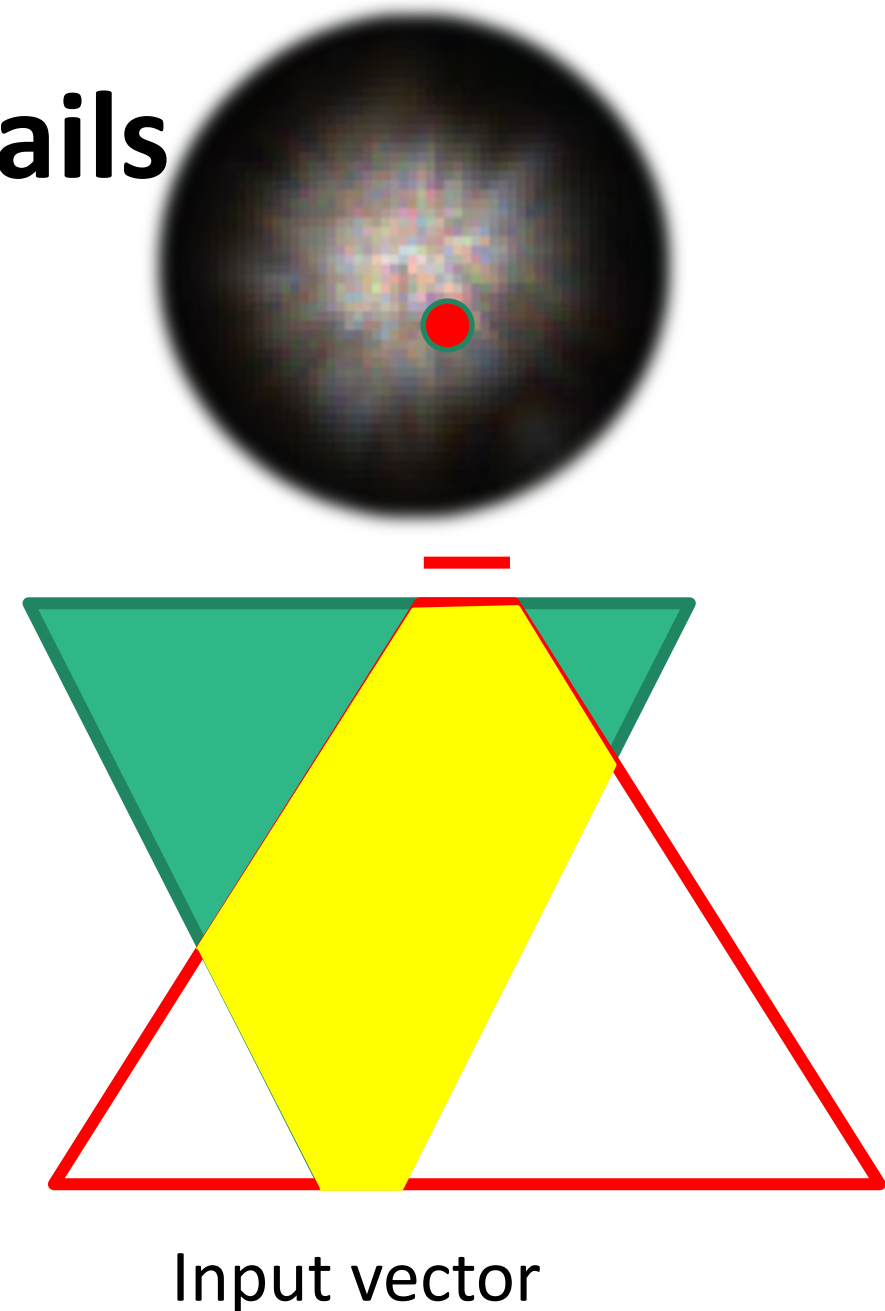
- Each intersection
- Calculate half-vector h
 - Light source and camera directions
- Project h to unit circle
- Look up value from the image
 - 2x2 image region if bilinear interpolation



Input vector

Partial Evaluation in Details

- Calculate ranges bottom→top
- Calculate ranges top→bottom
- Find the intersection
- Evaluate only valid ranges

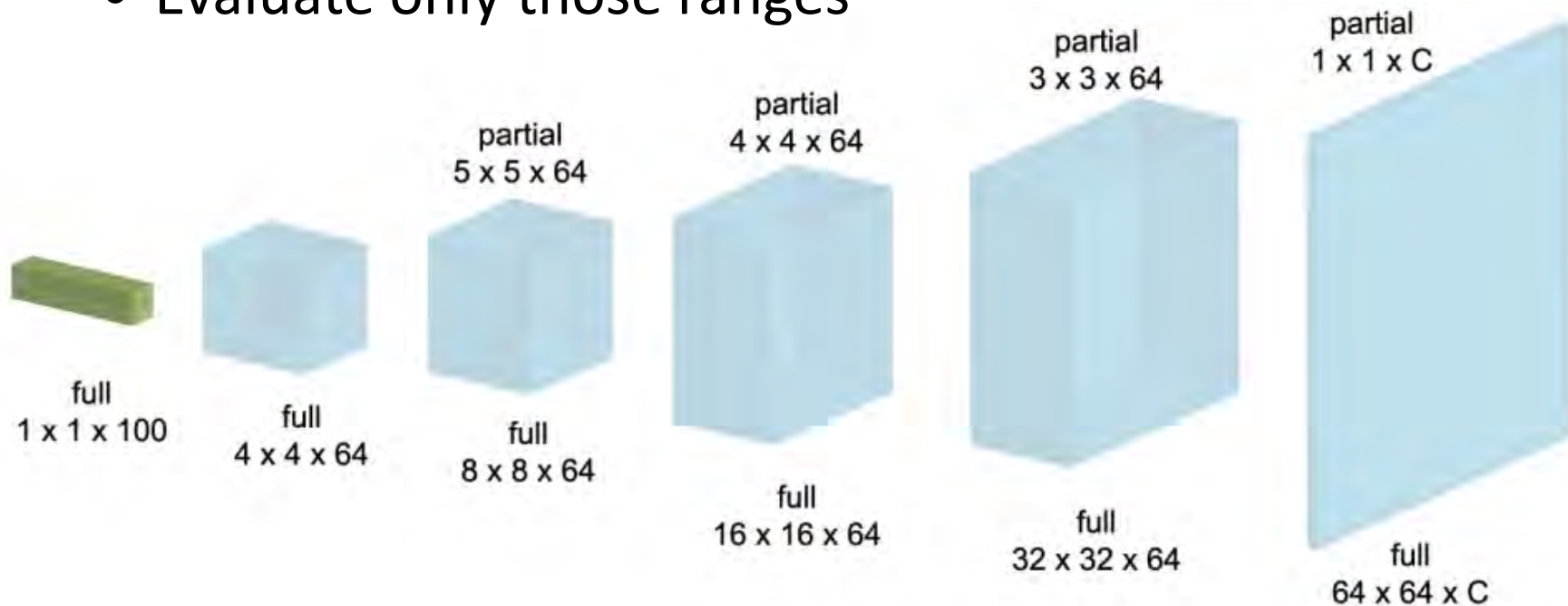




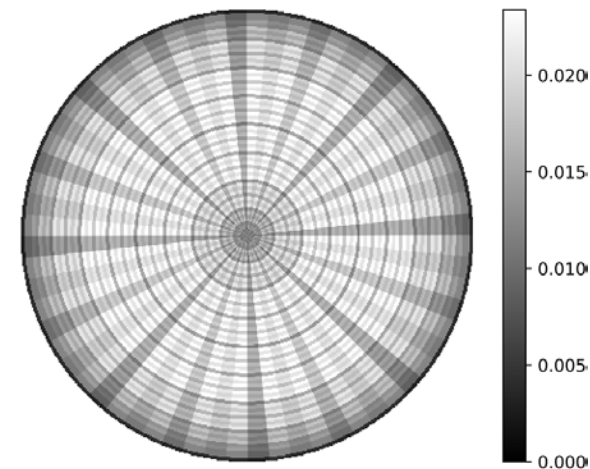
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Partial Evaluation of CNN

- Evaluate only what you need
 - 1.75% computation vs full eval
 - Compute valid ranges for all hidden layers
 - Evaluate only those ranges



Fraction of Computation
for Each Pixel



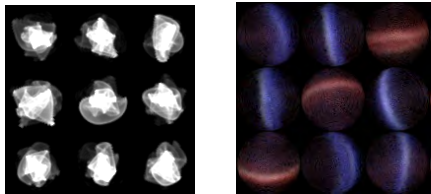
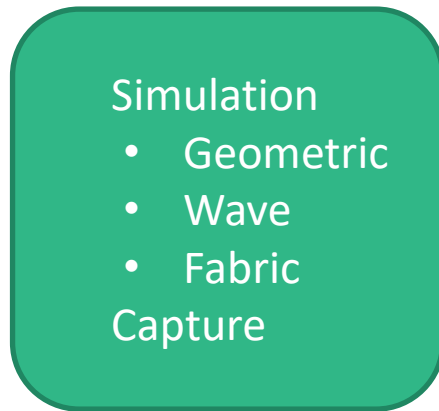


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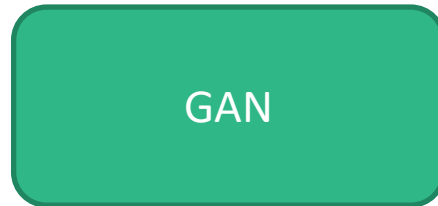
Our Pipeline

Training

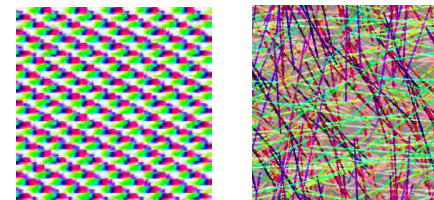
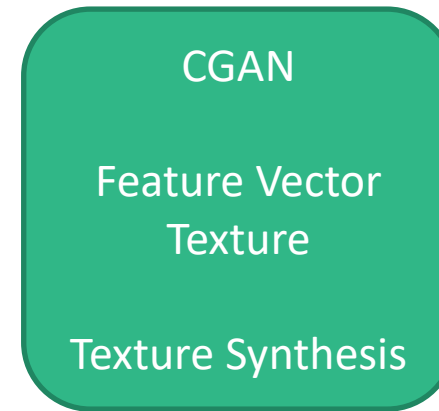
Data Acquisition



Stochastic



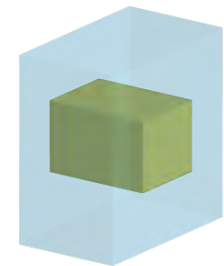
Spatial Correlation



Rendering



partial
4 x 4 x 64



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Learned from
geometric optics



Comparison:
Yan et al. 2016



Learned from
geometric optics



Learned from
measured data

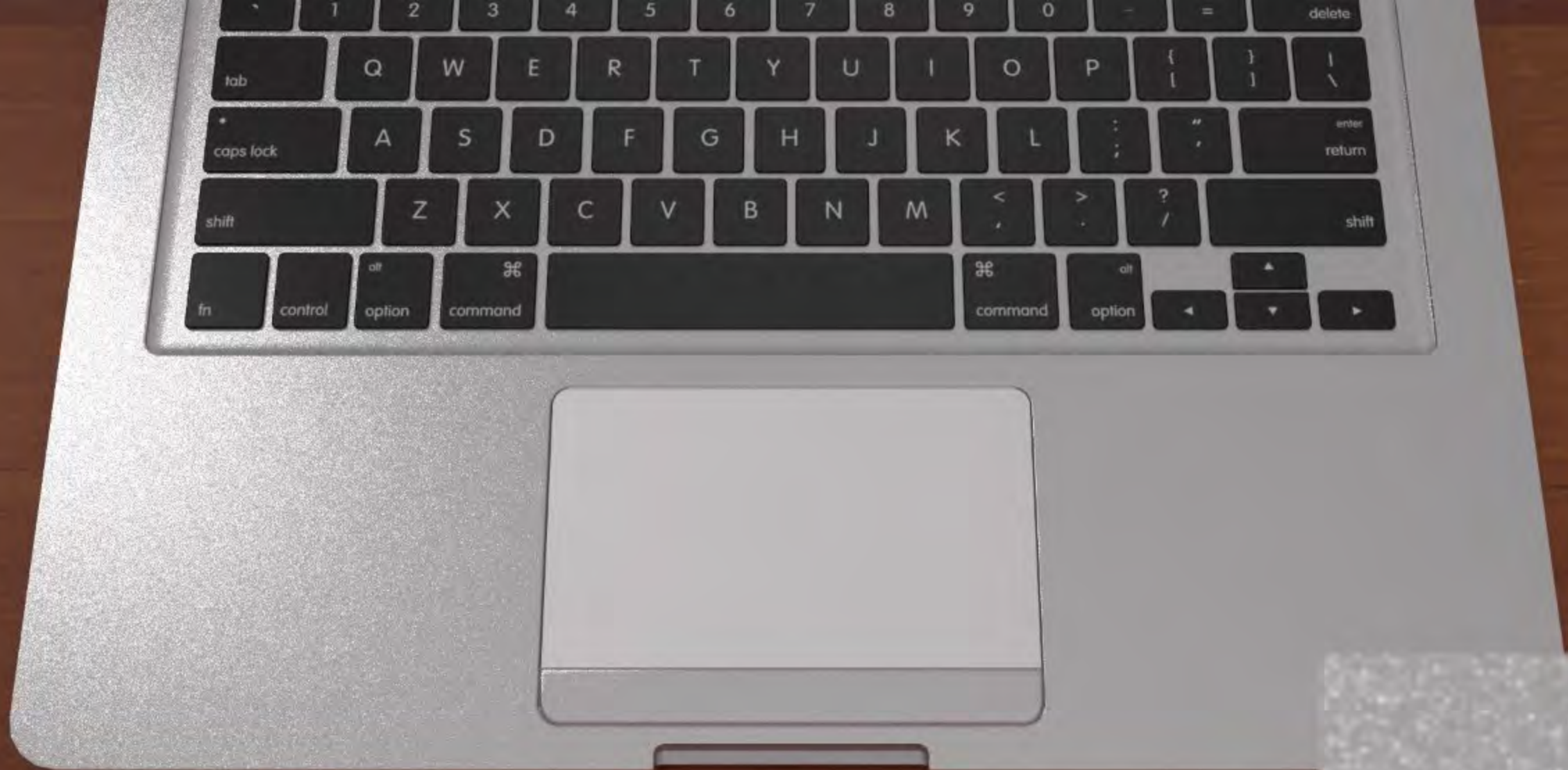


Directly using
measured data



Learned from
measured data

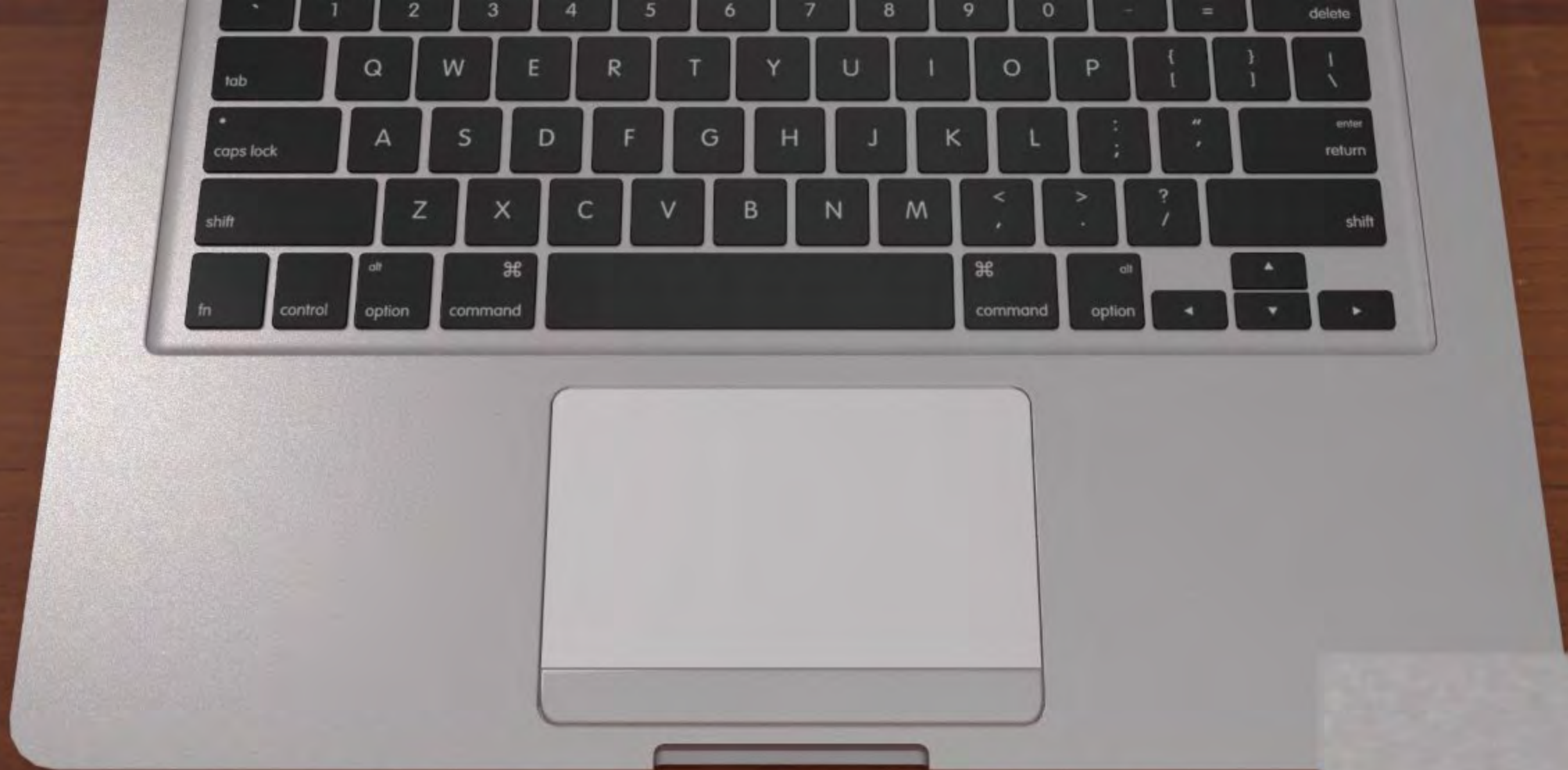




Learned from
geometric optics



Learned from
wave optics




Comparison:
Yan et al. 2018



Learned from
wave optics




Learned from
wave optics




Learned using
conditional GAN
with texture synthesis

Note: repetitive
pattern is
resolved

A top-down view of a white ceramic plate with a subtle concentric ring pattern, resting on a dark brown wooden surface with a visible grain. The lighting is soft, creating gentle shadows and highlights on the plate's surface.

Comparison:
Yan et al. 2016



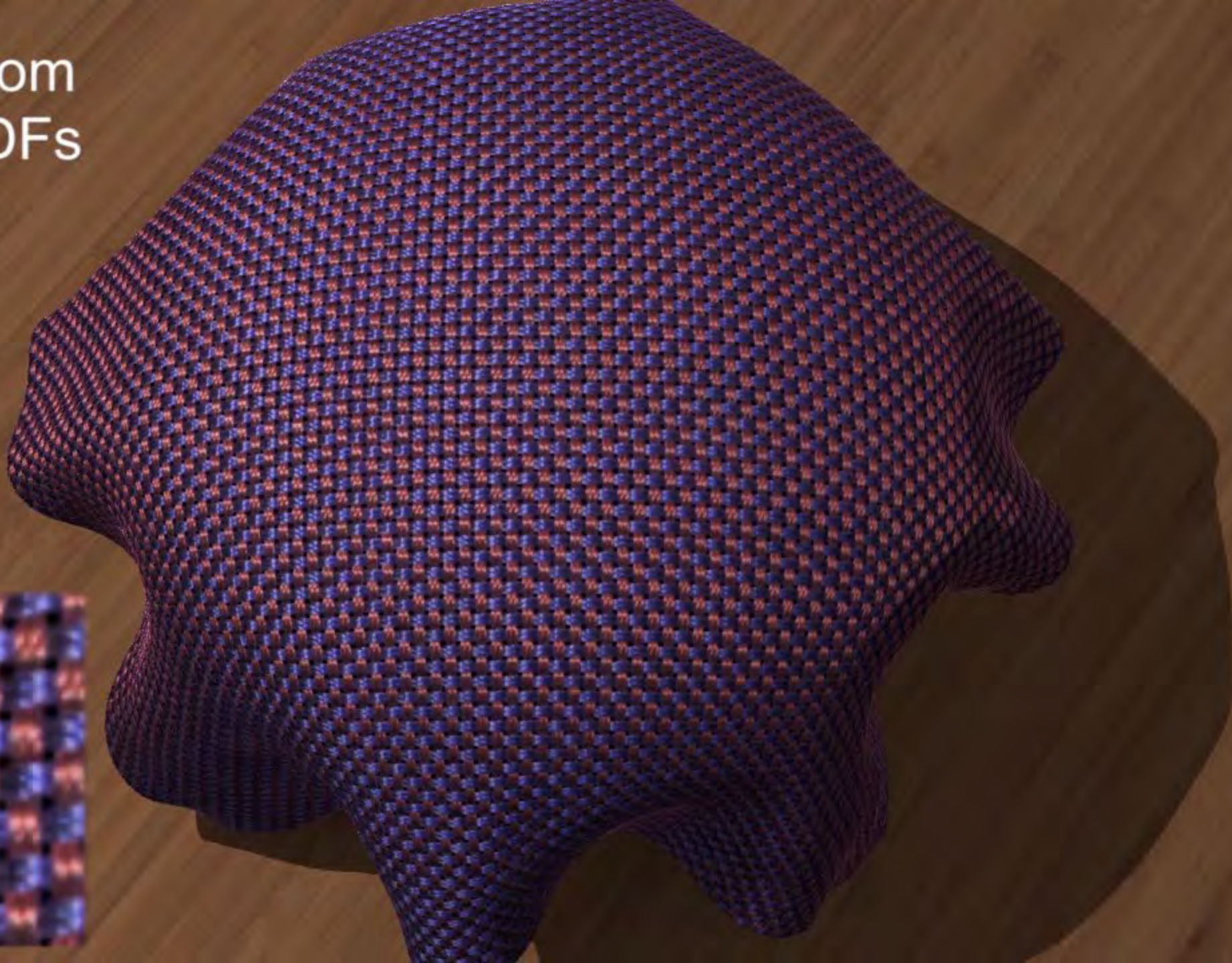
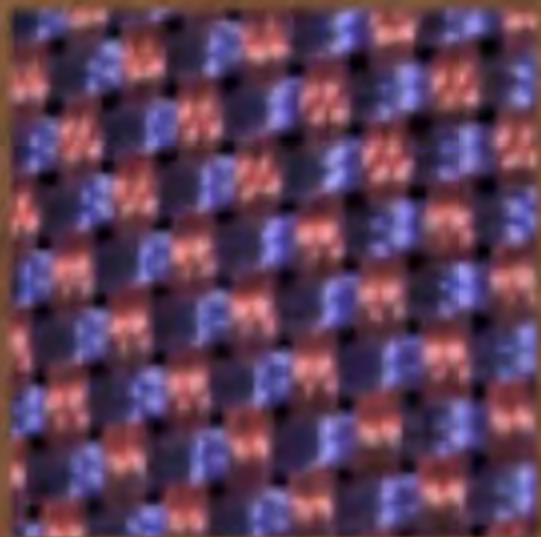
Learned using
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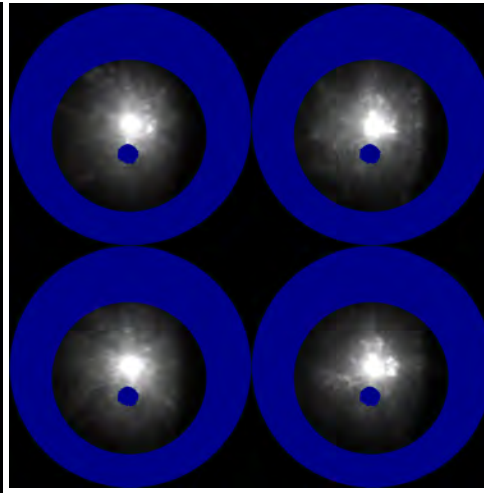
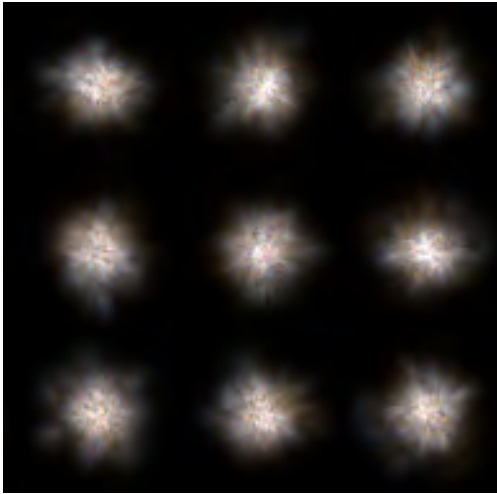
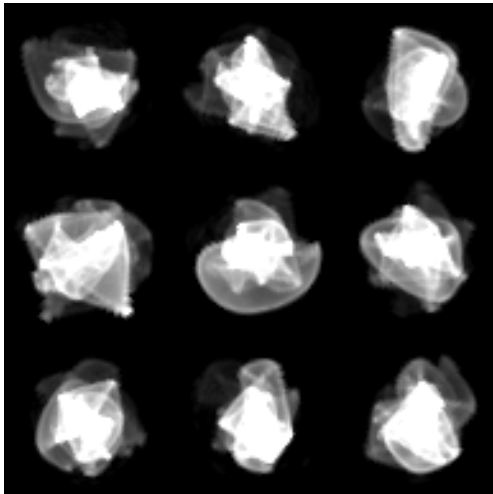
Learned from
fabric GNDFs





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NDFs

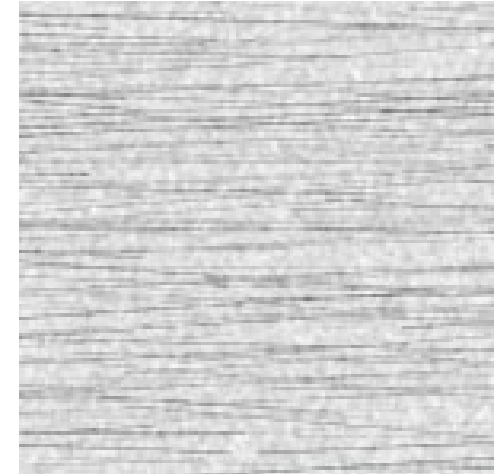
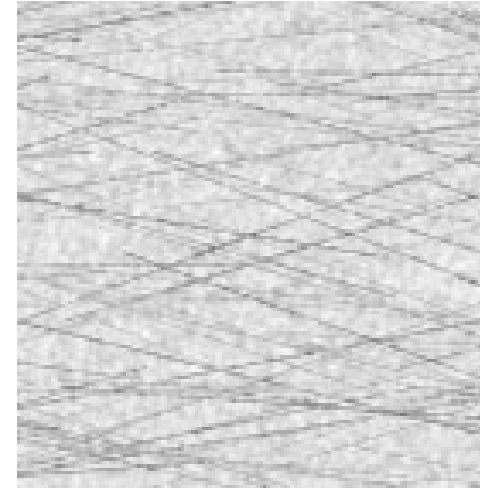
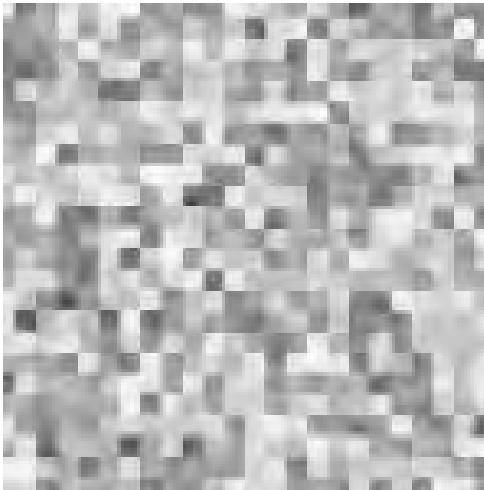


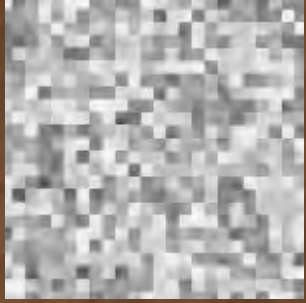
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Additional high fields





Heightfield





Heightfield



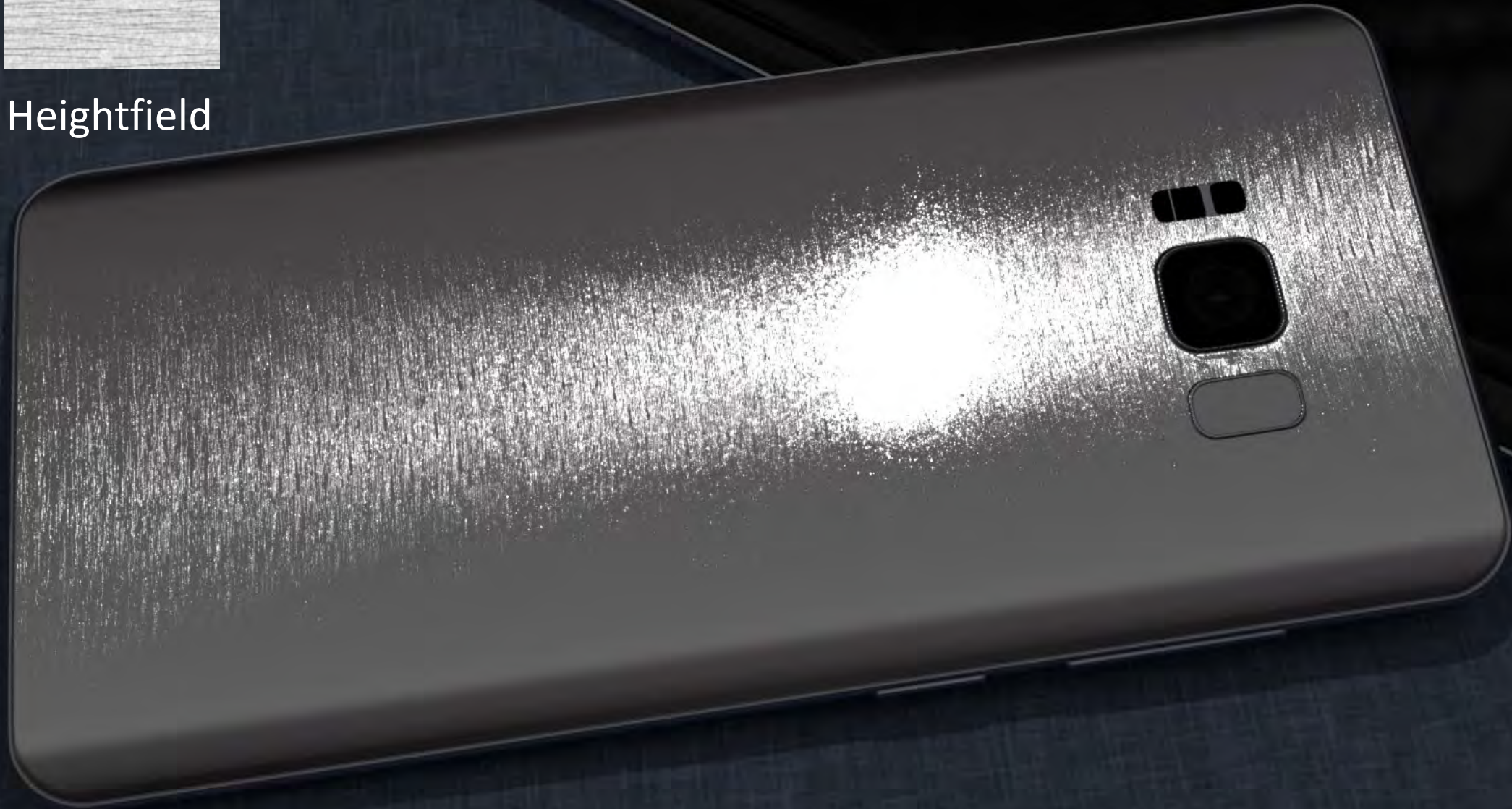


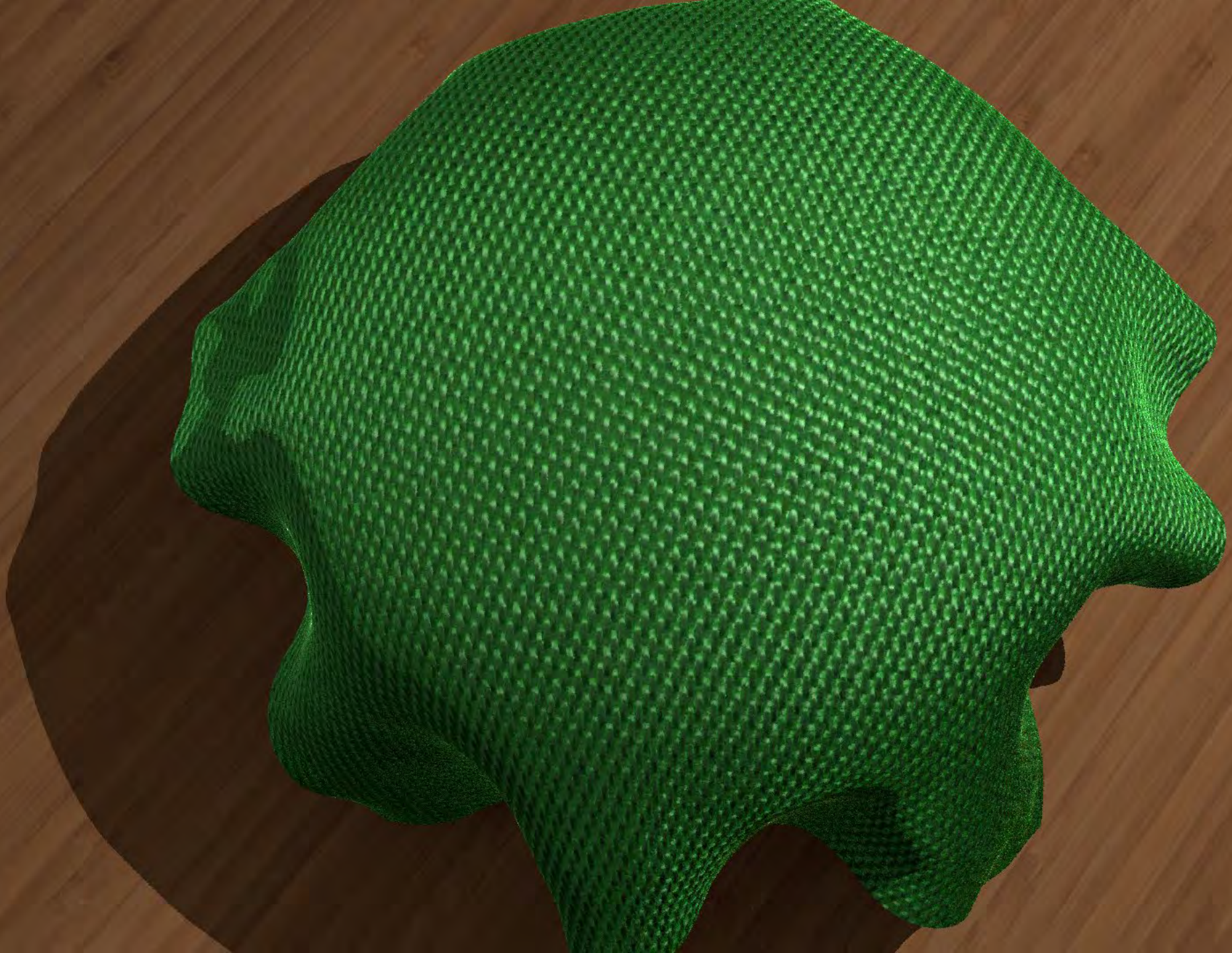
Heightfield





Heightfield









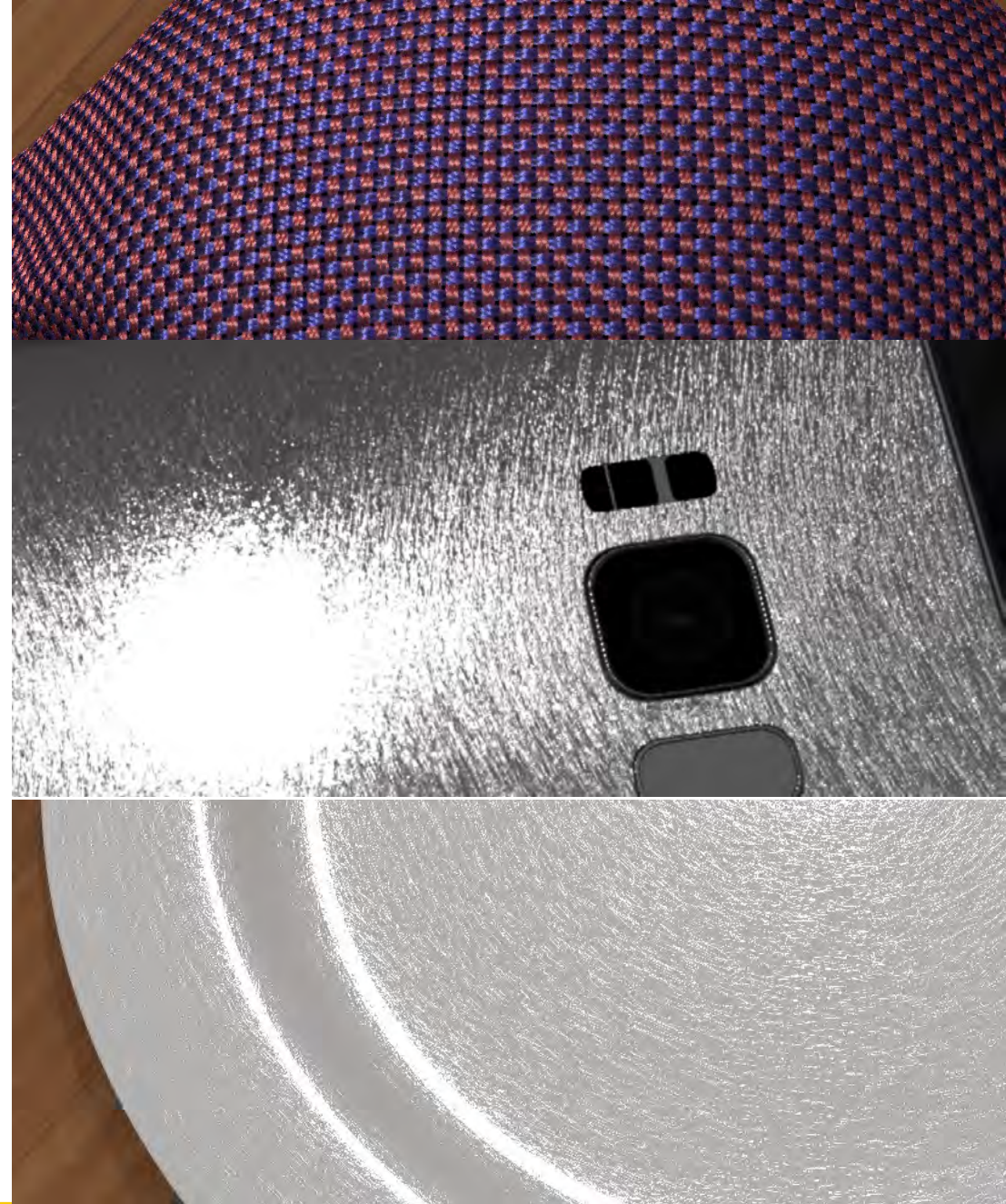
SIGGRAPH
ASIA 2019
BRISBANE

Render Time (direct only)

Scene	Type	Our Time	Prev. Time
Macbook	Geom.	4.5s	2.0s
Macbook	Wave	5.9s	234s
Plate	Geom.	12.3s	45.8s
Phone	Geom.	6.4s	3.3s
Cloth	Fabric	10.1s	n/a

Conclusion

- Render specular microgeometry
 - GAN
 - Measured materials
 - Fabrics
 - No explicit heightfield
- Partial Evaluation of CNN
 - 50x faster





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Thank you!

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Phone

point light + environment lighting

geometric optics, wave optics

moving light