



Building Volumetric Appearance Models of Fabric using Micro CT Imaging

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Fabric



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- Challenging to model and render



Silk satin



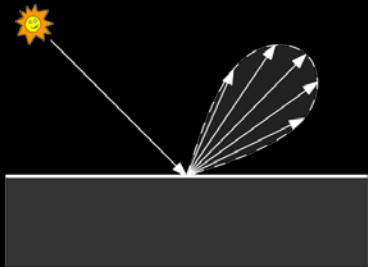
Gabardine wool



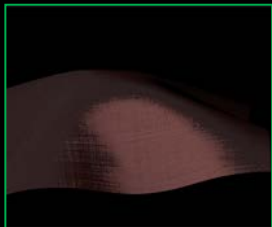
Velvet

Cloth Appearance Models

■ Surface-based

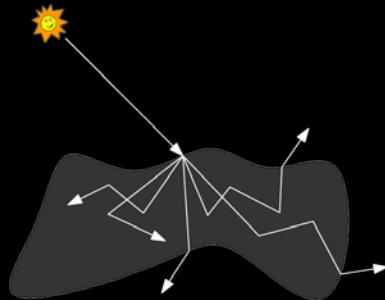


[Ashikhmin et al. 2000]



[Irawan 2008]

■ Volumetric



[Xu et al. 2001]



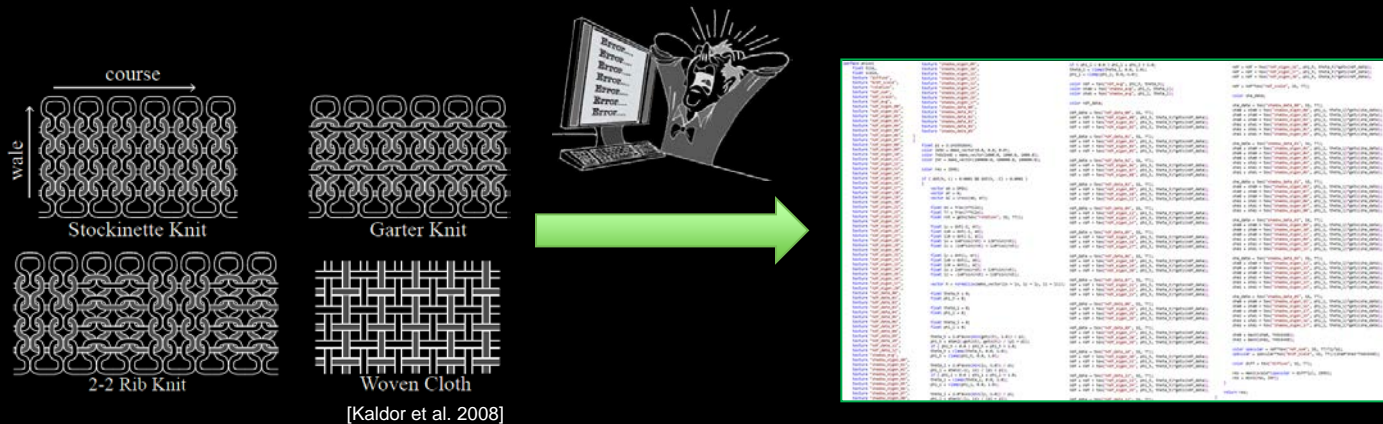
[Jakob et al. 2010]

Building Volumetric Models



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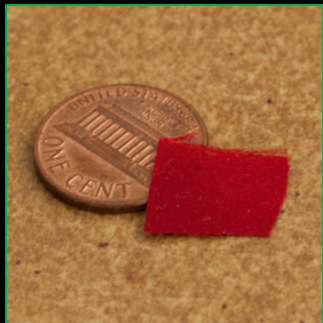
- A procedural process
- Requires significant manual effort



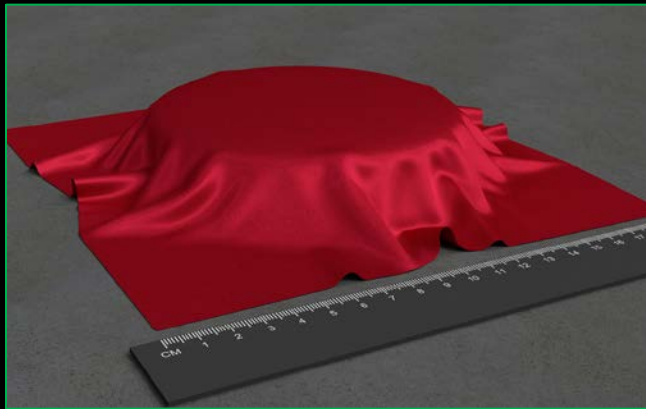


Our Goal

- Building high-quality volumetric models automatically



Material sample



Volumetric appearance model

Prior Work

- Appearance modeling

- [Dana et al. 1999], [Wang et al. 2008], ...
- [Kajiya and Kay 1989], [Jakob et al. 2010], ...



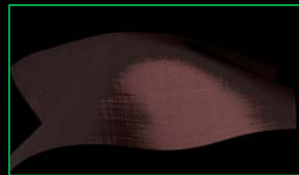
[Wang et al. 2008]



[Jakob et al. 2010]

- Cloth reflectance models

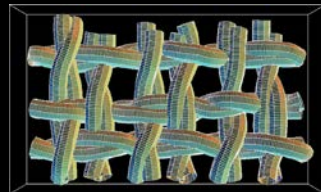
- [Irawan 2008], ...



[Irawan 2008]

- Cloth structure

- [Shinohara et al. 2010], ...

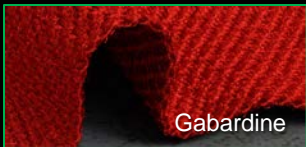
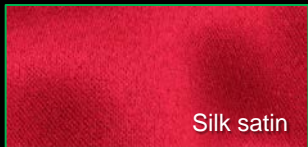


[Shinohara et al. 2010]



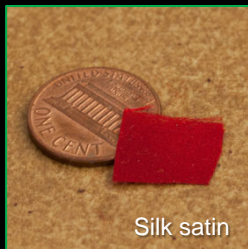
Our Contribution

- A new way of building high-quality volumetric appearance models for fabrics



- Model Construction
 - End-to-end pipeline
- Rendering
 - New sampling strategy

X-ray Computed Tomography

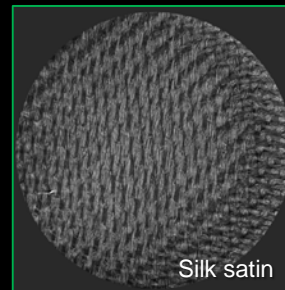
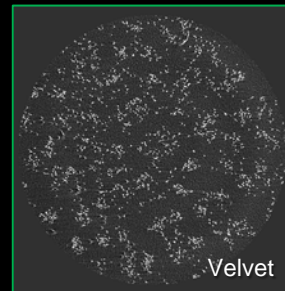


Material sample

Micro CT scanner in UTCT



Desktop micro CT scanner



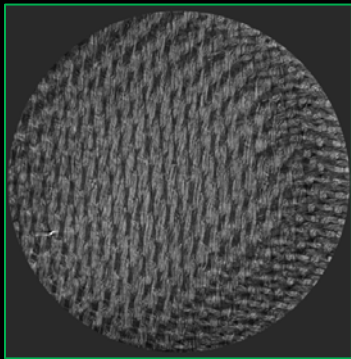
CT images



Volumetric Appearance Model

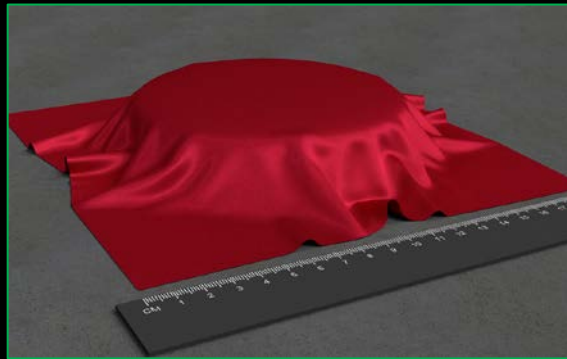


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Micro CT image

Extend



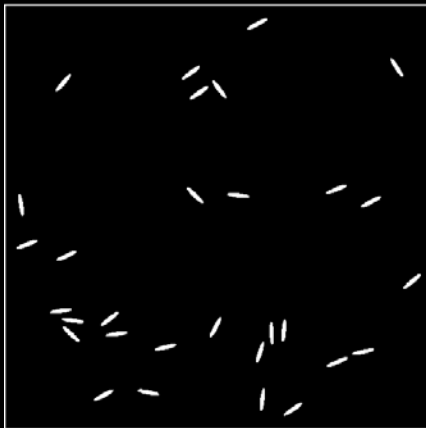
Volumetric appearance model



Micro-flake Model



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Anisotropic medium

Anisotropic
model

[Jakob et al. 2010]



Isotropic
model

Rendered image

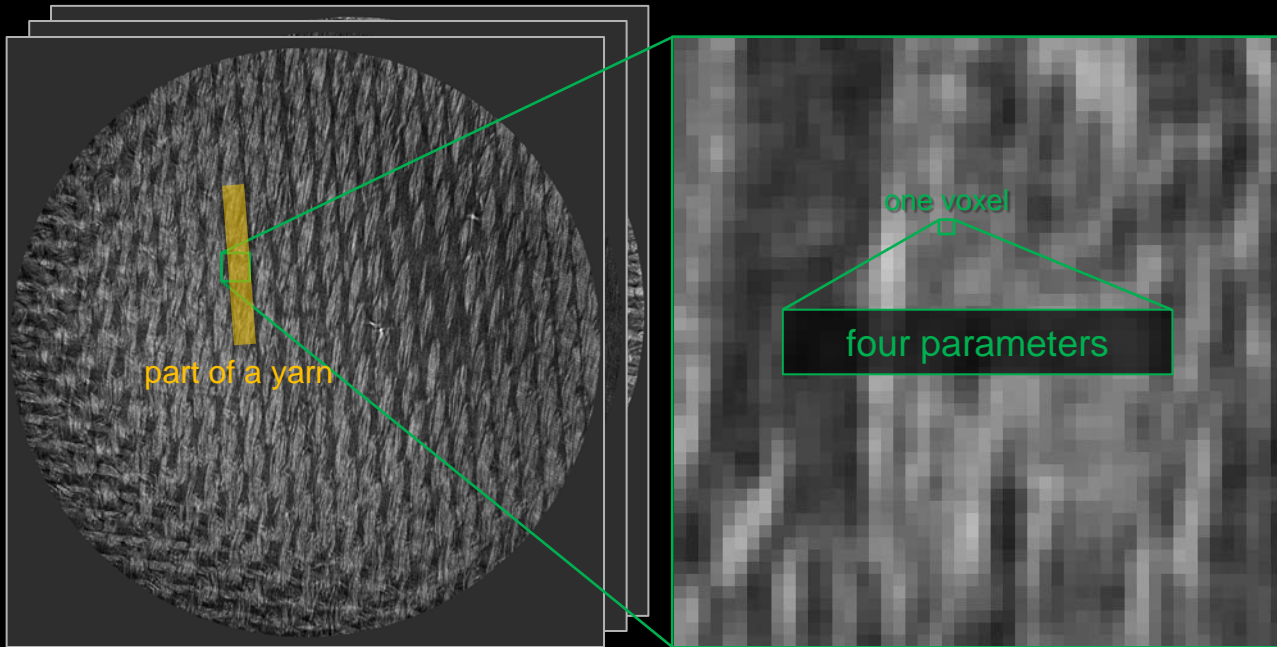
Crucial for cloth rendering



Micro-flake Model: Description



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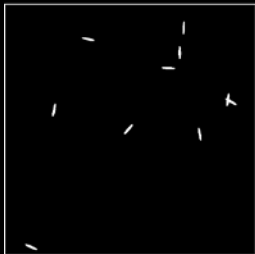
Micro-flake Model: Parameters



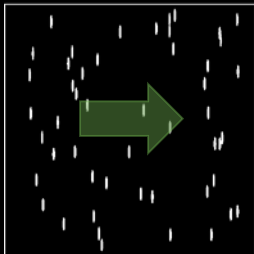
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Fiber arrangement

Flake density

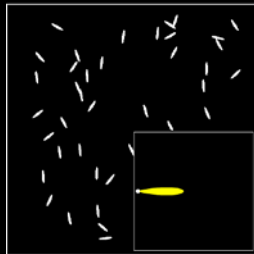


Flake orientation

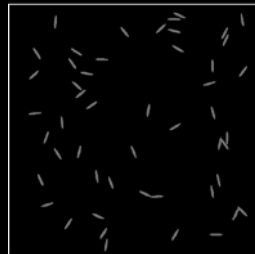


Fiber appearance

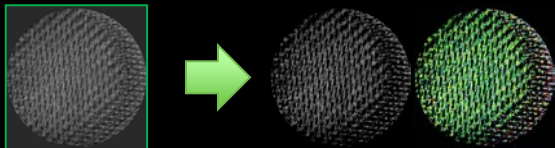
Flake spread



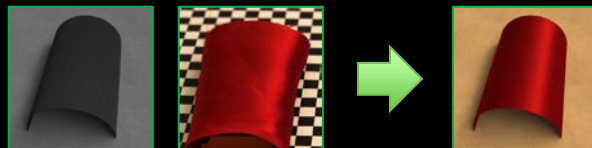
Single-scattering albedo



CT image processing



Appearance matching



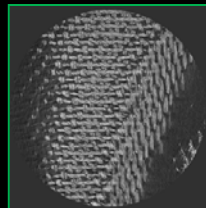


Our Pipeline

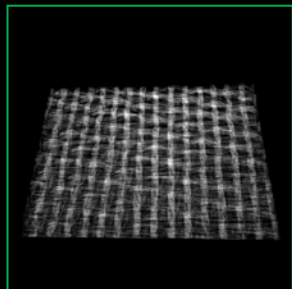


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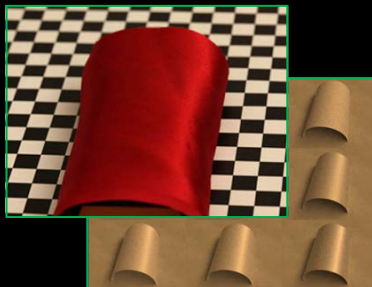
Input:



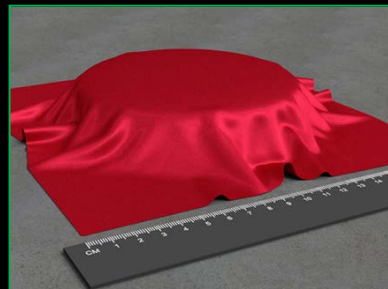
Micro CT images



CT image processing



Appearance matching



Rendering

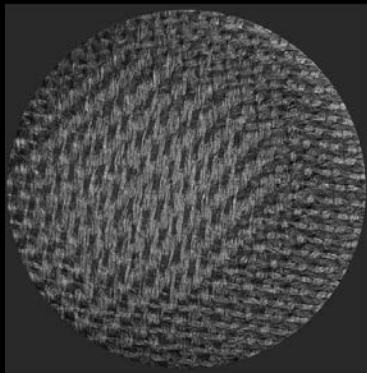


CT Image Processing: Goal



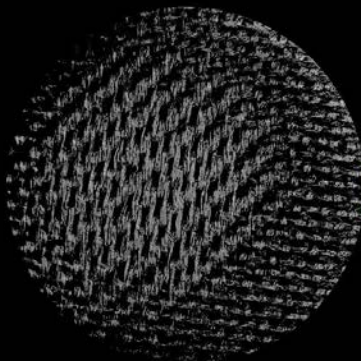
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Input

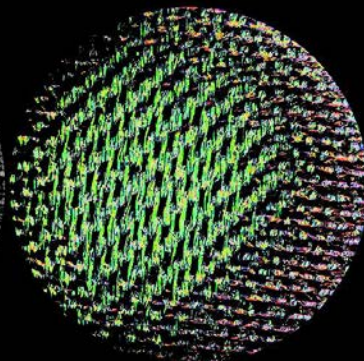


Micro CT images

Output

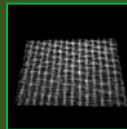


Flake density



Flake orientation

Outline



CT Image Processing



Appearance Matching



Rendering



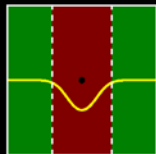
CT Image Processing



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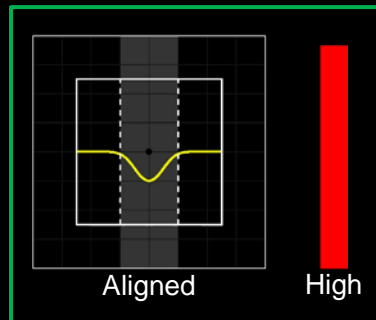
Fiber orientation detection

negative positive

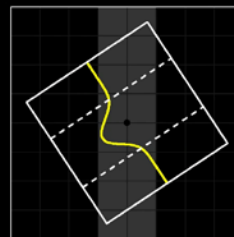


Filter

[Shinohara et al. 2010]



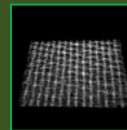
Orientation detected



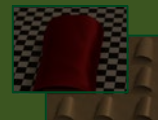
Low

Denoising

Outline



CT Image Processing



Appearance Matching

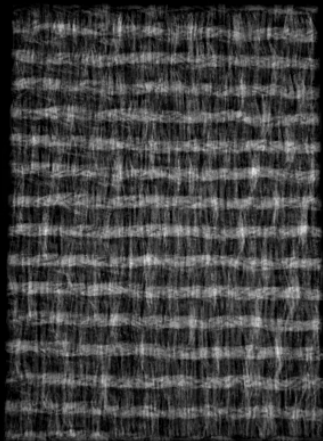


Rendering

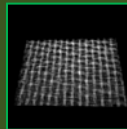
CT Image Processing: Result



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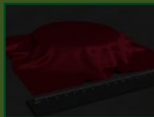
Outline



CT Image Processing



Appearance Matching



Rendering



CT Image Processing



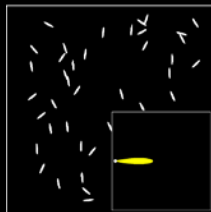
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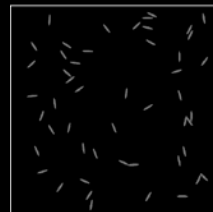
Flake density
(per-pixel scalar)



Flake orientation
(per-pixel vector)

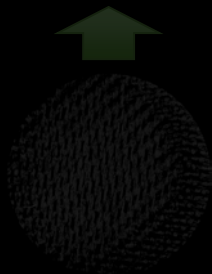


Flake spread
(global scalar)

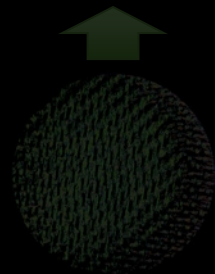


Single-scattering albedo
(global per-channel scalar)

To be solved in the next stage



Denoised density field

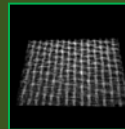


Computed orientation field

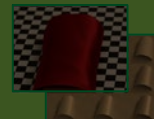


Density multiplier

Outline



CT Image Processing



Appearance Matching



Rendering

Appearance Matching: Goal



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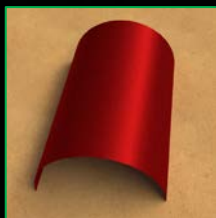


One photo
(measured appearance)

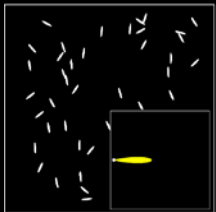


Match

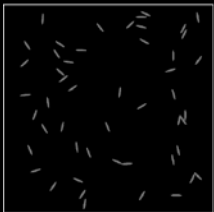
Inverse rendering
problem



Rendered image



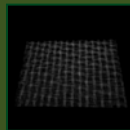
Flake spread



Single-scattering albedo



Outline



CT Image Processing



Appearance Matching



Rendering



Appearance Matching



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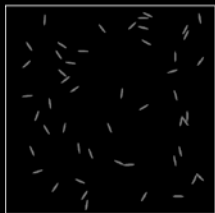
One photo
(measured appearance)

What to match?



Rendered image

Two statistical measures

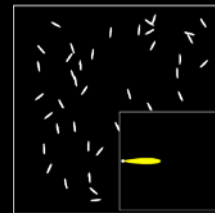


Single-scattering albedo



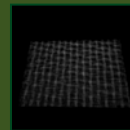
Mean

Standard
deviation

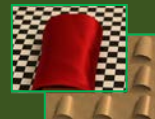


Flake spread

Outline



CT Image Processing



Appearance Matching



Rendering

Appearance Matching

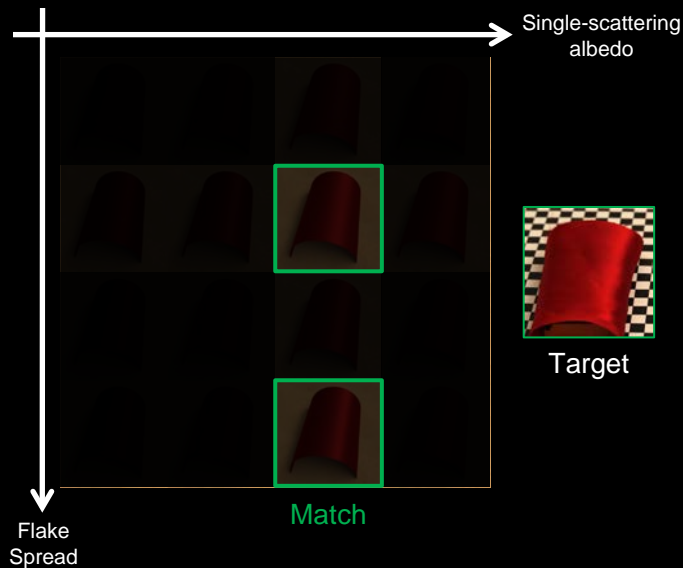


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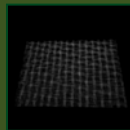
How to find the match?

- Binary Search

- Match mean
- Match standard deviation



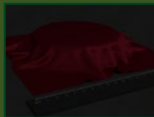
Outline



CT Image Processing



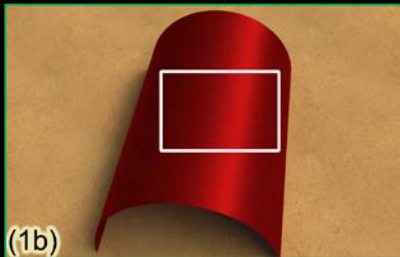
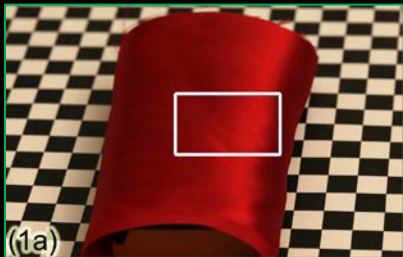
Appearance Matching



Rendering

Appearance Matching: Result

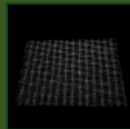
Appearance matching pair



Validation pair
(rotated sample, same lighting)



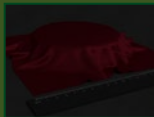
Outline



CT Image Processing



Appearance Matching



Rendering



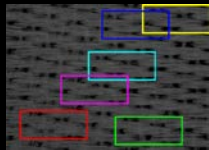
Rendering



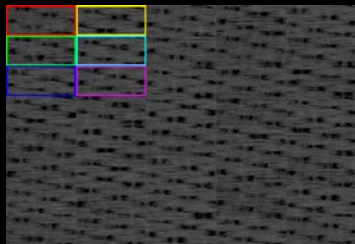
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- Before rendering...

- Data Replication



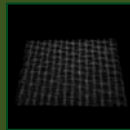
Original data



Tiled data

- Shellmap [Porumbescu et al. 2005]
- Monte Carlo volume path tracing
 - New sampling strategy

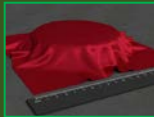
Outline



CT Image Processing



Appearance Matching



Rendering



Experimental Results

Building Volumetric Appearance Models
of Fabric using Micro CT Imaging



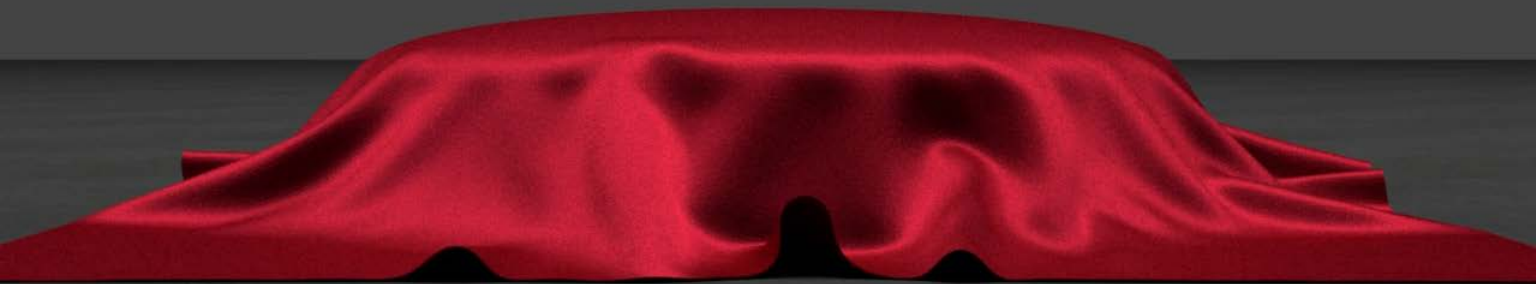
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Rendering: silk satin



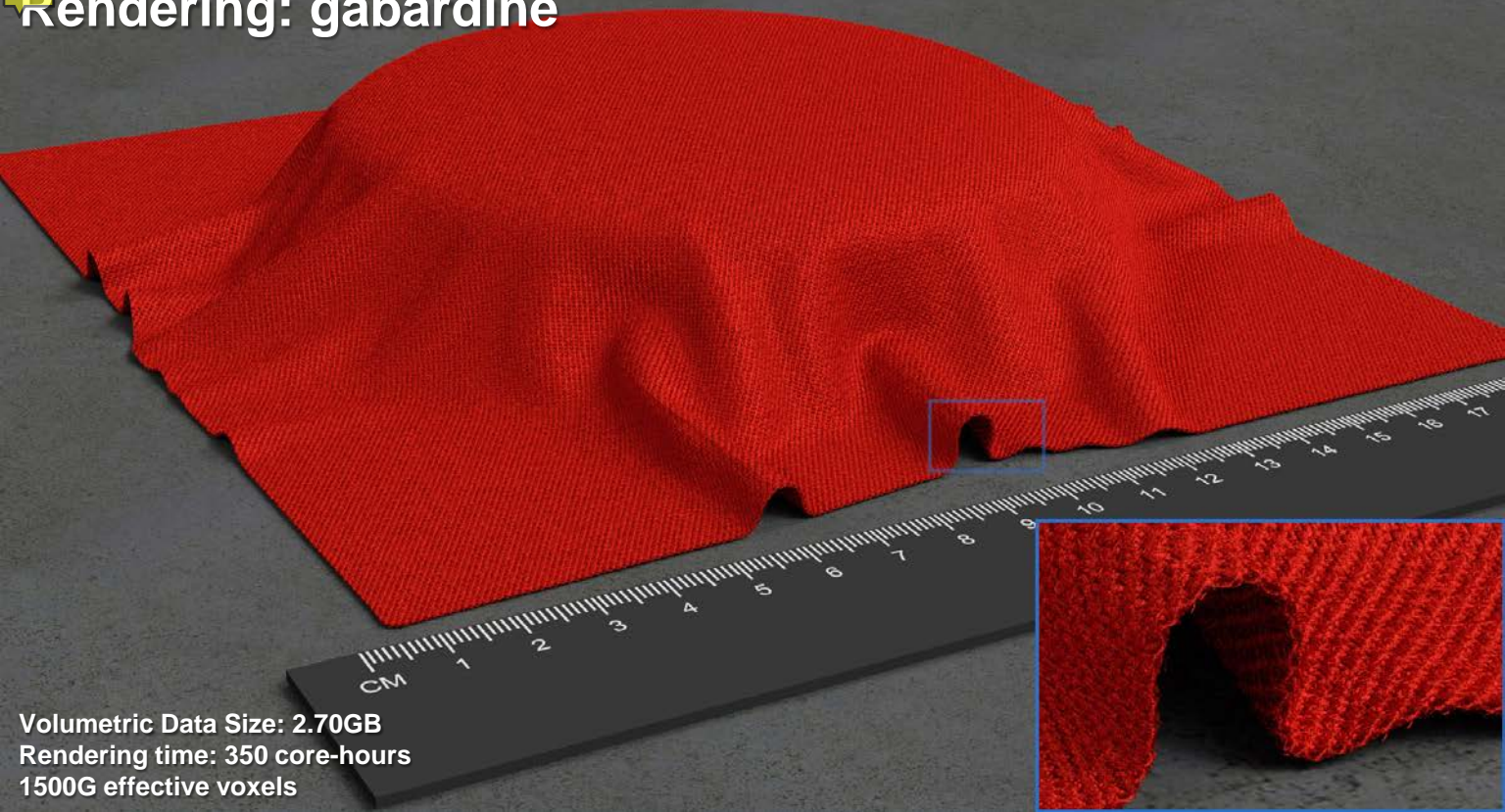
Volumetric Data Size: 800MB
Rendering time: 470 core-hours
500G effective voxels

 Rendered video: silk satin



Area lighting

Rendering: gabardine



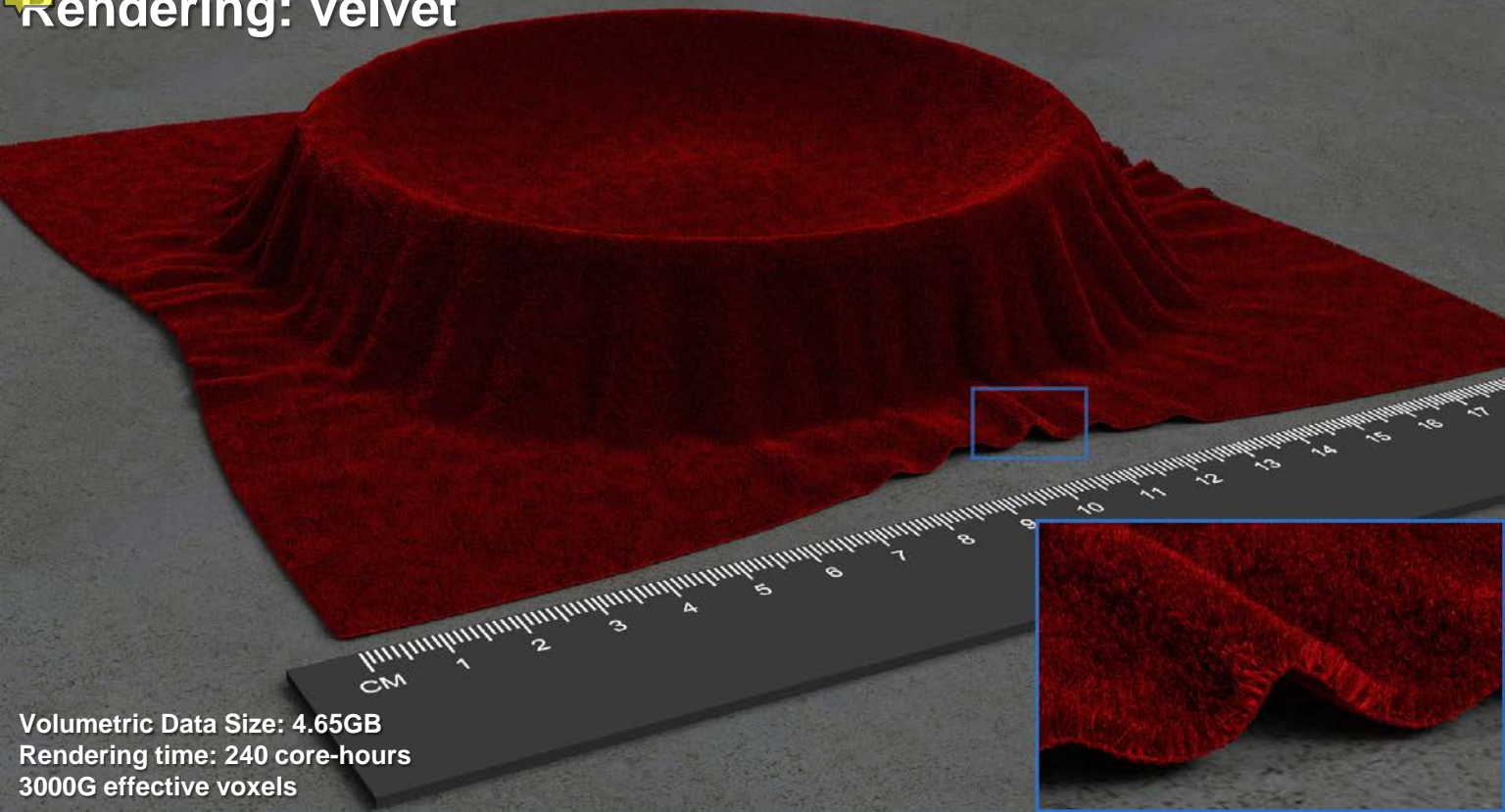
Volumetric Data Size: 2.70GB
Rendering time: 350 core-hours
1500G effective voxels

 Rendered video: gabardine



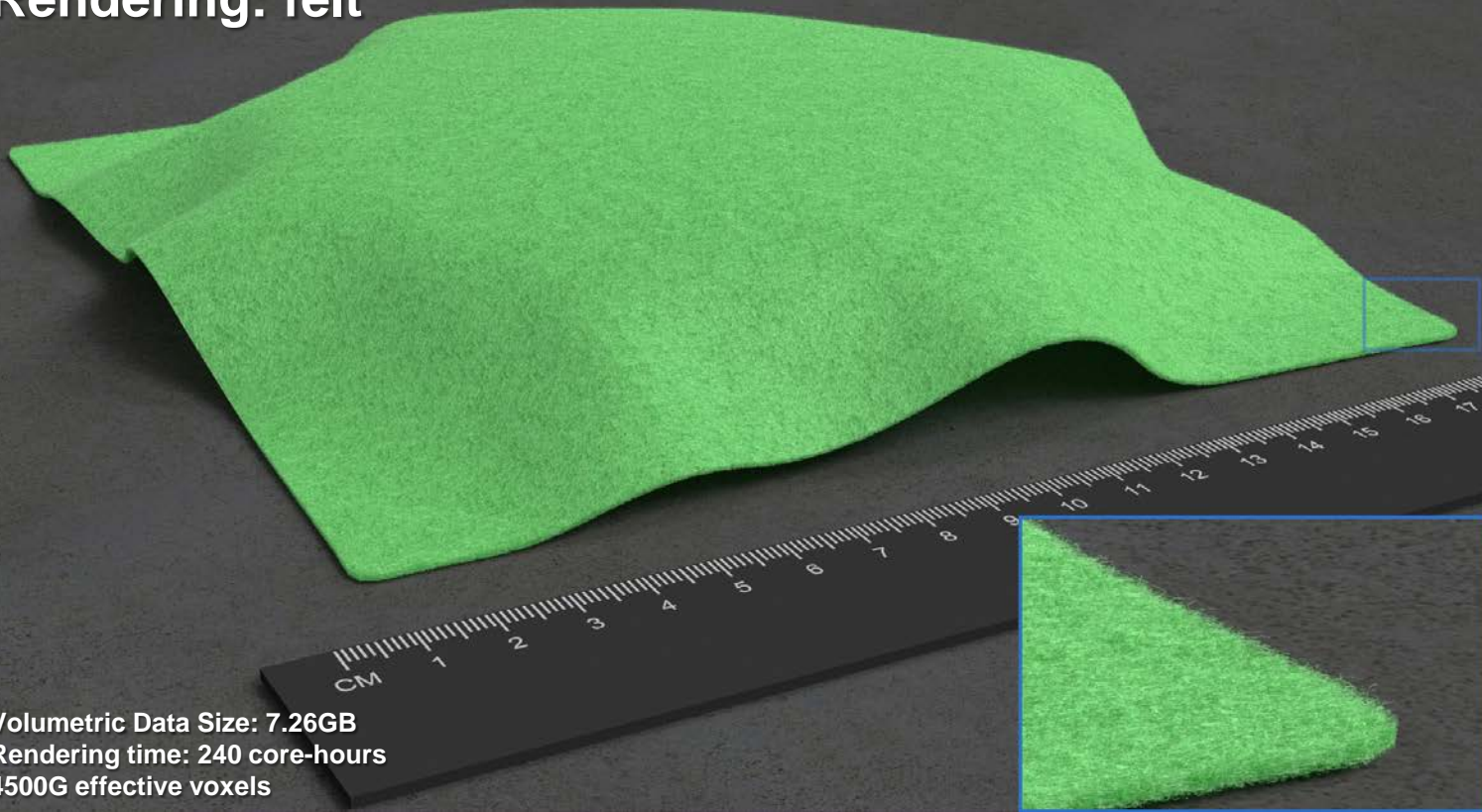
Environment lighting

Rendering: velvet



Volumetric Data Size: 4.65GB
Rendering time: 240 core-hours
3000G effective voxels

Rendering: felt



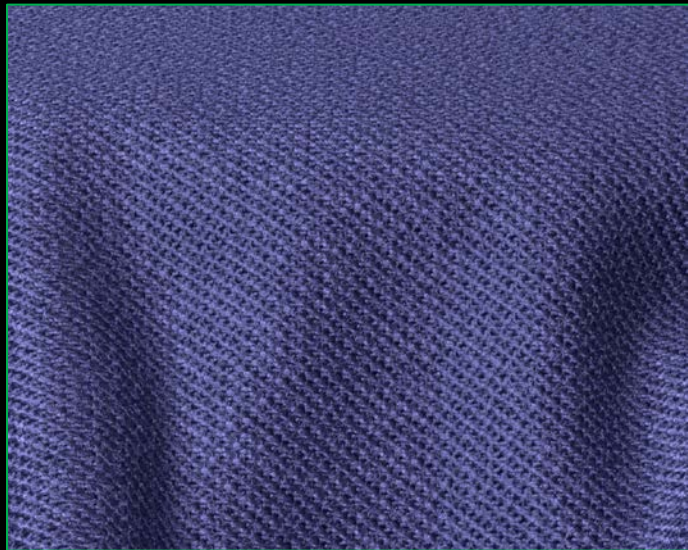
Volumetric Data Size: 7.26GB
Rendering time: 240 core-hours
4500G effective voxels



Edited Results



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Uniform albedo change



Orientation-based albedo change

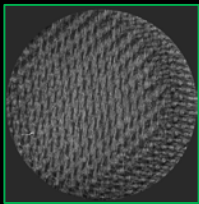


Conclusions



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- A new way of building volumetric appearance models



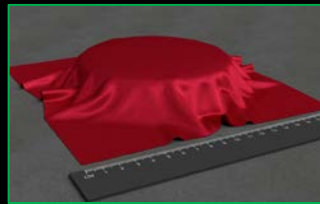
Structure:
micro CT imaging

+



Appearance:
photographs

=



Volumetric appearance models

- The power of structural information
- Future work
 - Multicolored fibers, synthesis-based data replication
 - Beyond fabrics and CT



Acknowledgements



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- Piti Irawan
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 - Autodesk

