



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

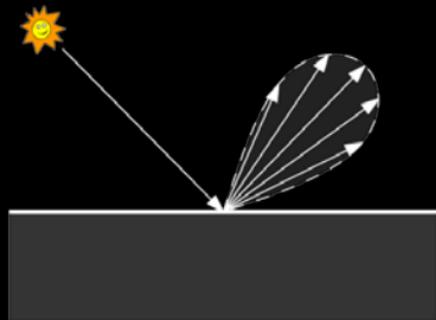


Velvet

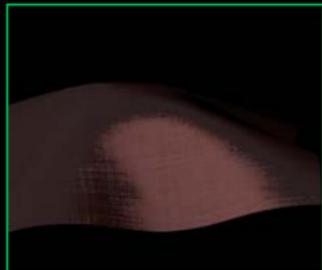


Cloth Appearance Models

- Surface-based

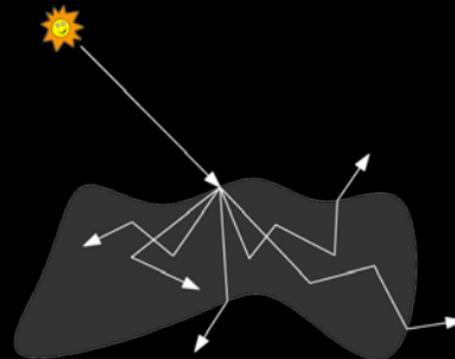


[Ashikhmin et al. 2000]



[Irawan 2008]

- Volumetric



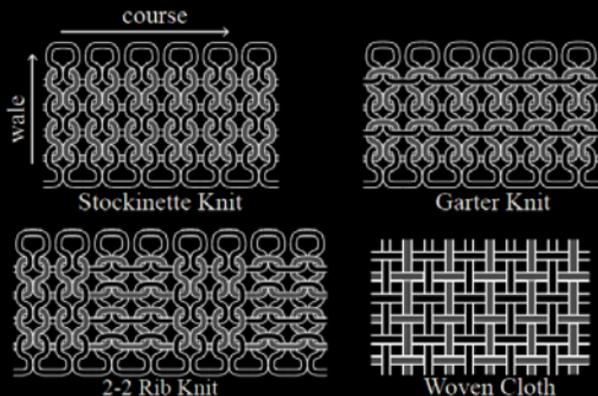
[Xu et al. 2001]



[Jakob et al. 2010]

Building Volumetric Models

- A procedural process
- Requires significant manual effort



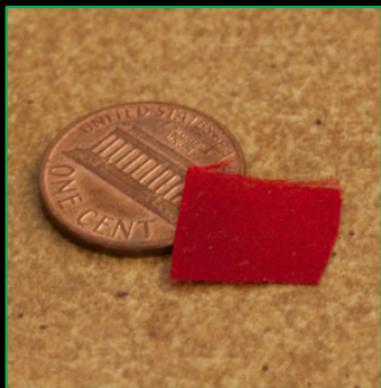
[Kaldor et al. 2008]



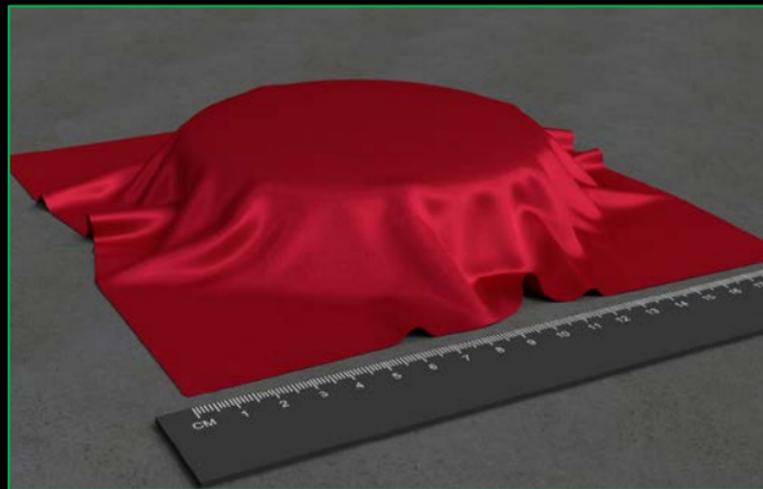


Our Goal

- 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], ...



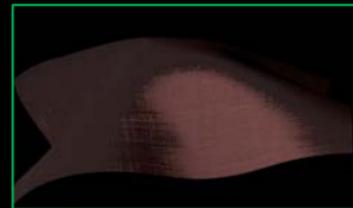
[Wang et al. 2008]



[Jakob et al. 2010]

- Cloth reflectance models

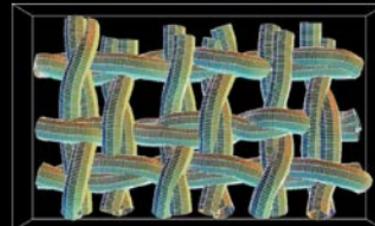
- [Irawan 2008], ...



[Irawan 2008]

- Cloth structure

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

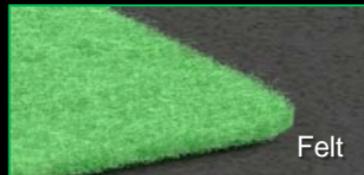


[Shinohara et al. 2010]



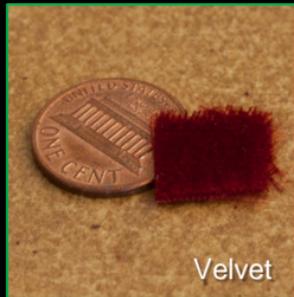
Our Contribution

- 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

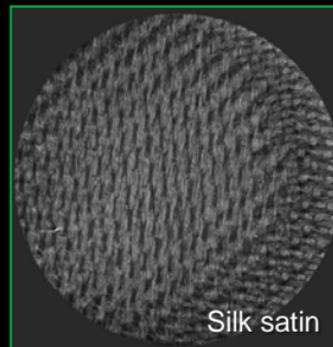
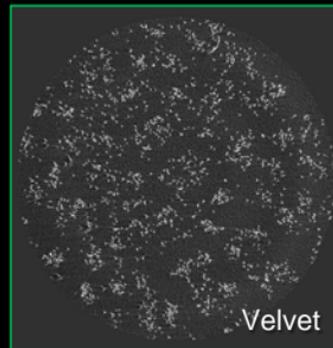


Material sample

Micro CT scanner in UTCT

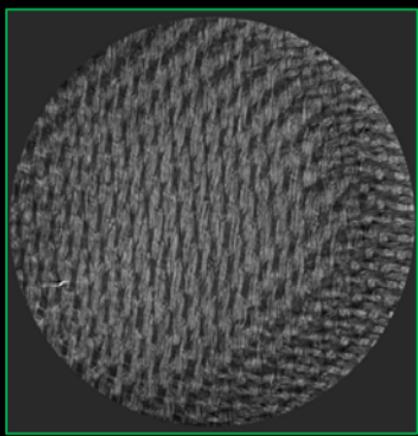


Desktop micro CT scanner



CT images

Volumetric Appearance Model



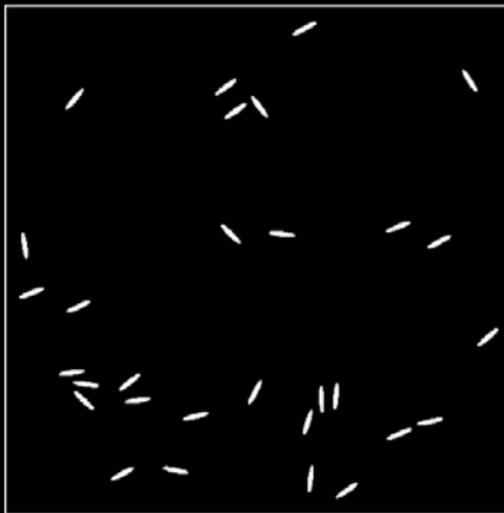
Micro CT image



Volumetric appearance model



Micro-flake Model



Anisotropic medium

Anisotropic model



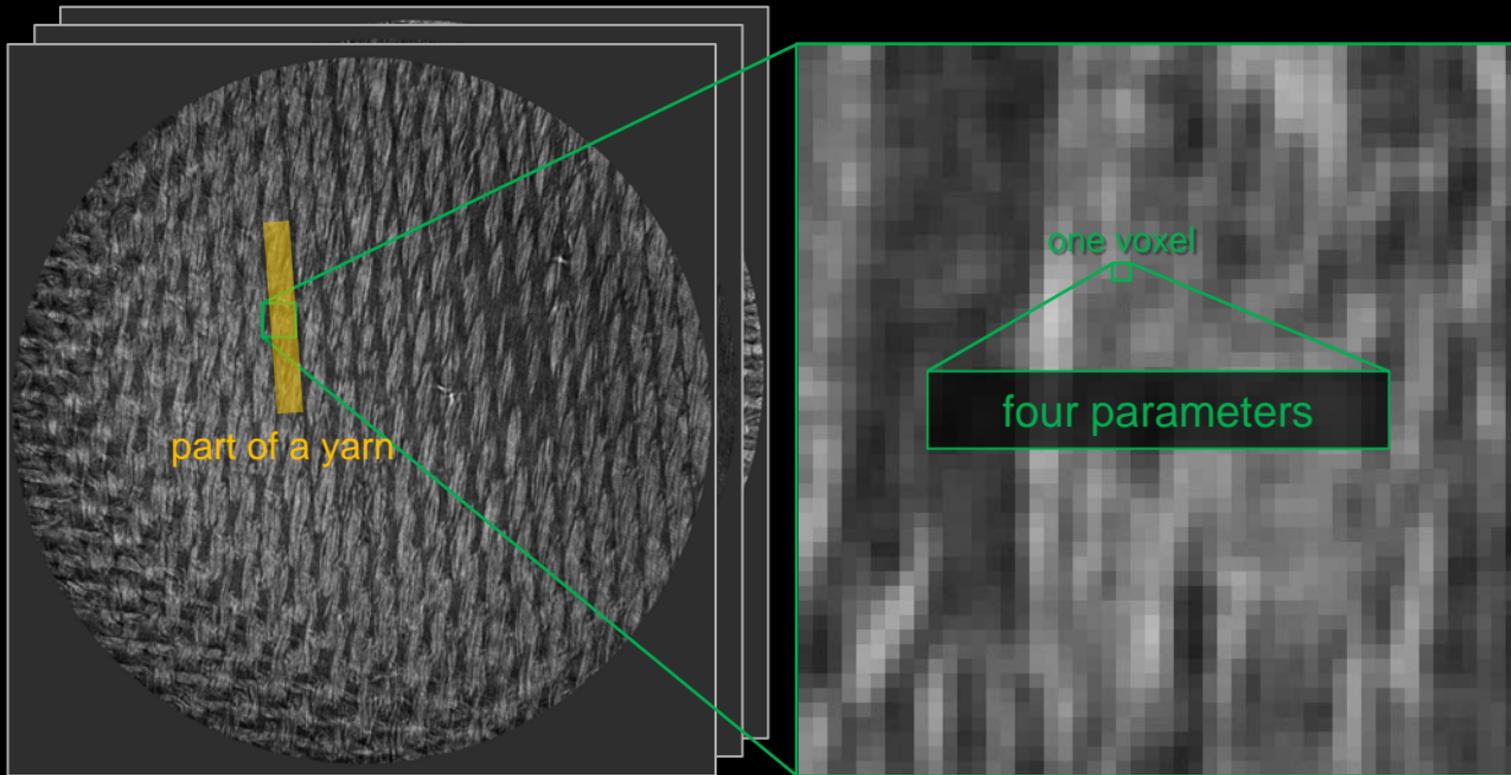
Isotropic model

Rendered image

Crucial for cloth rendering



Micro-flake Model: Description





Micro-flake Model: Parameters

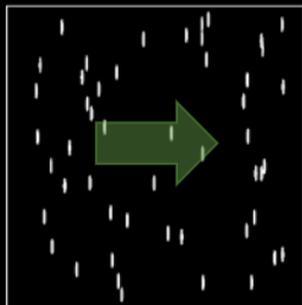
Fiber arrangement

Fiber appearance

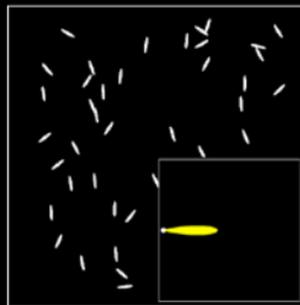
Flake density



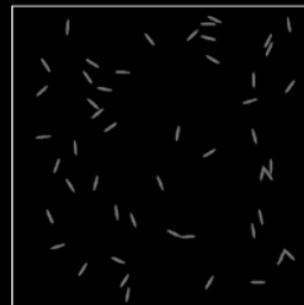
Flake orientation



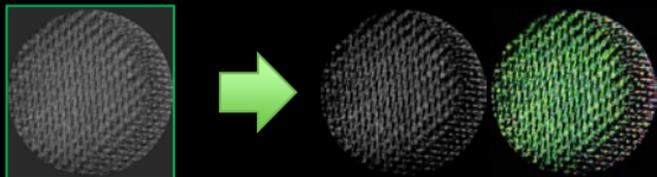
Flake spread



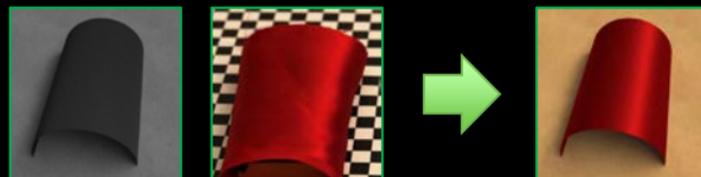
Single-scattering albedo



CT image processing

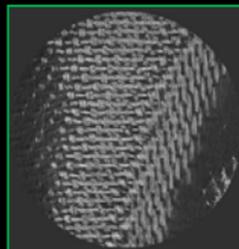


Appearance matching

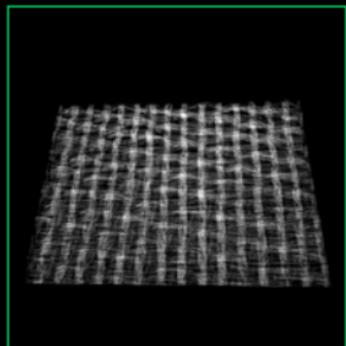


Our Pipeline

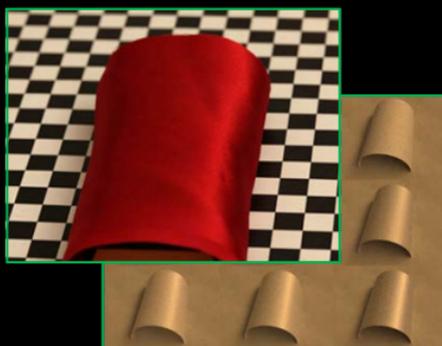
Input:



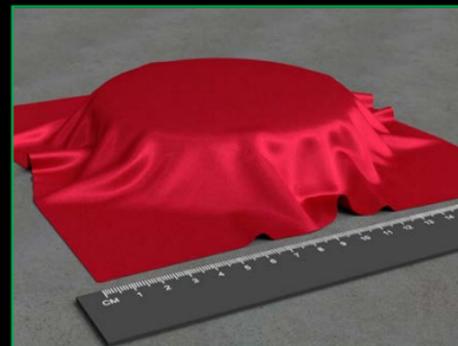
Micro CT images



CT image processing



Appearance matching



Rendering

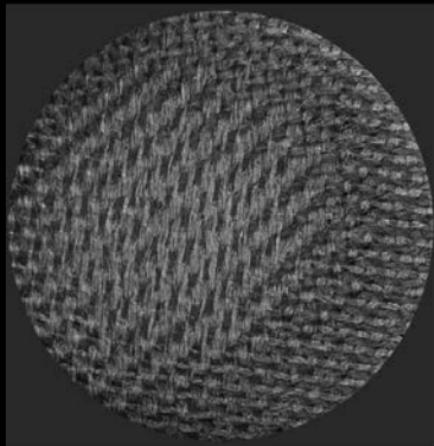


CT Image Processing: Goal



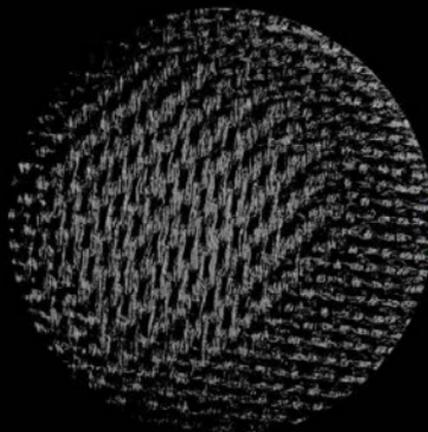
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Input

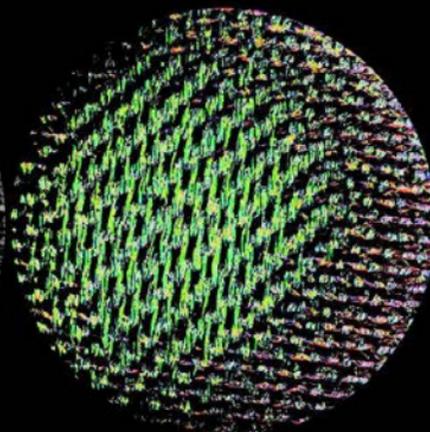


Micro CT images

Output

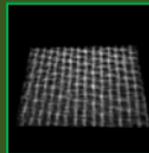


Flake density



Flake orientation

Outline



CT Image Processing



Appearance Matching

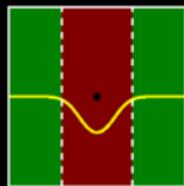


Rendering

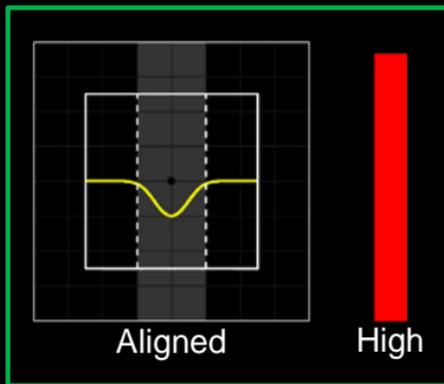
CT Image Processing

Fiber orientation detection

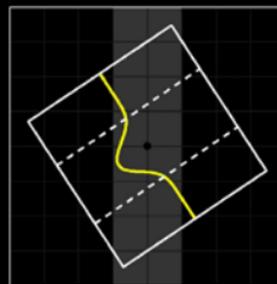
■ negative ■ positive



Filter
[Shinohara et al. 2010]



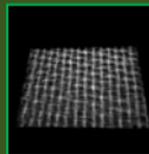
Orientation detected



Low

Denoising

Outline



CT Image Processing



Appearance Matching

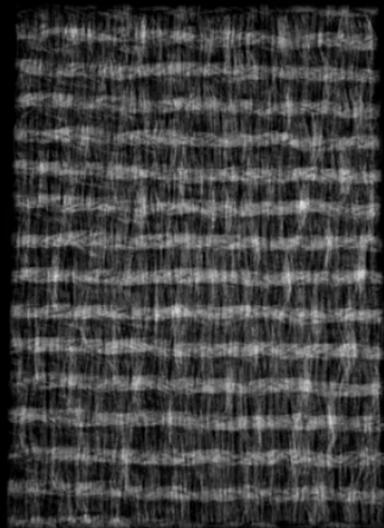


Rendering

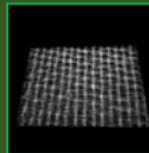
CT Image Processing: Result



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Outline



CT Image Processing



Appearance Matching



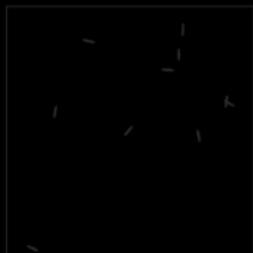
Rendering



CT Image Processing



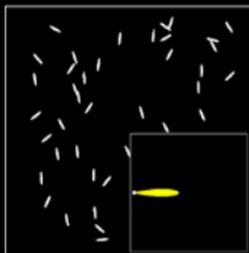
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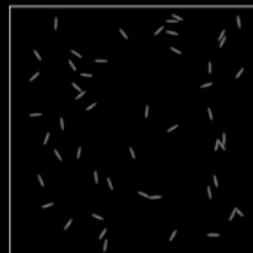
Flake density
(per-pixel scalar)



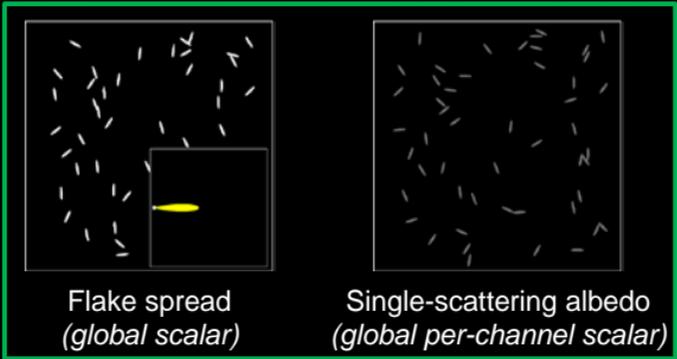
Flake orientation
(per-pixel vector)



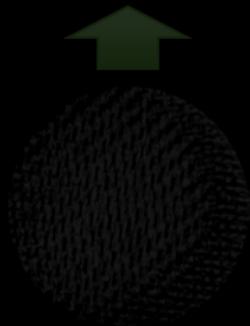
Flake spread
(global scalar)



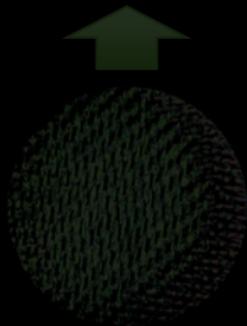
Single-scattering albedo
(global per-channel scalar)



To be solved in the next stage



Denoised density field

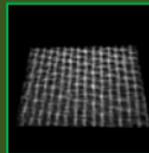


Computed orientation field



Density multiplier

Outline



CT Image Processing



Appearance Matching



Rendering

Appearance Matching: Goal



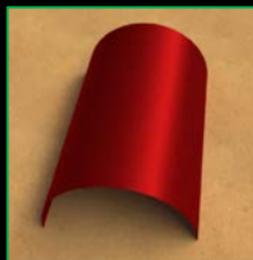
SIGGRAPH2011
VANCOUVER



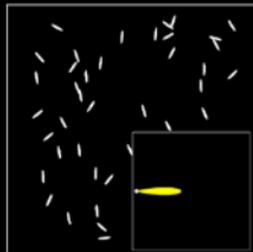
One photo
(measured appearance)



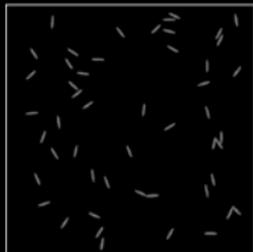
Inverse rendering
problem



Rendered image



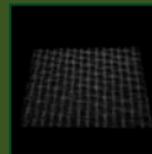
Flake spread



Single-scattering albedo



Outline



CT Image Processing



Appearance Matching



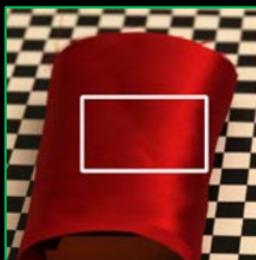
Rendering



Appearance Matching



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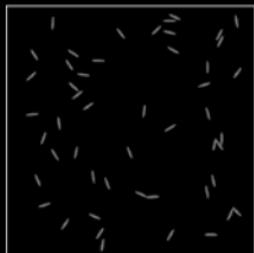
One photo
(measured appearance)

What to match?



Rendered image

Two statistical measures

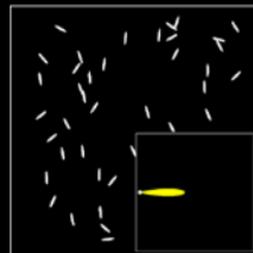


Single-scattering albedo



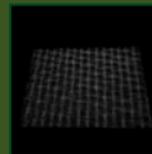
Mean

Standard
deviation



Flake spread

Outline



CT Image Processing



Appearance Matching



Rendering

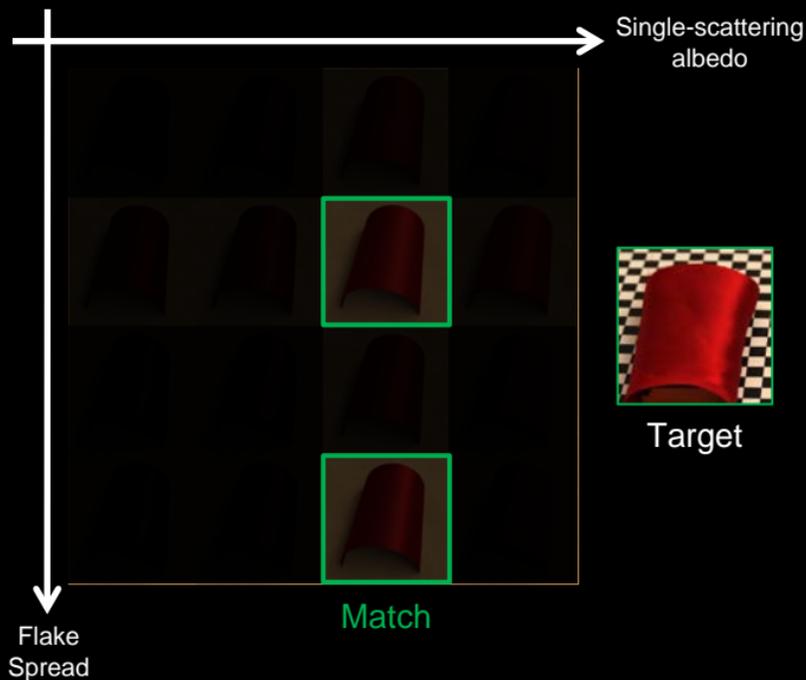
Appearance Matching



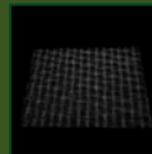
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How to find the match?

- Binary Search
 - Match mean
 - Match standard deviation



Outline



CT Image Processing



Appearance Matching



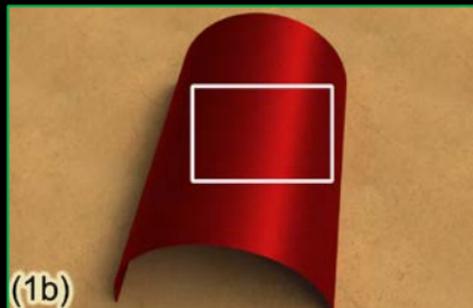
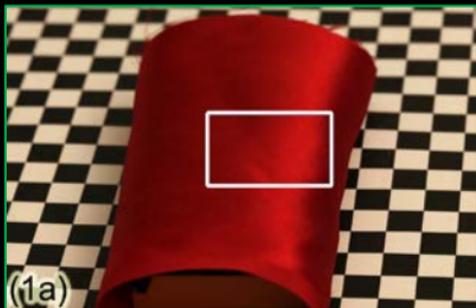
Rendering

Appearance Matching: Result



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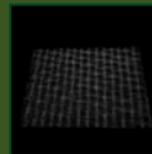
Appearance matching pair



Validation pair
(rotated sample, same lighting)



Outline



CT Image Processing



Appearance Matching

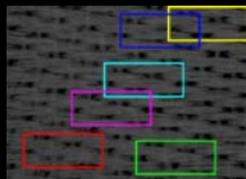


Rendering

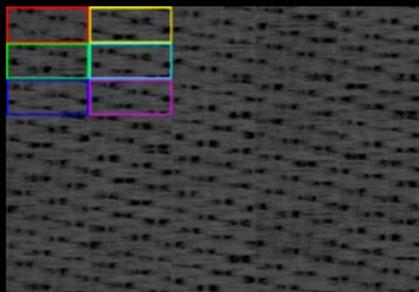
Rendering

- Before rendering...

- Data Replication



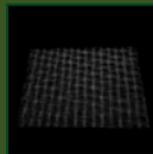
Original data



Tiled data

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

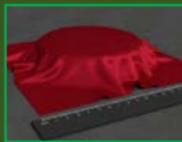
Outline



CT Image Processing



Appearance Matching



Rendering



Experimental Results

Building Volumetric Appearance Models
of Fabric using Micro CT Imaging



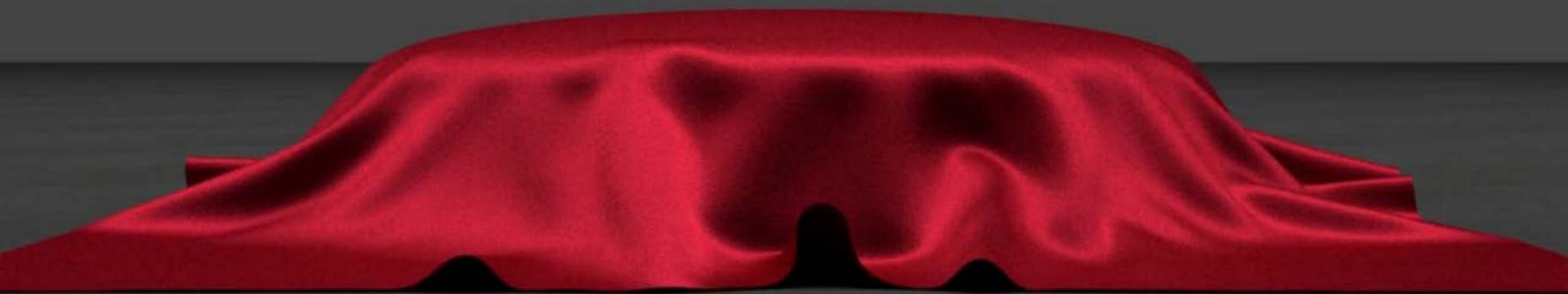
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Rendering: silk satin



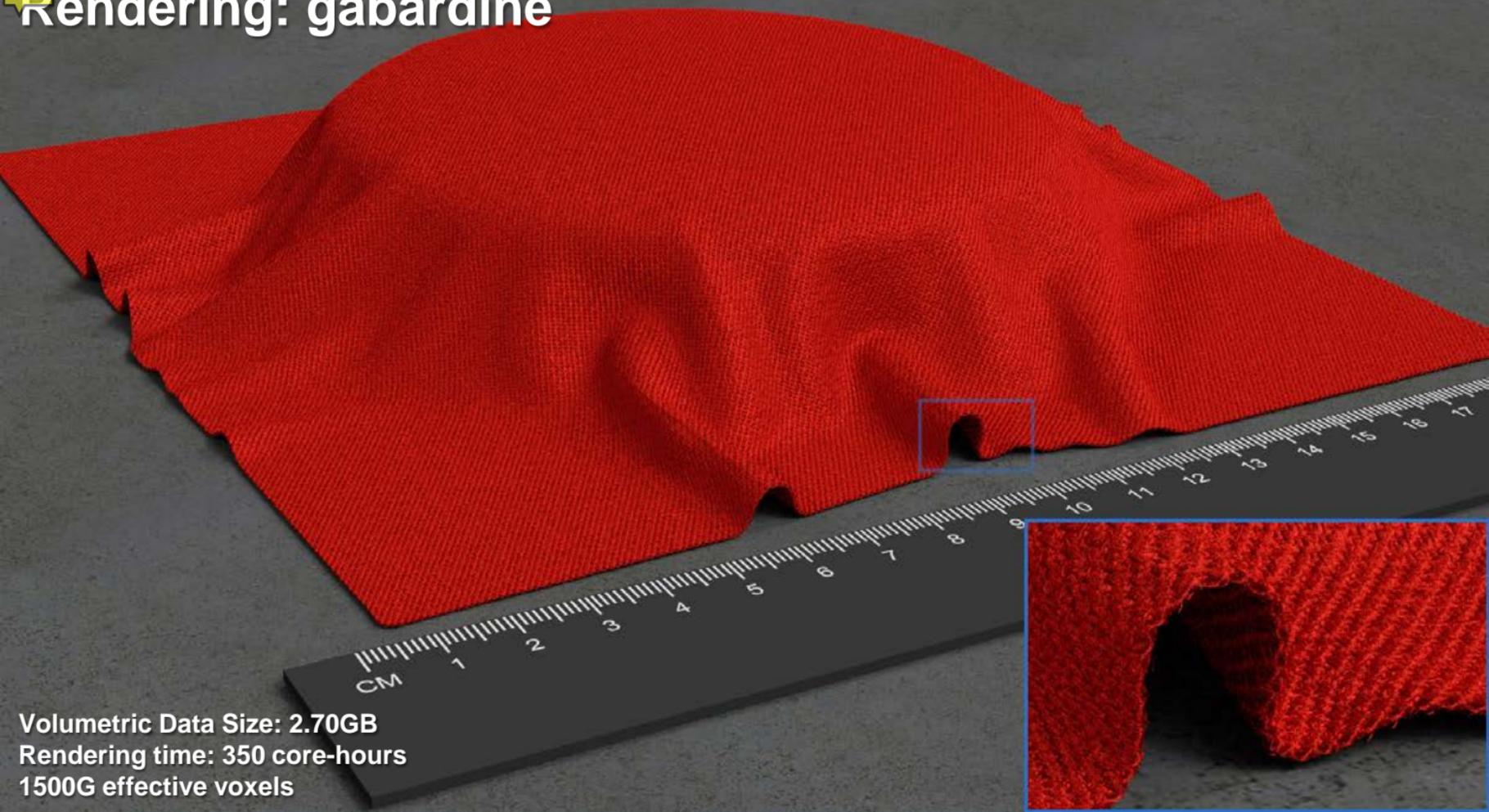
Volumetric Data Size: 800MB
Rendering time: 470 core-hours
500G effective voxels

 Rendered video: silk satin



Area lighting

Rendering: gabardine



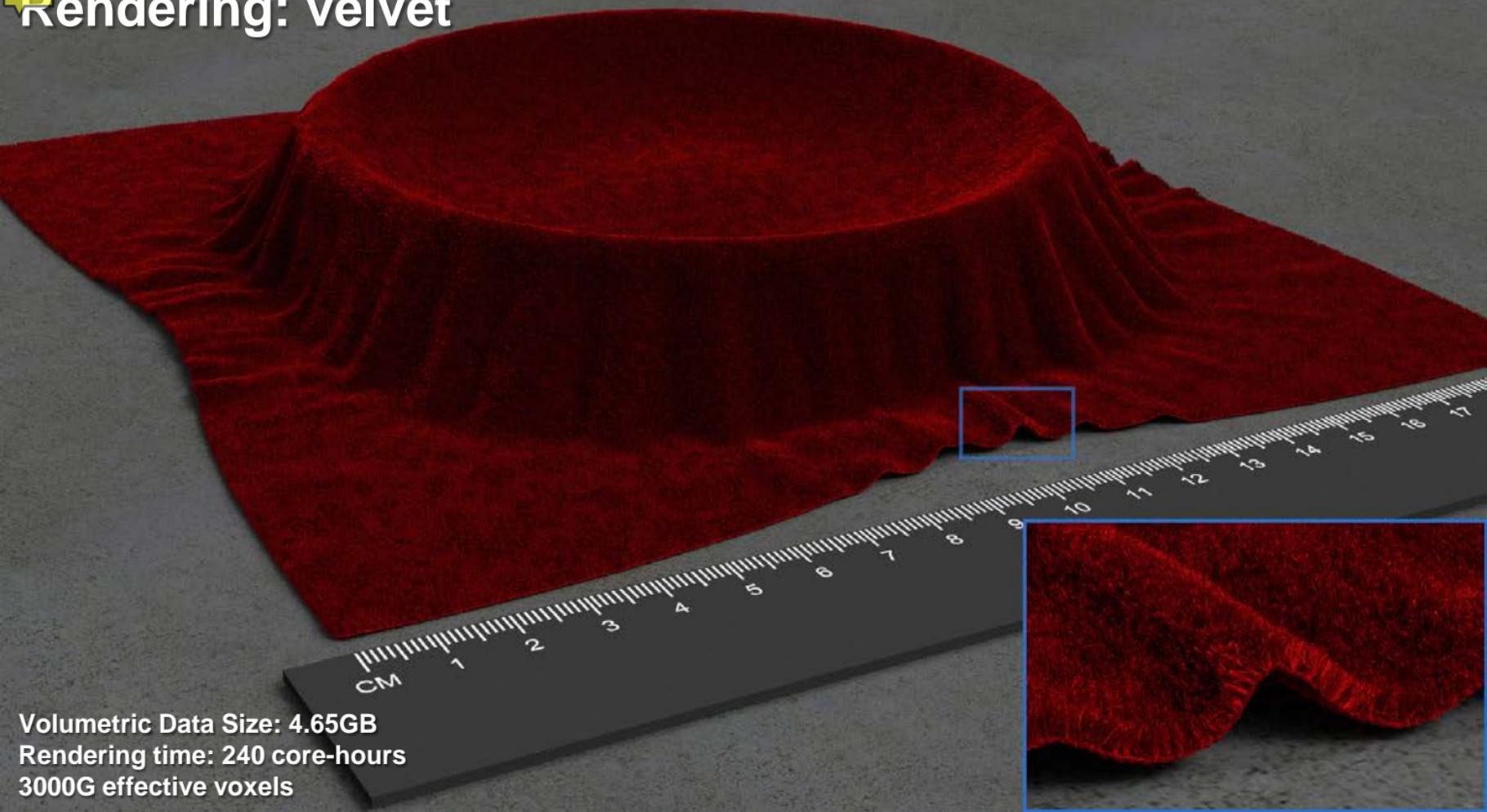
Volumetric Data Size: 2.70GB
Rendering time: 350 core-hours
1500G effective voxels

 Rendered video: gabardine



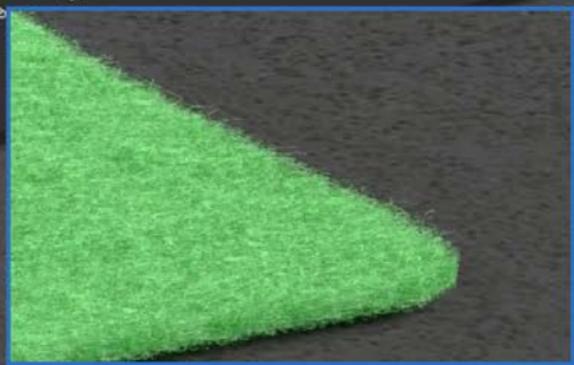
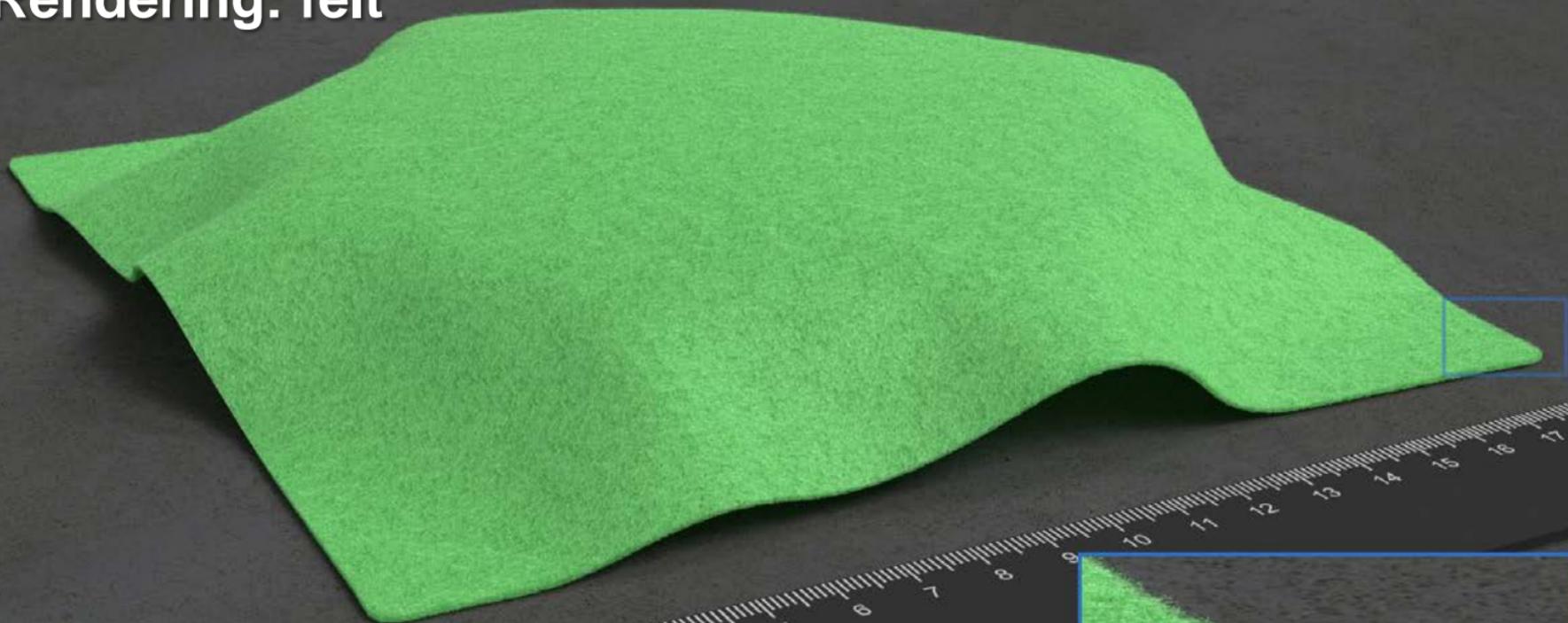
Environment lighting

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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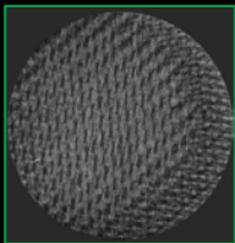
Uniform albedo change



Orientation-based albedo change

Conclusions

- A new way of building volumetric appearance models



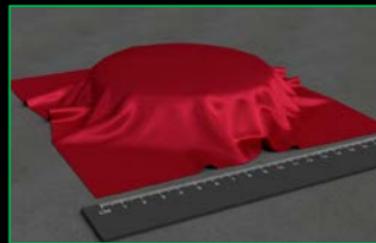
Structure:
micro CT imaging

+



Appearance:
photographs

=



Volumetric appearance models

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



Acknowledgements

- Jessie Maisano
- Piti Irawan

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 - NSF grants CCF-0644175, CCF-0702490, CCF-0811680, and IIS-1011919
 - Intel
 - Autodesk

