



SIGGRAPH2012



Structure-aware Synthesis for Predictive Woven Fabric Appearance

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Cornell University



Woven Fabric

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- Essential to our life
- Challenging to model and render



Denim fabric



Silk brocade



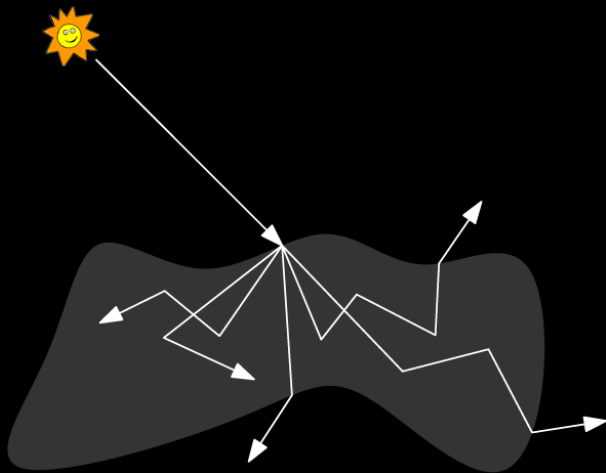
Polyester brocade

Fabric Appearance Models

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- Volumetric models



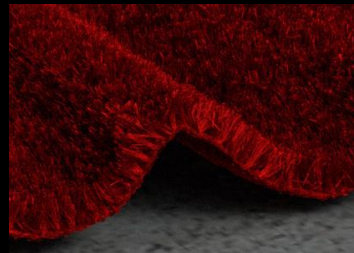
[Kajiya and Kay 1989]



[Jakob et al. 2010]



[Xu et al. 2001]



[Zhao et al. 2011]



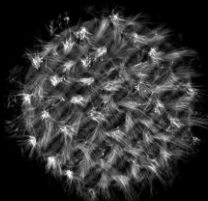
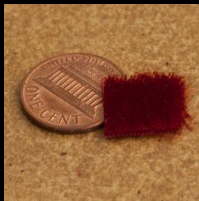
- Using micro computed tomography (CT) imaging [Zhao et al. 2011]

Fabric samples

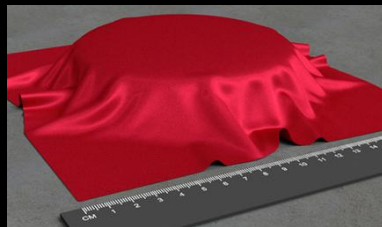
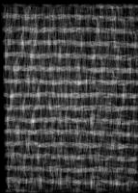
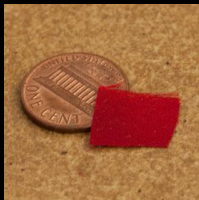
Processed CT images

Rendered images

Velvet



Silk
satin



- Assuming identical fibers, no large-scale designs

Our Goal

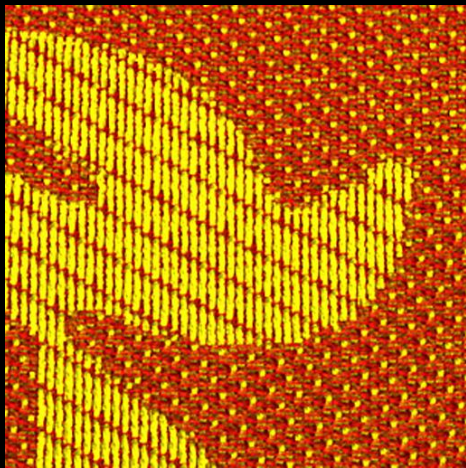
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- Creating volumetric models for woven fabrics



User-specified designs



Yarn-level geometries



Predictive



- Cloth appearance models

- **General:**

- [Wang et al. 2008], [Jakob et al. 2010], ...

- **Specialized:**

- [Sadeghi et al. 2011], [Irawan and Marschner 2012], ...

- Cloth model construction

- [Adabala et al. 2003], [Zhao et al. 2011], ...

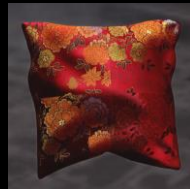
- Example-based synthesis

- **Pixel-based:**

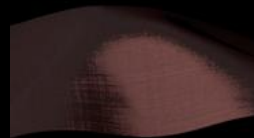
- [Heeger and Bergen 1995], [Ashikhmin 2001], ...

- **Patch-based:**

- [Efros and Freeman 2001], [Cohen et al. 2003], ...



[Wang et al. 2008]



[Irawan and Marschner 2012]



[Adabala et al. 2003]



[Zhao et al. 2011]



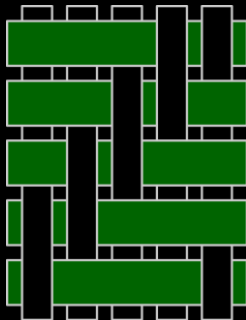
[Ashikhmin 2001]



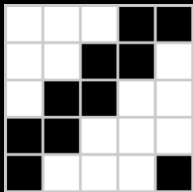
[Efros and Freeman 2001]



Industrial loom



Woven fabric



Weave pattern



Real fabric

Our System

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Industrial
loom



Physical material

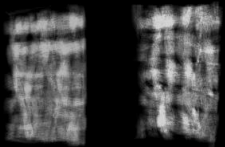


Weave pattern



Real fabric

Our
system



Scanned database



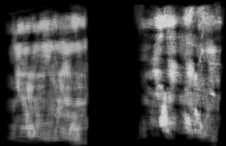
Weave pattern



Volumetric model



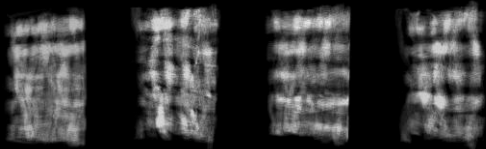
Our
system



Scanned database

Weave pattern

Volumetric model



Database Construction

- End-to-end pipeline

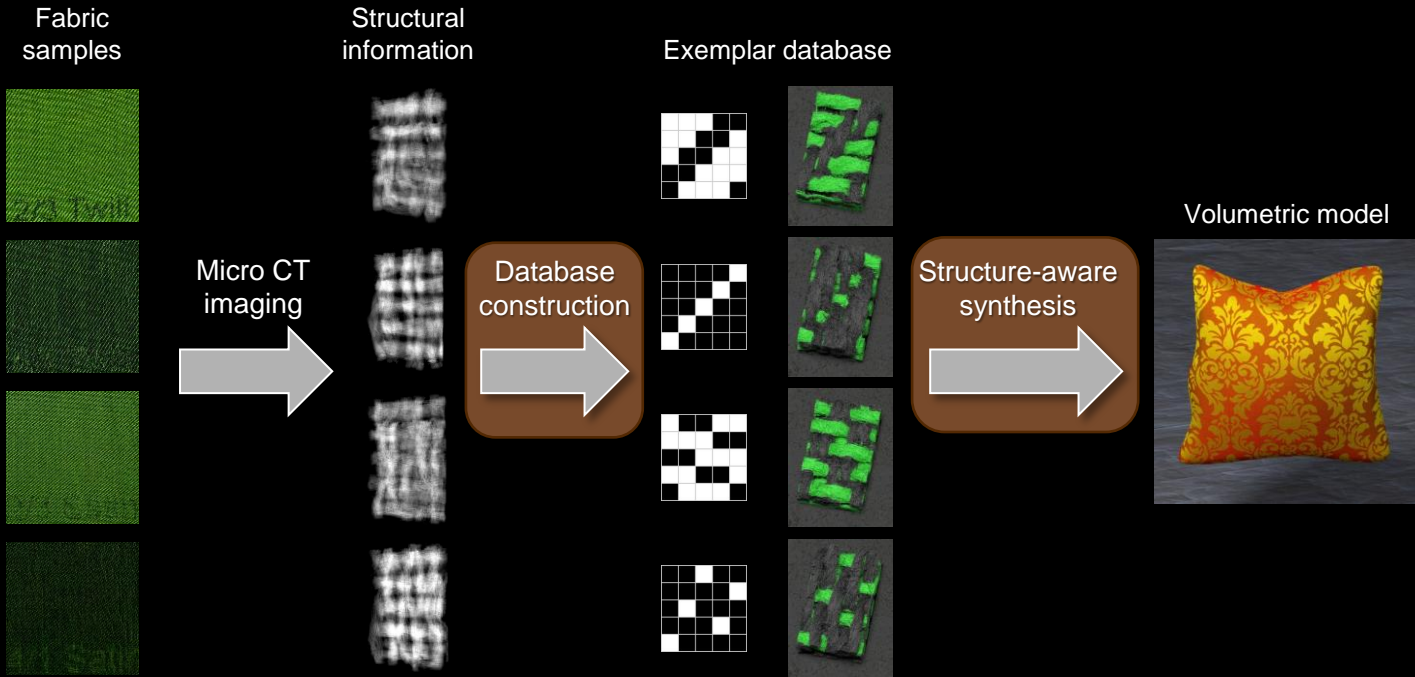


Structure-aware Synthesis

- Highly efficient algorithm

Pipeline

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Structure-aware Synthesis

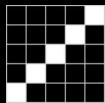
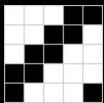
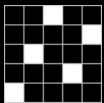
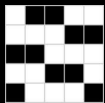
Problem Specification

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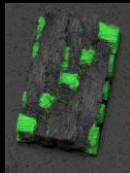
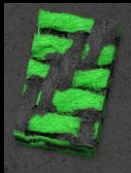
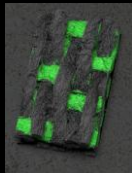
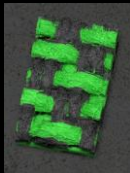
Exemplar database

Weave
patterns

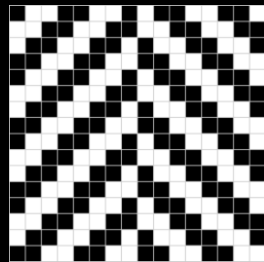


...

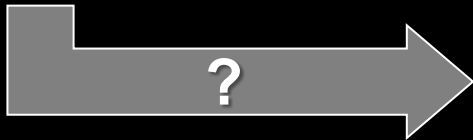
Volume
data



...



Input weave pattern



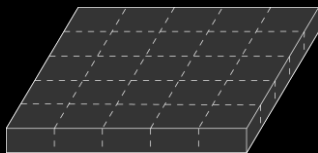
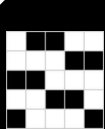
Output volume

Problem at the Yarn-level

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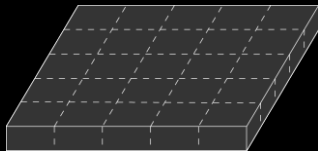
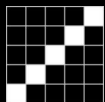


Exemplar database



25 blocks

⋮

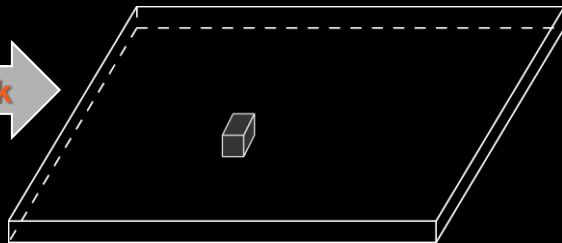


25 blocks

Block: a sub-volume corresponding to one yarn crossing

Reference a **block**

Output volume



1 million blocks

Principles for Example Block Selection

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- Correctness
 - Matching user-specified design

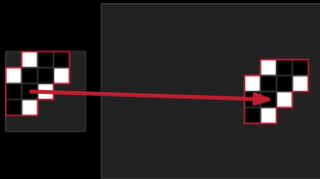
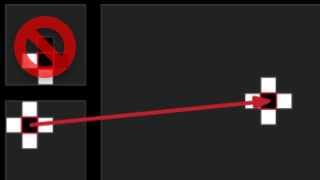
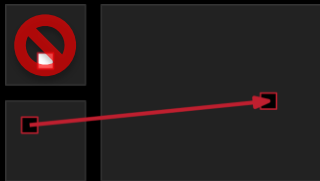
Break ties

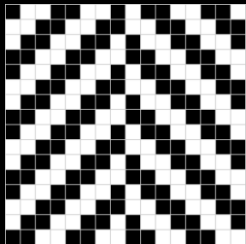
- Consistency
 - Matching neighboring blocks

Break ties

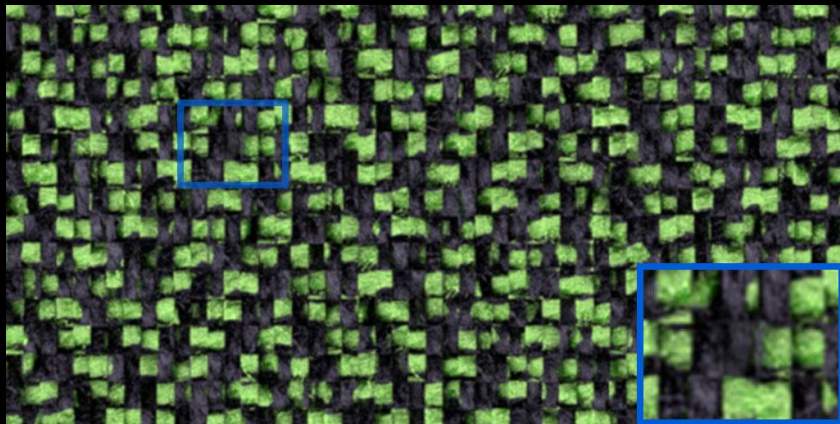
- Continuity
 - Copying continuous content

Exemplars Output Volume





Input weave pattern



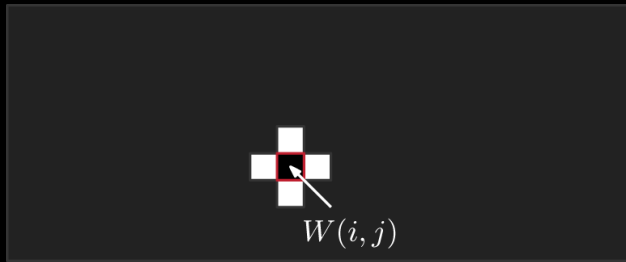
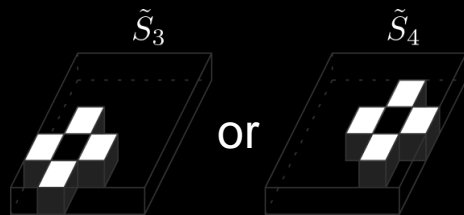
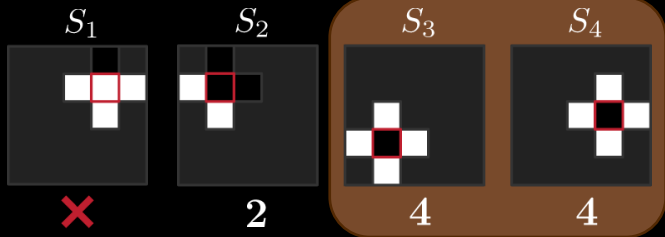
Output volume (top view)

Consistency

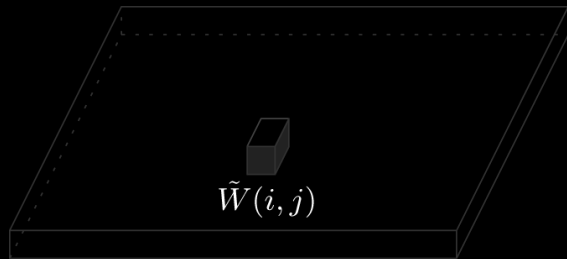
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Maximized consistency



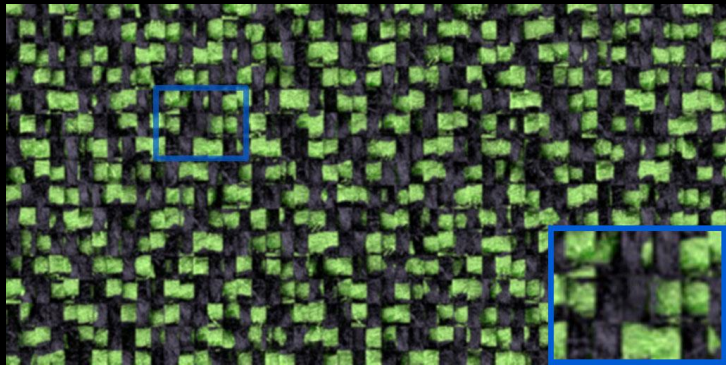
Input Weave Pattern W



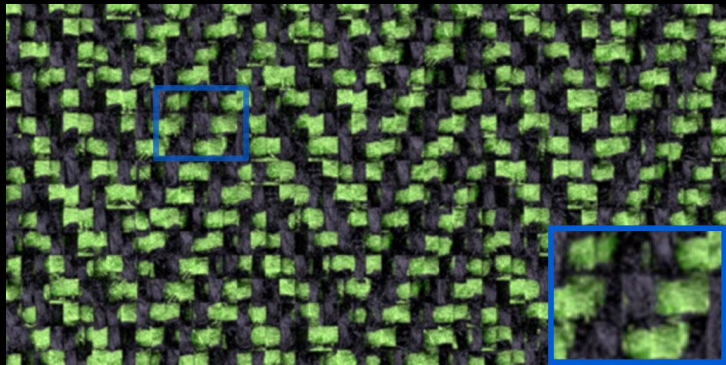
Output Volume \tilde{W}

Optimizing Consistency

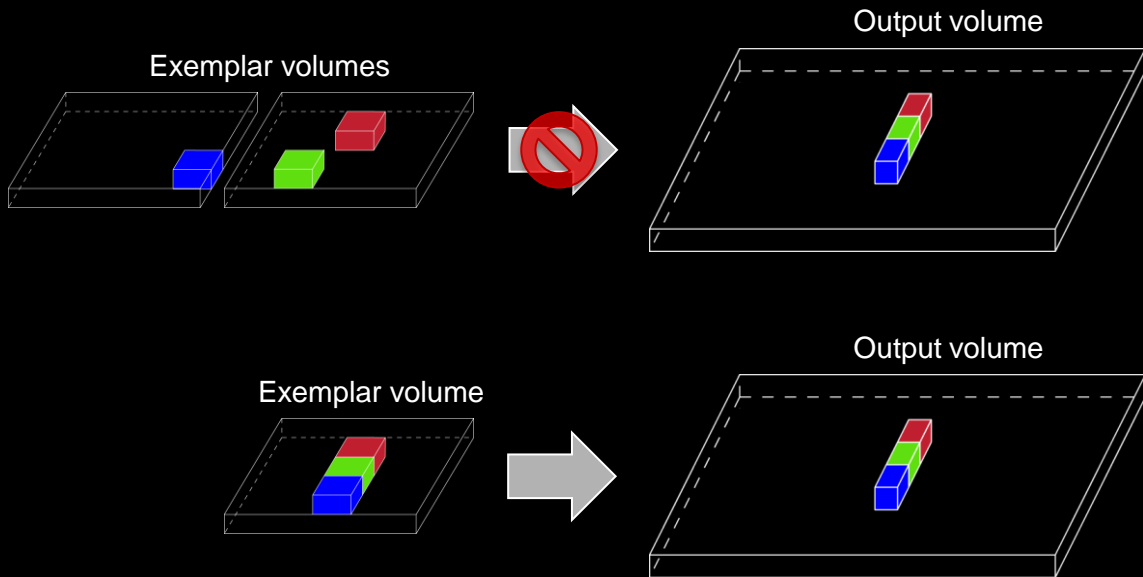
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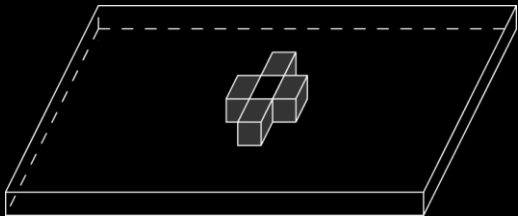


Without consistency

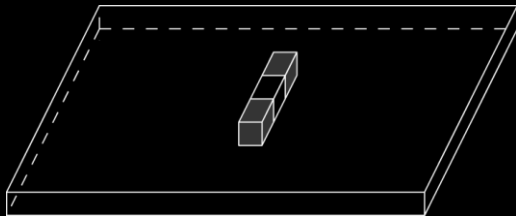


With consistency





2D continuity



1D continuity

- Optimizing 2D continuity

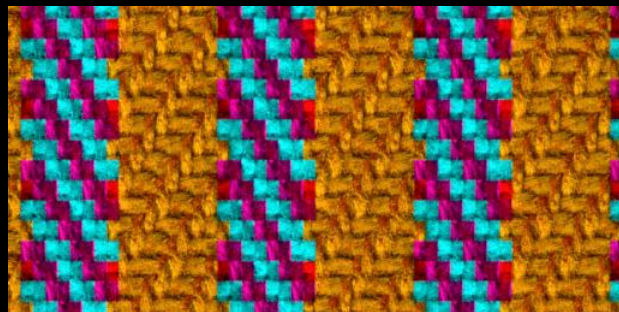
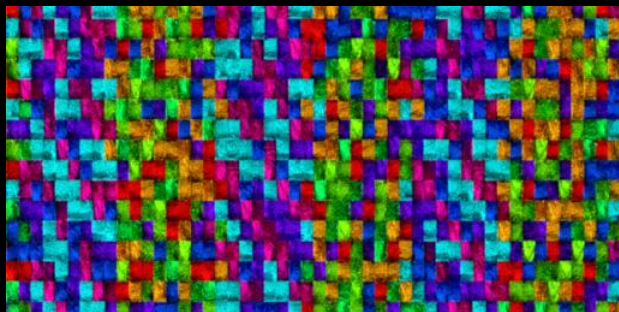
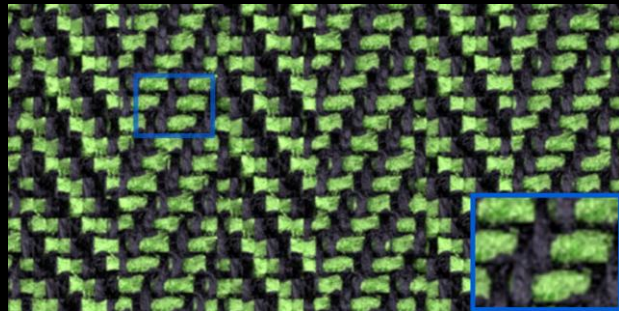
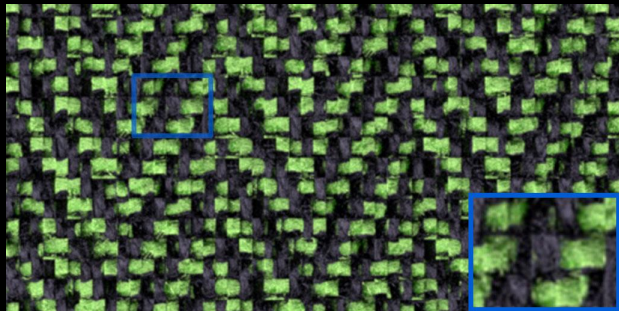
- Generally NP-hard
- Approximation algorithms

- Optimizing 1D continuity

- Solvable in polynomial time
- Dynamic programming

Continuity

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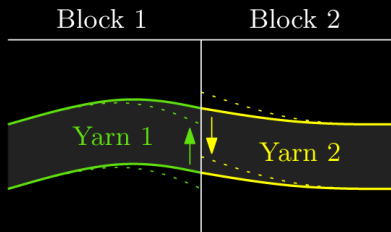
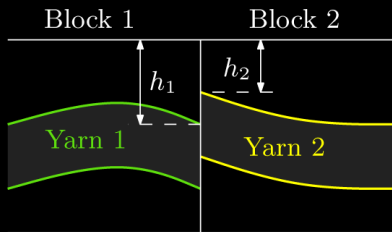


Without continuity

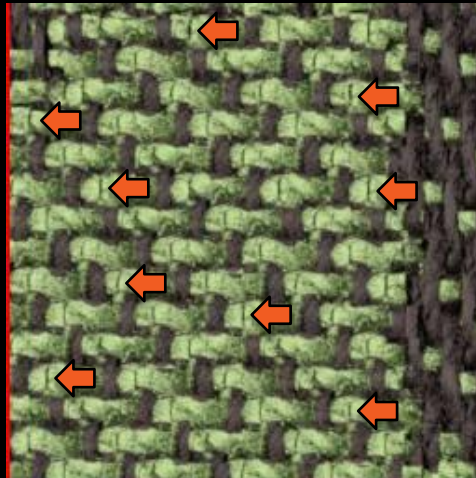
With continuity



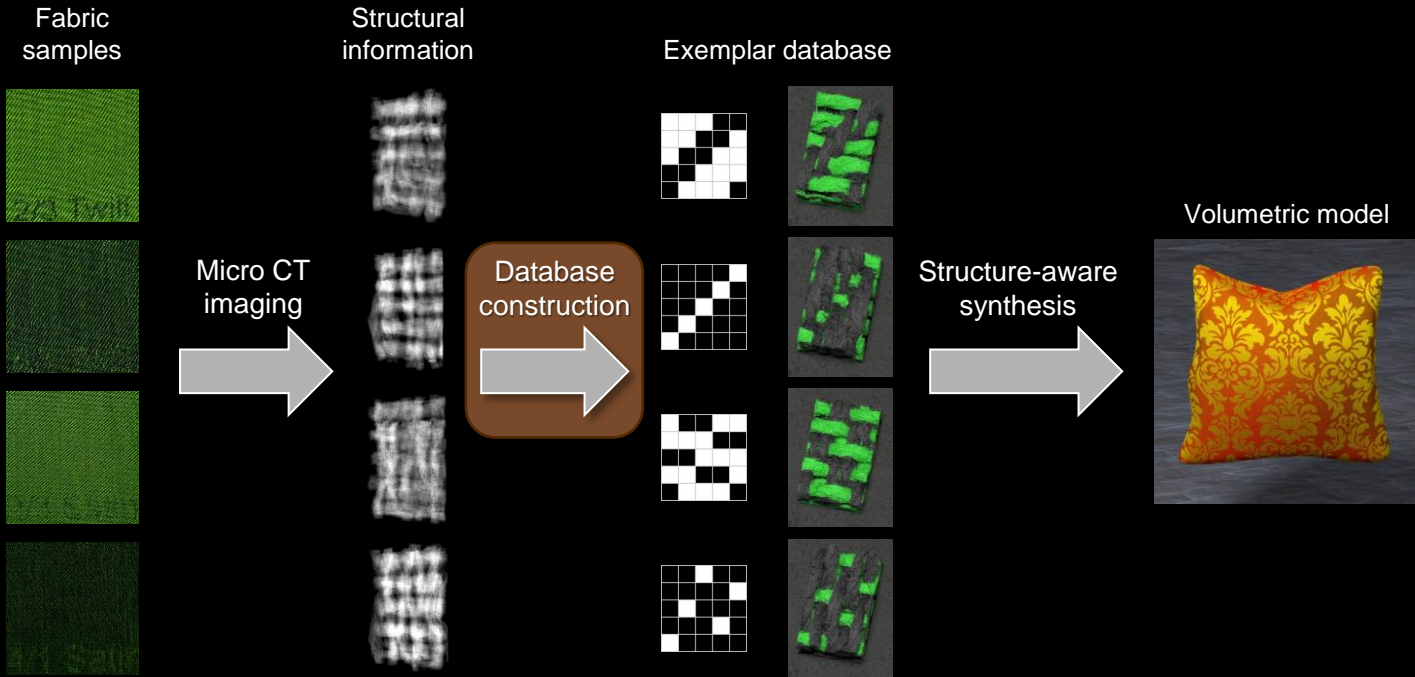
- Edge fixing



With
edge-fixing



Without
edge-fixing





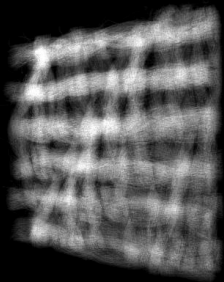
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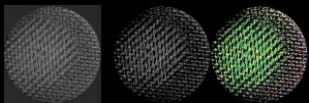
Database Construction

Database Creation: Overview

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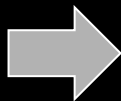


Density, orientation

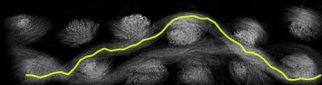


CT image processing

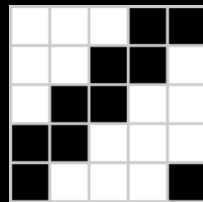
[Zhao et al. 2011]



Yarn ID information



Yarn tracking



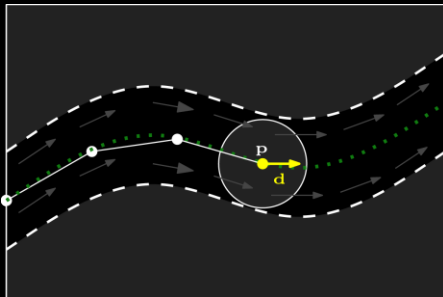
Weave pattern

$$\left\langle \frac{\mathbf{p}_1(t_1) - \mathbf{p}_2(t_2)}{\|\mathbf{p}_1(t_1) - \mathbf{p}_2(t_2)\|_2^3}, \frac{\partial \mathbf{p}_1}{\partial t_1} \times \frac{\partial \mathbf{p}_2}{\partial t_2} \right\rangle$$

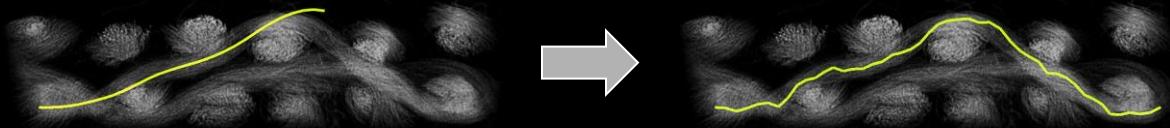
Weave pattern
detection



- Tracking process



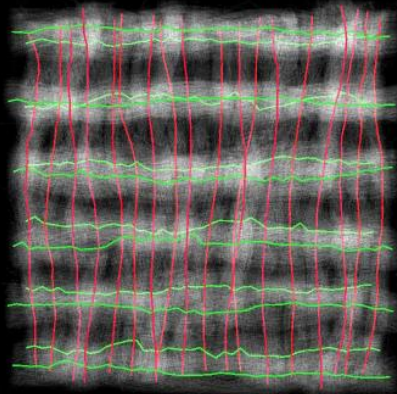
- Correction



- Voxel segmentation

Yarn Tracking Result

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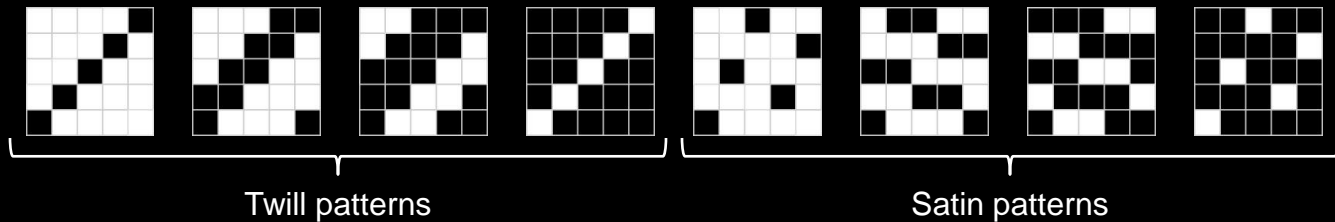
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Experimental Results



- 8 Exemplars



- Exemplar volume

- Resolution: $575 \times 350 \times 300$
- 25 Blocks

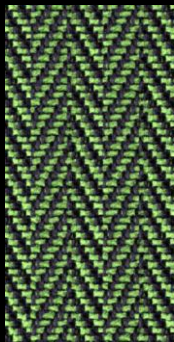


Industrial
loom



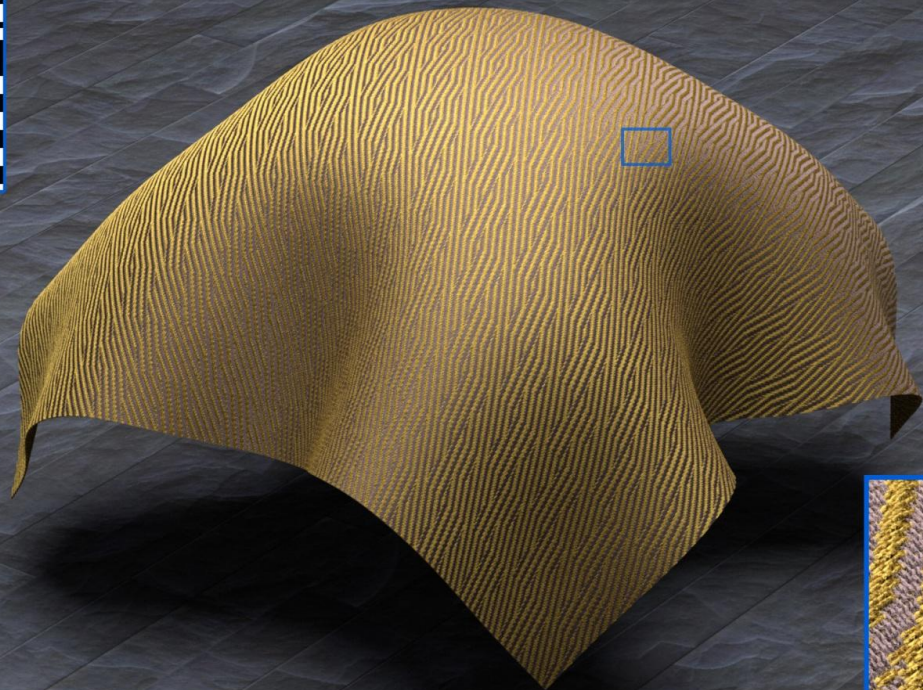
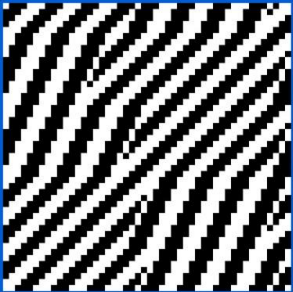
Photographs
of fabricated
fabrics

Our
system



Rendered
images

Input Weave Pattern: 900×1500
 3.26×10^{12} effective voxels



Input Weave Pattern: 1800×1500
 6.52×10^{12} effective voxels





Input Weave Pattern: 1800×1500
 6.52×10^{12} effective voxels

Input Weave Pattern: 1800×1500
 6.52×10^{12} effective voxels



Input Weave Pattern: 1800×1500
 6.52×10^{12} effective voxels





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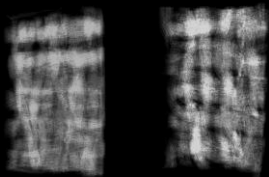
Conclusion



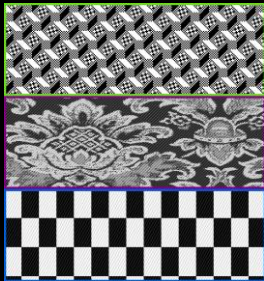
- Limitations
 - Only modeled the front layer
 - Assume a grid-like structure
- Future work
 - Extend our technique to support more structures

Summary

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Exemplar database



Input weave patterns



Volumetric appearance models
with complex designs

- New level of quality for general woven fabrics
- Useful for textile design and other textile applications

Acknowledgements

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- Brooks Hagan (Rhode Island School of Design)
- Jessie Maisano (The University of Texas at Austin)
- Funding
 - Intel Science and Technology Center – Visual Computing
 - NSF grants CCF-0644175 and IIS-1011919
 - Amazon

Thank you!

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Industrial
loom



Physical material

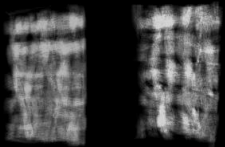


Weave pattern



Real fabric

Our
system



Scanned database



Weave pattern



Volumetric model