Eurographics 2011
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Goal-Based Caustics

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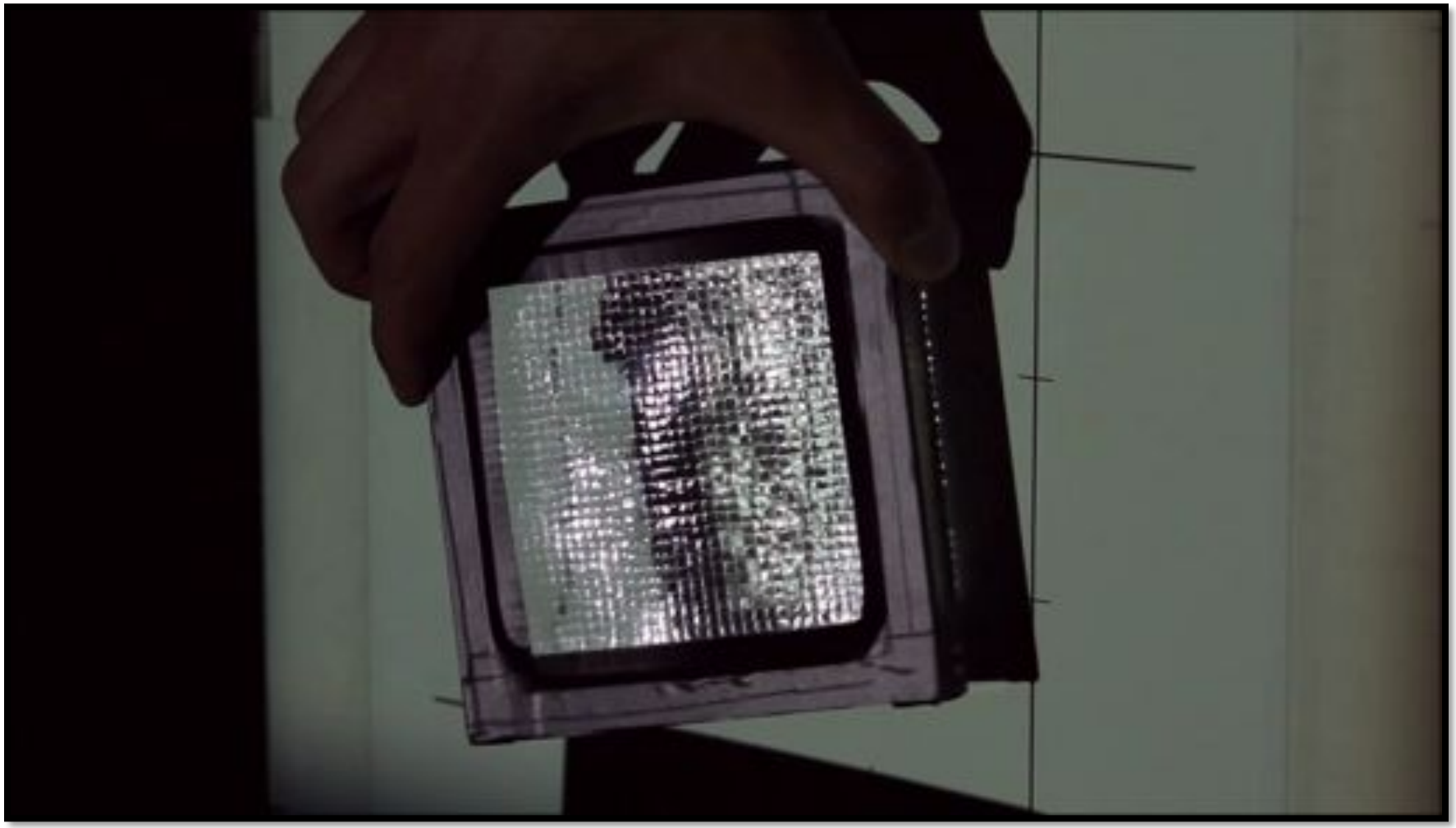
Caustics

http://www.flickr.com/photos/0olong/394133110/

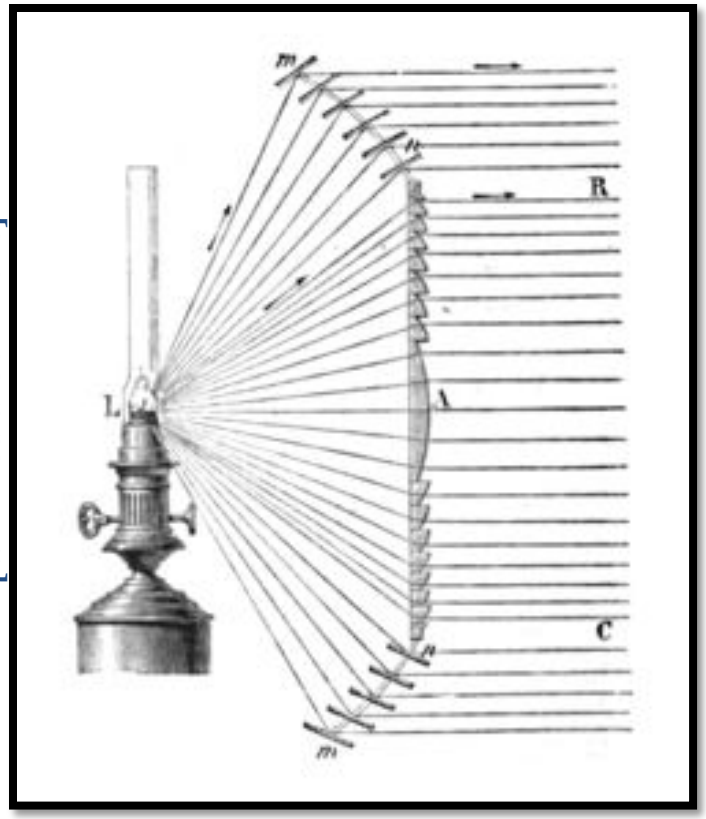
http://www.flickr.com/photos/0olong/23446852/

Sneak peek



Lens Design

- Fresnel Lens

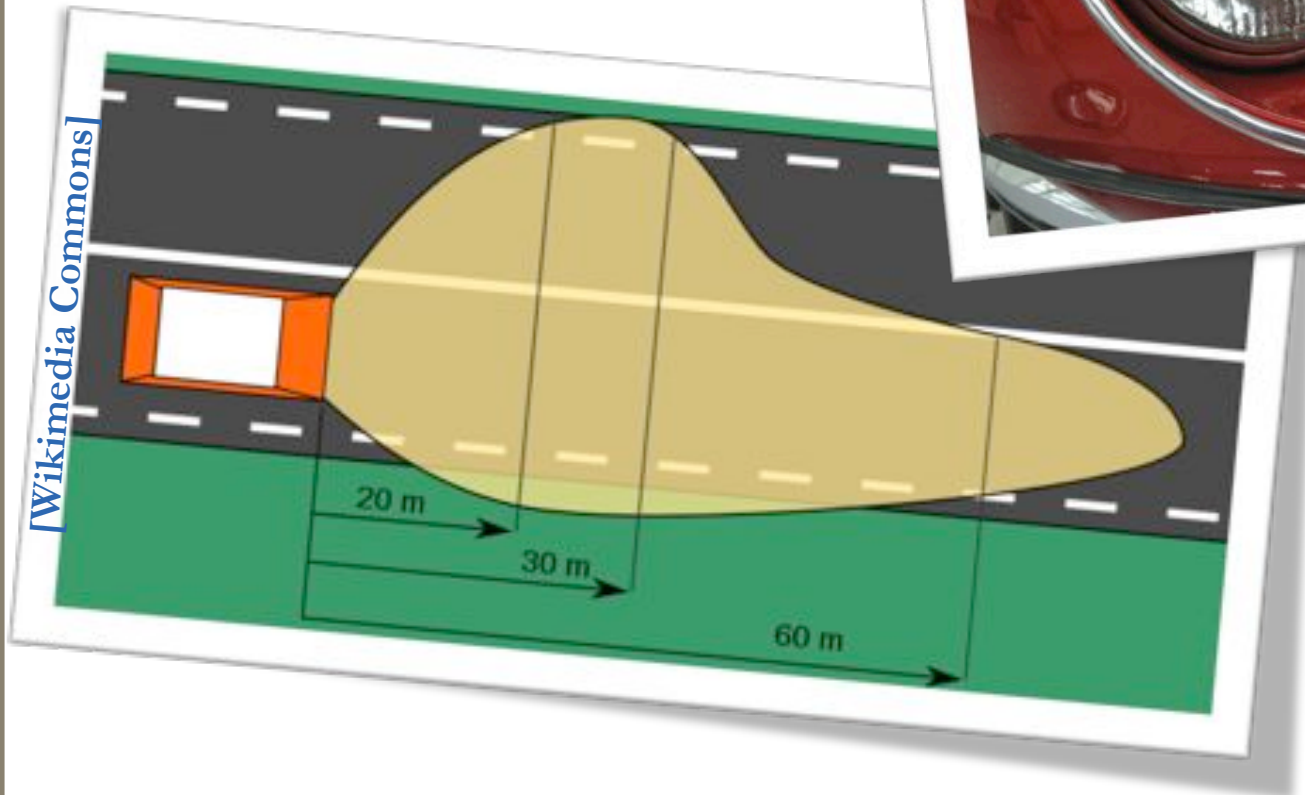


[Wikimedia Commons]

[Wikimedia Commons]

Lens Design

- Car headlight design



Mirror Design

- Makyoh mirrors

http://www.docbug.com/Pictures/Makyoh/index.html

Problem Statement

Applications

Applications

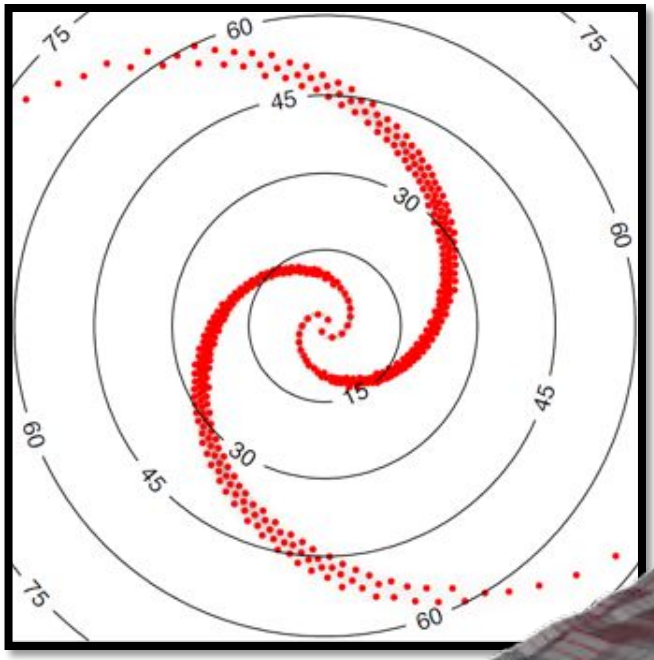
Previous Work

- Weyrich et al. SIGGRAPH 09
- Finckh et al., ECCV 10

Previous Work

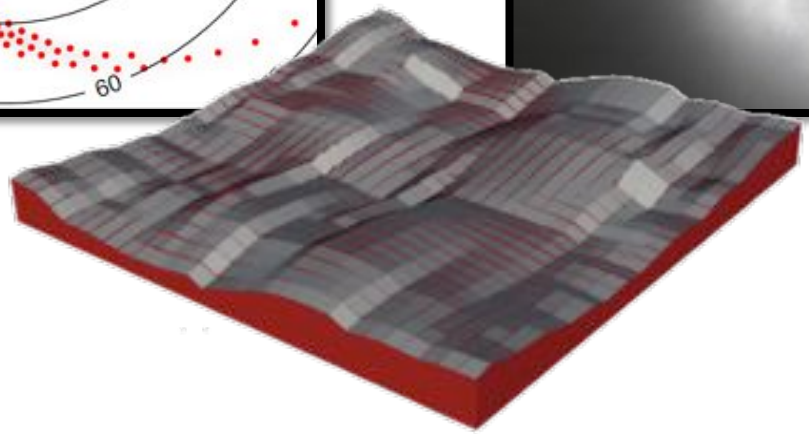
- Weyrich et al., SIGGRAPH 09

Stippled Representation



Physical Capture

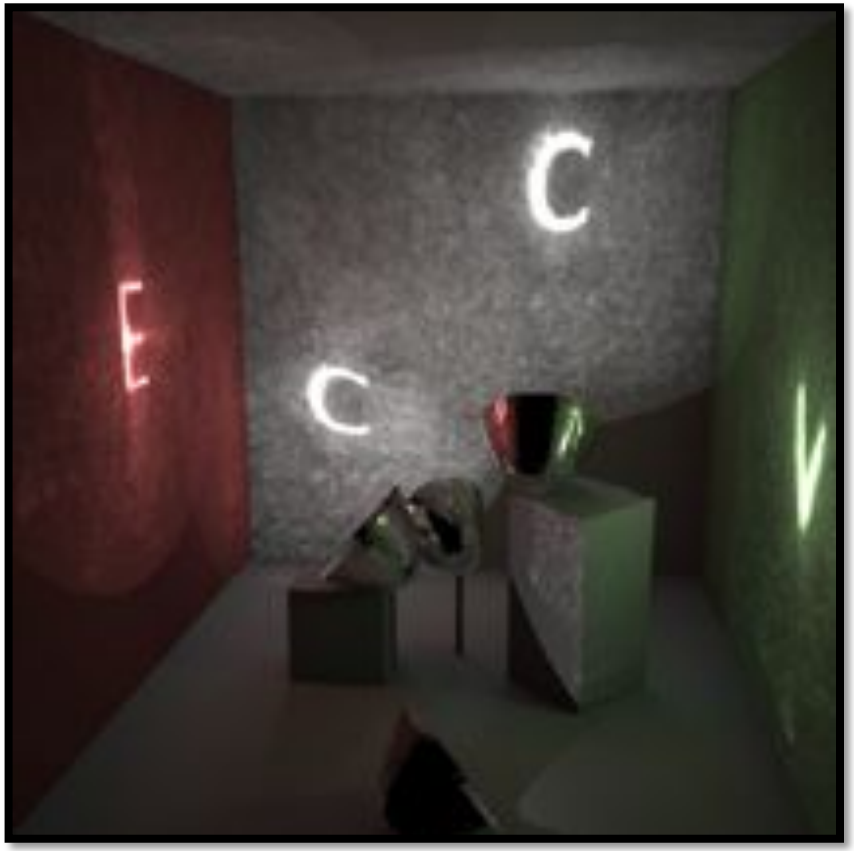
[Weyrich et al, SIGGRAPH 09]



Generated Surface

Previous Work

- Finckh et al., ECCV 10



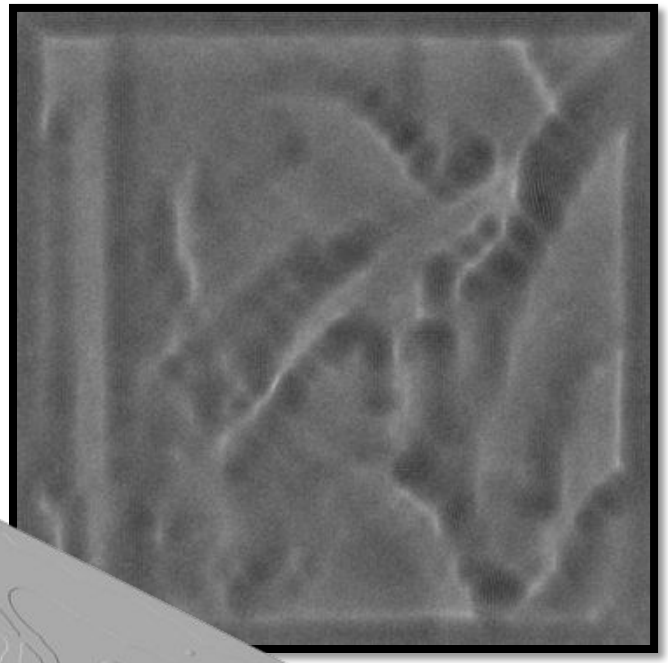
[Fickh et al.,ECCV 10]

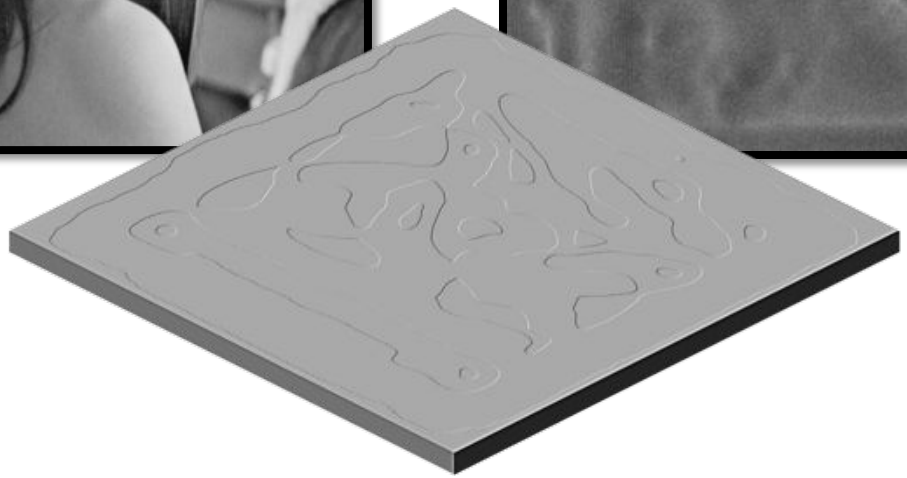
Previous Work

- Finckh et al. Limitations

Goal image

Simulated Caustic of Lena

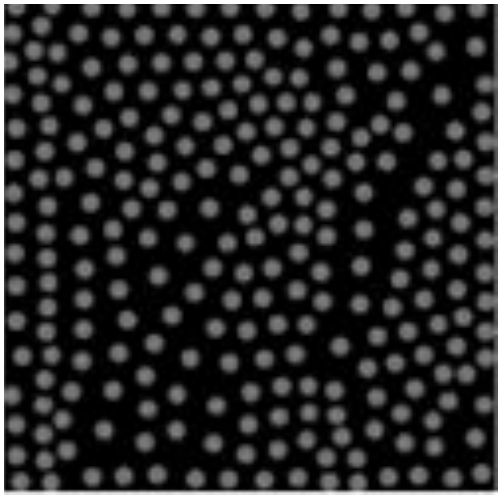




Generated Surface

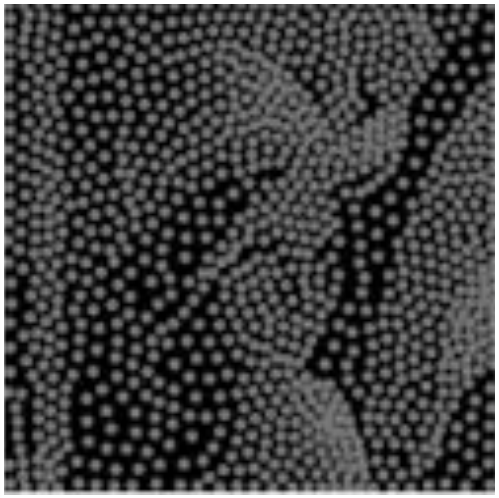
Previous Work

- Weyrich et al., Limitations

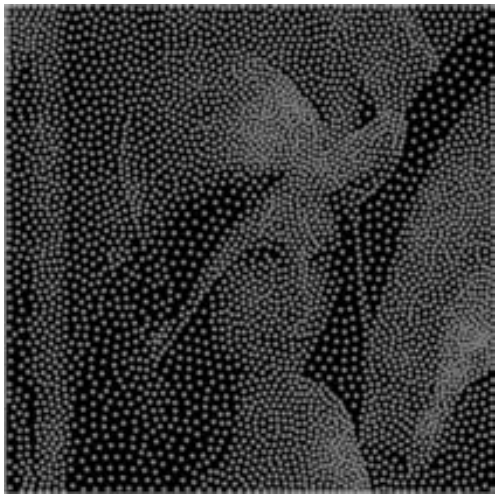


256 points

Goal Image



1024 points



4096 points

16K points

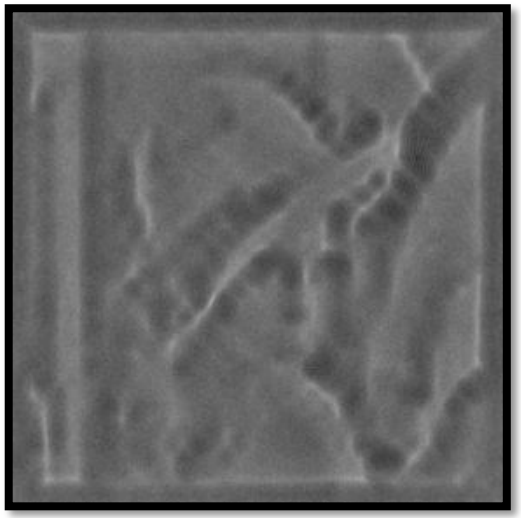
Our Method

- Our Goals
  - Generate physical surfaces
    - Consider manufacturing limitations
  - Reflection & Refraction
  - High quality caustics

Weyrich et al.

16K Stipple points

Finckh et al.



Our Decomposition

1024 Gaussians

Methodology

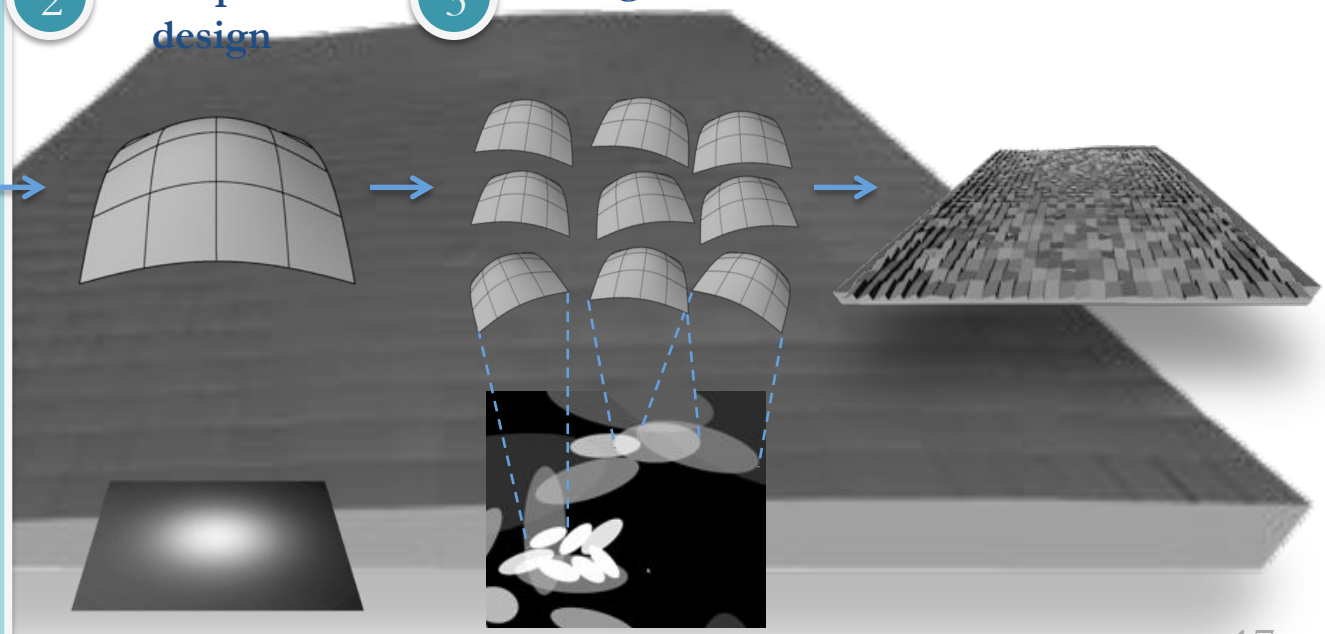
Algorithm Outline

Goal Image

1 Decomposition

2 Micropatch design

3 Arrangement



Step1: Decomposition

1

Goal Image

Decomposition

- Goals
  - High quality results
  - Few primitives
- Use EM
  - Dempster et al. 77

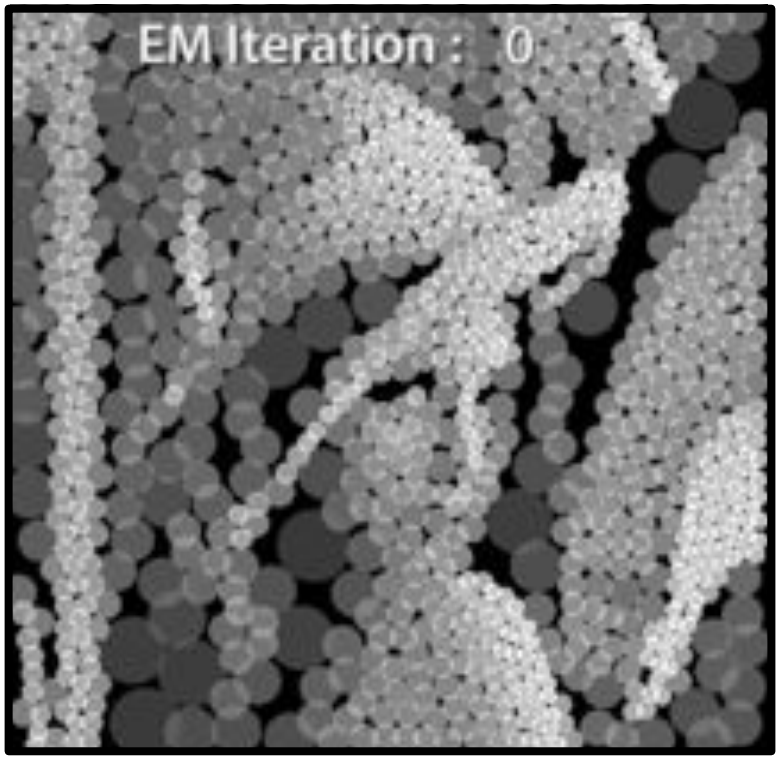
Step1: Decomposition

1

Step1: Decomposition

1

Gaussians



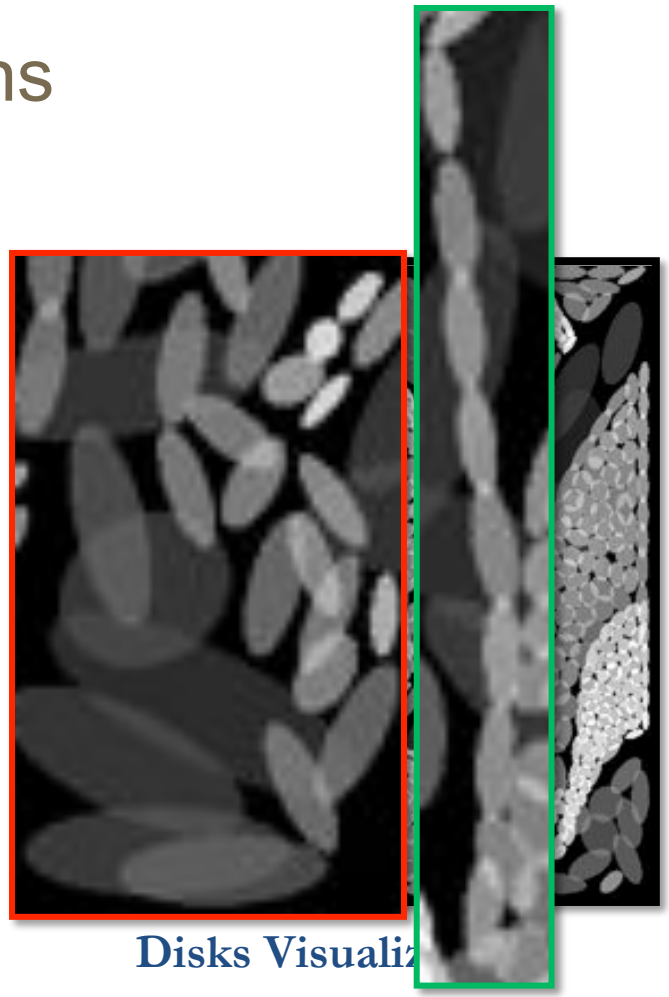
Disks Visualization

Step1: Decomposition

1

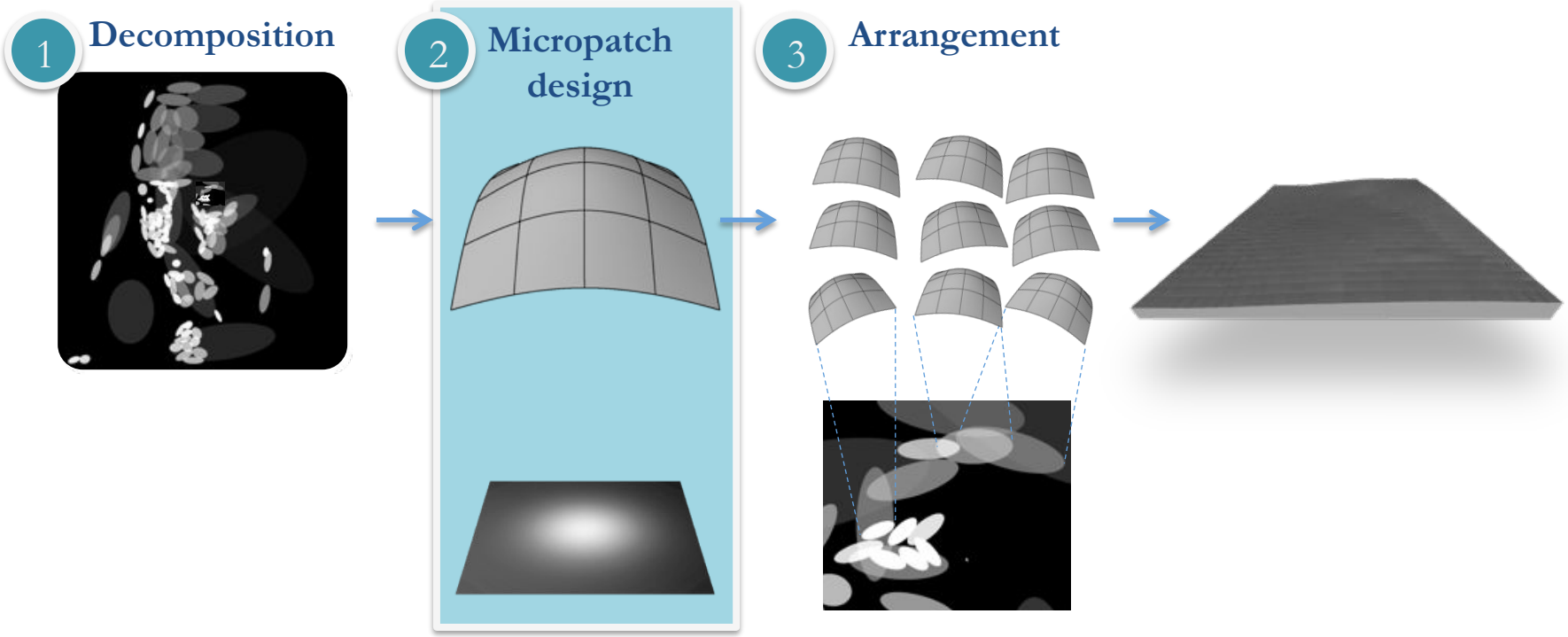
- EM Benefits
  - Continuous Tones
  - Overlapping Gaussians
  - Anisotropy

Gaussians



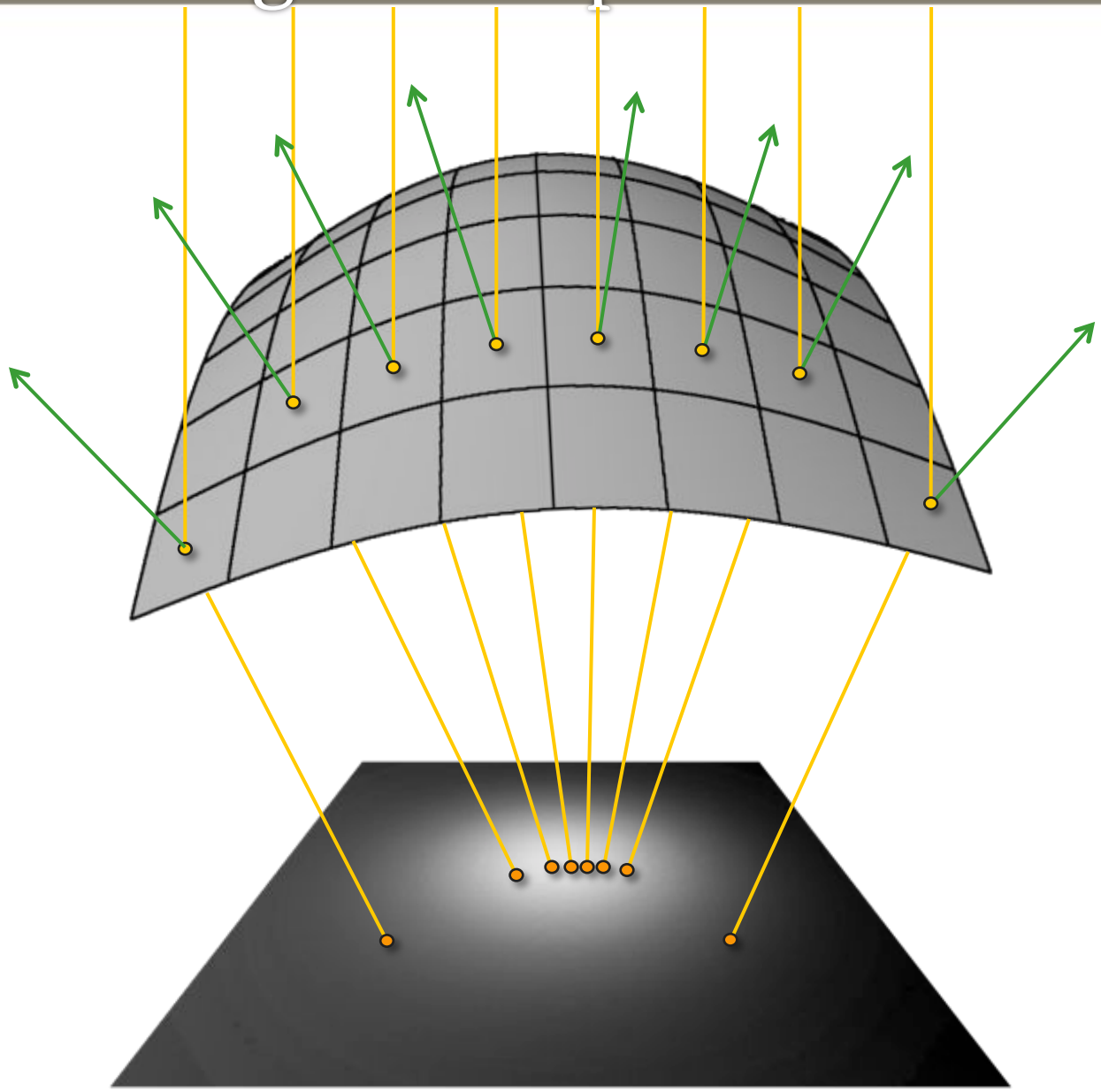
Disks Visuali

Algorithm Outline



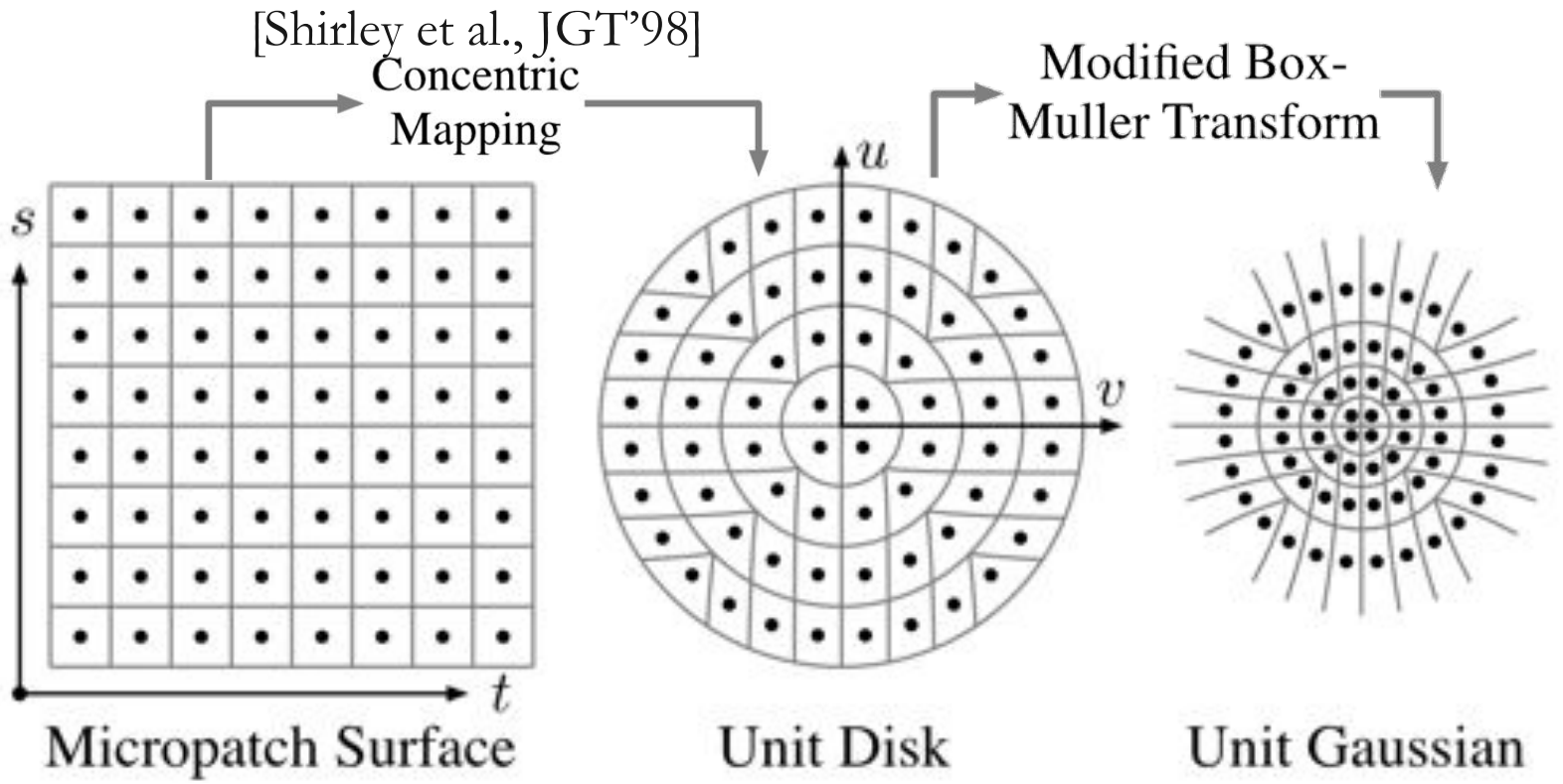
Step2: Generating a micro-patch

2



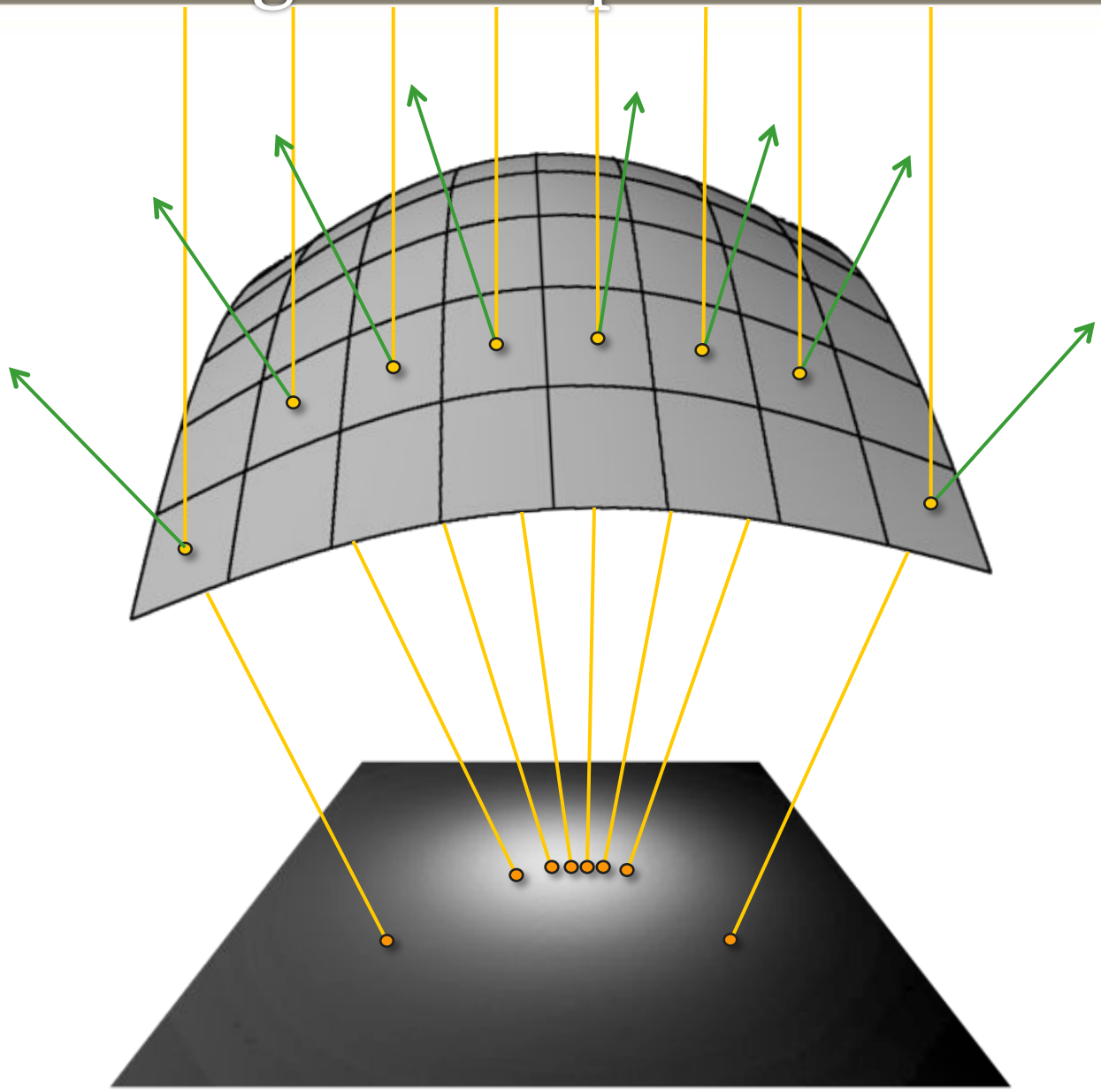
Step2: Generating a micro-patch

2. Low distortion mapping
   - Smooth & Continuous micro-patch

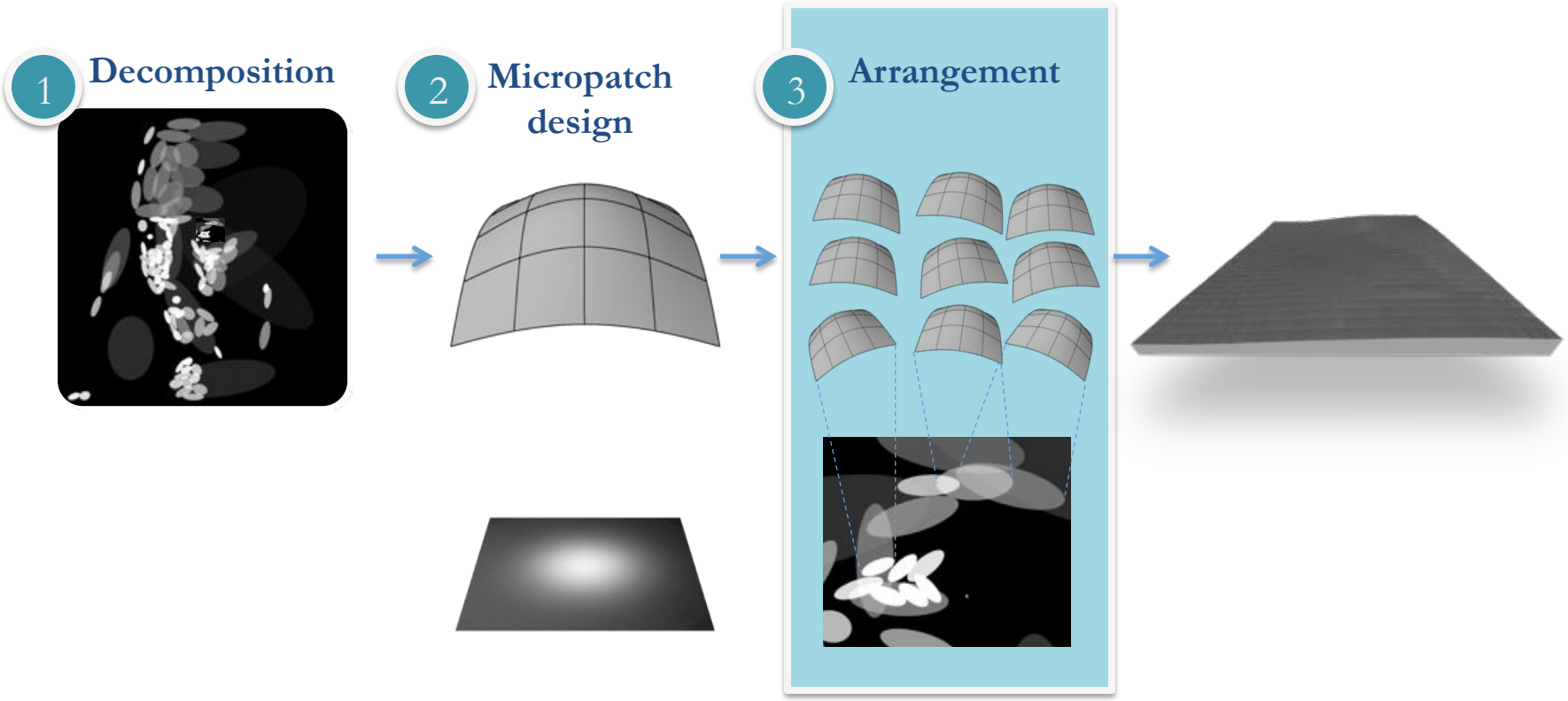


Step2: Generating a micro-patch

2

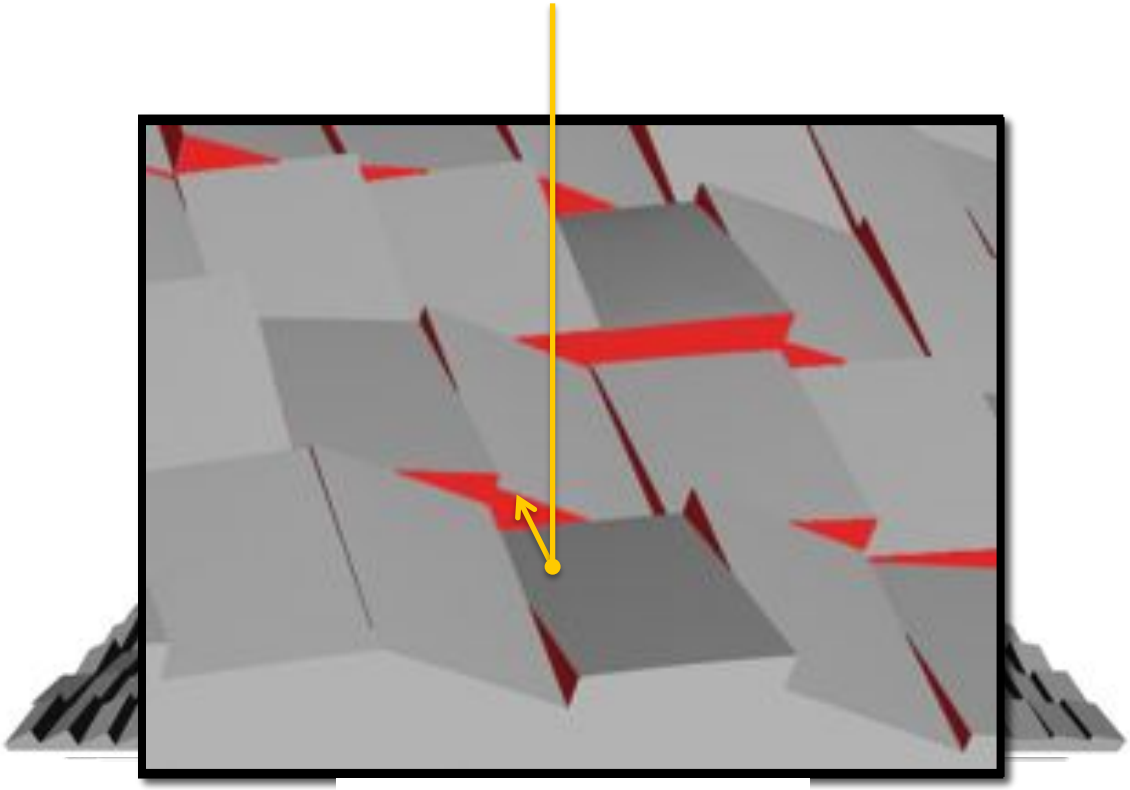


Algorithm Outline



Arranging micro-patches

3



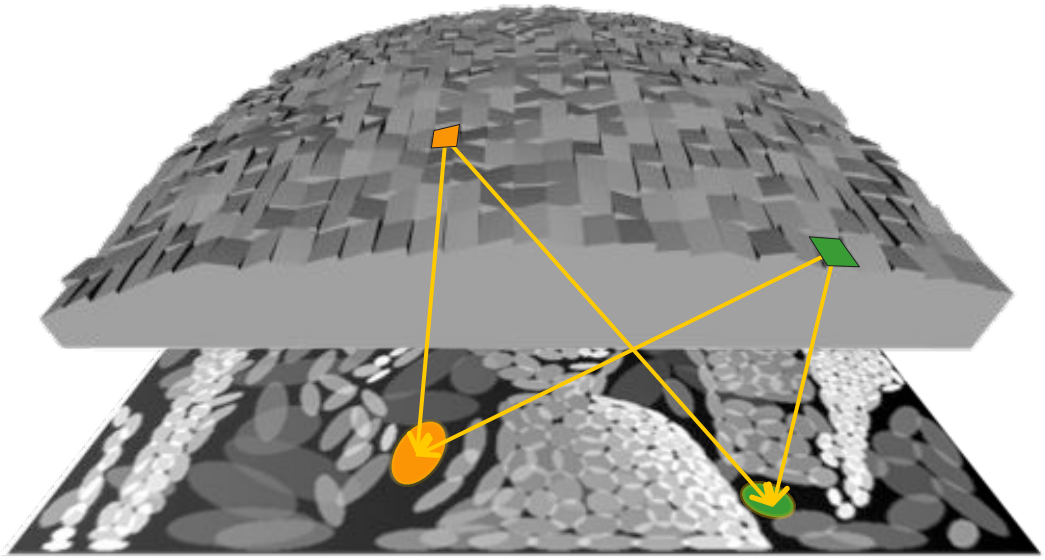
Random Assignment

- Goals
  - Smooth surface
  - Minimize the surface area of verticals

Arranging micro-patches

3 Optimization Algorithm

– Simulated Annealing



$E=S+C/m^2$

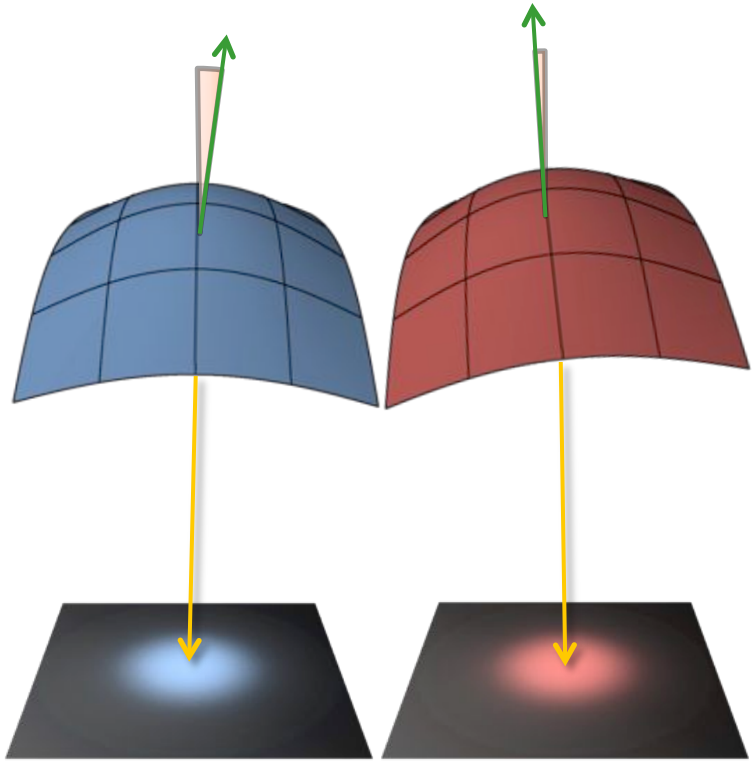
- Metric:

  – C: Continuity term
  – S: Regularization term

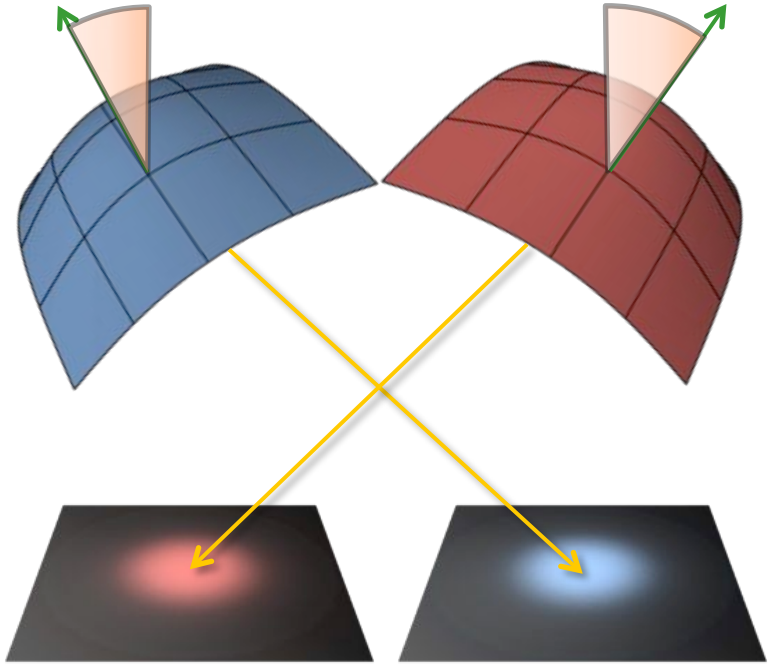
Arranging micro-patches

3

- Regularization term



Nearby Target Assignment

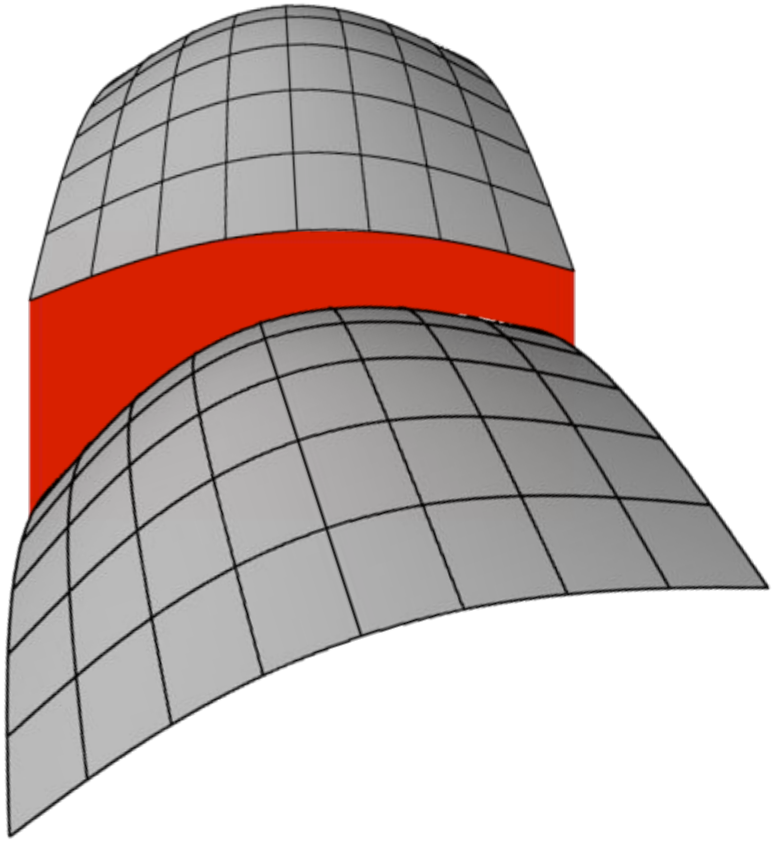


Distant Target Assignment

Arranging micro-patches

3

- Micro-patch Continuity term

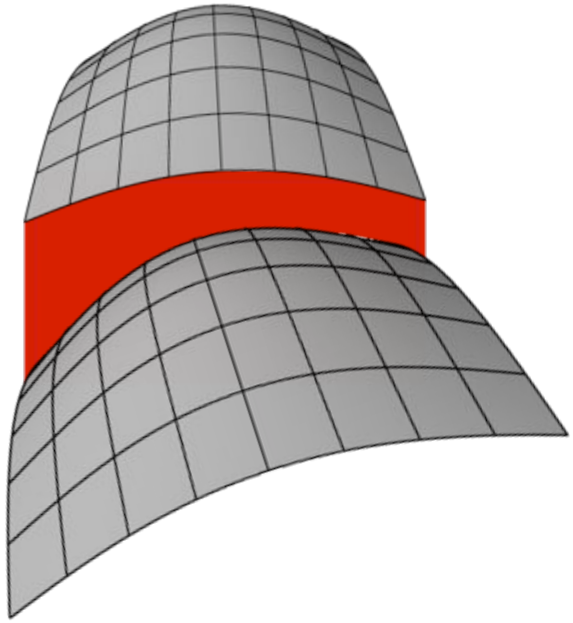


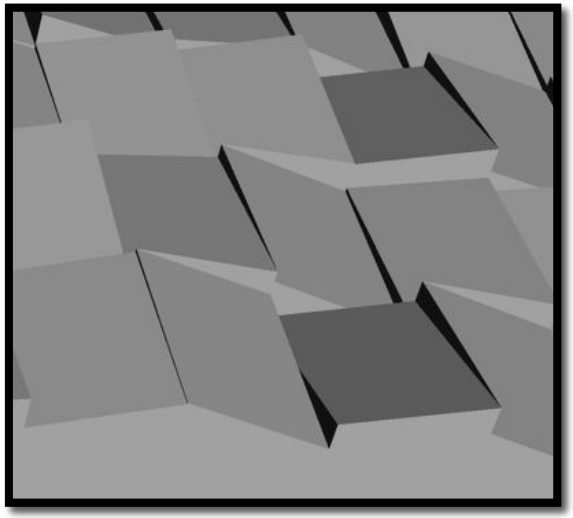
– Minimize Surface Area of Vertical Faces

Arranging micro-patches

3

- Verticals SA evaluation
  - Expensive to compute
- Approximation
  - Micro-patches with quads

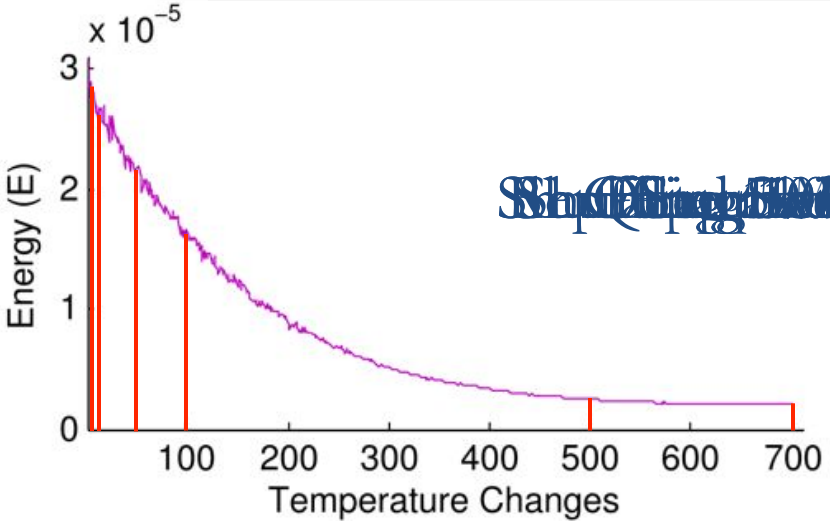




micro-patches quads

Arranging micro-patches

3



Simulated Results

Simulated Results

- Lena - 900 Gaussians

Input Image

Decomposition

PBRT Rendering

Surface

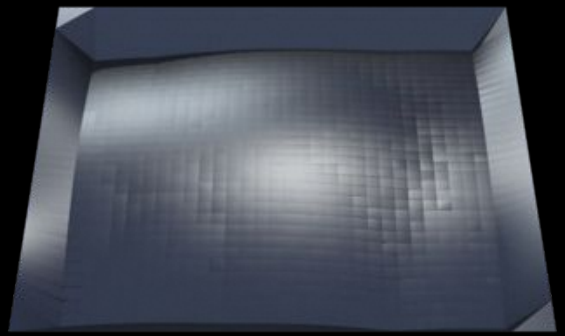
Simulated Results

- Aphrodite - 900 Gaussians

Input Image

Decomposition

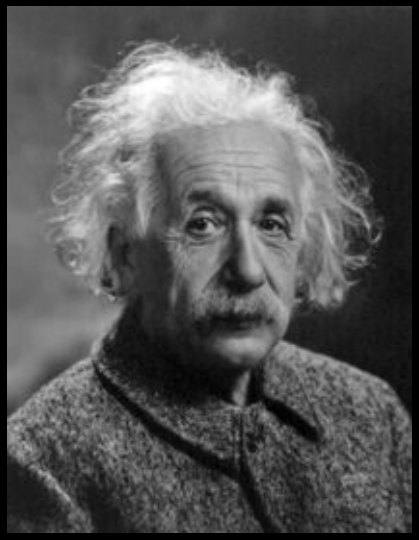
PBRT Rendering



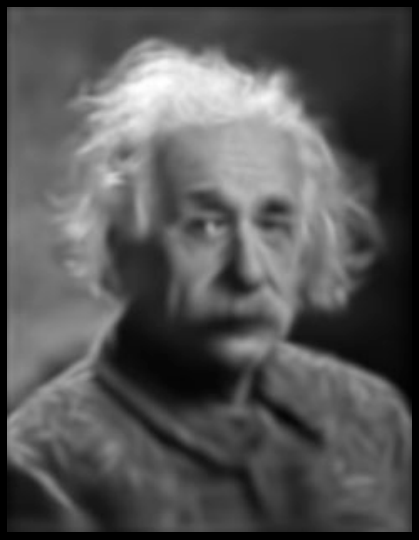
Surface

Simulated Results

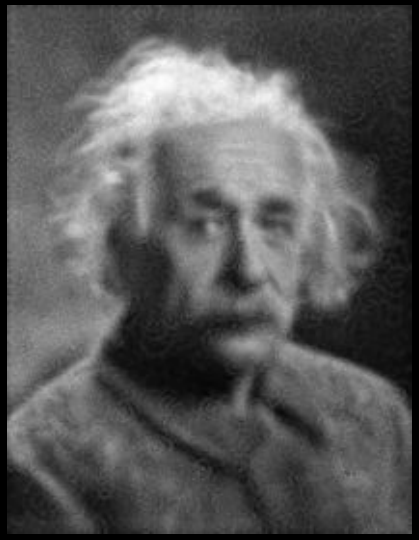
- Einstein – 1024 Gaussians



Input Image



Decomposition



PBRT Rendering

Surface

Simulated Results

- Depp – 900 Gaussians

Input Image

Decomposition

PBRT Rendering

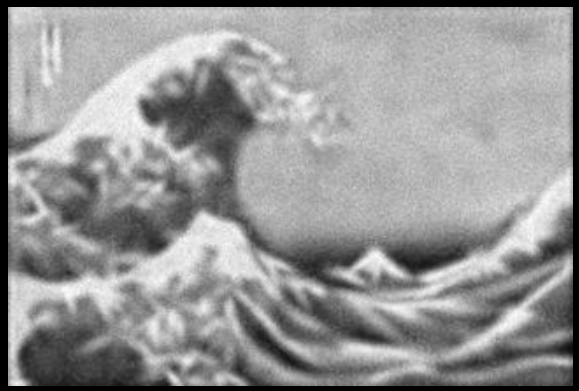
Surface

Simulated Results

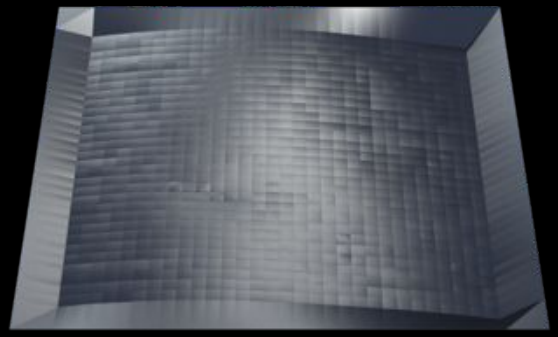
- The Great Wave - 900 Gaussians

Input Image

Decomposition



PBRT Rendering



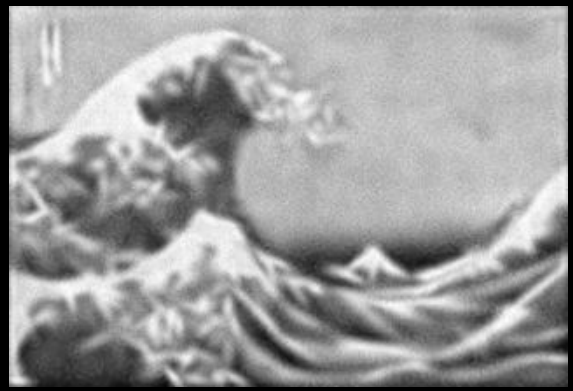
Surface

Simulated Results

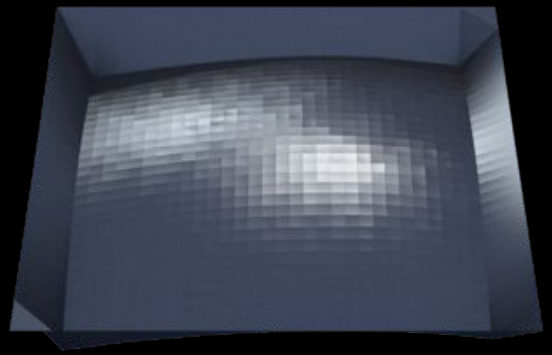
- The Great Wave - Reflective

Input Image

Decomposition



PBRT Rendering



Surface

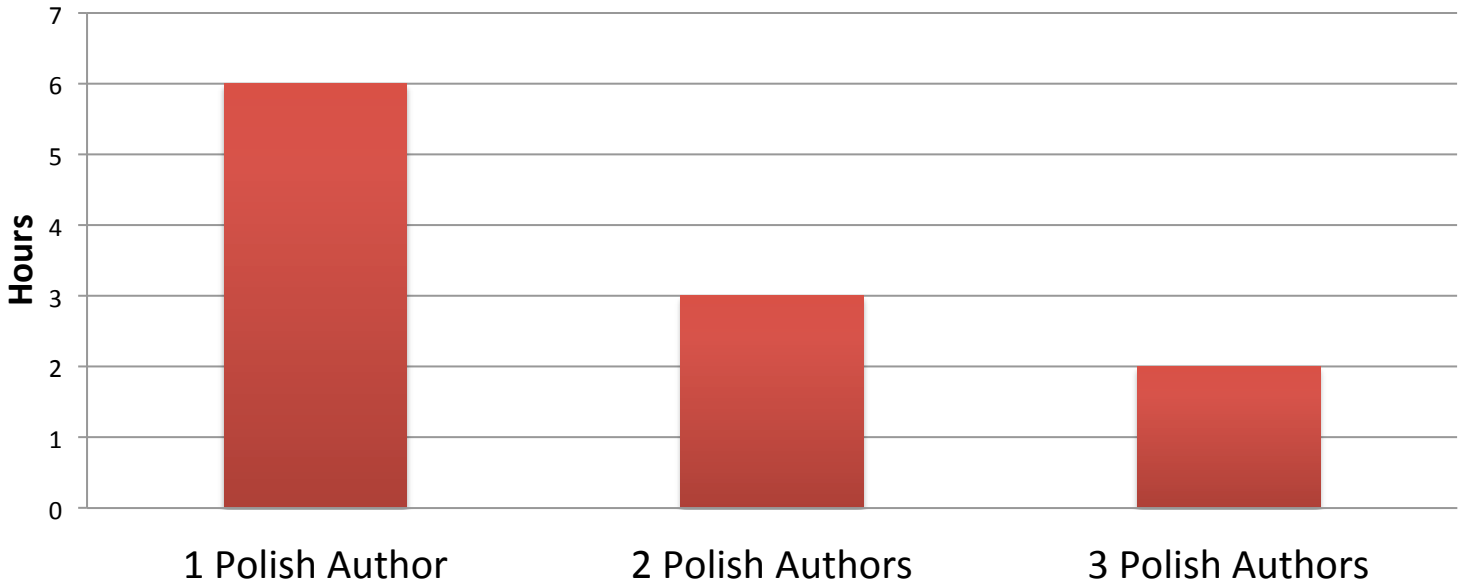
Physical Results

Fabrication

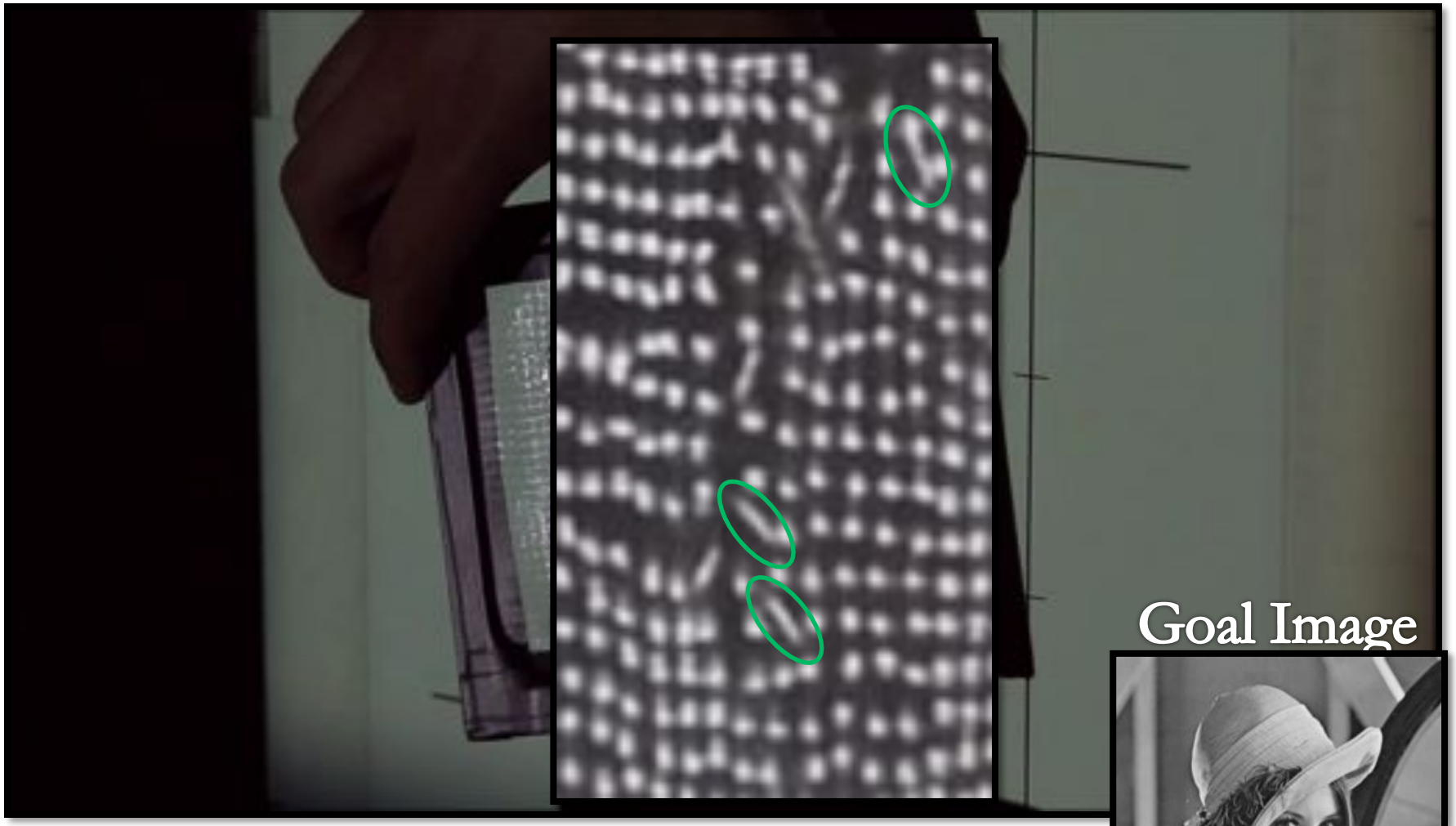
Fabrication

- Roland DGA EGX-600
  - Cutting area: 61x40x4.2 cm
  - Resolution: 0.01mm
  - Bit: 0.13mm tip
- Fabrication
  - 1-3 days
  - 1-2 hours of polishing

Polishing Time

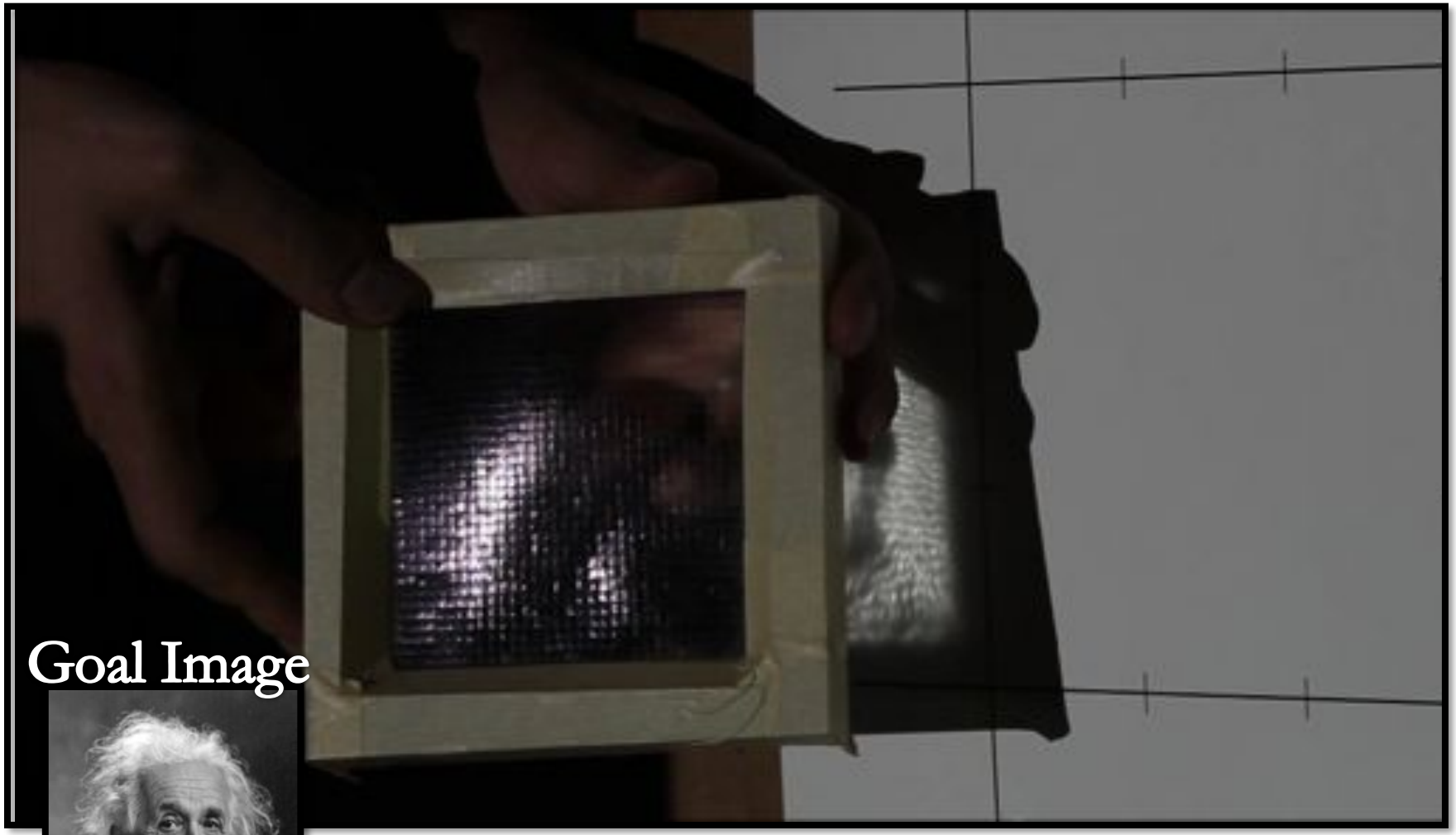


Results - Video

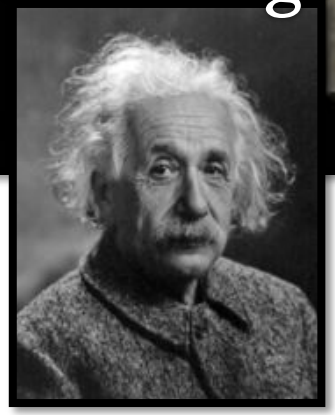


Goal Image

Results - Video



Goal Image



Results - Video

Goal Image

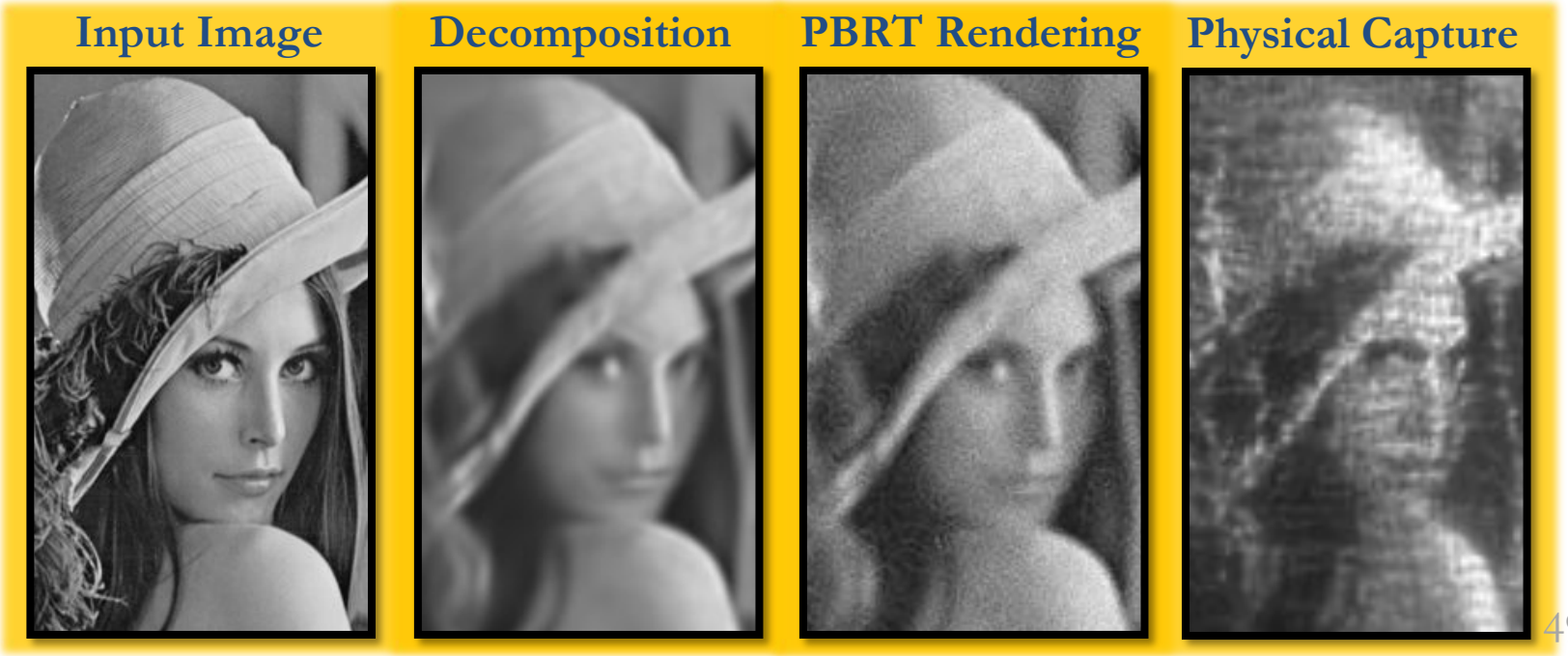
Live Demo

Limitations & Future Work

Limitations

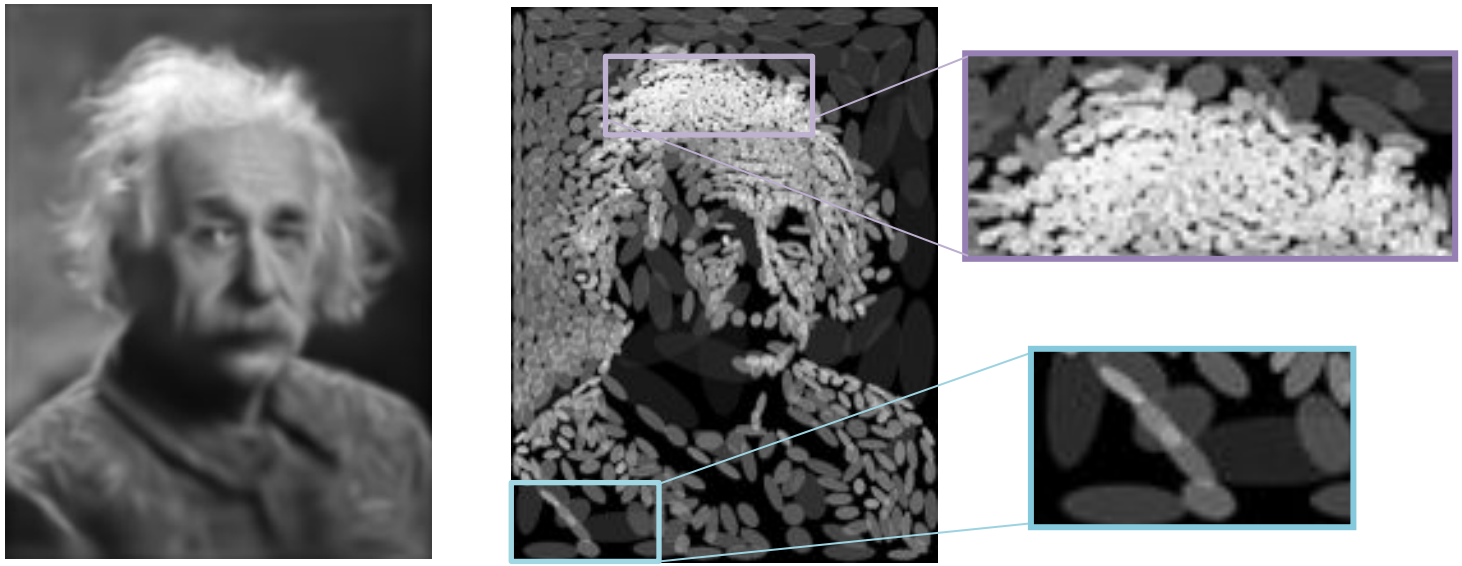
- Fabrication Time:
  - 1-3 days
  - 1-2 hours polishing

- Manufacturing Accuracy

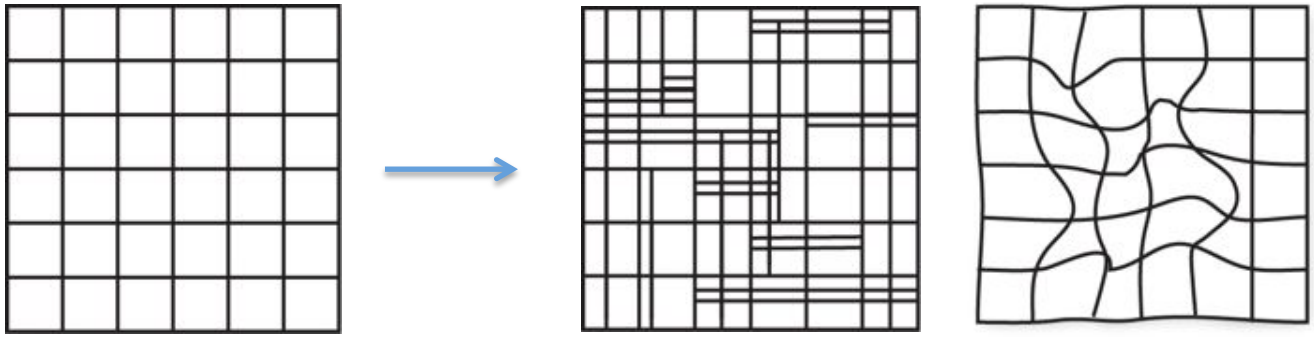


Limitations

- Equal Area micro-patches

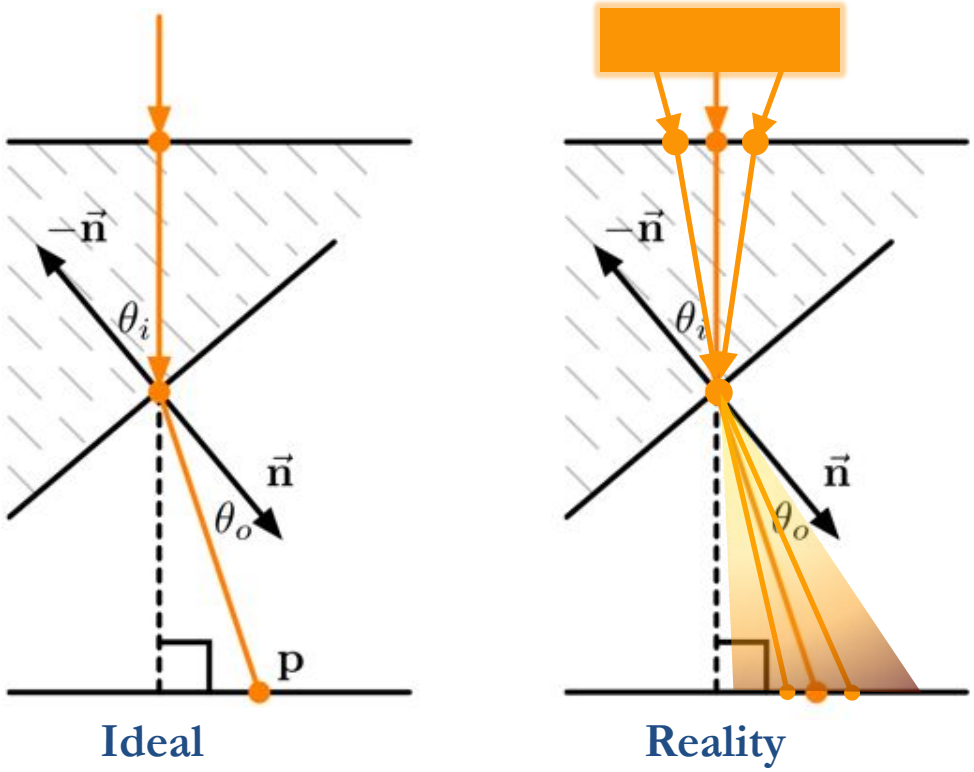


  - Darker regions are less detailed



Limitations

- Assumptions
  - Light Source: Negligible solid angle
  - Surface: Perfectly Specular



- Area Light & BRDF/BTDF de-convolution

Conclusion

- Robust Method
- Manufacturable Surfaces
- High Quality Caustics
- Validated
  - Simulation
  - Fabrication

- Acknowledgments
  - Maurizio Nitti
  - Amit Bermano
  - Christian Regg
  - Sandro Buenter
  - Manuel Lang
  - The lab at DRZ

- Thank you for your time