Mesh Addition Based on the Depth Image (MABDI)

Lucas Chavez

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Outline

Outline

Overview

Motivation for this work: provide a map of the environment

Examples applications:

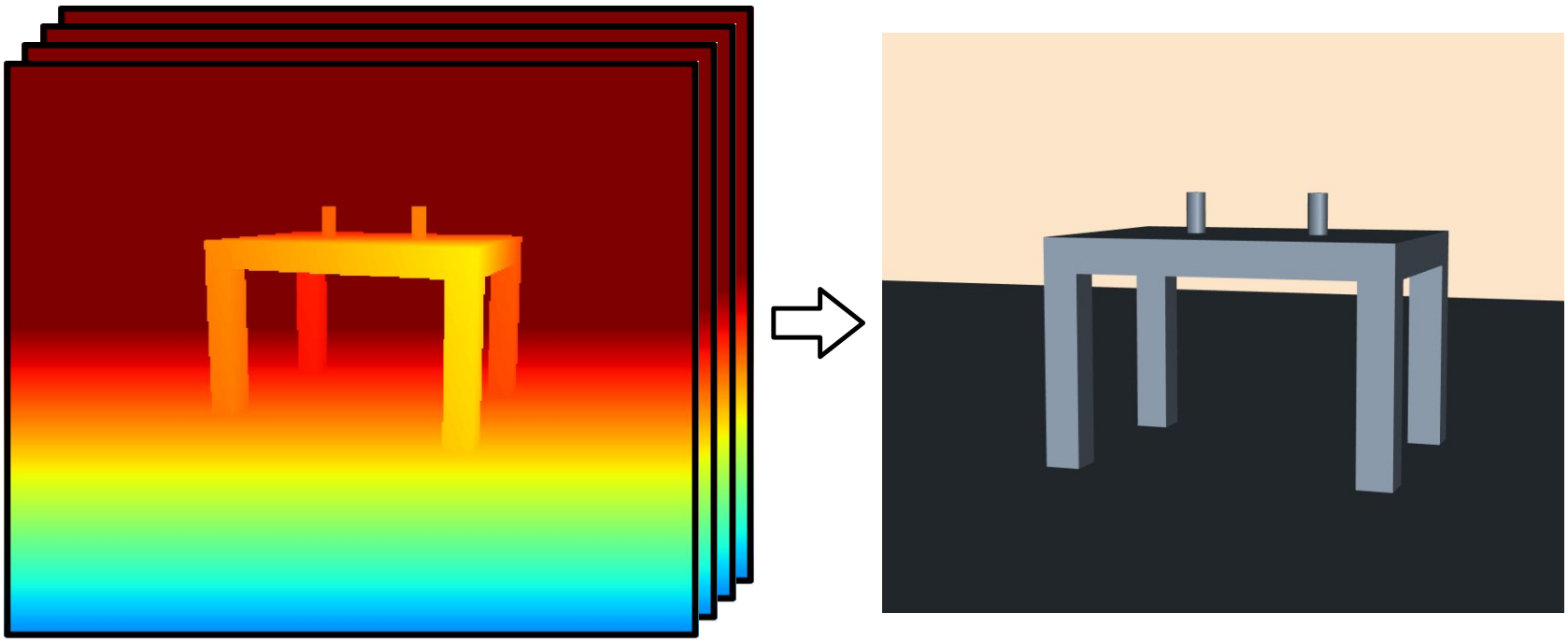
- Autonomous agents (robots)
- Teleoperation (human)

Overview

In the literature this is referred to as the SLAM problem

- Simultaneous Localization and Mapping
- Environmental Mapping
- Research began around 1987
- Sensing and computing technology

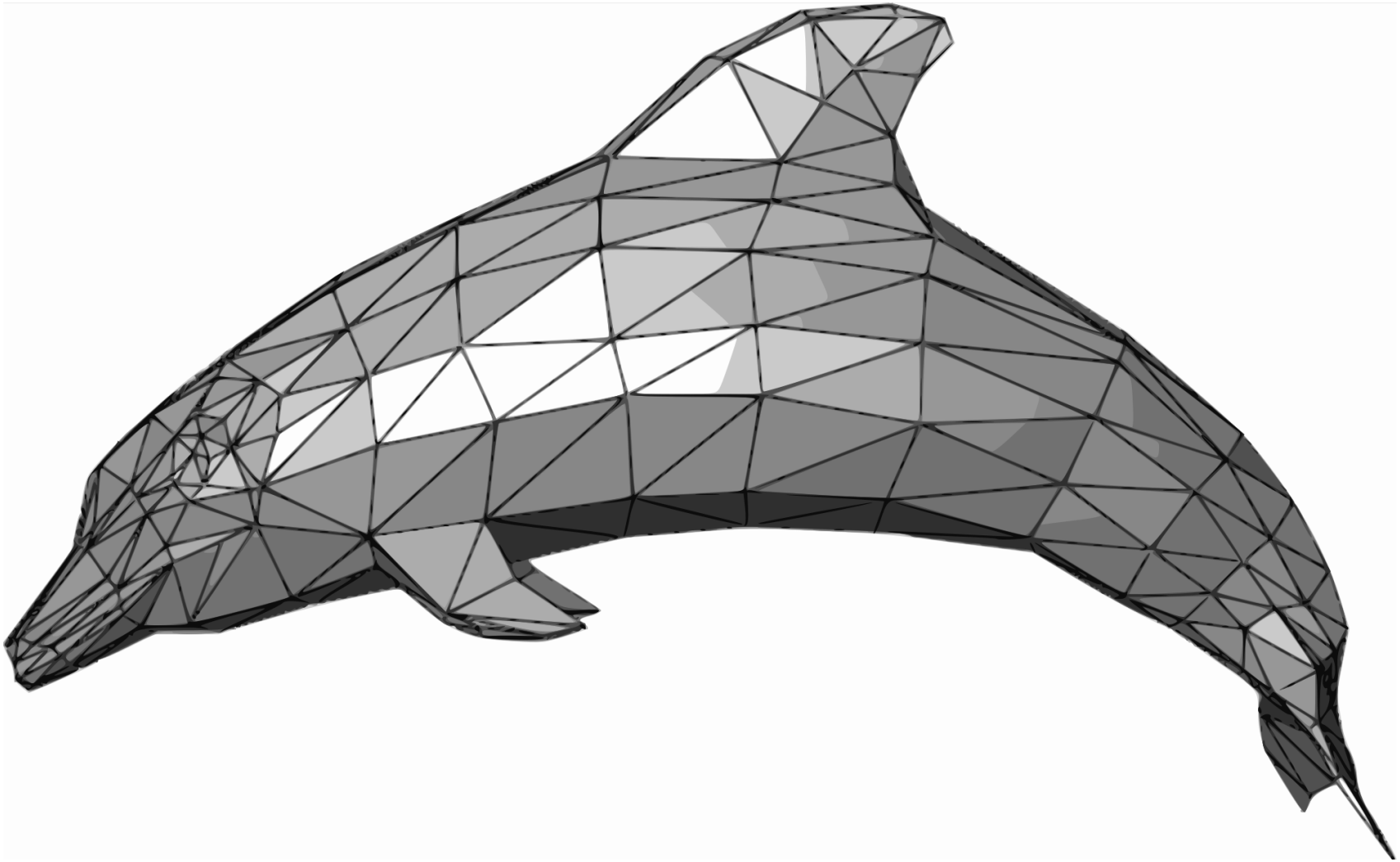
Overview



RBG-D Sensor

- 30 frames per second
- D - 9 million pixel values per second
- Algorithms must handle a high rate of data

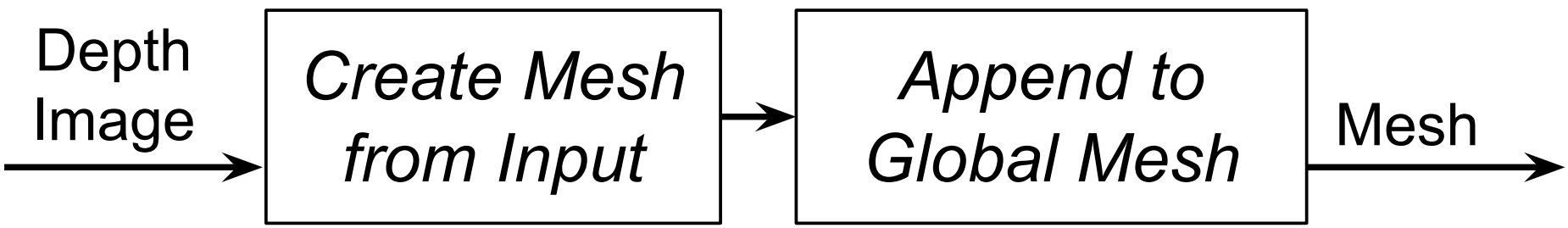
Mesh



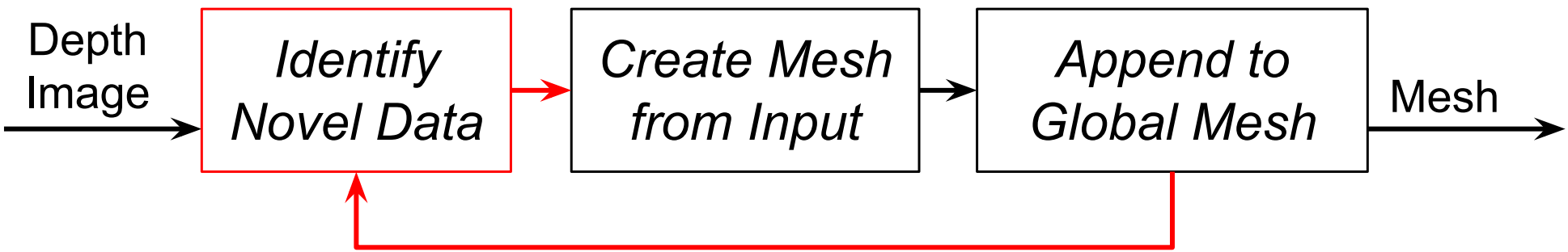
Mesh

- Supported
- Computationally Inexpensive
- Low Memory Requirement

Pipeline


Depth Image
Create Mesh from Input
Append to Global Mesh
Mesh

Pipeline

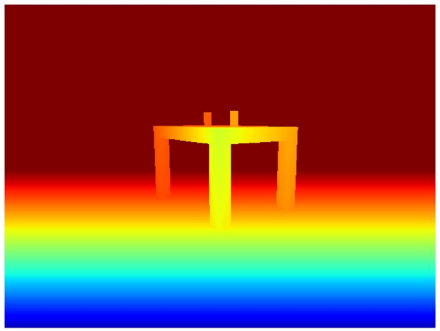

Depth Image
Identify Novel Data
Create Mesh from Input
Append to Global Mesh
Mesh

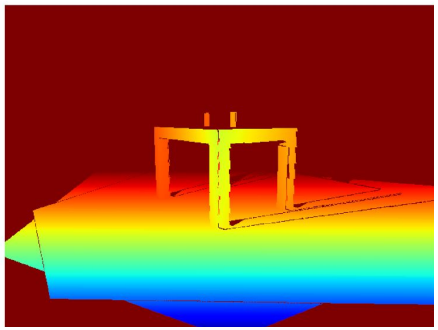
Contribution

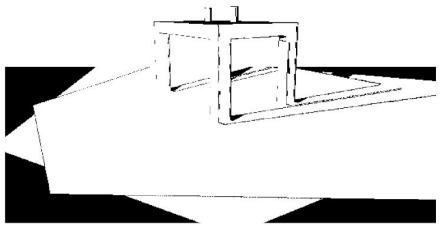
MABDI's algorithmic design identifies redundant information and removes it *before* it is added to the global mesh.

Outline

MABDI Algorithm







Simulated for the Experiments

Input
Depth Image (D) and Pose (P) from sensor.

D

P

Classification

Generate Expected Depth Image (E)

E

Classify Depth Image (D):

Classification is based on the difference between expected (E) and actual (D).

(D_n) are novel values in the depth image (D).

D_n

Surface Reconstruction:

Novel Surface (S) generated from Novel Values (D_n).

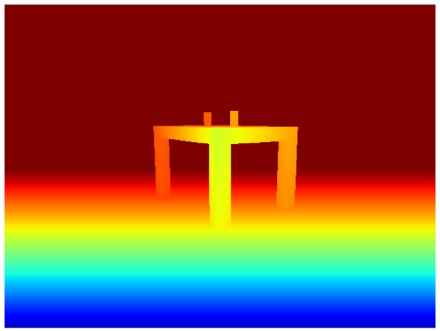
Any surface reconstruction algorithm can be used.

S

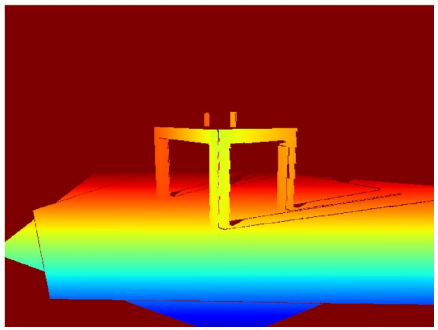
Add Novel Surface (S) to Global Mesh (M)

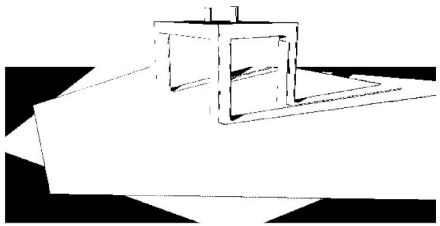
M

MABDI Algorithm



D





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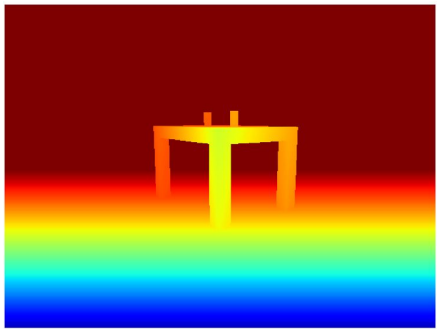

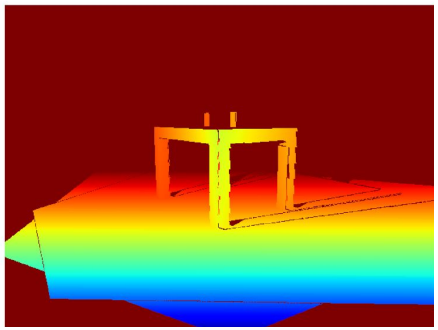

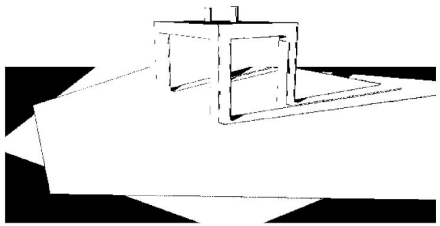

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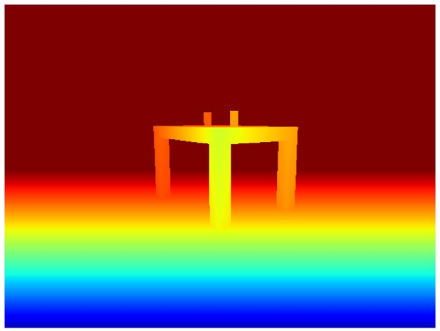

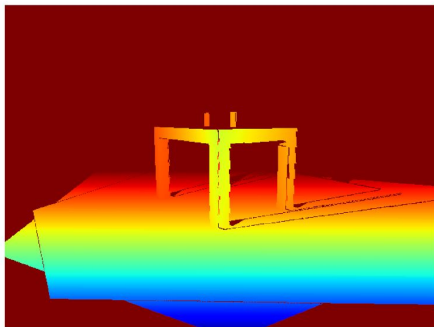

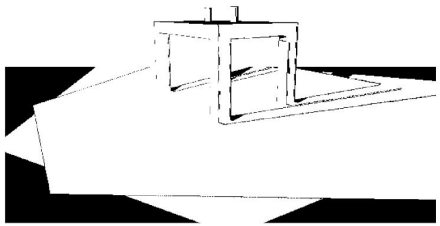

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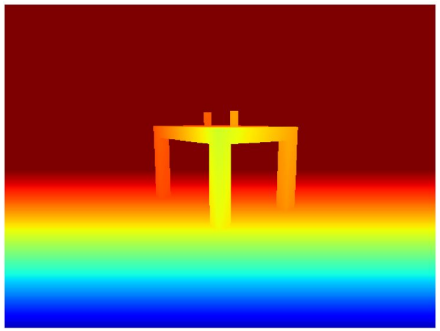

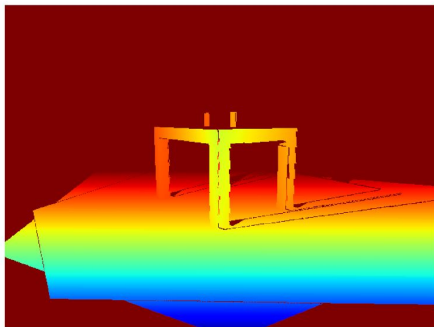

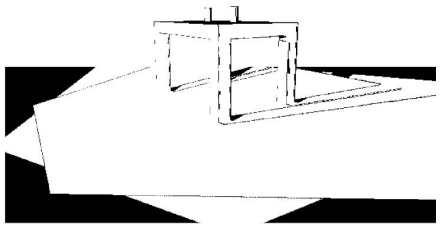

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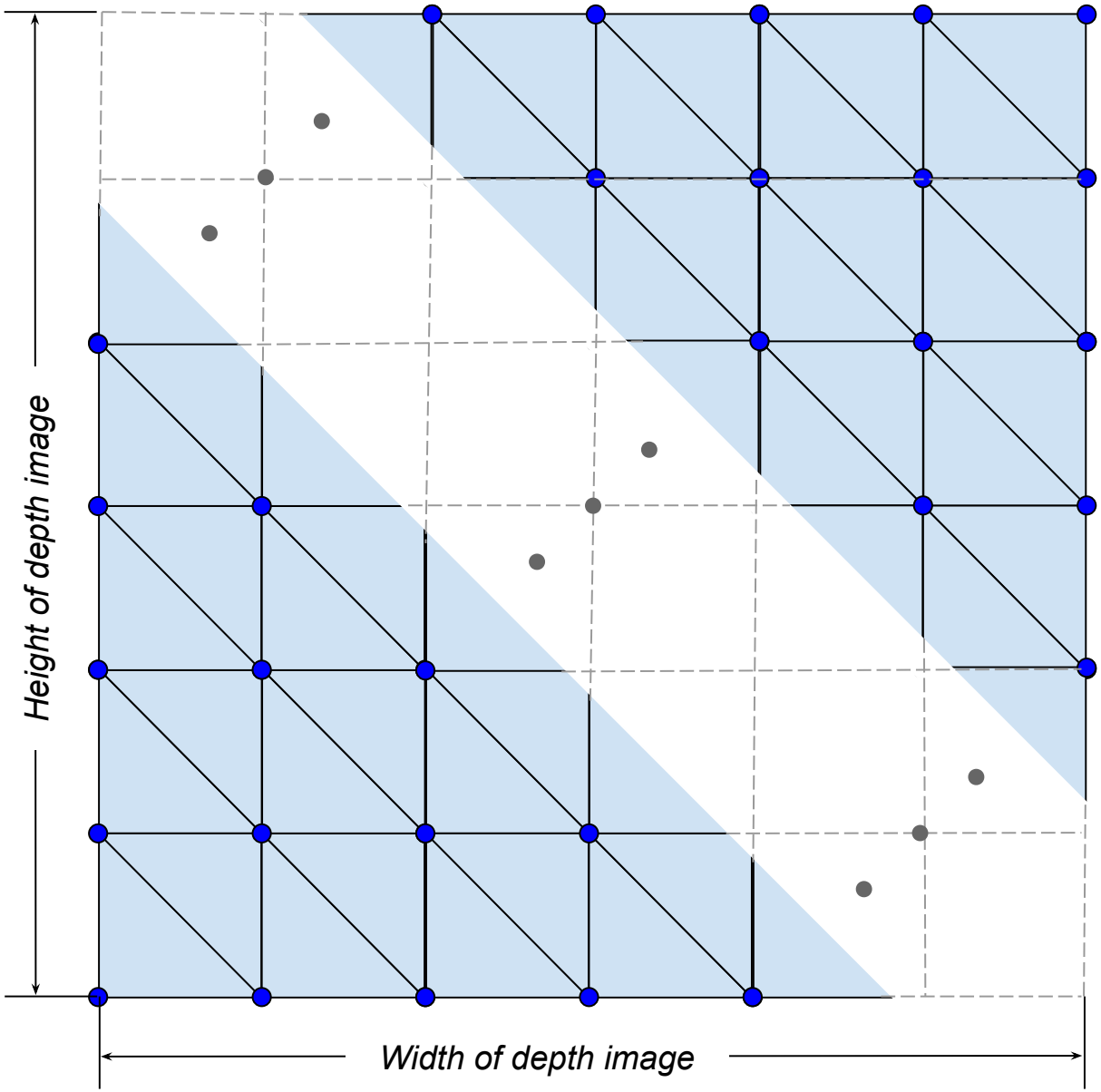
Initial Mesh

Surface Reconstruction component is responsible for creating the novel surface S from the novel points D_n

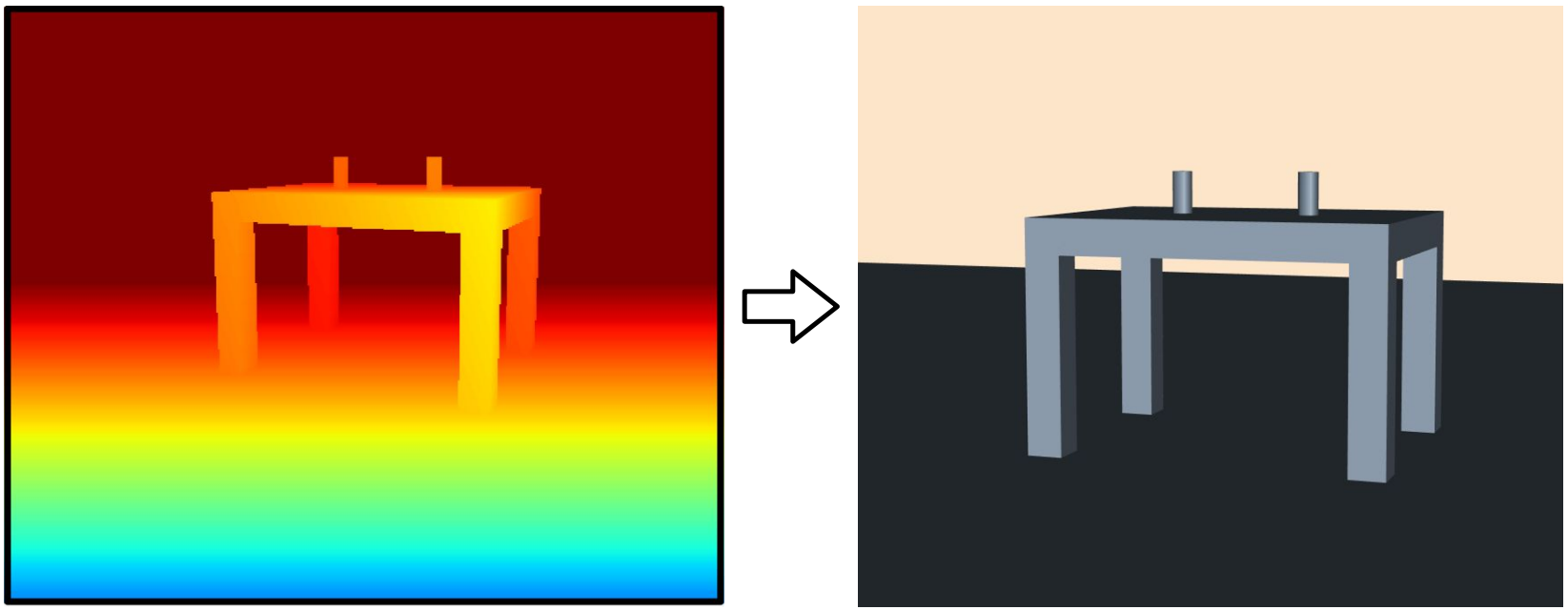
My Method:

- Define topology in 2D, on the depth image
- Project to 3D
- Remove elements

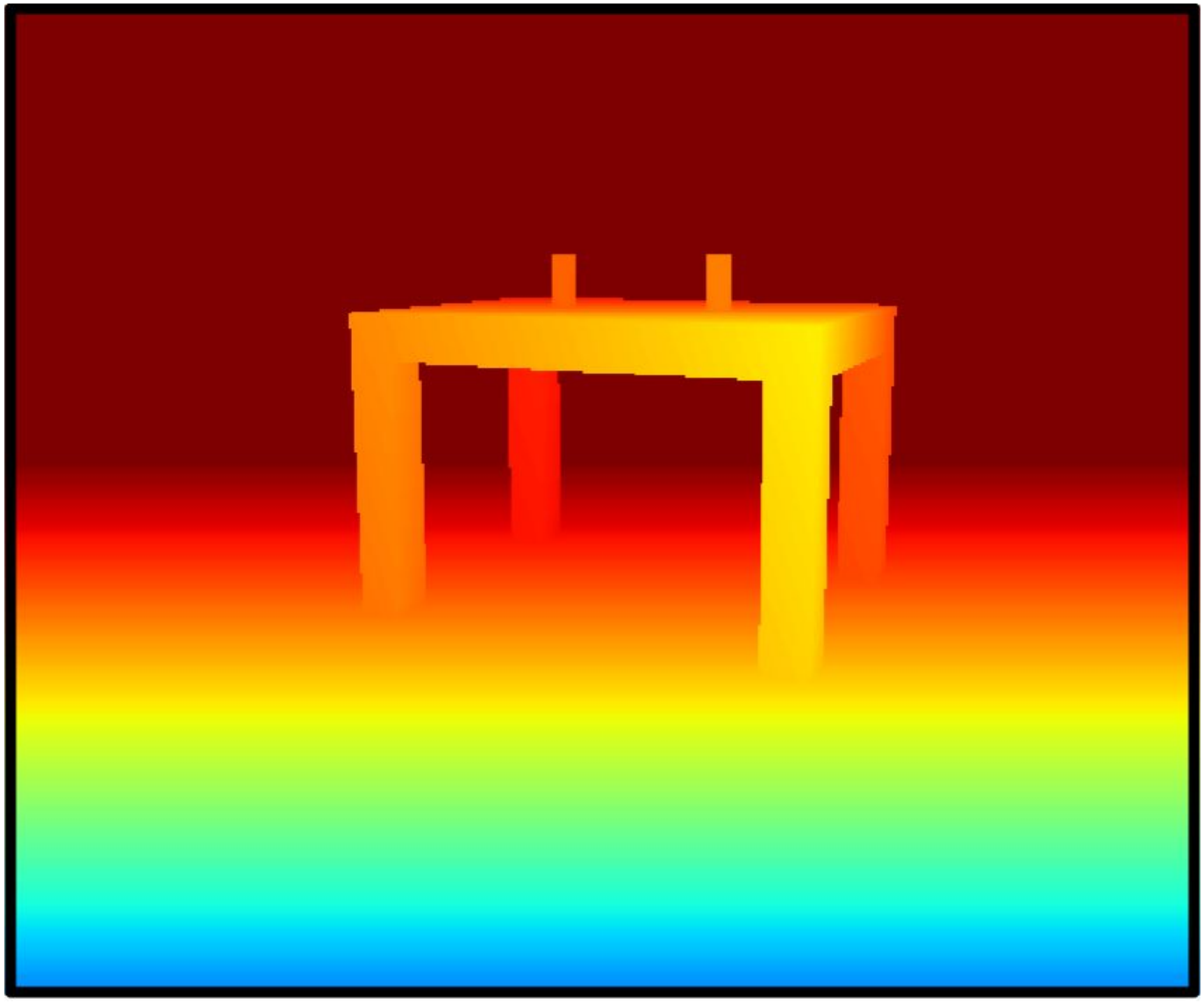
Initial Mesh



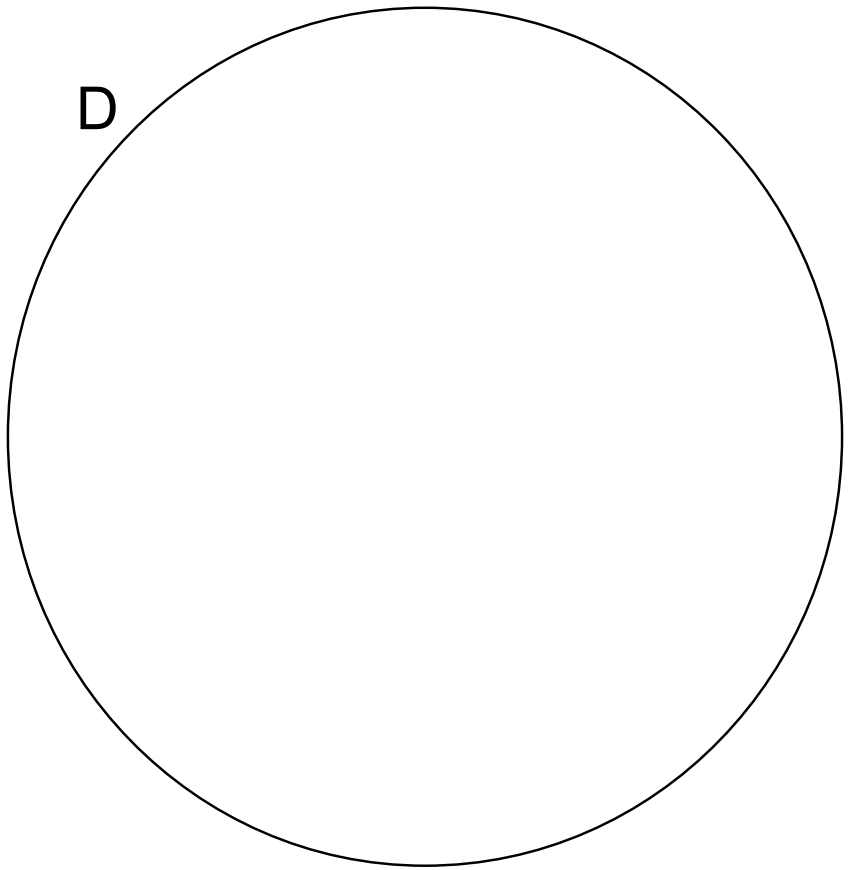
Initial Mesh



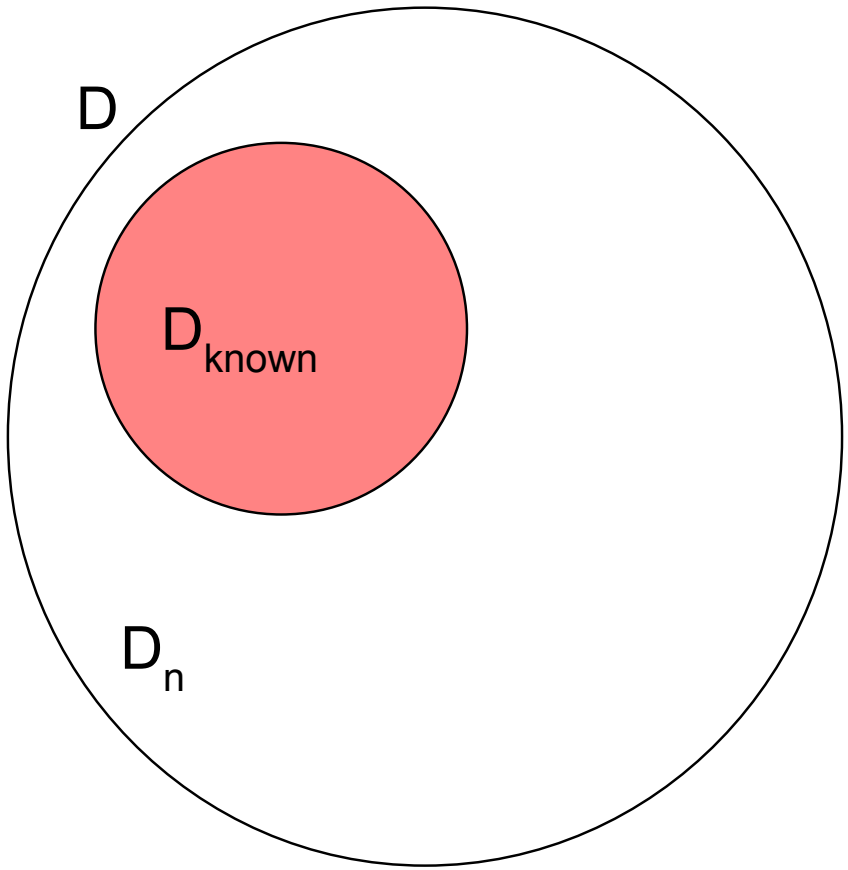
Removing elements



Removing elements



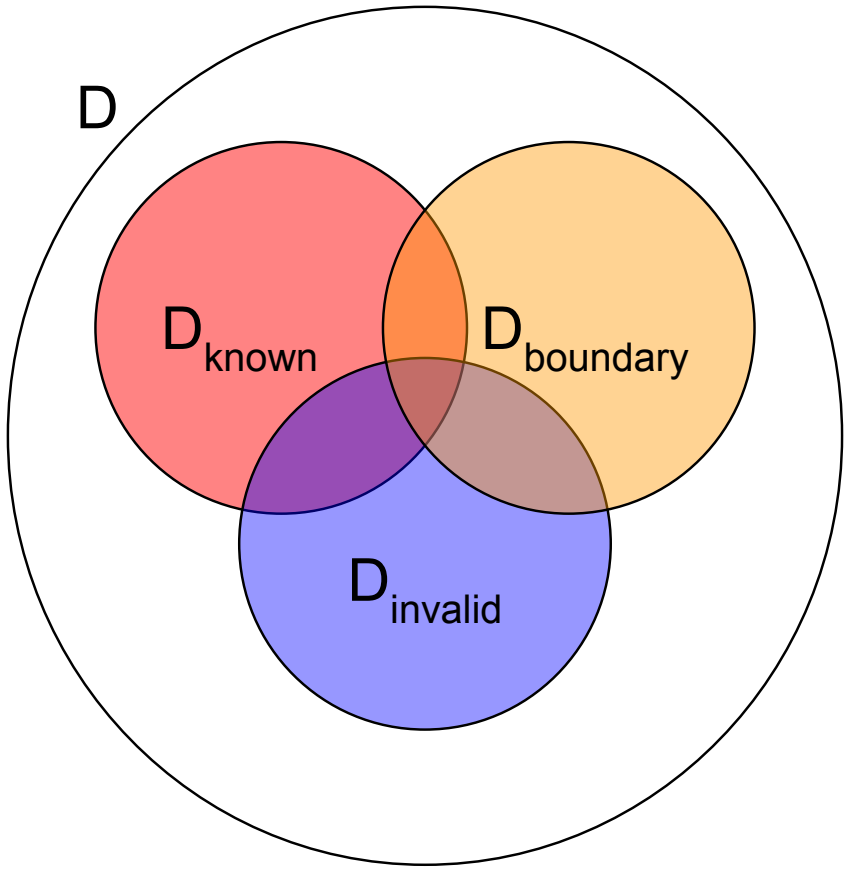
Removing elements



$$D_n = |D - E| > threshold$$

$$D_{known} = D \setminus D_n$$

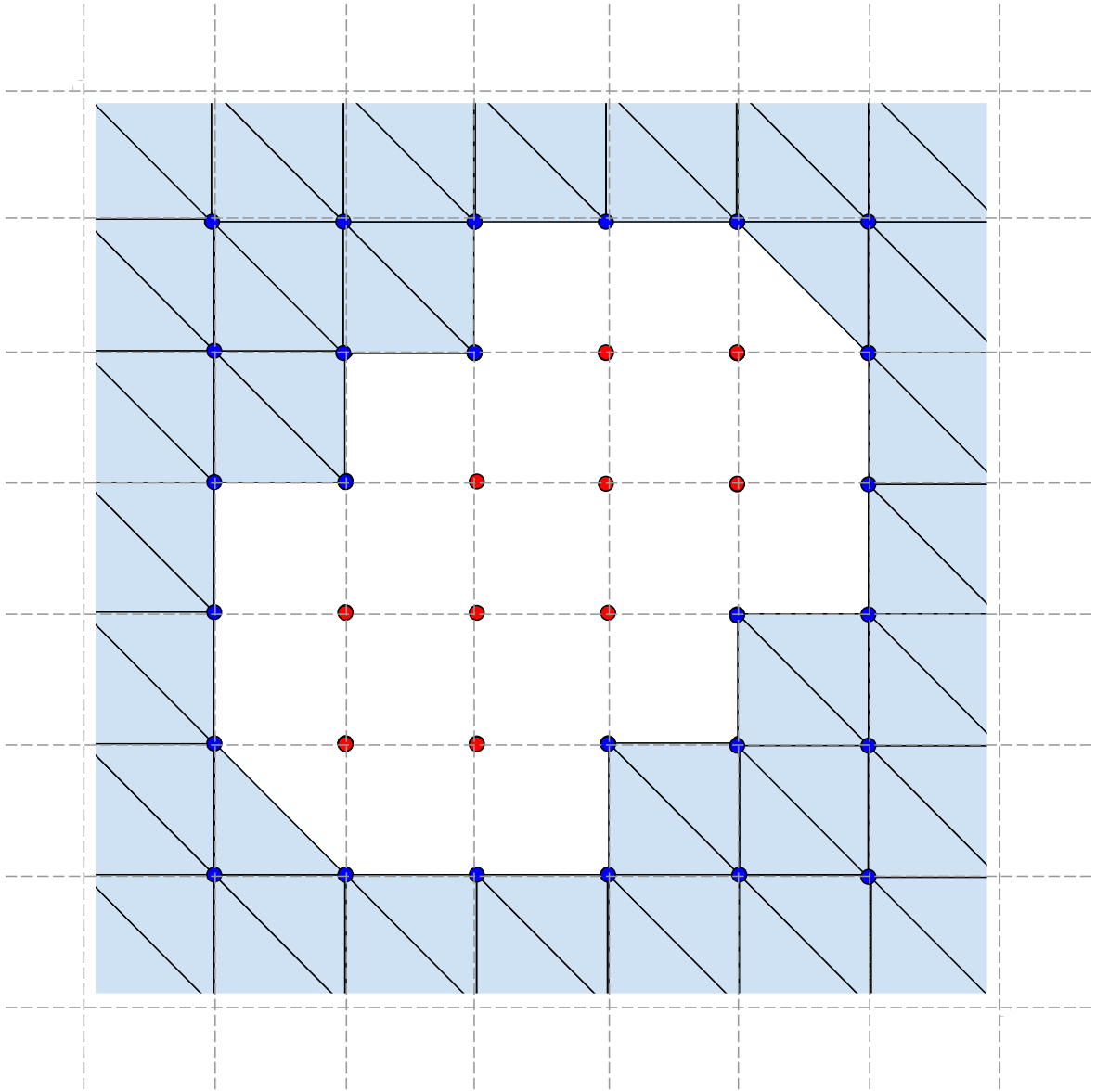
Removing elements



$$K = \begin{bmatrix} 2 & -1 \\ -1 & 0 \end{bmatrix}$$

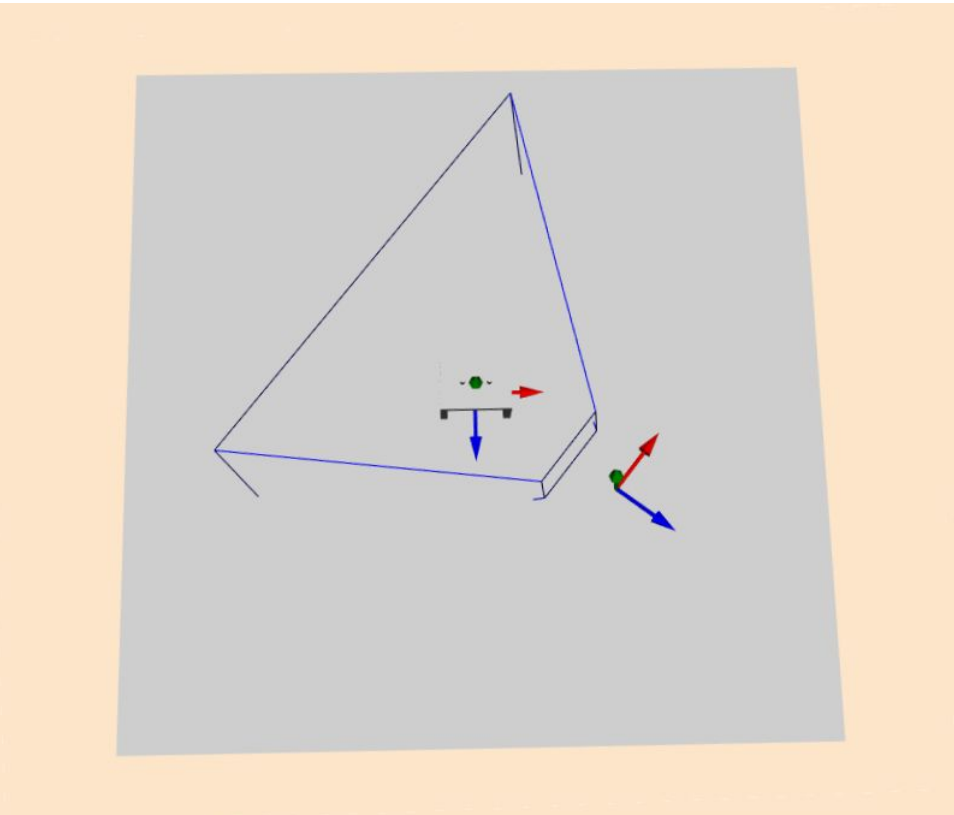
$$D_{boundary} = (D * K) > threshold$$

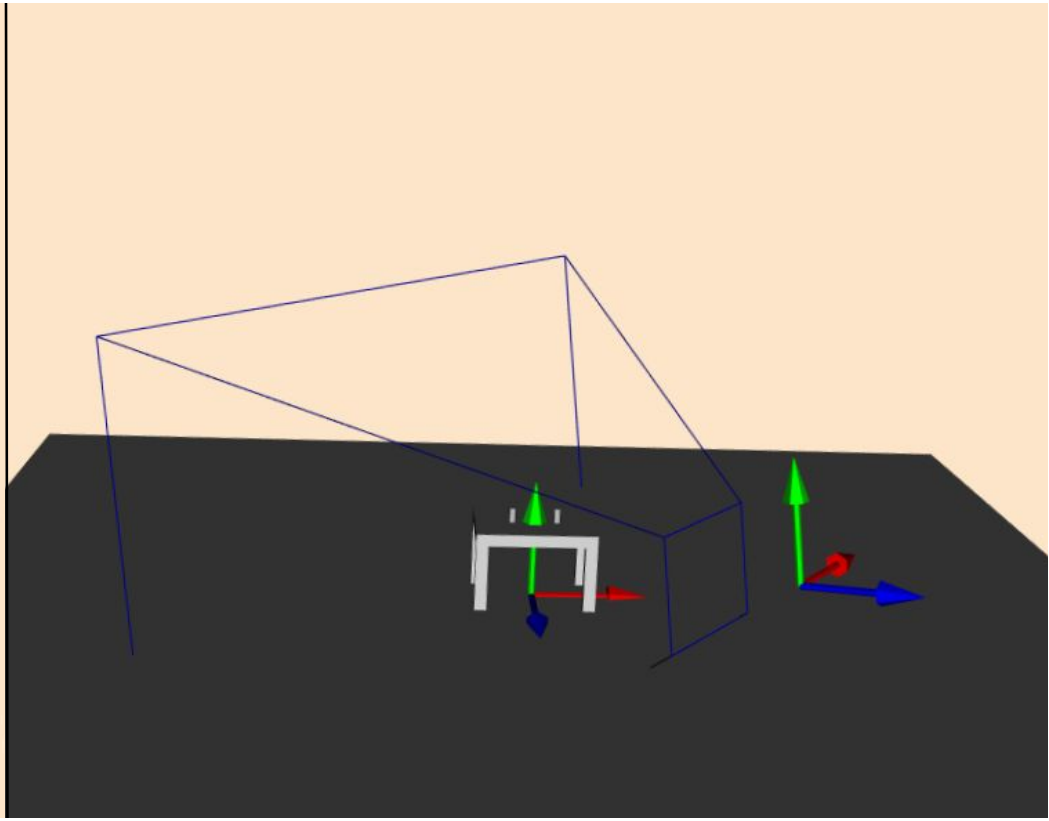
Removing elements



Outline

Overview

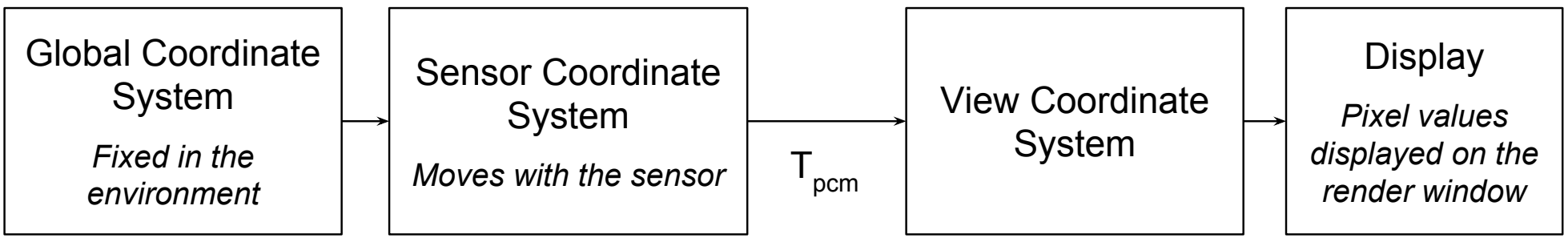




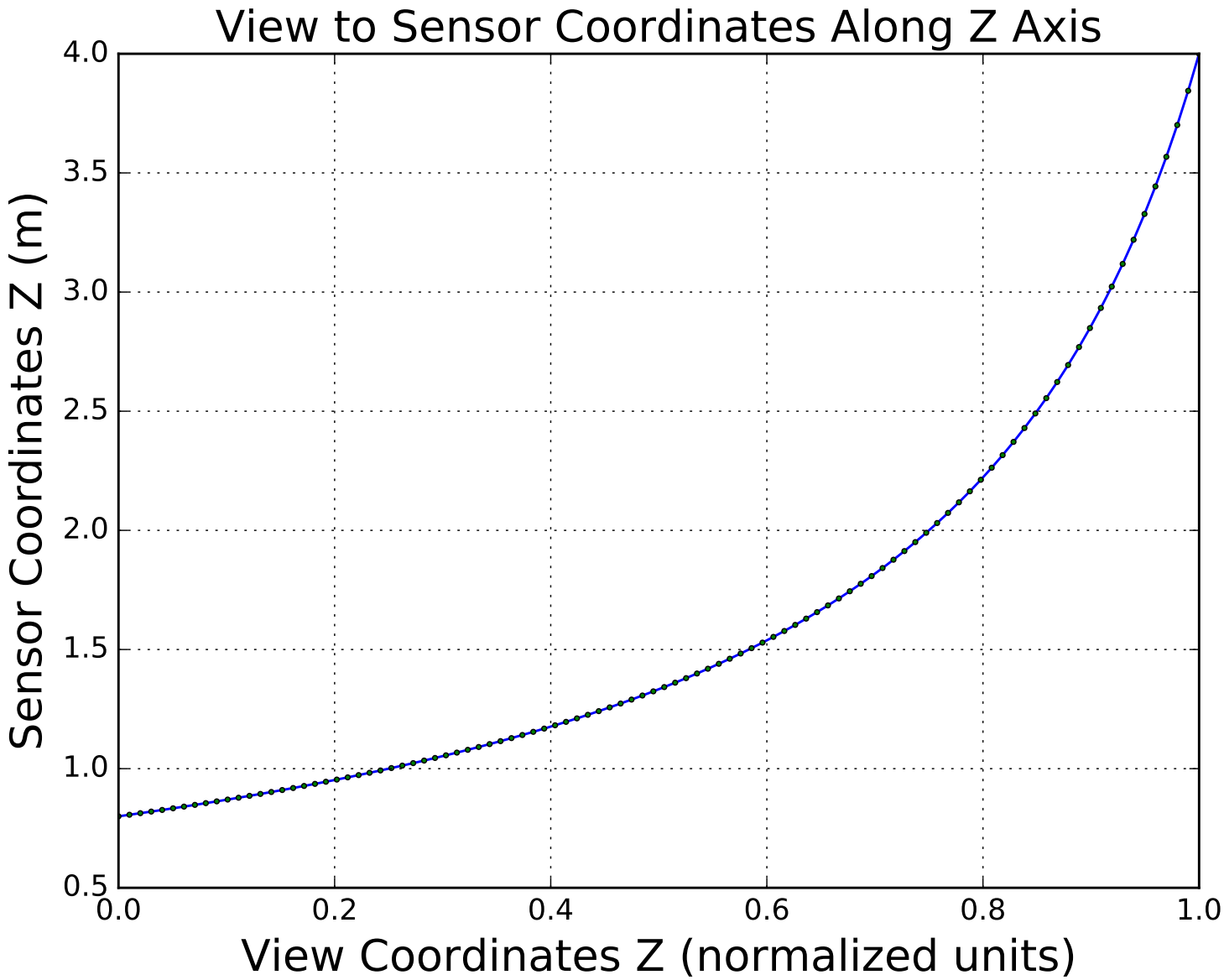
Simulating a RGB-D Sensor

- Adding noise to the depth image
- Sensor path

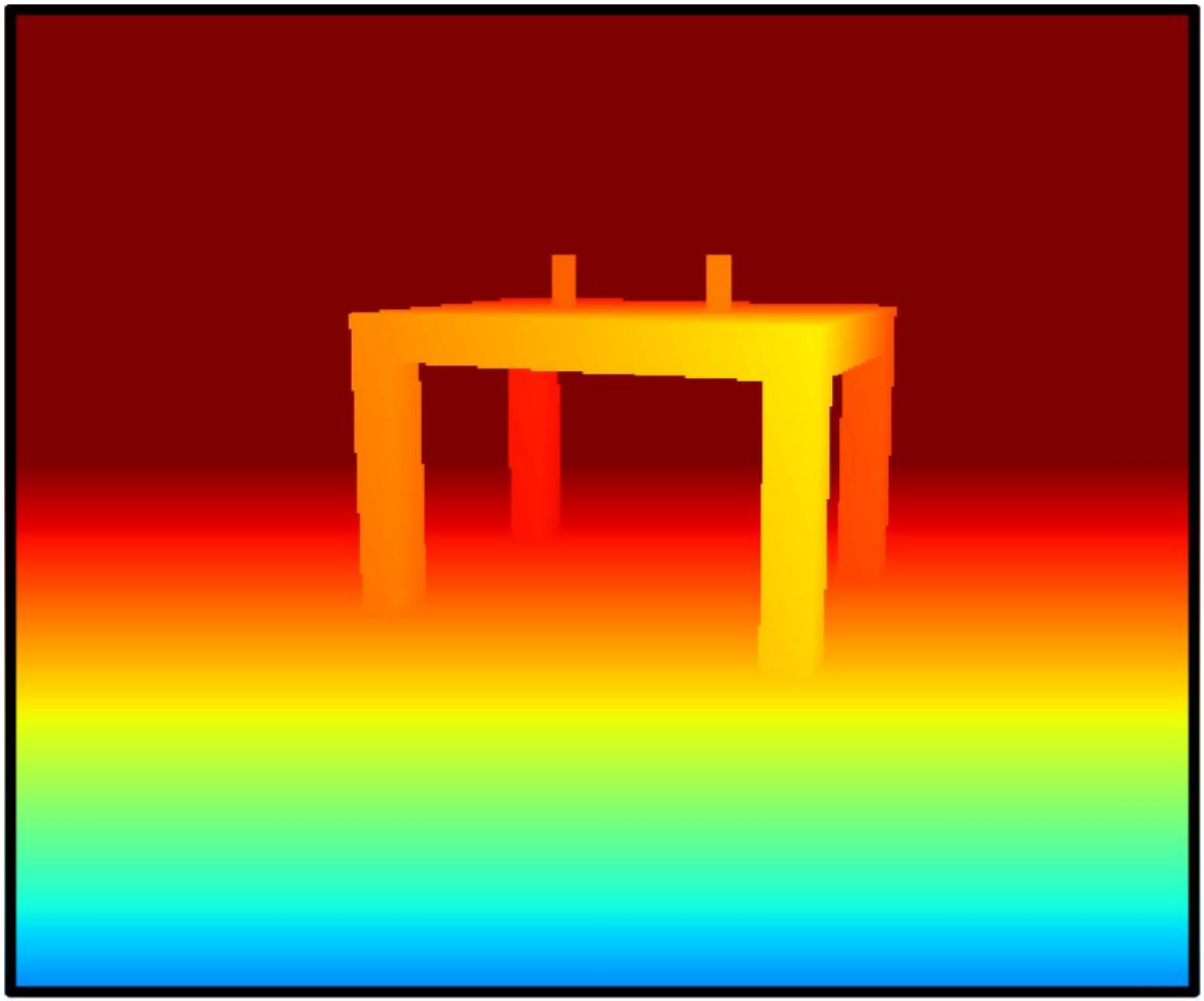
Rendering Pipeline



T_{pcm}


View to Sensor Coordinates Along Z Axis
Sensor Coordinates Z (m)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.2
0.4
0.6
0.8
1.0
View Coordinates Z (normalized units)

Adding Noise



Adding Noise

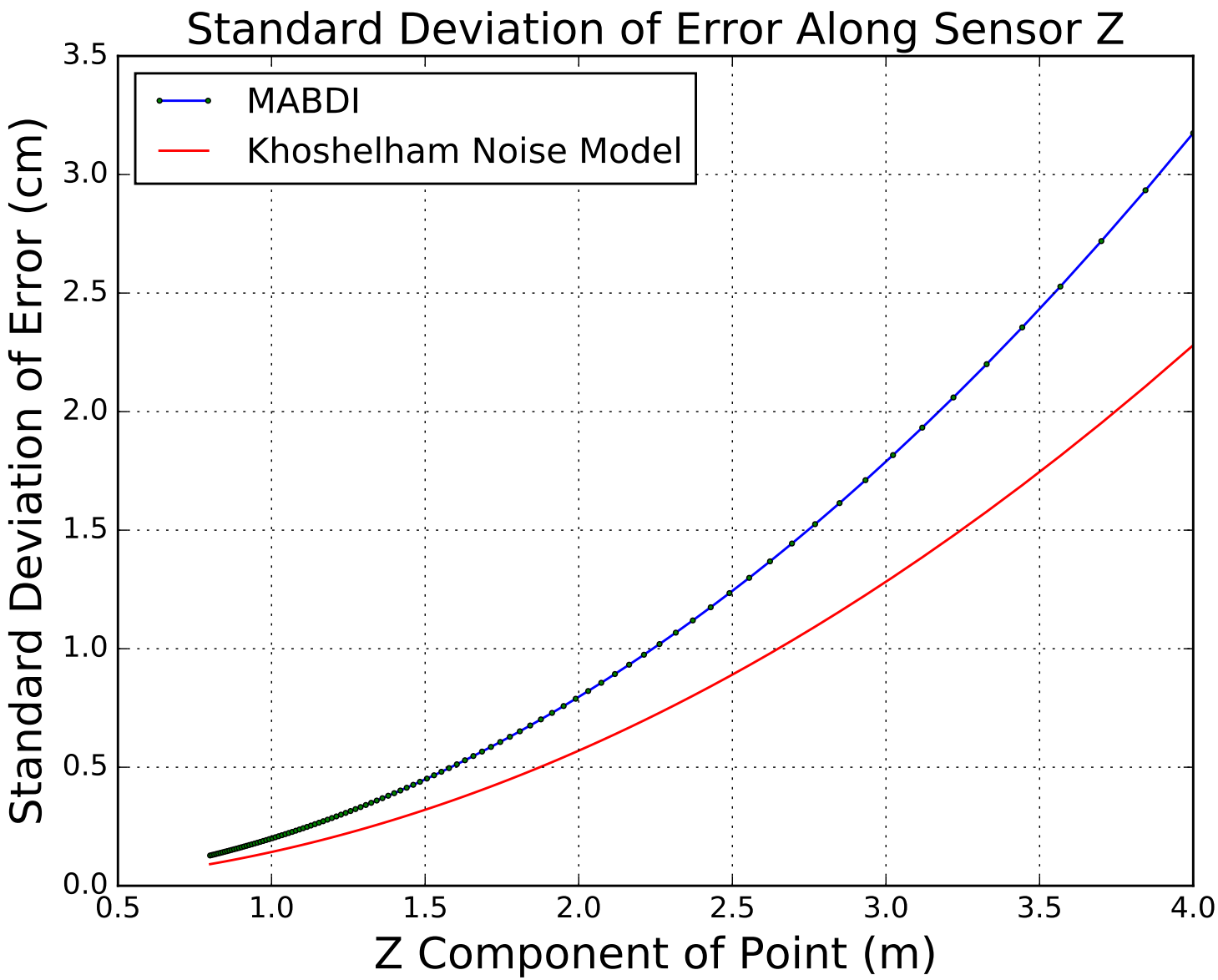
$$D_{noisy}(i,j) = D(i,j) + \mathcal{N}(\mu{=}0, \sigma{=}0.002)$$

Adding Noise

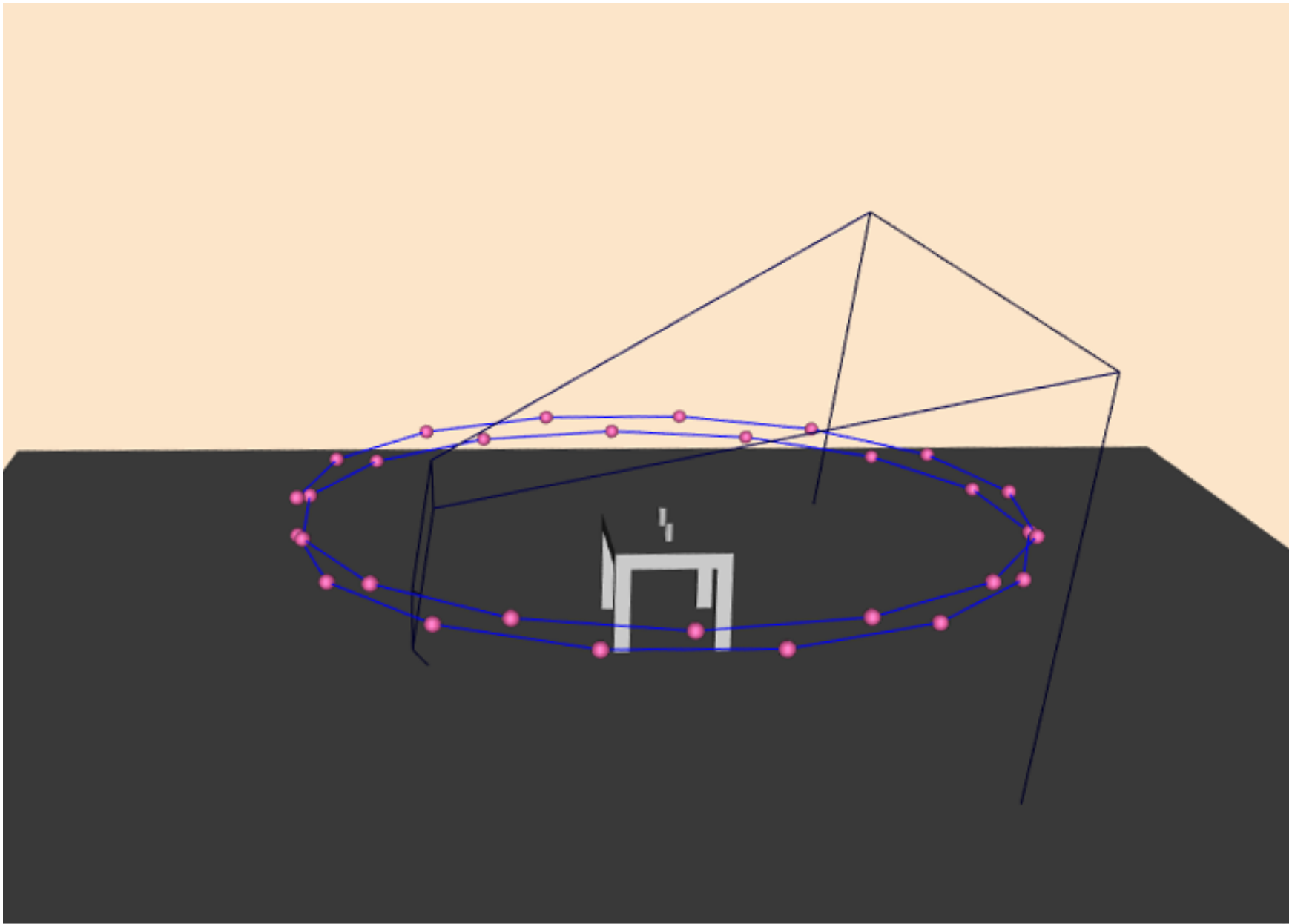
K. Khoshelham and S. O. Elberink, "Accuracy and resolution of Kinect depth data for indoor mapping applications." *Sensors (Basel, Switzerland)*

$$\sigma_z = 1.425\text{e}{-5} \times Z^2$$

Adding Noise



Sensor Path

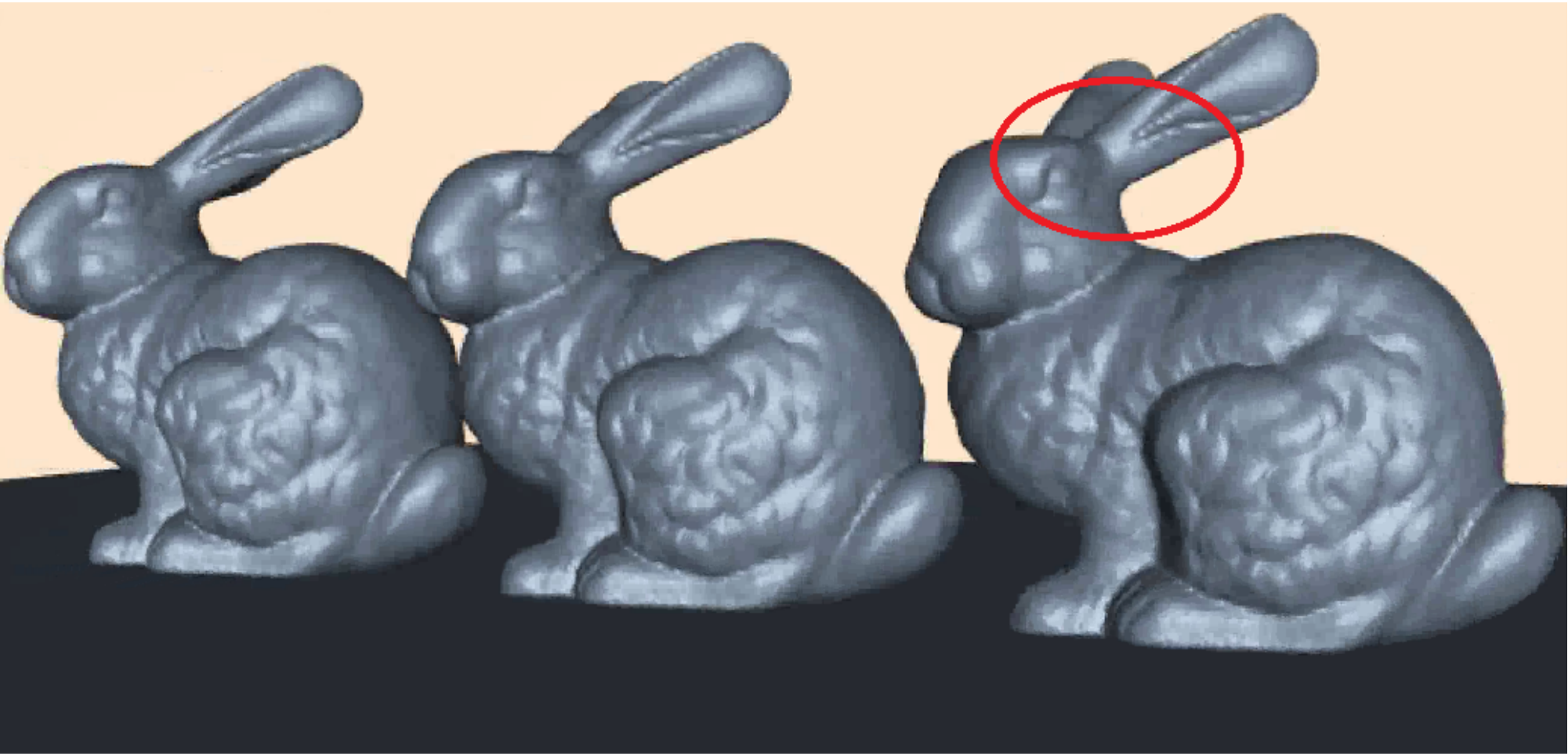


Simulation Parameters

	Environment	Noise	Dynamic	Iterations
Experiment 1	Table	False	False	30
Experiment 2	Bunnies	True	False	50
Experiment 3	Bunnies	True	True	50

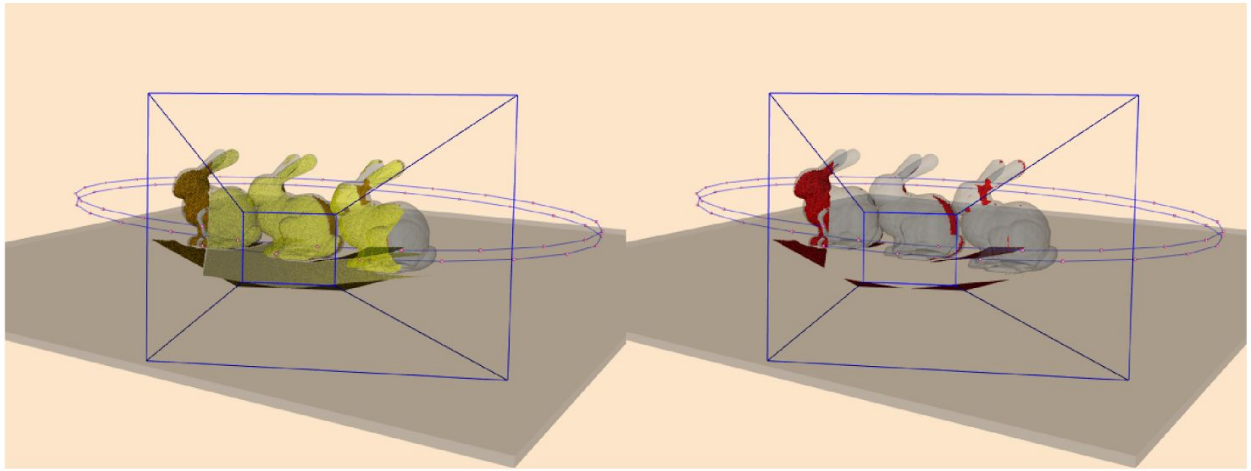
Outline

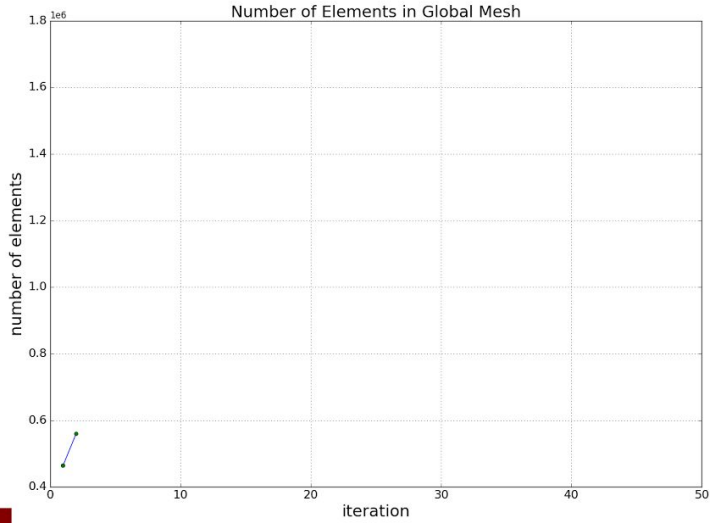
During the Experiment

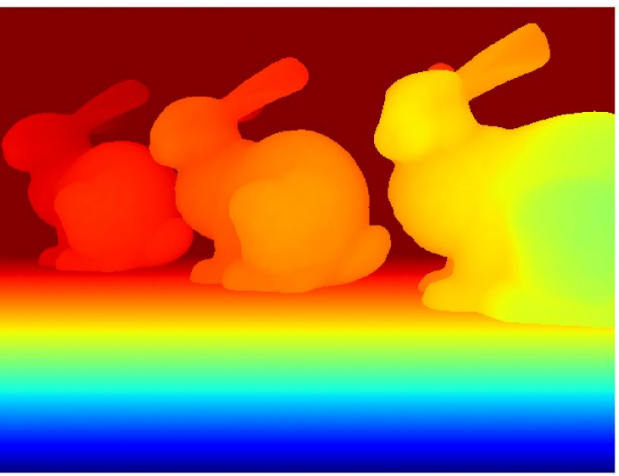


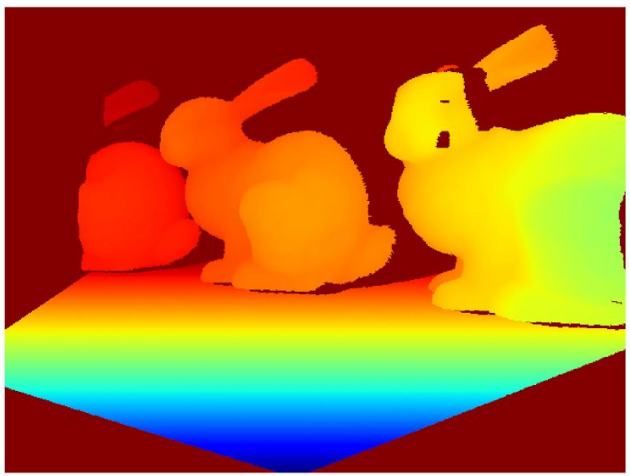
During the Experiment

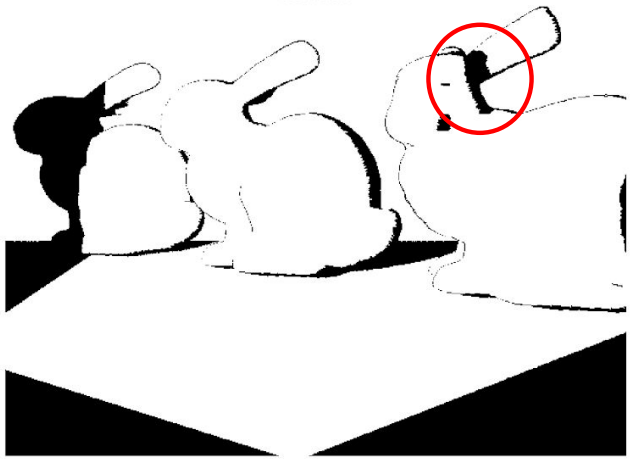
(a) (b) (c)







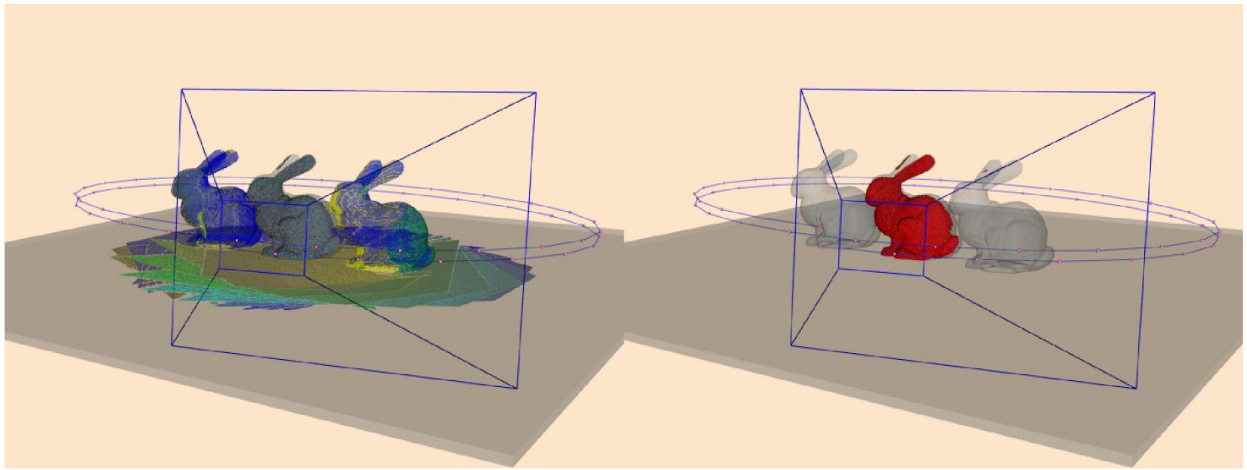




(d) (e) (f)

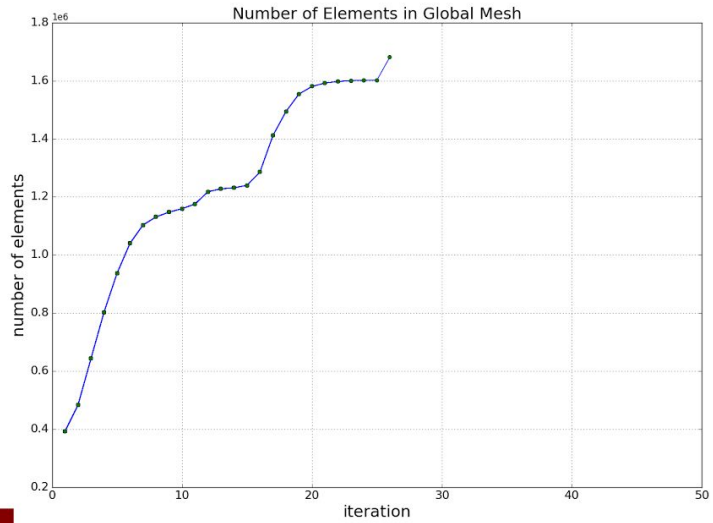
During the Experiment

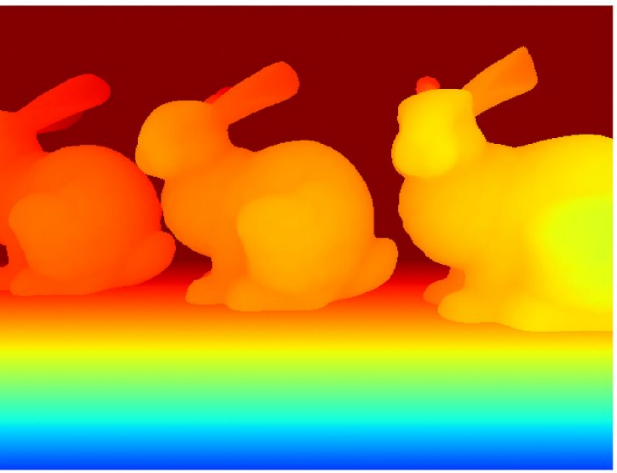
(a)



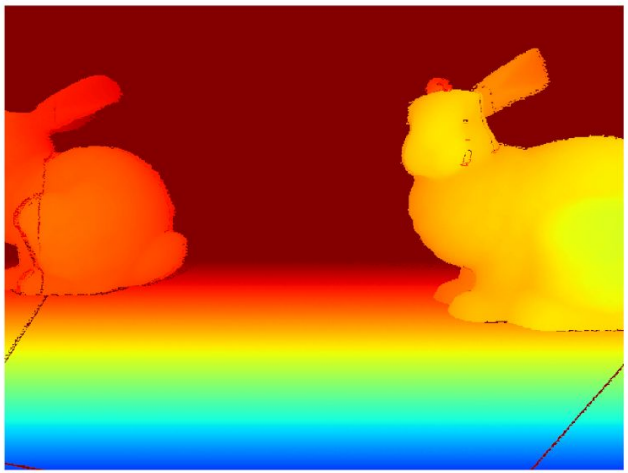
(b)

(c)

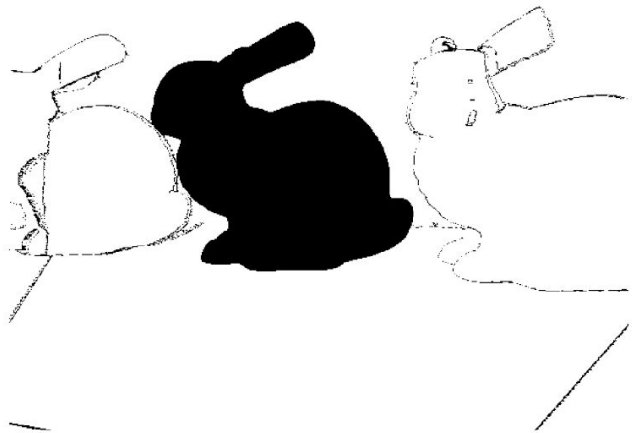




(d)

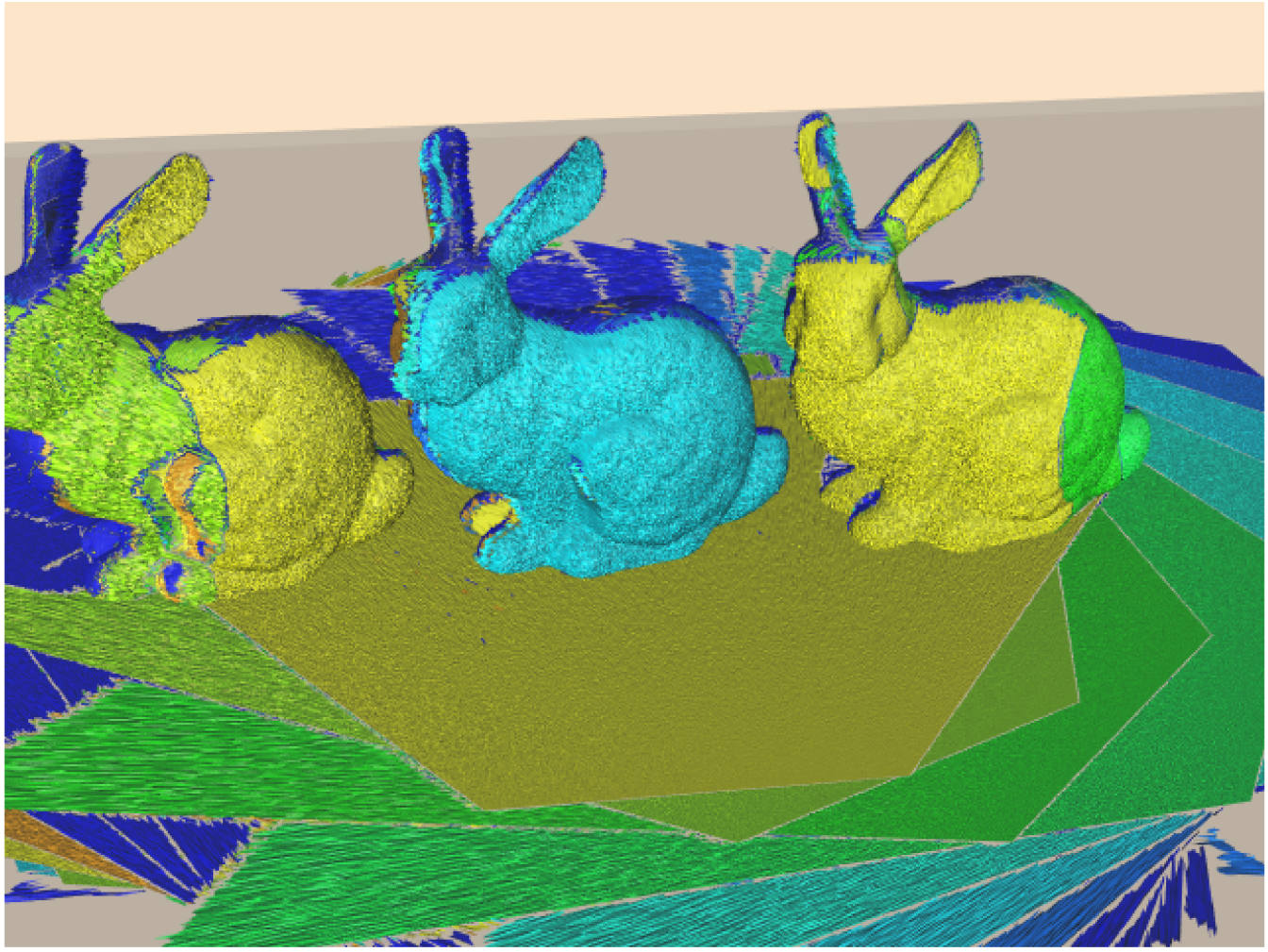


(e)

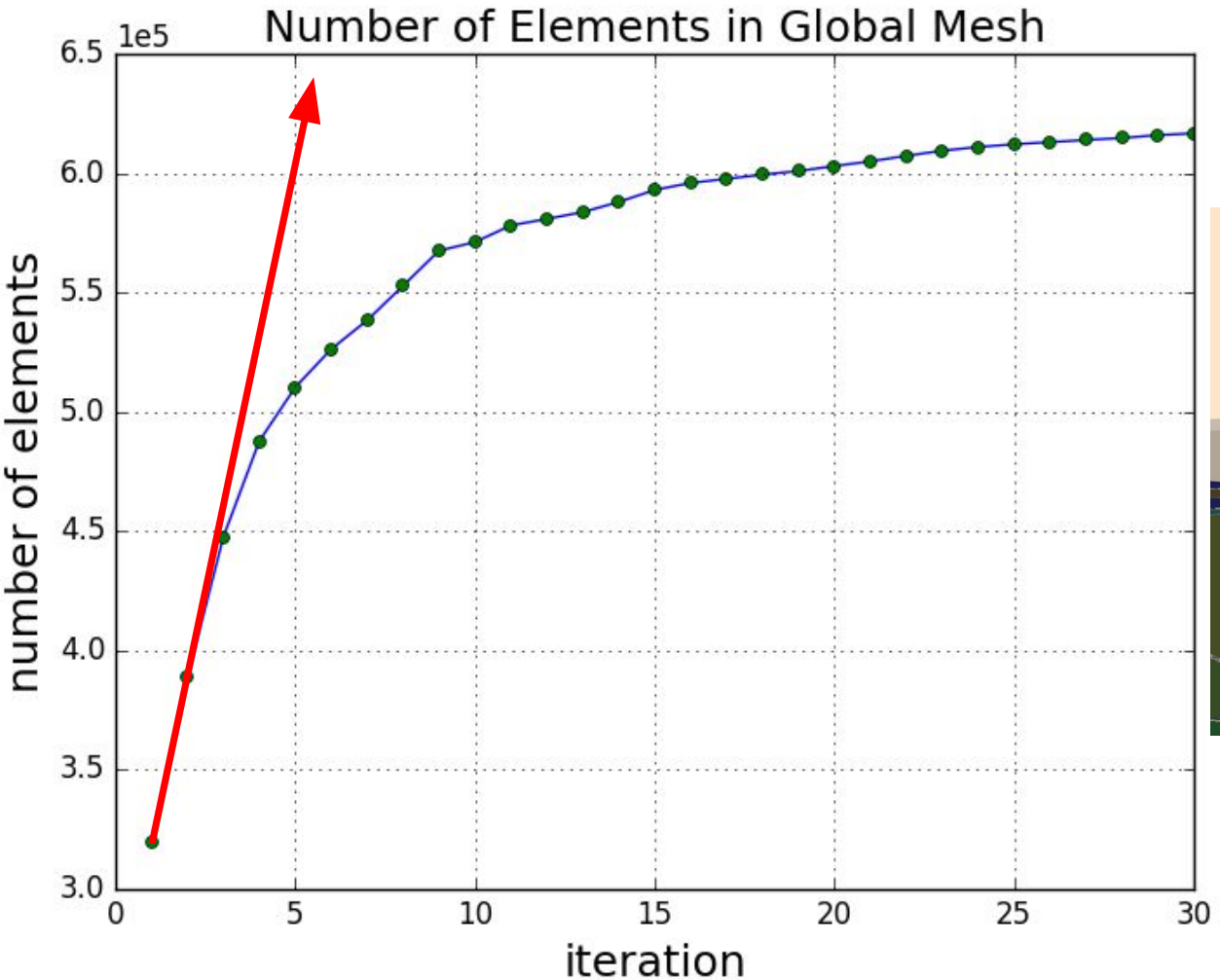


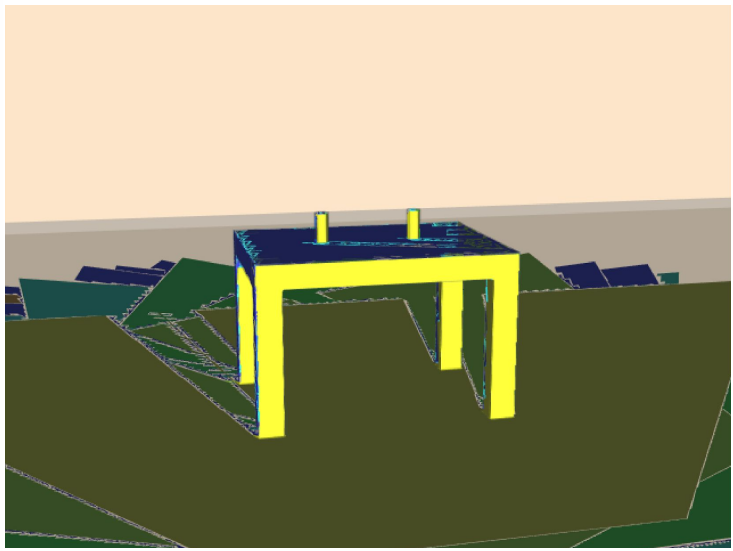
(f)

Mesh Quality



Mesh Progression





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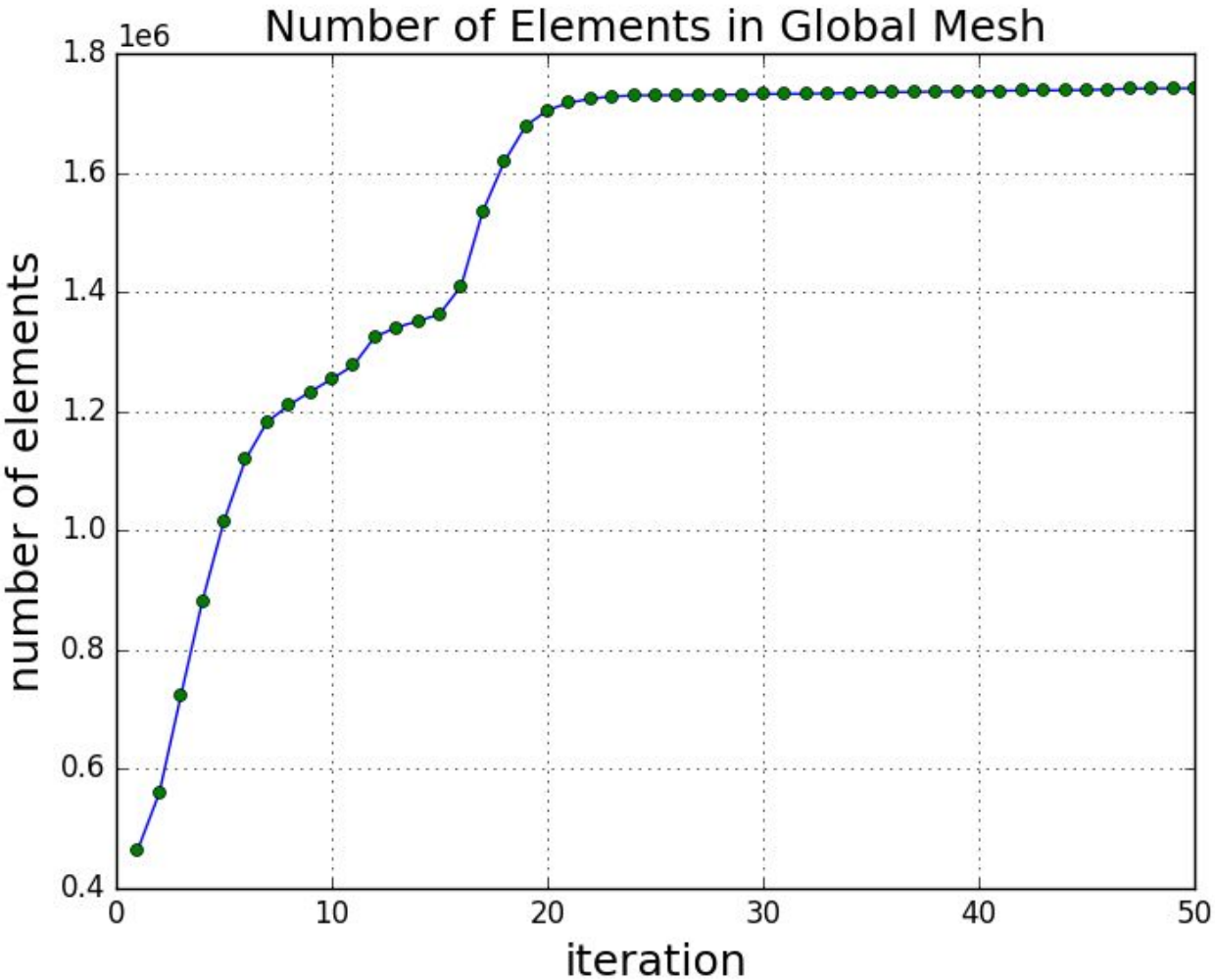
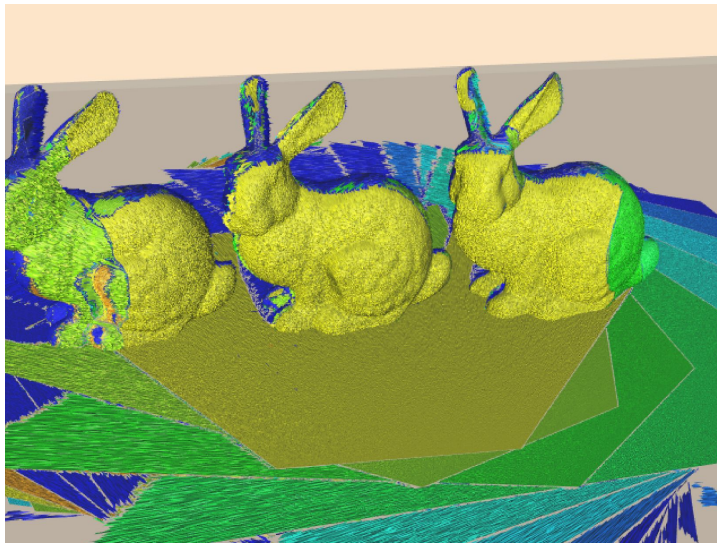
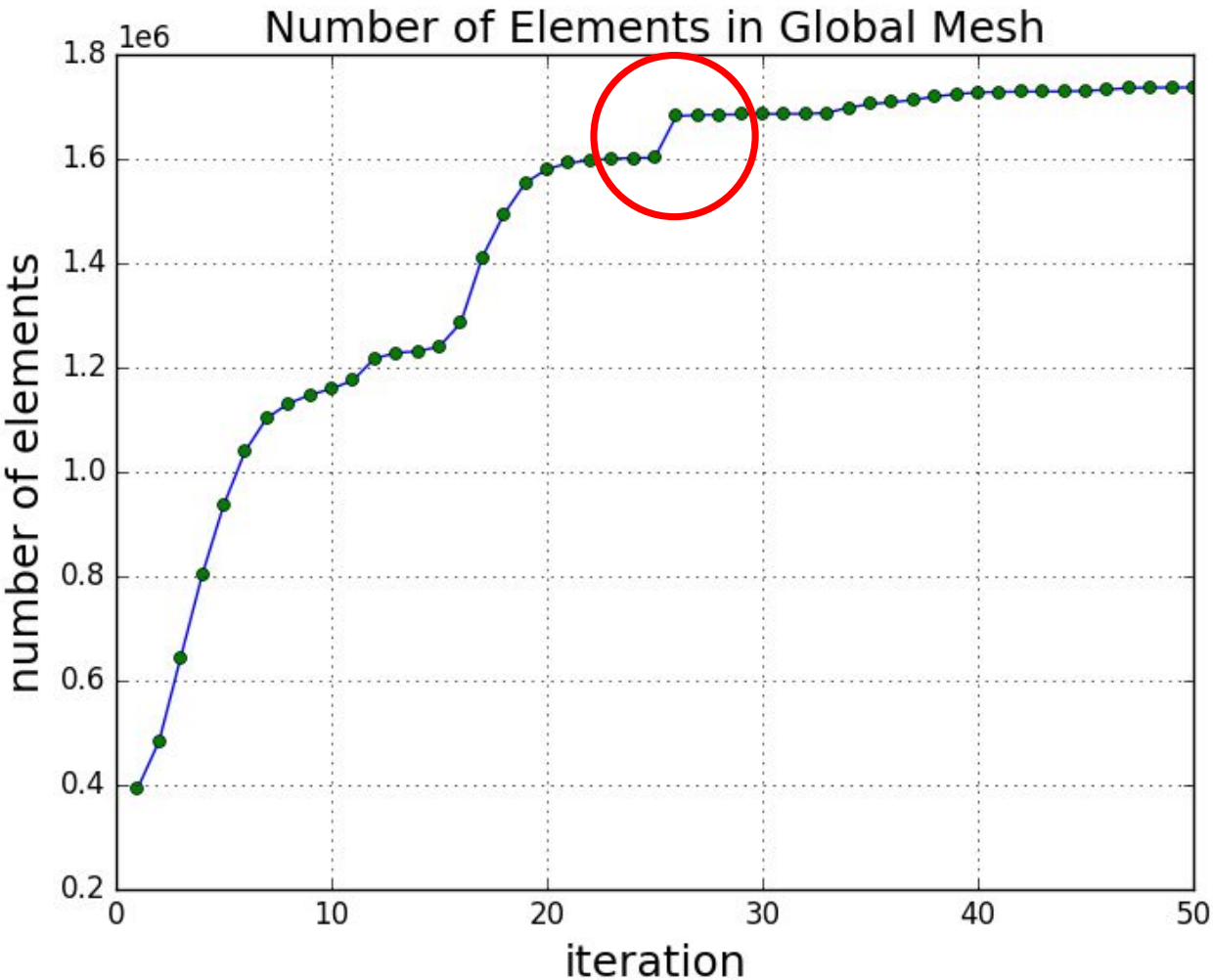
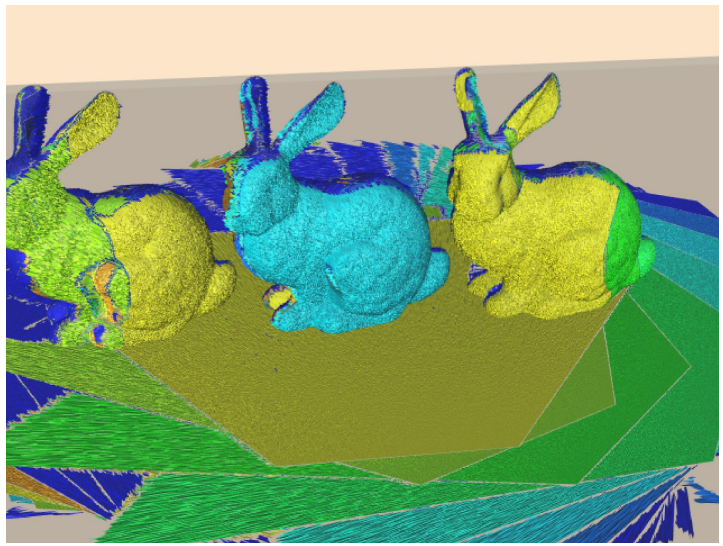




Mesh Progression





Outline

Conclusion

- The MABDI algorithm runs at around 2Hz on a consumer grade laptop with an Intel i7 processor.
- MABDI's algorithmic design identifies redundant information and removes it *before* it is added to the global mesh.
- MABDI does this by leveraging the difference between what we are actually seeing and what we expect to see.
- MABDI can work in conjunction with any current mesh-based surface reconstruction algorithms, and can be thought of as a general means to provide introspection to those types of reconstruction methods.

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Thank you for your attention