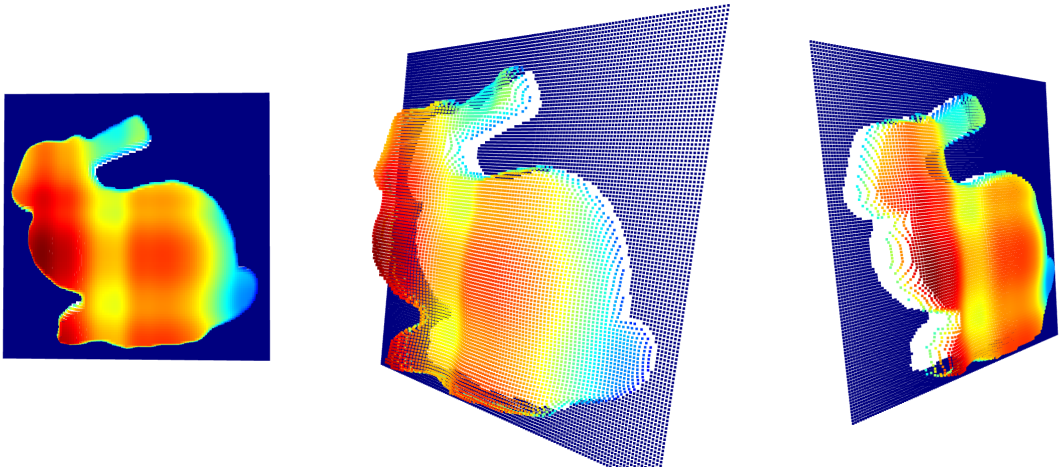
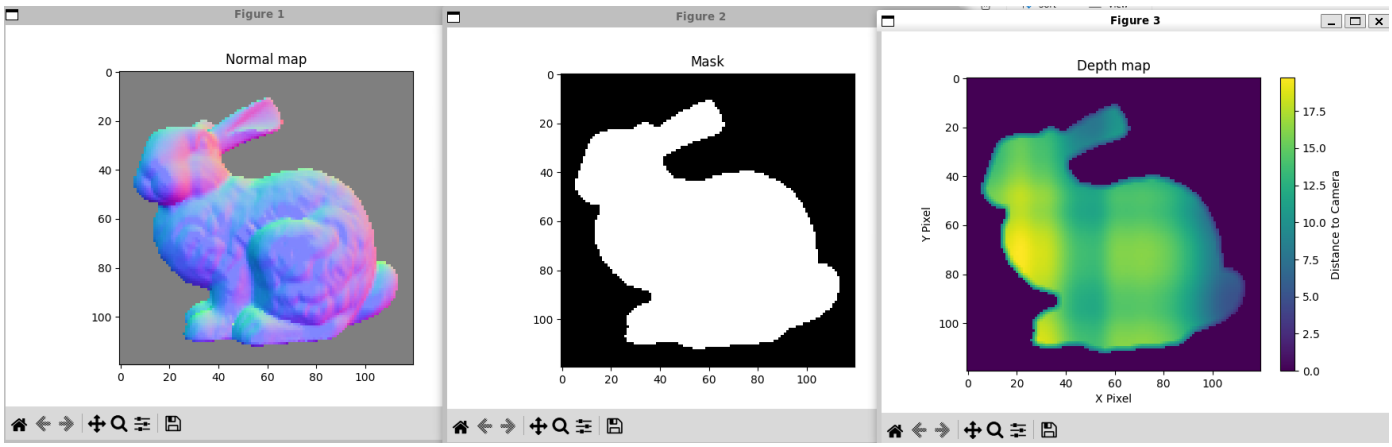
Photometric Stereo

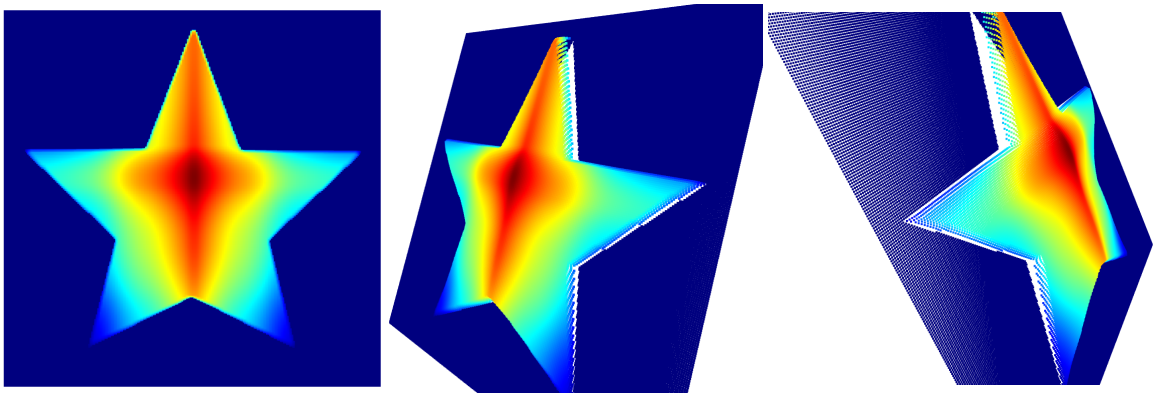
Reconstruct surfaces

Bunny





Star



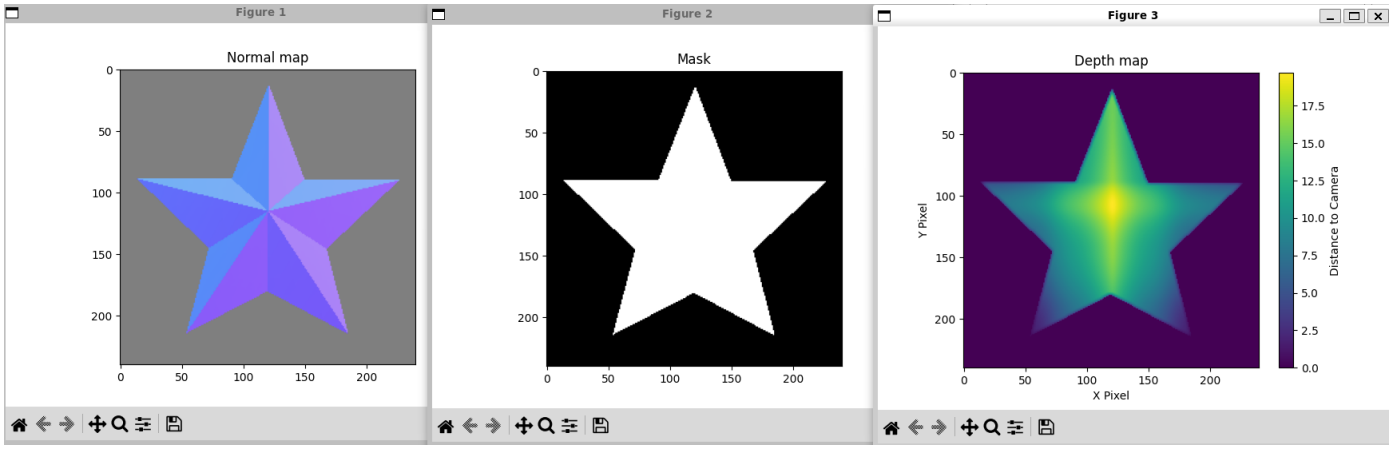
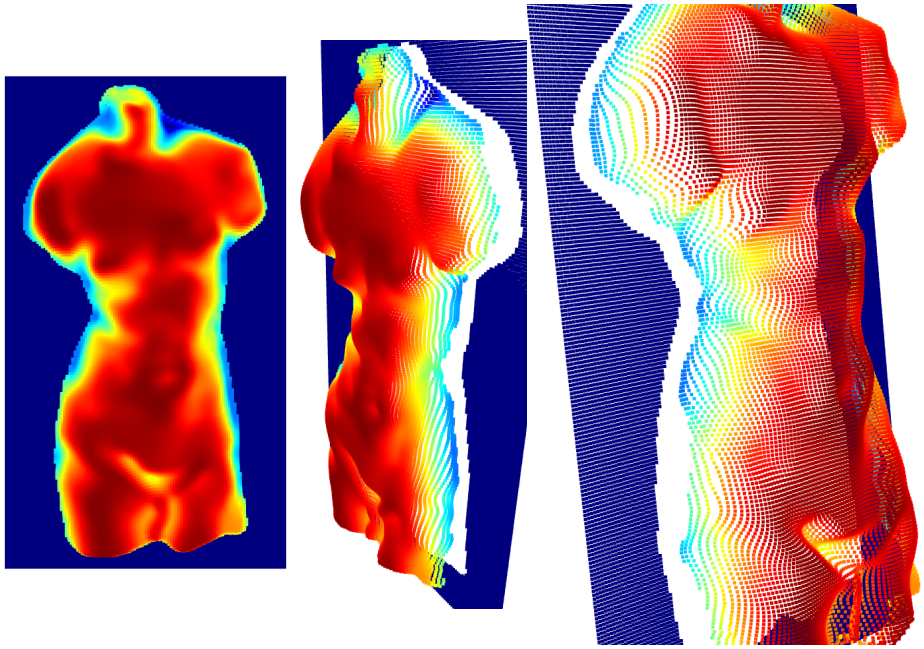


Figure 1
Normal map
Figure 2
Mask
Figure 3
Depth map
Y Pixel
X Pixel
Distance to Camera

Venus



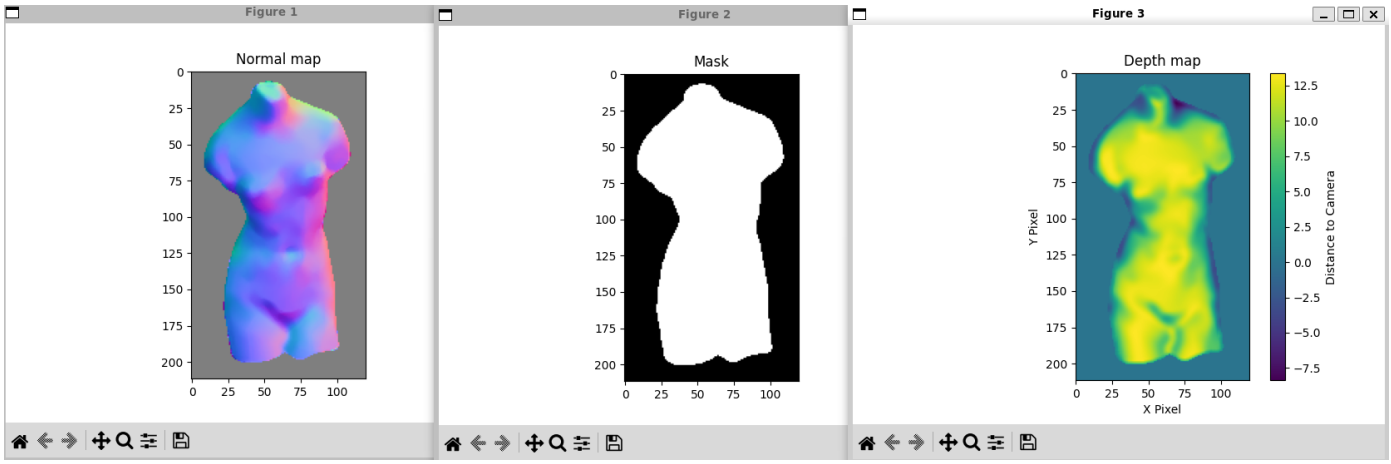
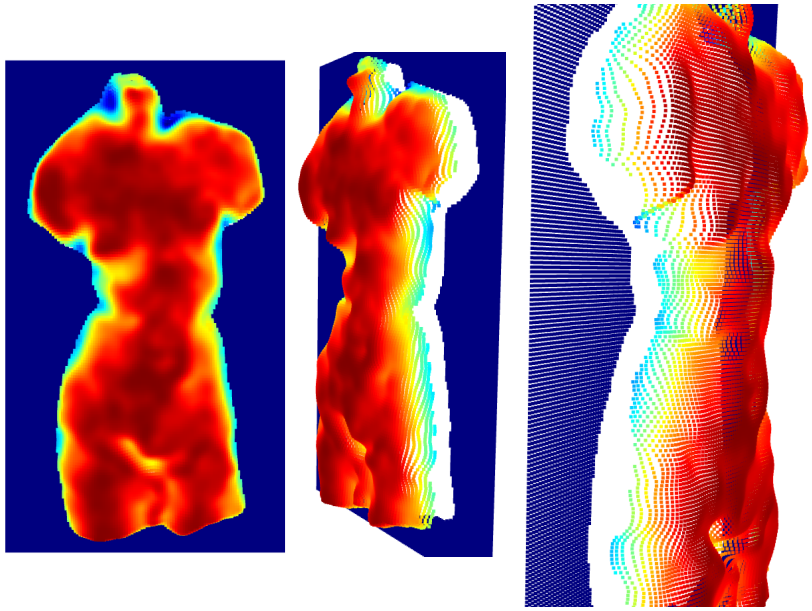
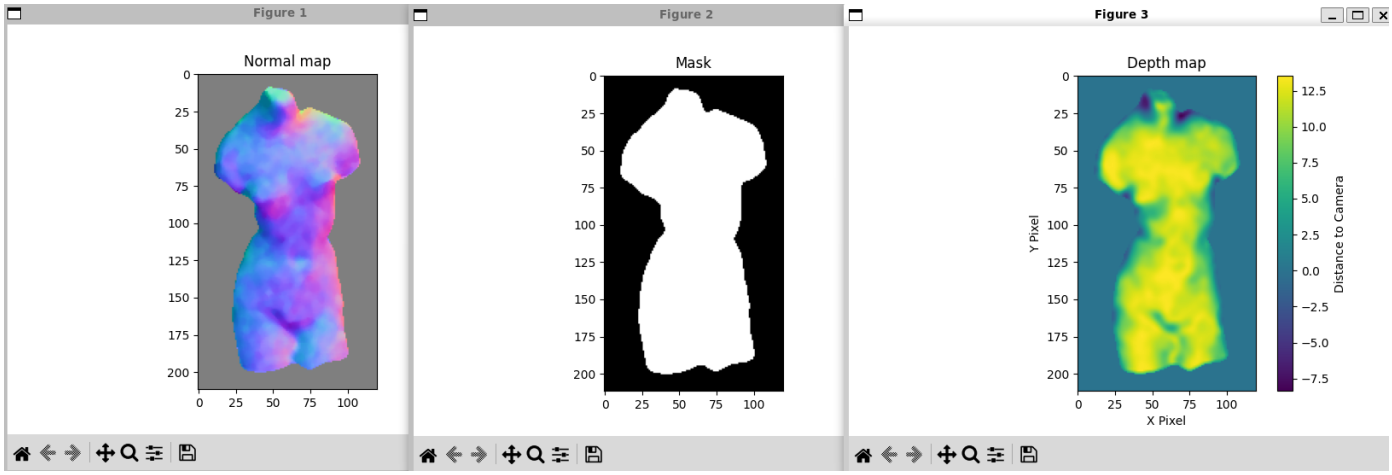


Figure 1
Normal map
Figure 2
Mask
Figure 3
Depth map
Y Pixel
X Pixel
Distance to Camera

Noisy Venus





Implementation Method

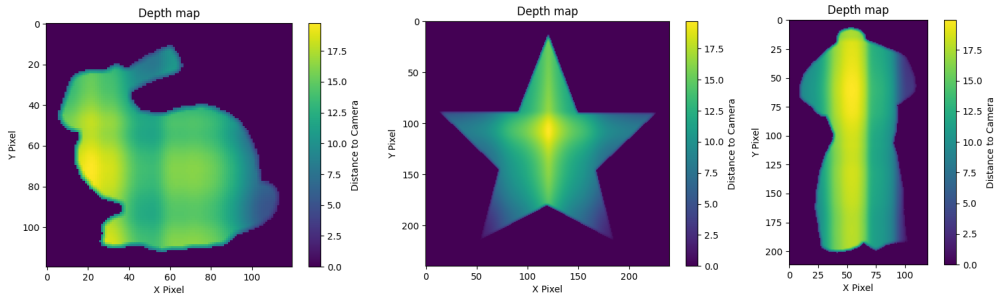
Normal Estimation

$$i_{x,y}^{m} = l_m K_d n \ \rightarrow \ I = L K_d N$$

$$I = L K_d N \ \rightarrow \ L^T I = L^T L K_d N \ \rightarrow \ K_d N = (L^T L)^{-1} L^T I N = \frac{K_d N}{||K_d N||}$$

Integral Method

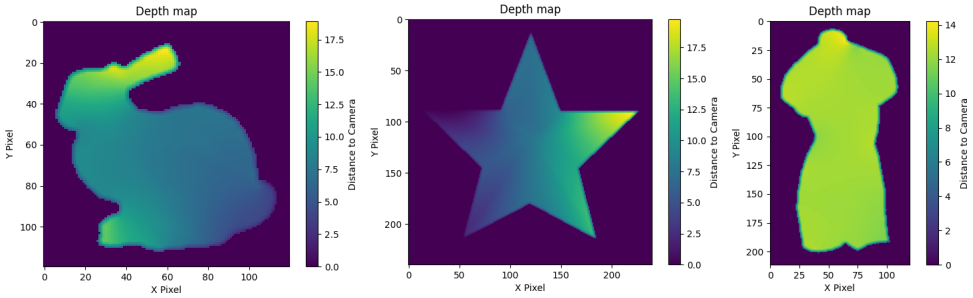
$$\tilde{z}(x,y) = \sum_{i=0}^{x-1} \left. \frac{\partial z_{\text{approx}}}{\partial x} \right|_{(i,0)} + \sum_{j=0}^{y-1} \left. \frac{\partial z_{\text{approx}}}{\partial y} \right|_{(x,j)}$$



Matrix Method

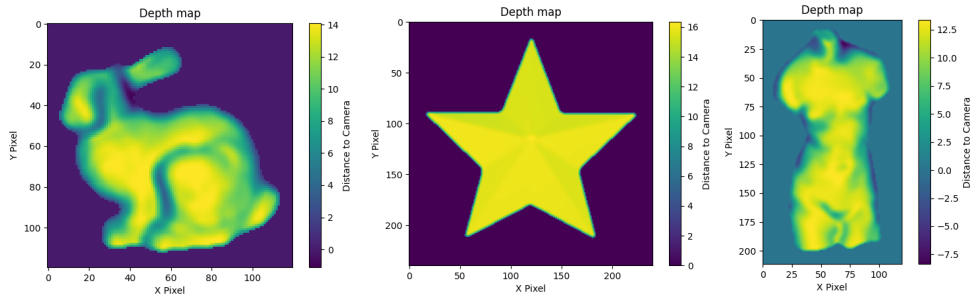
$$z_{x+1,y} - z_{x,y} = -\frac{n_x}{n_z}$$

$$z_{x,y+1} - z_{x,y} = -\frac{n_y}{n_z}$$



Dot Product Method

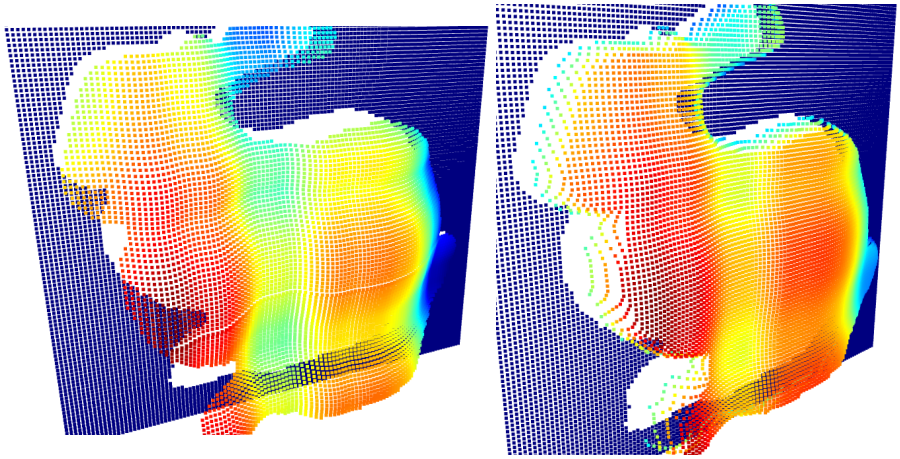
$$Z_{x,y} = N_{x,y} \cdot [0, 0, 1]^T$$



Post Processing

Gaussian Filter

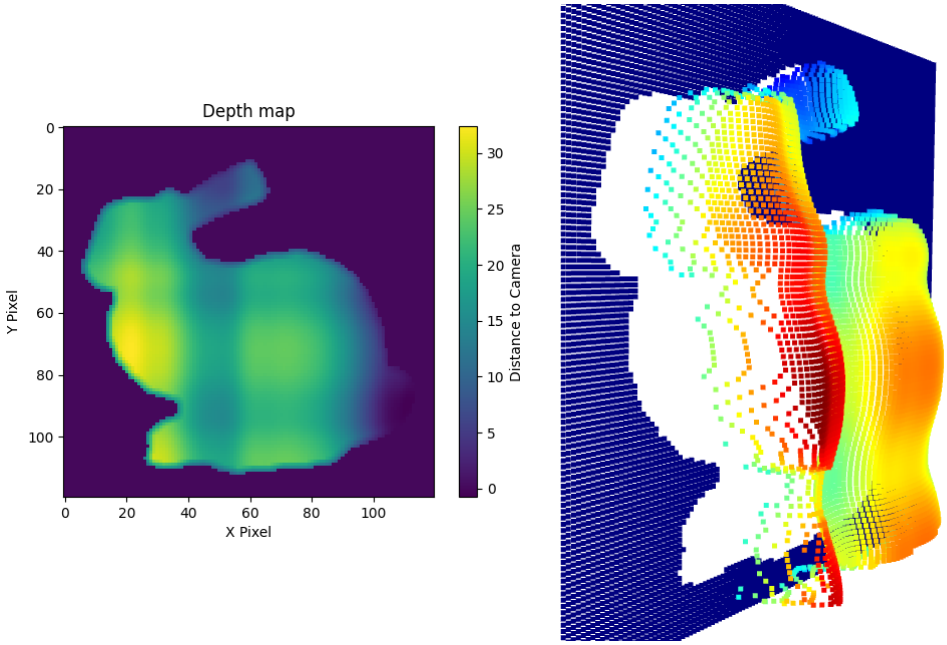
I find that the edge of the 3d model with a depth map causes an extrema, so I apply a Gaussian Filter to smooth the whole depth map.

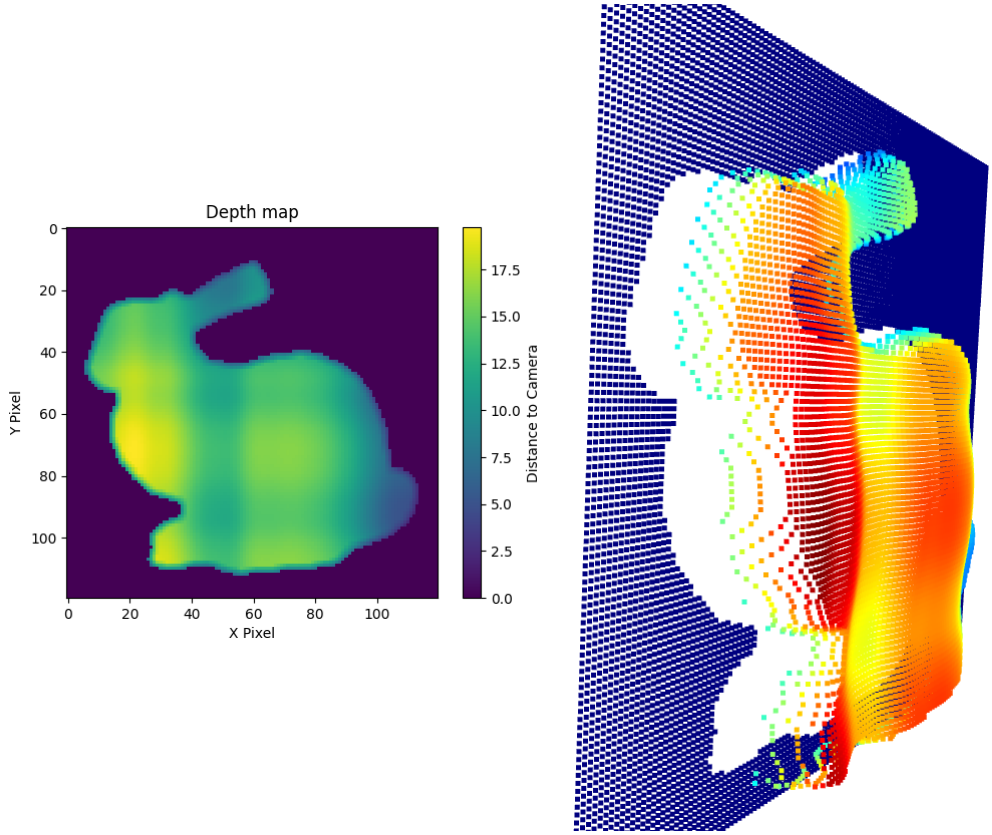


Standardize and Normalize

The result of the above three methods is that the difference between the maximum and minimum is huge; therefore, I apply standardization and normalization to the depth map.

- Comparison





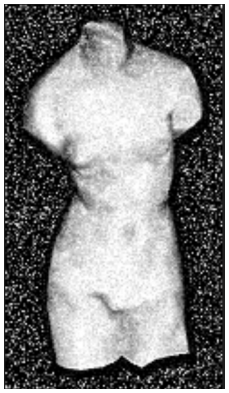
Remove Noise Algorithm

The algorithm is inspired by stack overflow question, I found it efficiently detects the edge of Venus, thus applying a median filter to remove the remaining noise and mask it to get a better image from the source image.

1. Source Image

2. Morphological Transformations

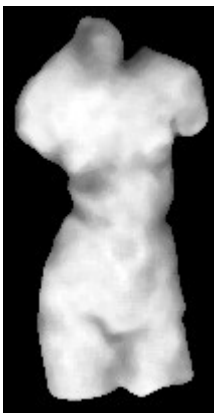
2. Divide the original image by the morphologically transformed image.



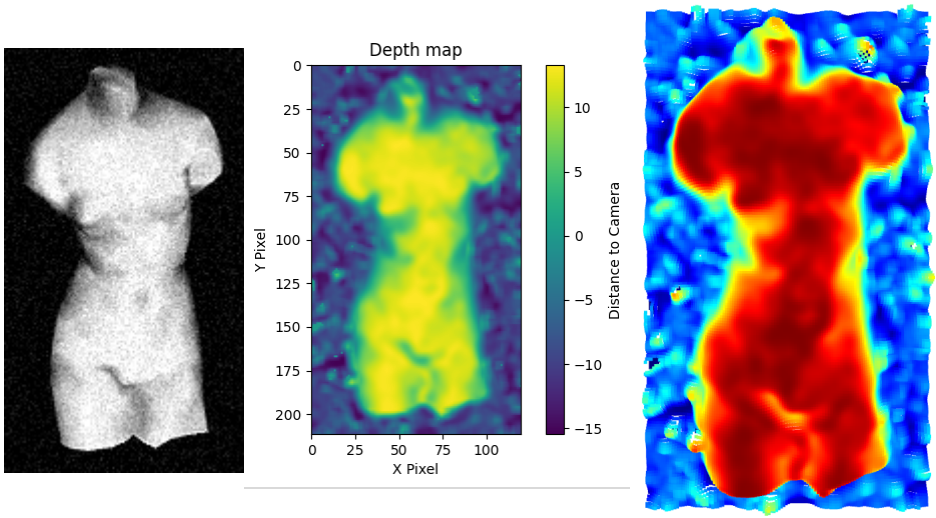
3. Threshold of the divided image.

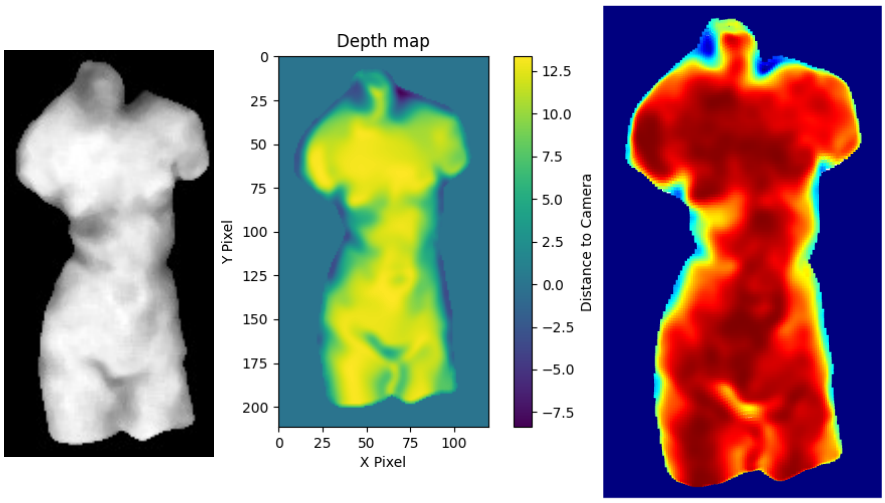
4. Median Blur the threshold image.

5. Masked origin source with threshold image, and do median filter again.



- Comparison


Depth map
Y Pixel
X Pixel
Distance to Camera


Depth map
Y Pixel
X Pixel
Distance to Camera