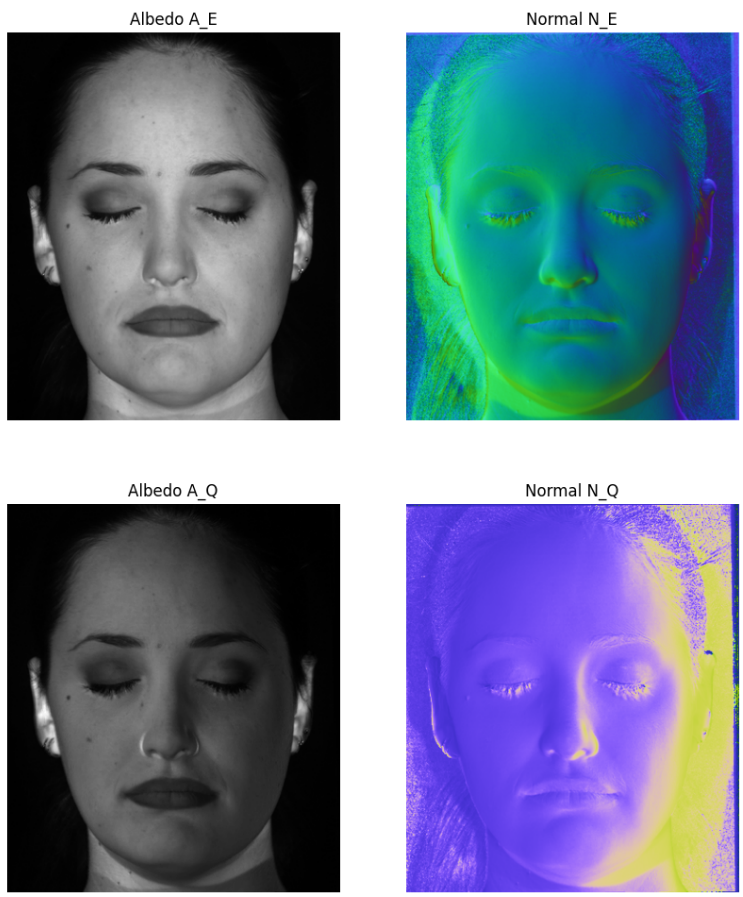
Assignment 5, 15-663

(Prachi Garg)

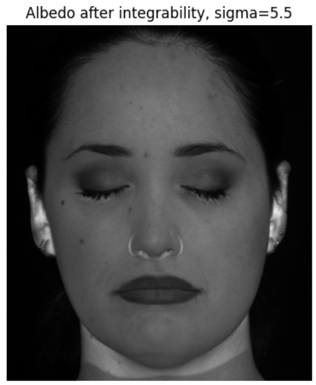
1 Photometric Stereo

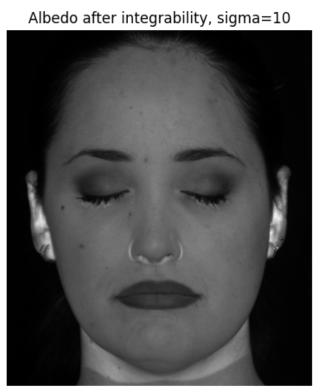
1.1 Uncalibrated photometric stereo

Non-diagonal invertible matrix Q:
Q = [[4, -5, -2], [5, -6, -2], [-8, 9, 3]]

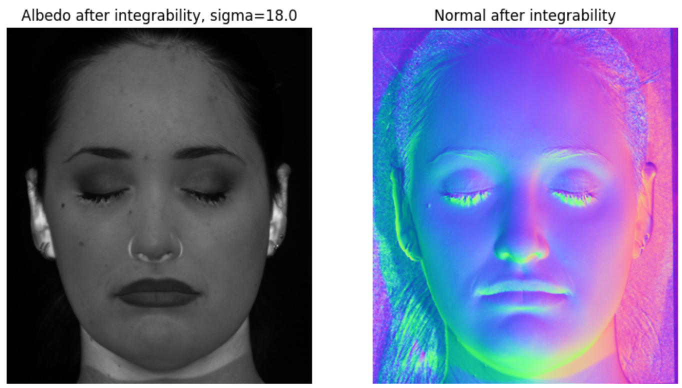


1.2 Enforcing integrability





I notice that the range of values in albedo (hence contrast in normalized albedo) varies by vairation in σ, but normal doesn't change. I end up using a $\sigma = 6.0$ and $\epsilon = 1e - 12$.



1.3 Normal integration

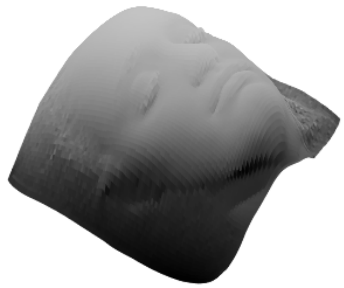
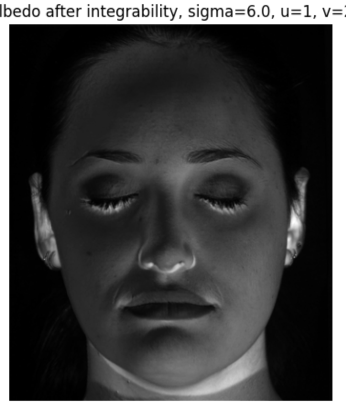


Figure 1: These are uncalibrated case depth and 3D surfaces. GBR for all till now: $\mu = 0, v = 0, \lambda = -1$.

Varying GBR:



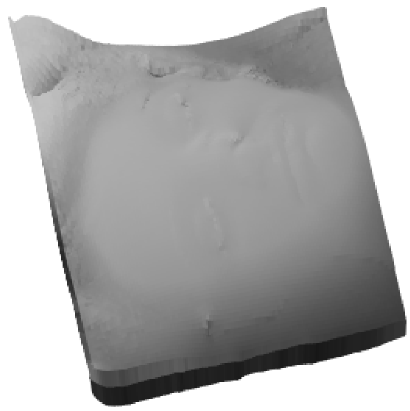
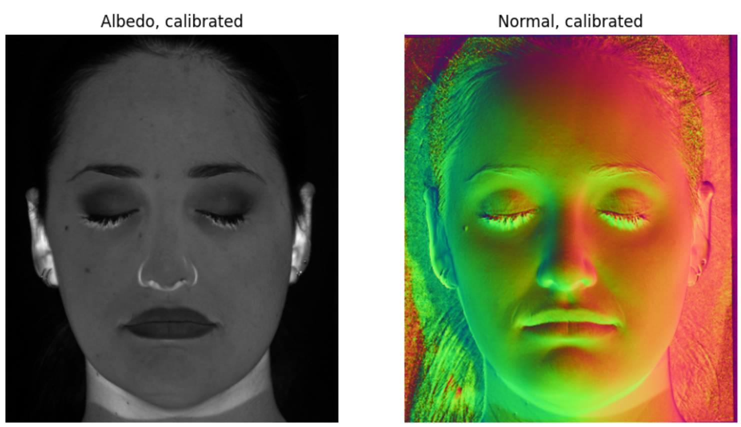


Figure 2: These are uncalibrated case depth and 3D surfaces. GBR for this surface: $\mu = 1, v = 2, \lambda = -1$. I notice that the values $\mu = 0, v = 0, \lambda = -1$ provide the best result.

1.4 Calibrated photometric stereo



Calibrated versus uncalibrated. The face shape in the calibrated case is a lot clearer (notice the face features like eyelashes, nose and lips), even the face boundary is a lot clearer, the uncalibrated case has lower contrast. The uncalibrated process involves taking a blur and computing gradients which becomes noisy for computing normal directions and hence gives less accurate normal, depth and shapes. The albedo however can be matched with appropriate choice of σ.

Figure 3: These are calibrated case depth and 3D surfaces. GBR for all till now: $\mu = 0, v = 0, \lambda = -1$.

Issues faced - even though I could perfectly produce the normal as in Figure 1 and Figure 3, and followed all the steps for getting normalized depth maps from the normal field, the depth map seem to have a black area at the top left corner which I could not resolve.

2 Own shapes

2.1 Object 1

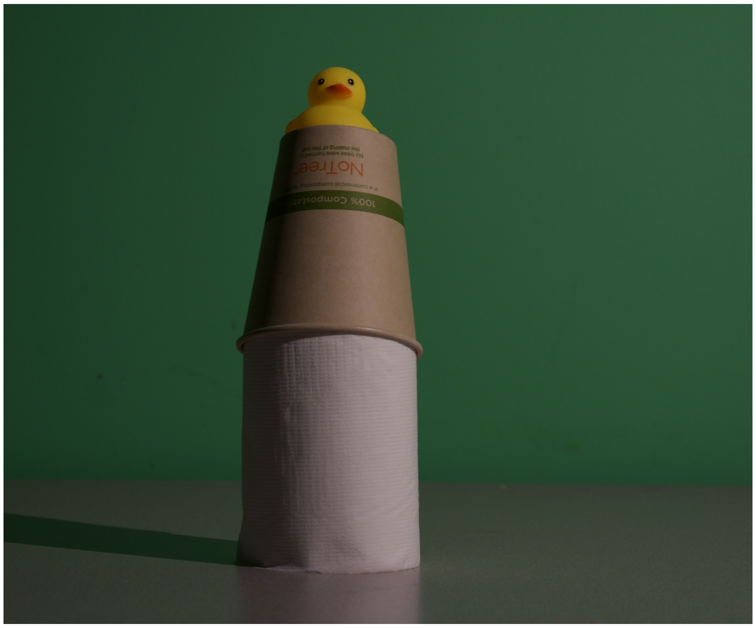


Figure 4: **Object 1.** Captured Image of object without any glossiness.

Figure 5: Taking a crop around the tweety area, avoiding interreflections and occlusions. Got rid of shadow in the background to large extent by center crop.

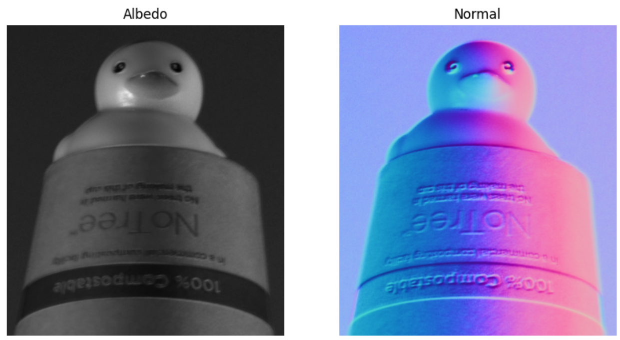


Figure 6: The eyes of the yoda are visible in the Albedo, rest is mostly black due to the glare from the eyes.

Figure 7: Depth with poisson solver, $\mu = 0.0, v = 0.0, \lambda = -1, \sigma = 4, \epsilon = 1e - 5$

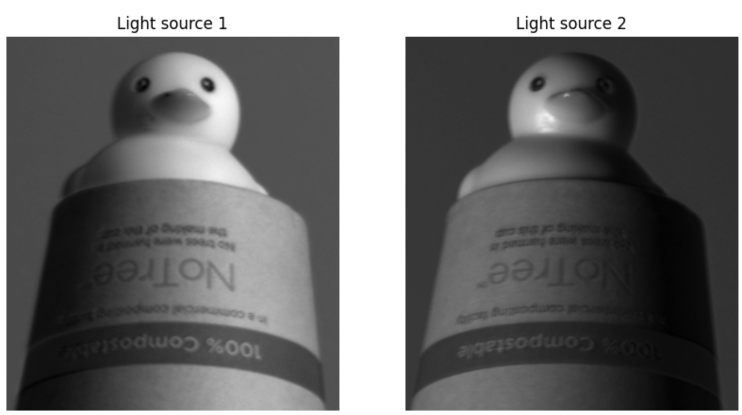


Figure 8: **Rendering Light to the obtained psuedo-normal.** L1 = [-0.99, -0.99, -0.0], L2 = [-0.99, 0.99, 0.48]

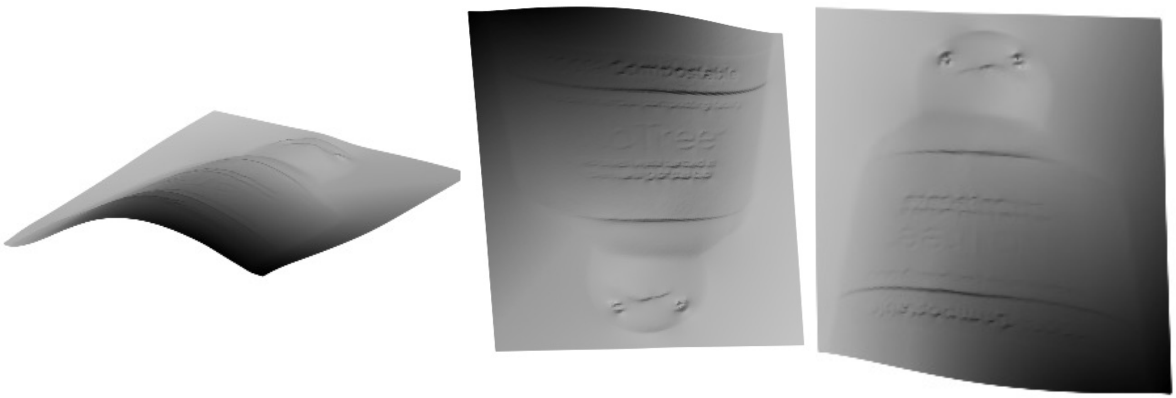


Figure 9: Surface reconstructed. The curved shape of the tweety on top of the cup is visible in view 1, 'Notree' text on the cup can be read in view 2, eyes and nose of the tweety are also well reconstructed in view 3. The eyes have some extra layers as it violates the assumptions of photometric stereo.

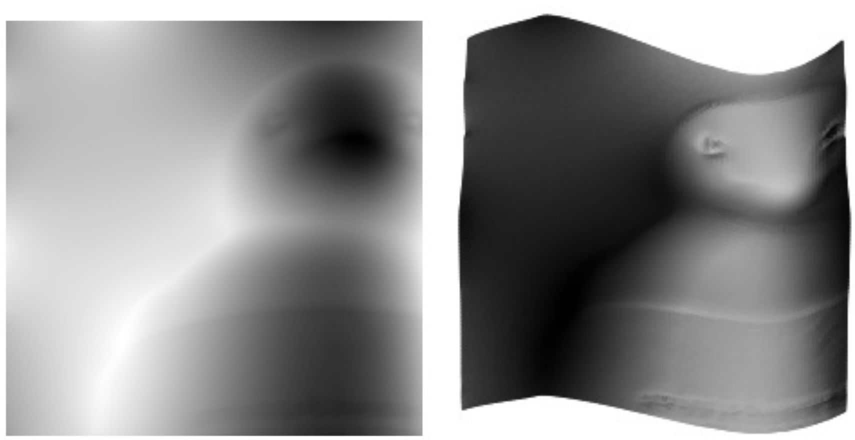


Figure 10: Issues faced: This is using the frankot integrator, the tweety seemed to be translated in the depth map for the same normal and albedo as the final result.

2.2 Object 2

Figure 11: **Object 2.** Captured Image, notice the sharp glare in the eyes of the Yoda.

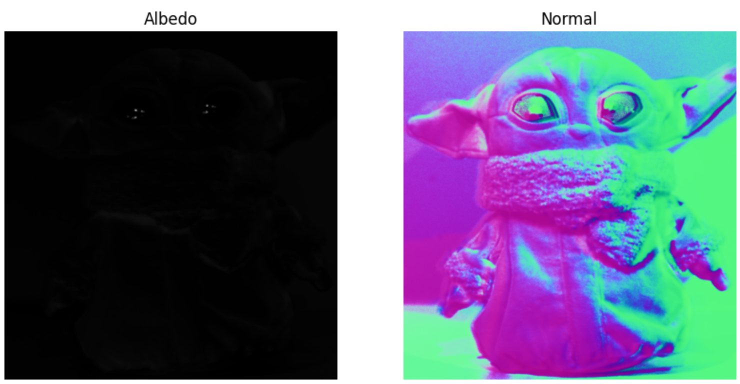


Figure 12: Depth with poisson solver, $\mu = 1.1, v = 1.3, \lambda = -1, \sigma = 4, \epsilon = 1e - 5$. Notice the eyes and ears of Yoda are visible in the depth map if you look closely.

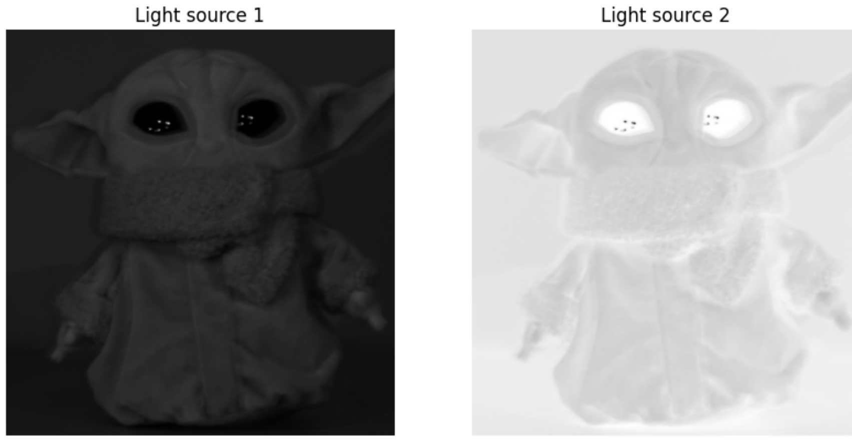


Figure 13: **Rendering Light to the obtained psuedo-normal.** L1 = [-0.95, 0.0, 0.0], L2 = [0.1, 0.0, 0.0]

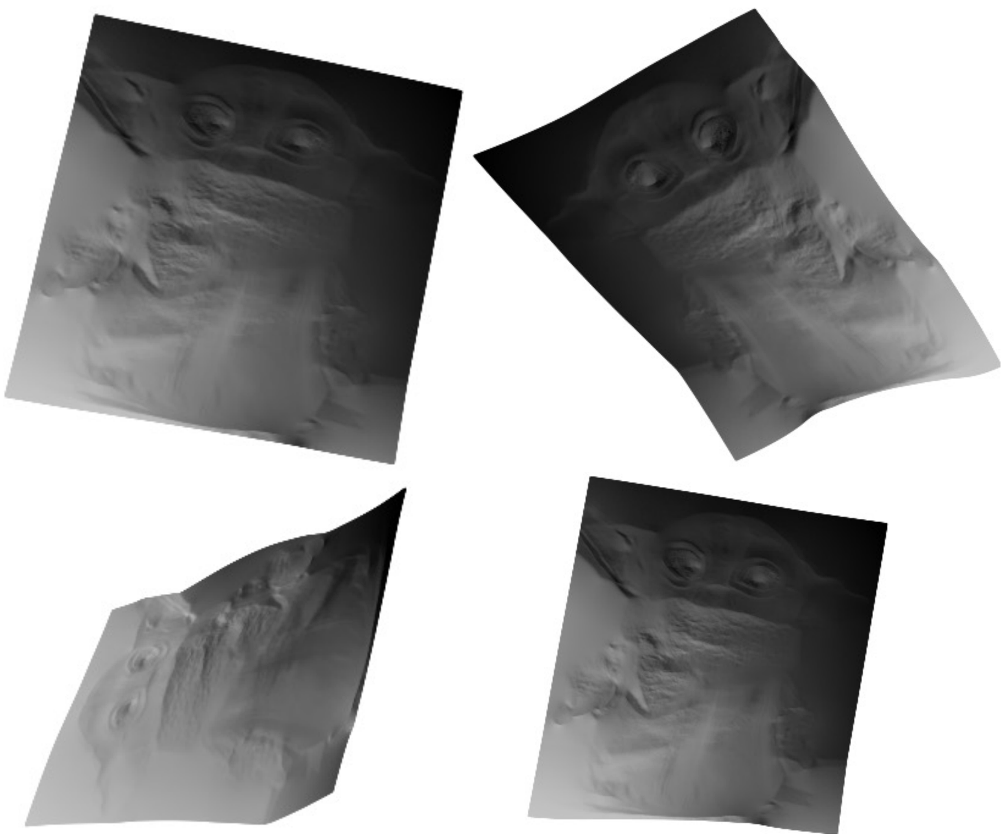


Figure 14: Surface reconstructed. Notice the eyes, ears and muffler parts have been reconstructed quite well. Even the hands are clearly visible.

3 Bonus: Entropy minimization

- I started

$$0 \leq \lambda \leq 5$$

$$-5 \leq \mu \leq 5$$

$$-5 \leq \upsilon \leq 5$$

as in the paper and used number of bins $m = 256$. I check for the set of GBR parameters corresponding to pseudo normals giving albedo with the minimum entropy from these set of parameters.

- Then I search over the range

$$step1value - 1.0 \leq step1value \leq step1value + 1.0$$

in 8 bins to get final set of values with least entropy.

- finally recompute the Albedo, Normals, depth, surface for the final minimum entropy GBR values as reported along with my images below.

- Issue faced - np.log was giving entropy as 'nan', I added a small ϵ for rectification.

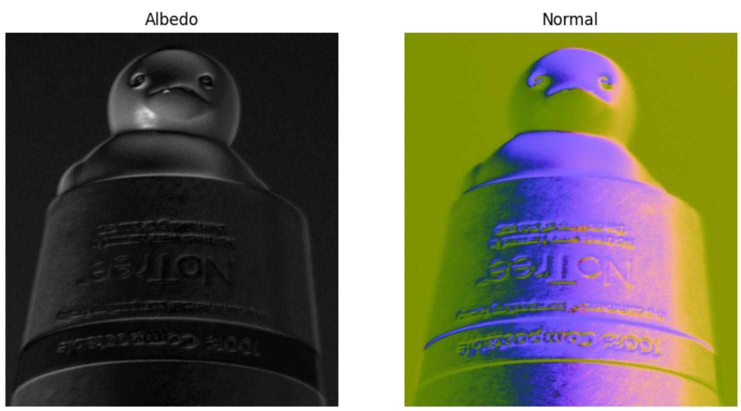


Figure 15: **Entropy minimization.** Minimum entropy $= 3.91$ at $\lambda = 1.143, \mu = -3.143, \upsilon = 5.0. \sigma = 4.0, \epsilon = 1e-2$

Discussion and debugging credits - Aman Mehra, Sriram Narayanan, Hanyu (thanks for help debugging light rendering in Q2!)

Figure 16: Depth with poisson solver, the overall outer shape is visible.

Figure 17: Surface reconstructed. Notice the text on the cup is better reconstructed, and additional details around the tweety's mouth are better. In addition, the surface has sharper edges overall.

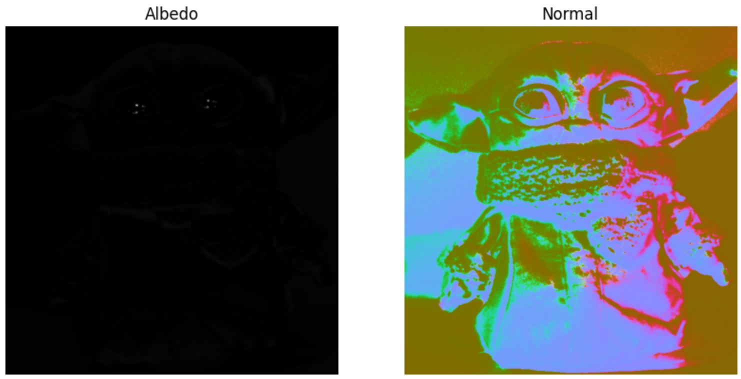


Figure 18: **Entropy minimization.** Minimum entropy $= 1.5603$ at $\lambda = 0.8571, \mu = -4.0, v = -6.0.\sigma = 4.0, \epsilon = 1.5e-2$.

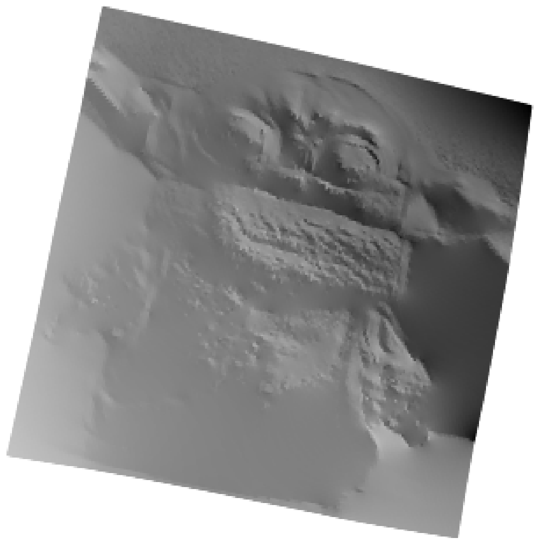


Figure 19: Surface reconstructed. Notice the eyes, ears and muffler parts have been reconstructed quite well. Even the hands are clearly visible.

Figure 20: **Entropy minimization.** Minimum entropy = 3.94 at $\lambda = 2, \mu = 0.0, v = 0.0. \sigma = 4.0, \epsilon = 1.0$. **Observation:** As compared to before, after entropy minimization, the depth maps and surface reconstruction becomes highly sensitive to the ϵ value chosen, otherwise I got spikey surface reconstruction with lower ϵ.

Figure 21: Surface reconstructed has some artefacts.