15-463 Computational Photography (Fall 2023)

Assignment 5

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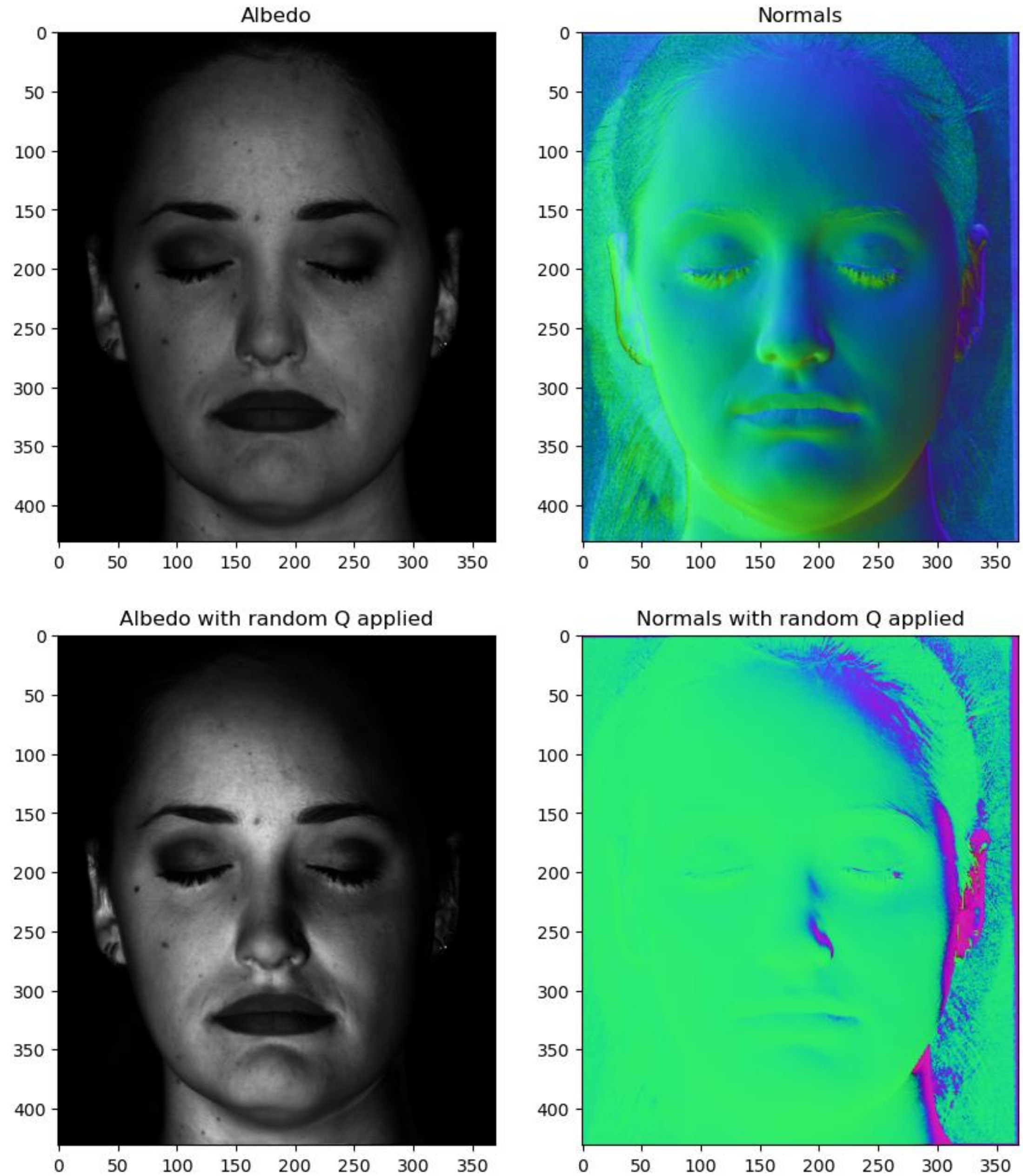
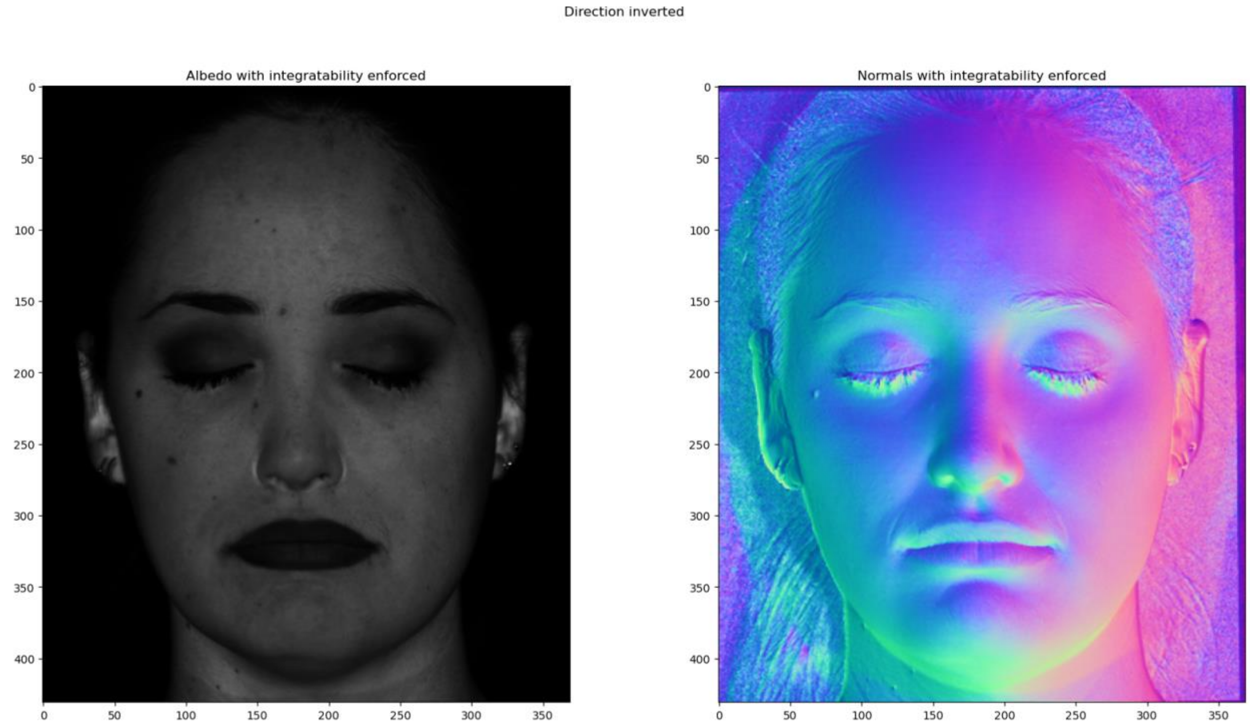
1. Photometric stereo

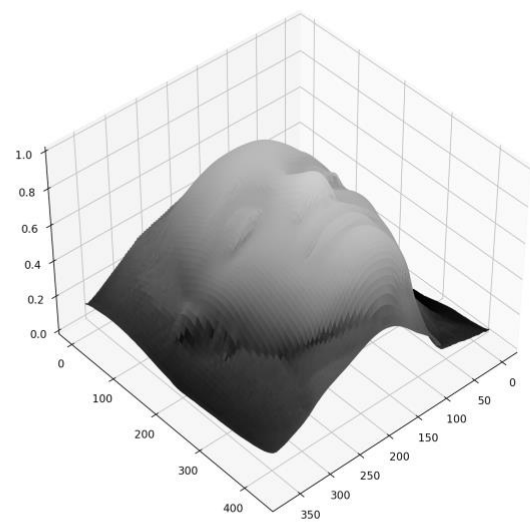
[Uncalibrated photometric stereo]

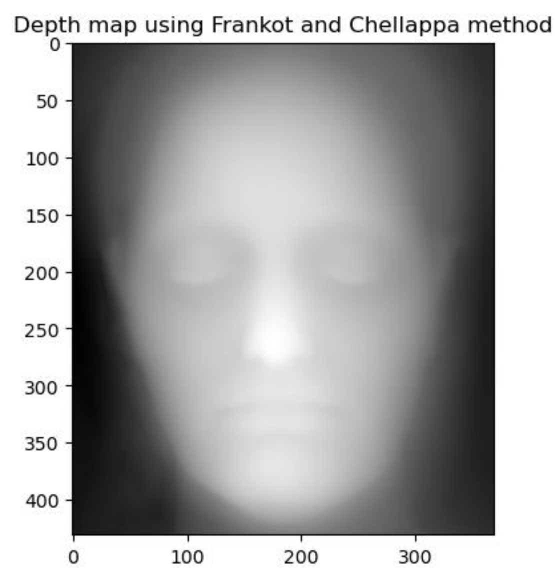


[Enforcing integrability]

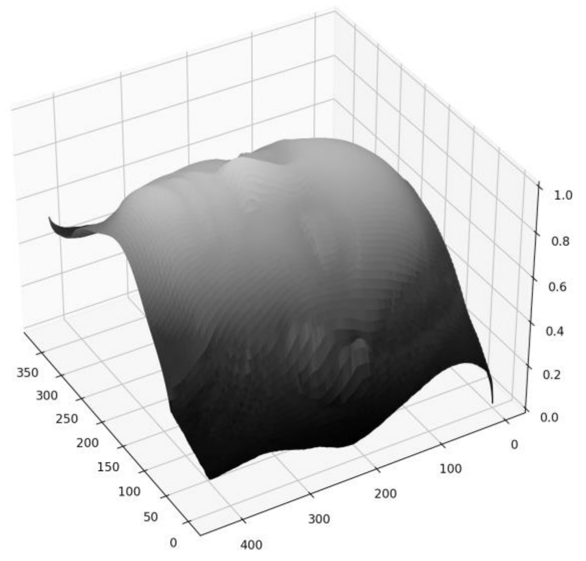


[Normal integration]

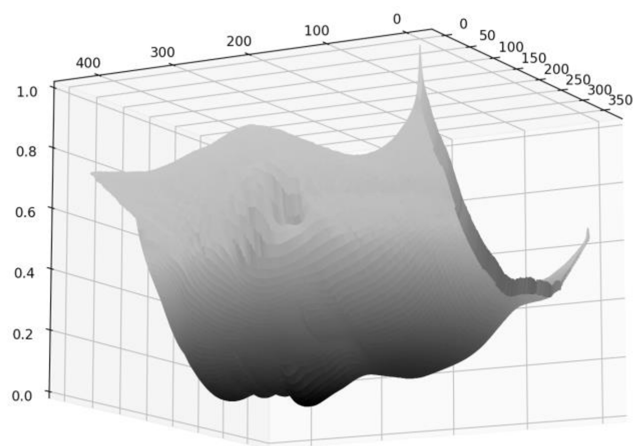




Decided to use Frankot and Chellappa method because it produced more uniformly plain background indicating more accurate depth estimation. It was produced with the best G matrix u=v=0, l=3



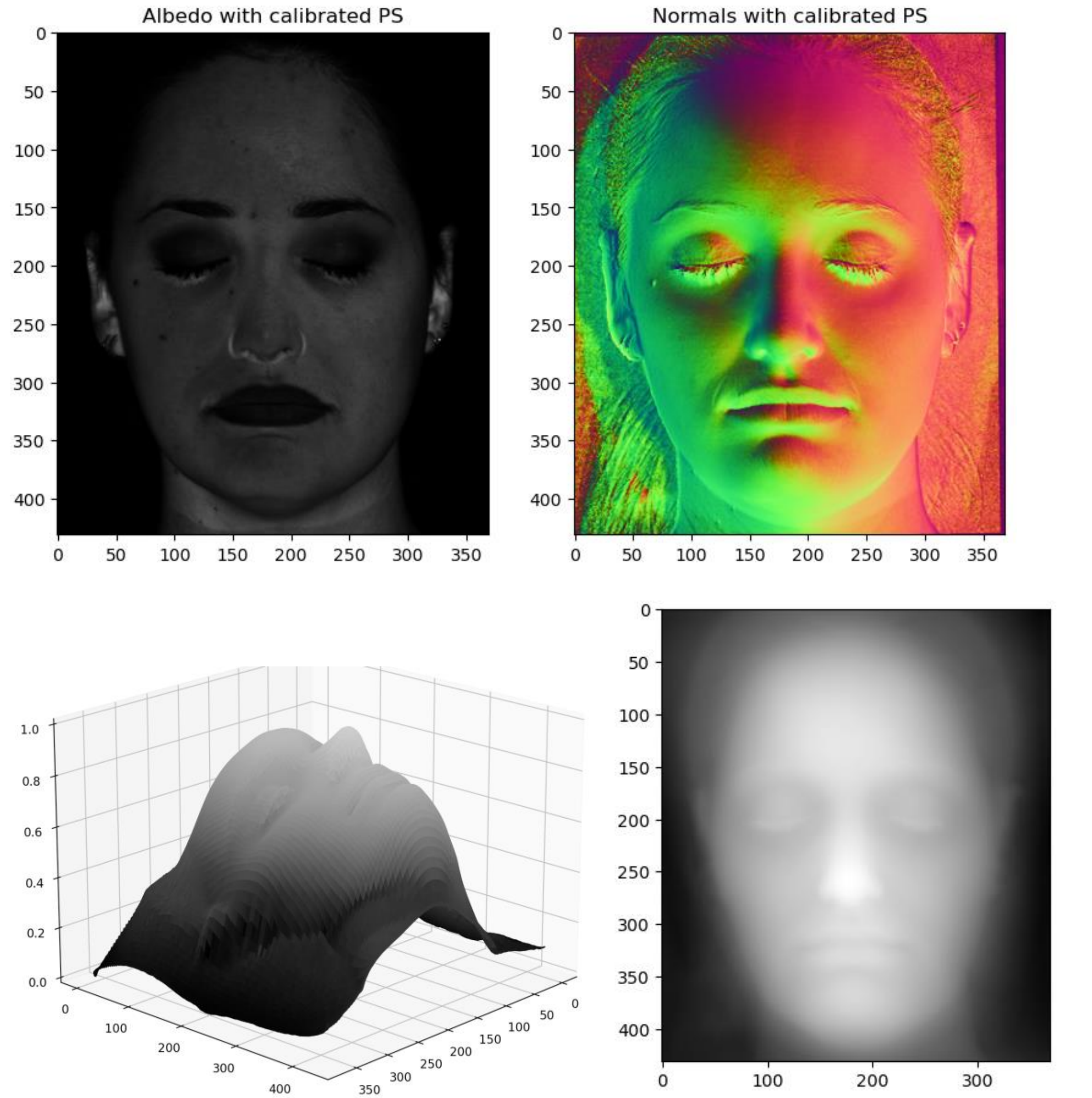
u = v = l = 3



u = v = 3, v = 6

When different u, v, and l values were experimented, the diff set of values sometimes produced flatter surfaces or inversed surfaces.

[Calibrated photometric stereo]

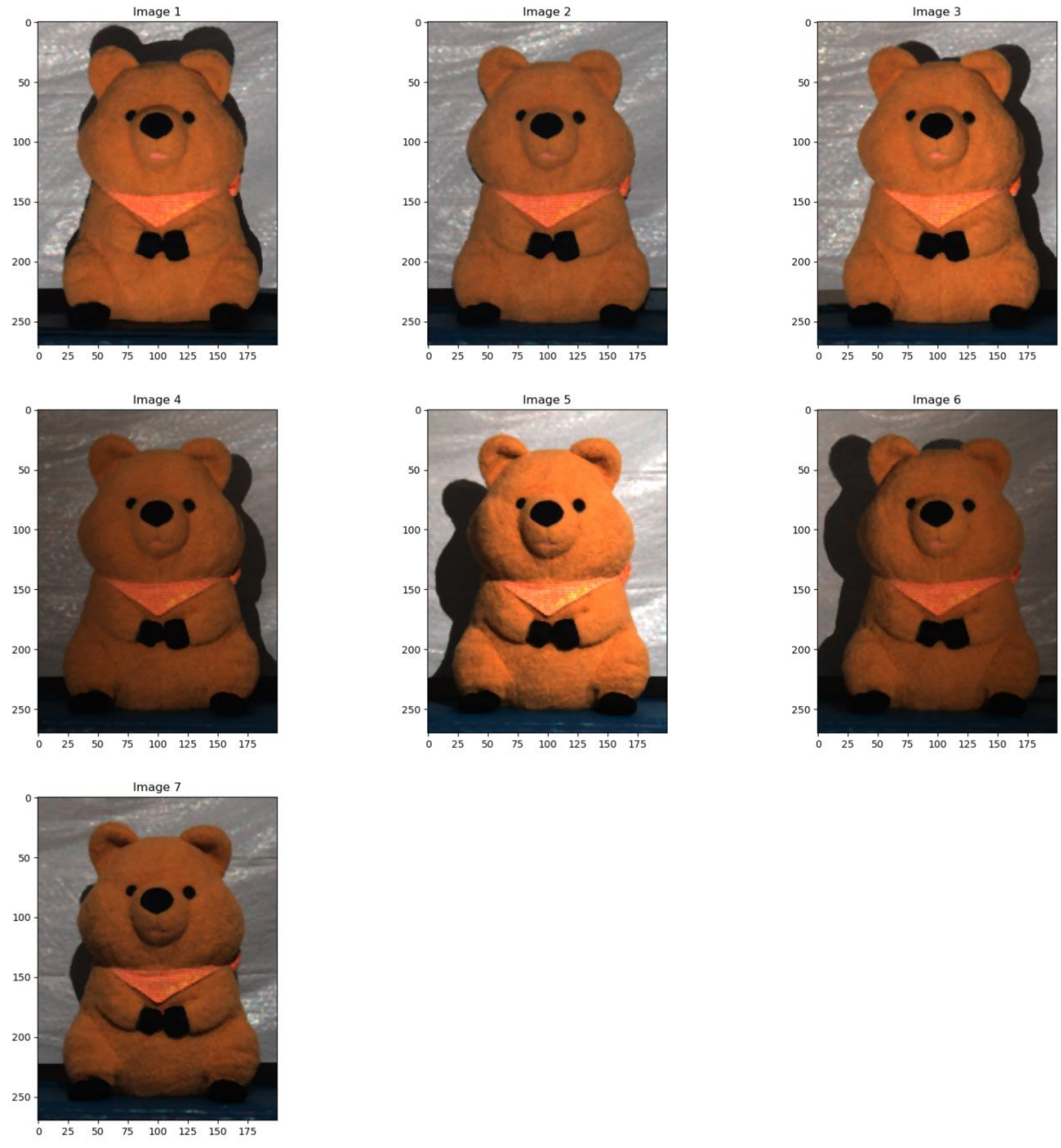


Compared to the uncalibrated method, calibrated photometric studio produced sharper and more accurate estimation result on depth of background. We can also see more clear artifacts from inter reflection on regions such as ears, necks, … etc. in the albedo image.

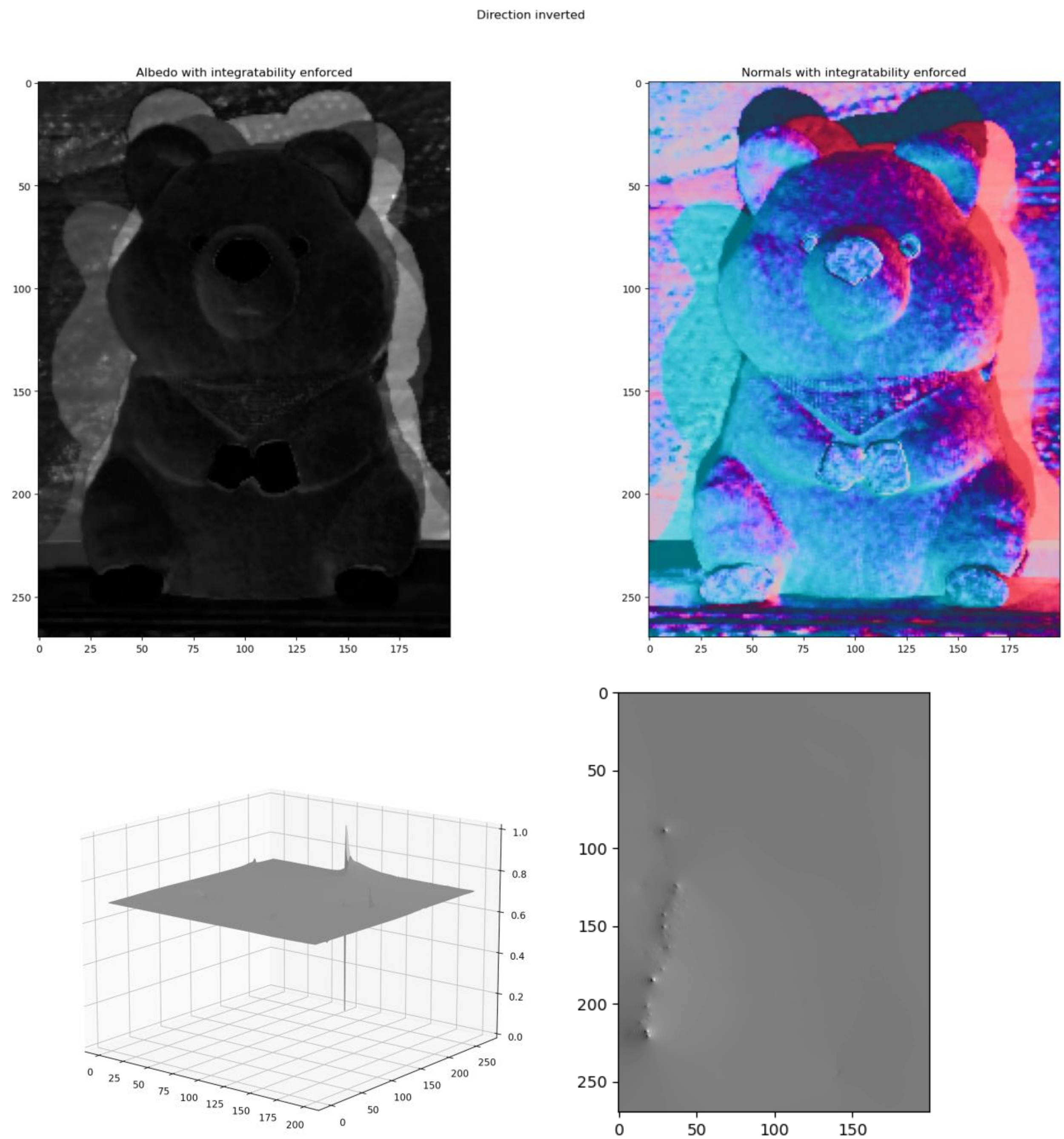
2. Capture and reconstruct your own shapes

TODO: Additionally, show a rendering of both objects under a new lighting direction of your preference. ??

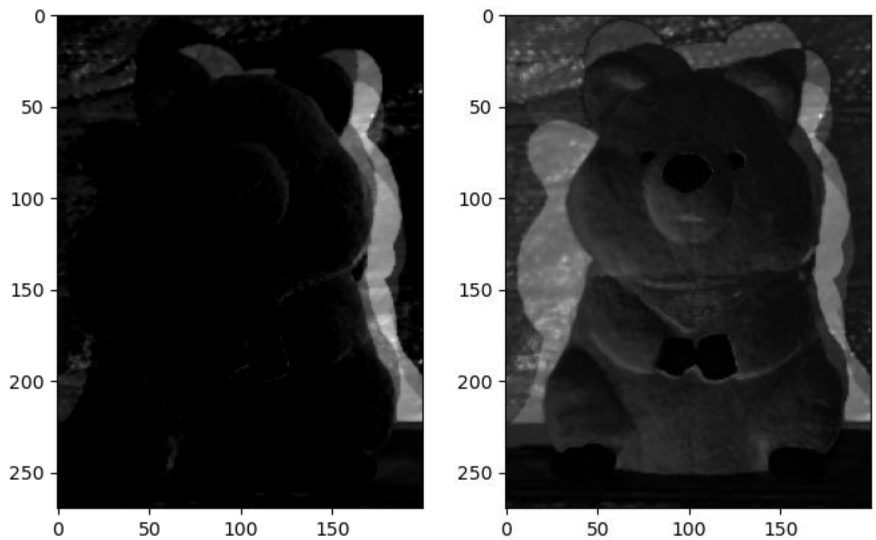
[A case violating the assumptions of photometric stereo]



This scene violates the assumption of photometric stereo because it includes a lot of inter-reflection between the furs, glossy eyes, and glossy white background with shadows from the doll.



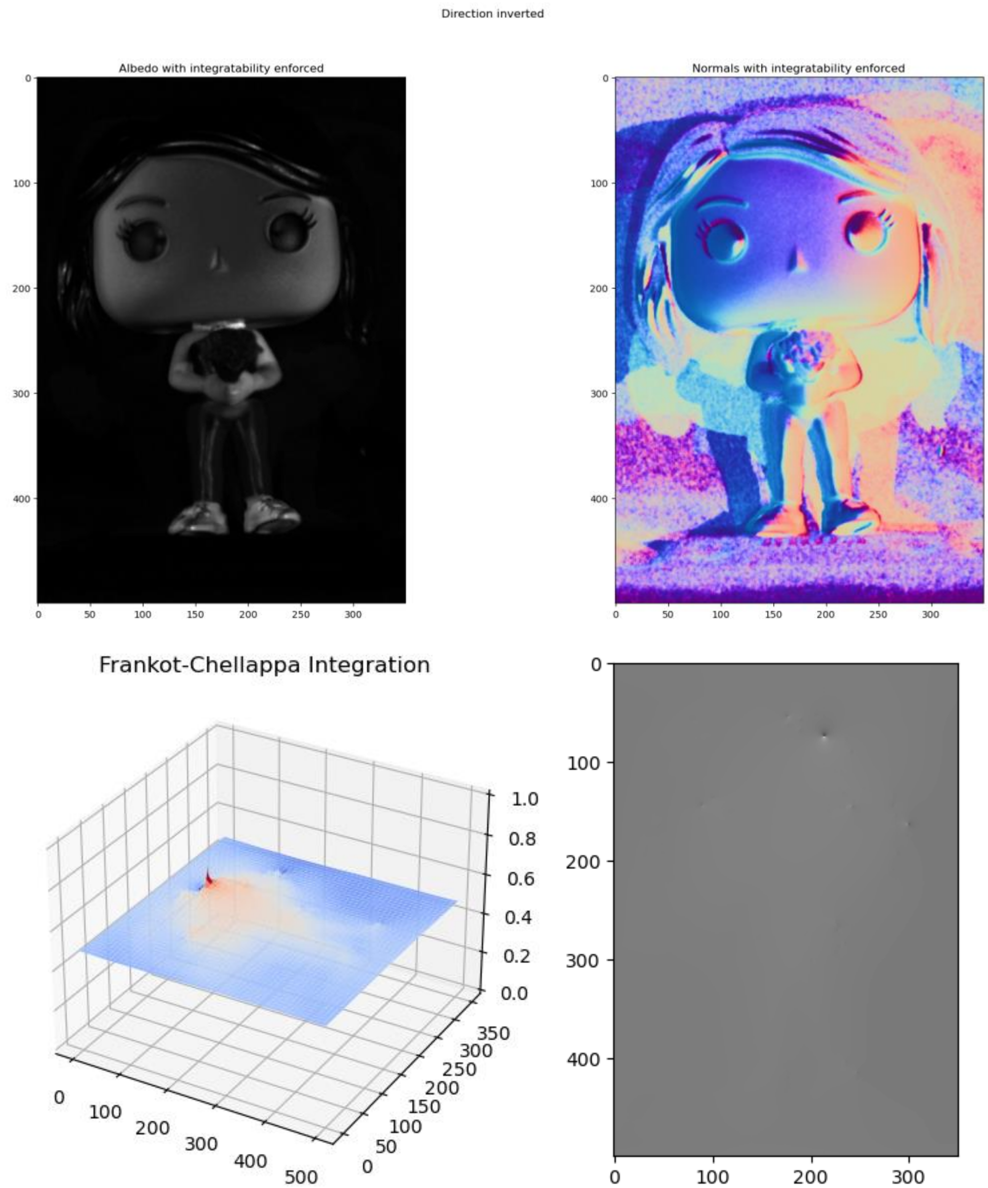
As a result, it produced just a plane depth map with some spikes.



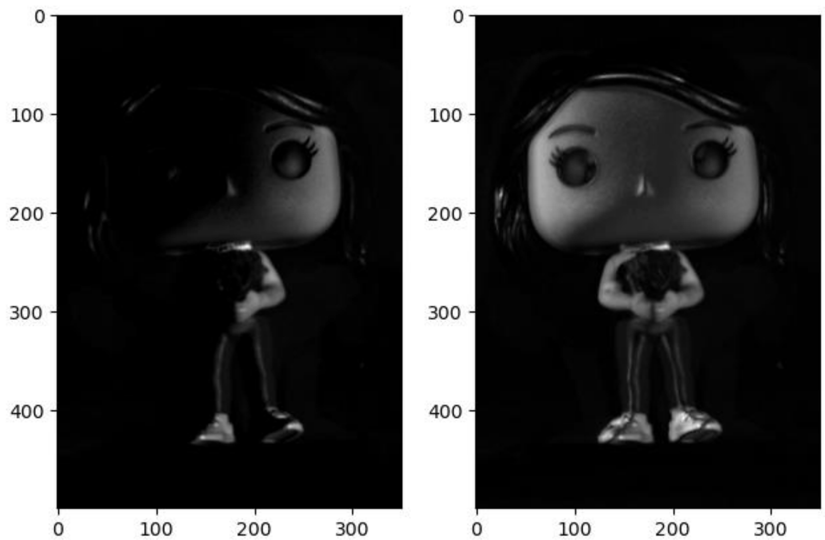
Above images show the rendered images with selected light source. Because of inaccurate estimation, the rendered image showed lots of artifactes (e.g., mutiple shadows).

[A case satisfying the assumptions of photometric stereo]

I picked diffusive doll with less inter-reflection and scanned it with diffusive dark background.



The result was not satisfying. The estimated depth map showed some three-dimensional shape around the doll but very flat and low resolution. In the estimated normal, we can see still the effect of shadow casted on the background. Thus, if we could eliminate the background, I believe it will produce more satisfying result. Also, considering the fact that the scene was very dark and the integration of gradient field is very sensitive to noise, decreasing noise will be key factor for improving the result (here, I tried box filter with kernel size = 3 but couldn’t achieved much improvement).



However, rendering image with diff light source produced satisfying result.

3. Bonus: Resolving the GBR ambiguity

[Entropy minimization]

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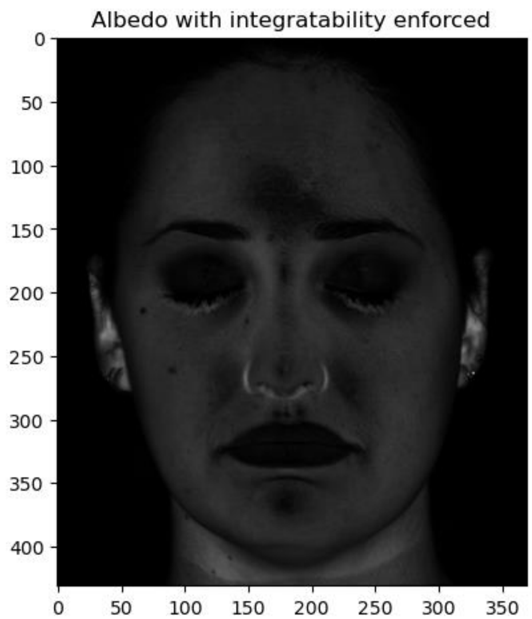
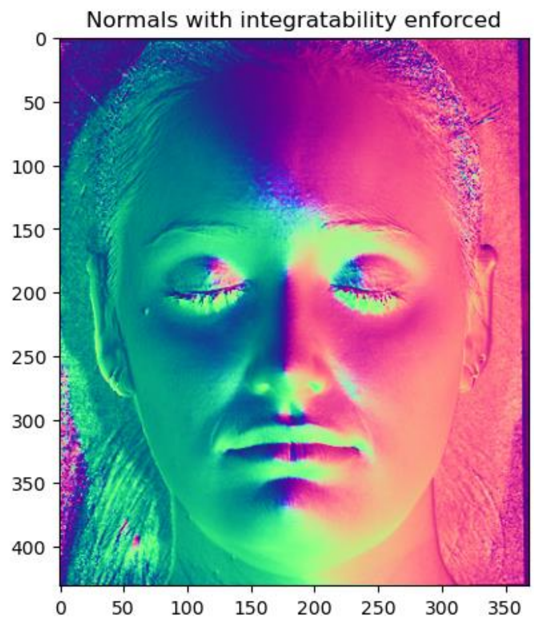
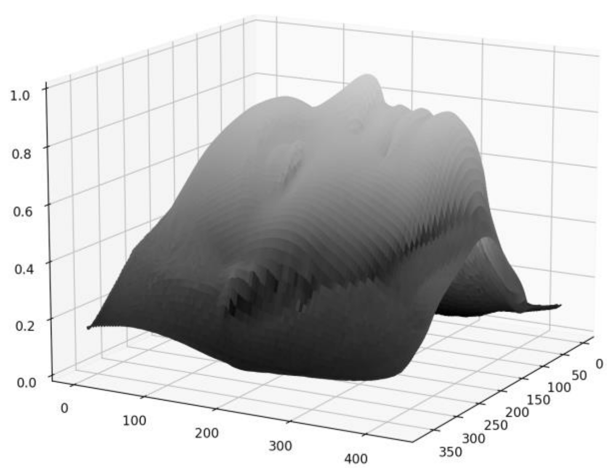
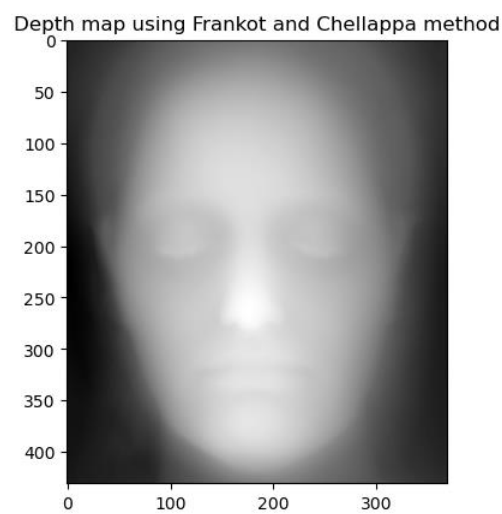
Optimal GBR Transformation:
 [[1.         0.         0.        ]
 [0.         1.         0.        ]
 [0.12507475 0.02050372 9.94146262]]
```



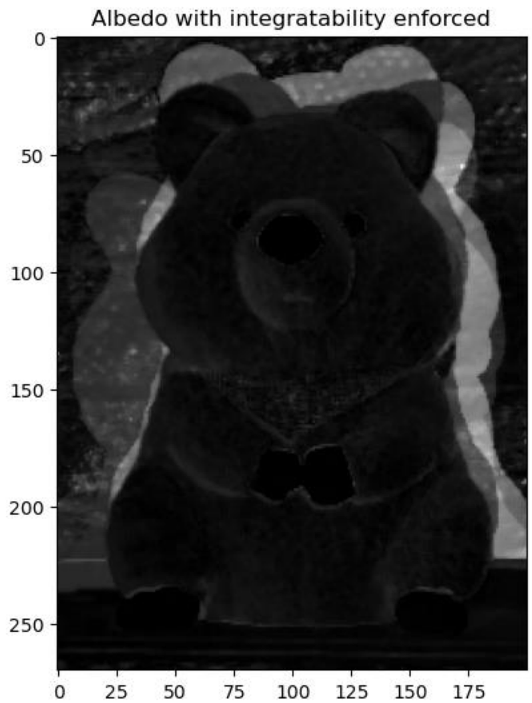


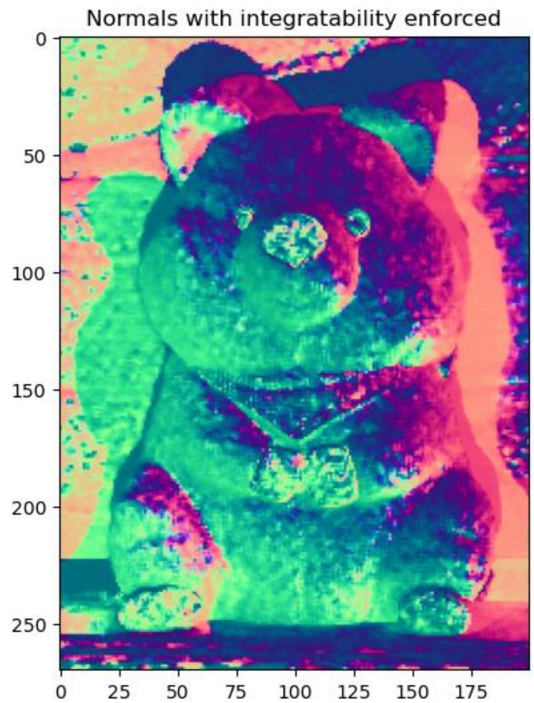


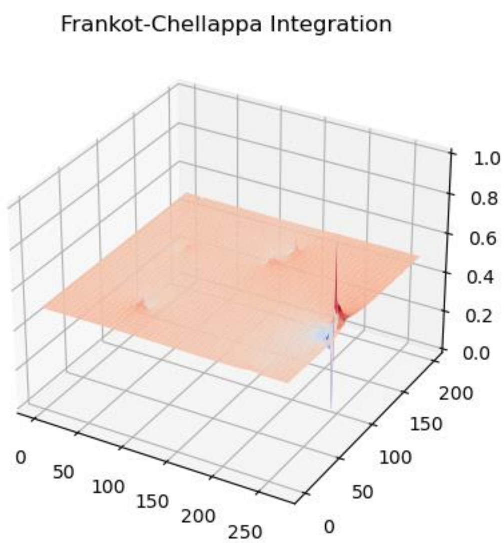


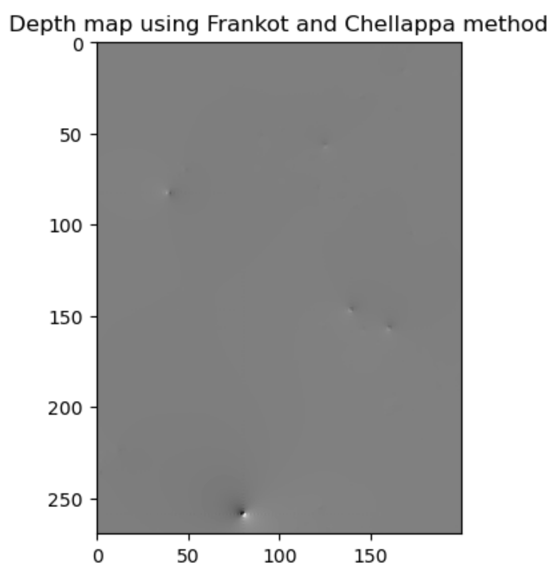
I randomly generated G matrix with confined range of u, v, and l and searched best G matrix minimizing entropy of albedo. With the optimal G matrix minimizing entropy of albedo among 3000 times of trial, it was able to produce sharper depth estimation, which is closer to the result of calibrated photometric studio. However, we can see some error of estimated normal and albedo on the front head.

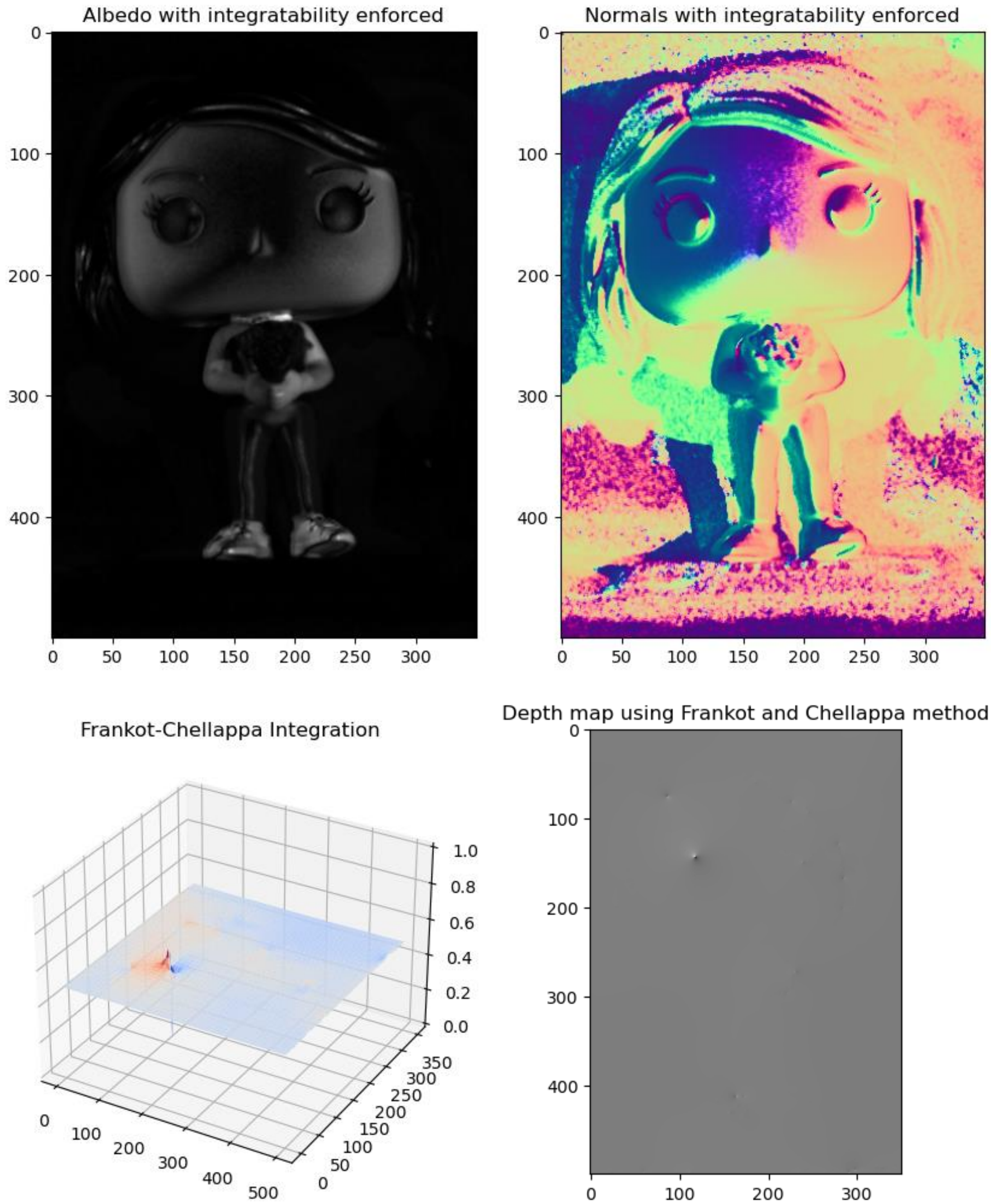
When this method was applied for my objects, it didn’t give satisfying result. Regardless of entropy minimization, the inaccurately computed B_e might resulted the inaccurate estimation.










Albedo with integratability enforced
Normals with integratability enforced
Frankot-Chellappa Integration
Depth map using Frankot and Chellappa method