Introduction to Computer Vision Assignment #1

Due April 2(Tue) PM 3:30

1. **Photometric Stereo**

The object of this assignment is to implement the photometric stereo algorithms both calibrated and uncalibrated to reconstruct the surface of an object. You may assume the surface is Lambertian. The data set for this assignment is from the Yale face image DB (<http://vision.ucsd.edu/~iskwak/ExtYaleDatabase/Yale%20Face%20Database.htm> ).

1. **First part: Calibrated photometric stereo**

Use the given photometric images with known light source directions for this test. You can use MATLAB, C++ or Python for your implementation. Following is the implementation guide:

* Refer the following papers on photometric stereo.

- R. J. Woodham, [Photometric Method for Determining Surface Orientation from Multiple Images](http://www.cs.ubc.ca/~woodham/papers/Woodham80c.pdf). *Optical Engineering* 19(1)139–144 (1980).

- Ying Wu. "Radiometry, [BRDF and Photometric Stereo" (PDF)](http://users.eecs.northwestern.edu/~yingwu/teaching/EECS432/Notes/lighting.pdf). Northwestern University. Retrieved 2015-03-25

* Preprocessing

- Read the images.

MATLAB: [ambimage,imarray,lightdirs]=LoadFaceImages;

[width, height, nImages] = size(imarray);

- Subtract the ambient image from other images.

- Threshold so that no pixel value is smaller than zero (negative)

- Crop the images so that only the face regions remain while the background and hair regions are excluded.

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* Photometric stereo

- Determine the light source direction vector (s) from the azimuth and elevation angles for each image

- Compute the albedo(ρ), surface normal (**n)** using given images (you may try to use any combination of three or more images).

- Show your estimated albedo map and surface normal map using color code (i.e., map *x, y, z* components of the surface normal **n** linearly in the RGB channels, respectively, as did in [1]).

- Evaluate your results by synthesizing the face images in different light source directions while keeping the same albedo and normals you obtained.

- How about to increase the number of images you use?

- Is there any way to improve your reconstruction result?

1. **Second part: Uncalibrated photometric stereo**

For the same data in the first part, assume that you don’t know the light source directions. Apply the uncalibrated photometric stereo method to these data, and reconstruct possible GBRs.

* Read the following paper on Bas-relief ambiguity.

P. N. Belhumeur, et.al., [The Bas-Relief Ambiguity](https://link.springer.com/content/pdf/10.1023%2FA%3A1008154927611.pdf), IJCV 1999

A. L. Yuille and D. Snow. [Shape and Albedo from Multiple Images using Integrability](https://pdfs.semanticscholar.org/f2d4/22a9f16c3359086421653a2b012adb3e7105.pdf). In CVPR, pages 158–164, 1997.

* Use the same pre-processed photometric stereo images in Part 1.
* Estimate possible surface normal, albedo (**B**) and light source directions (**s**) using SVD.
* Display the reconstructed surface normals using color code
* Synthesize images with some light source direction s\* which is different from the light sources in **s**.
* Is there any idea to resolve the Bas-Relief ambiguity?

**Submission instructions: what to hand in**

* Submission instructions:
* Upload the electronic file that includes the report, source code, and data in a single zip format with the name “**ICV\_assignment#1\_yourname.zip**” on the ETL class homepage.
* The report should include the brief description of the problems, results, and discussions

[1] Boxin Shi et. al. [Self-calibrating Photometric Stereo](https://www.microsoft.com/en-us/research/wp-content/uploads/2016/02/yichenw-cvpr10_photometricstereo.pdf), CVPR2010.

* MATLAB Reference
* [Quick tutorial page on how to use Matlab](http://www.math.utah.edu/lab/ms/matlab/matlab.html)
* [Quick tutorial page on how to use Image Processing Toolbox](http://www.eng.auburn.edu/%7Esjreeves/Classes/IP/IP.html)
* [HelpDesk from Mathworks](http://www.mathworks.com/access/helpdesk/help/helpdesk.shtml)

Note: All works should be individual-based. NO copy is allowed.