Computational Photography

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Programming Assignment 2

High Dynamic Range Images

Total of Points of the Assignment: 100

The goal of this assignment is to familiarize the students with high dynamic range (HDR) images. For this, you will be exploring and **creating HDR images from a sequence of low dynamic range (LDR) images captured with multiple exposures**. In order to display them on LDR displays, you will be also implementing some **simple tone mapping operator**. The assignment will also familiarize you with the concept of camera response curves used for mapping exposure values to pixel values.

Prepare an illustrated report (pdf) to be uploaded through Moodle. For each task, indicate if you satisfactorily completed it. In case you could not complete it, explain why. Also, list any difficulties you have faced for completing the work.

For all tasks use the images "office_1.jpg" to "office_6.jpg" provided with this assignment and **also** available in the "…\toolbox\images\imdemos" of MATLAB.

Task 1 (2.5 points): **Build a table containing the exposure times of these six images** (they were all acquired with the same aperture setting). For this, use any image visualization software that allows you to access the image's **EXIF metadata**. For instance, you could use *FastStone Image Viewer* (free for noncommercial use). In this case, used the option "*View -> Image Properties …*". **You will need this table to complete Tasks 2 and 3**.

Do some research about the meaning of "EXIF metadata". What is it and what kinds of data are stored in these fields? Open an image in the RAW format using *FastStone* see the available information.

Task 2 (5 points): Use the images "office_1.jpg" to "office_6.jpg" to **obtain the camera's response curves** using the free version (Version 1.0) of the software HDR Shop (available at http://www.hdrshop.com/) . For this, use the option "Create -> Calibrate Camera Curve …". Save the obtained curve to be used in other tasks.

Task 3 (2.5 points): **Create an HDR image from the image sequence "office_1.jpg" to "office_6.jpg" using HDR Shop**. For this, use the option "*Create -> Assemble HDR from image sequence…*". Using the resulting image, explore all options of the menu "View -> Exposure …".

__**Important**__: When computing a camera calibration curve or creating an HDR image using HDR Shop, **you should provide the exposure times (in seconds) associated with each LDR image** in the column "Abs. Scale" (absolute scale) of the window that will show up asking for the image sequence to be used as input. Thus, for instance, if the exposure time for a given image is 1/3 seconds, you should type 0.3333 in the corresponding entry in the "Abs. Scale" column.

Task 4 (65 points): Write a MATLAB script (or a program in your preferred programming language) to **create an HDR image from the provided six LDR images**. For this, you will need the exposure times from Task 1, as well as the camera's response curve from Task 2. Remember that since the input images are not in RAW format, you need to perform gamma expansion before starting the computation (see slides and suggested readings about Gamma Correction in the course page). With gamma expanded values, let $I_k(i,j)$ be the value of the pixel with coordinates (i,j) associated with image k. Remember that $I_k(i,j)$ is the exposure value modified by the camera's response curve. Thus, use $I_k(i,j)$ to index the camera's response curve table to obtain the actual exposure value (X): $X_k(i,j) = E(i,j) * T_k$, where E(i,j) is the pixel's irradiance and T_k is the exposure time of image k. Using T_k (from task 1), compute E(i,j). Note that camera's response curves (separate curves for R, G and B) computed by HDR Shop store the log of the exposures. Thus, for a given color channel, $X_k(i,j) = \exp(C(I_k(i,j)))$, where C is a 1-D array representing the camera's response curve. Also note that corresponding pixels in the multiple images (*i.e.*, pixels with the same coordinates (i,j)) can produce different E(i,j) values. Discard saturated and under-exposed values, and compute the average of the remaining values as the final irradiance value E(i,j) for pixel with coordinates (i,j). After this, you have an HDR image with values E(i,j) for all pixels! You can now simulate multiple exposures for this image by multiplying it by the desired exposure time. Use MATLAB's *tonemap* command to create an LDR version of your HDR image and display it.

Task 5 (5 points): Use MATLAB's command ***makehdr*** to create an HDR image from the six images you used as input for your script (without gamma expansion). Is the resulting HDR image exactly the same as the one you computed in Task 4? If not, how big are the differences and what could explain such differences? Use MATLAB's *tonemap* command to obtain an LDR version of the HDR image computed in Task 5, and compare it to the LDR version of your own image computed in Task 4. Are they exactly the same? If not, how big are the differences and what could explain such differences?

Take this opportunity to also try the functions *hdrread,* and *hdrwrite* available in MATLAB's Image processing toolbox.

Task 6 (20 points): **Implement the global version of Reinhard's photographic tone mapping operator** (see slides and suggested readings) and apply it to your HDR image from Task 4. Display the result and compare it with the one obtained with the use of MATLAB's *tonemap* command.