High Dinamic Range : Lab 4

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1 Introduction

This assignment is made out of three sections. Each section corresponds with each of the three papers provided.

The laboratory encourage to implement the transformation of a given stack of different exposure images into a single HDR image. After that, Global and local tone mapping are implemented in order to obtain an image, where the difference of both methods facing the contrast reduction is noticed.

2 HDR Imaging

HDR Imaging consist on transforming the different exposure images into a single HDR image. This approach is faced in Debevek and Malik [**debevec1997**]. Which can be implemented in three steps:

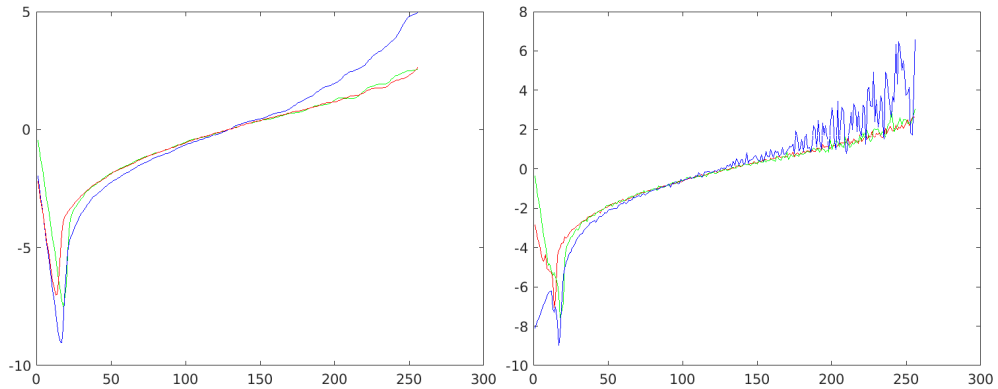
2.1 Image Linearization

The method that we employ has to solve a system of equations, where the number of equations depends on the number of pixels that are being used. This imposes the requirement of downsampling the image, so that the computer is able to solve it. This downsampling has been performed with the imresize function in MATLAB. The scale factor used for this downsampling is 1/20 for both, the height and the width.

The downsampled images are the input for the "gSolve" function, already implemented at [**debevec1997**], to obtain the camera response function.

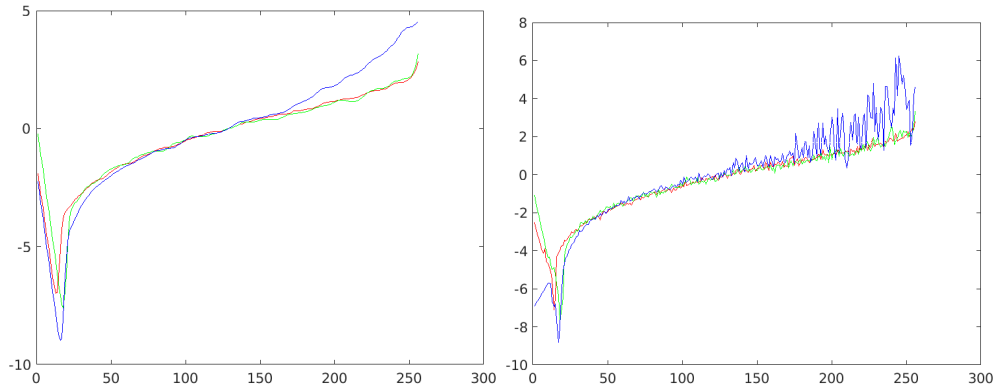
In fig.1a and fig.2 the response curves using different parameters are shown. The effect of using the smoothness term are very noticeable, mainly in the blue channel. The effect of the weighting schema is not so noticeable, but in fig.1a and fig.2a, it can be seen at the end of the function, how the weighting scheme avoids a quick "escalation".

Figure 1: Log exposure with weight schema



(a) Response curve with lambda 20 (b) Response curve with lambda 0.001

Figure 2: Log exposure without weight schema



(a) Response curve with lambda 20 (b) Response curve with lambda 0.001

2.2 Radiance map

Once we get the camera response function for each of the channels, the HDR radiance map E is obtained. To do so, the following equation is used:

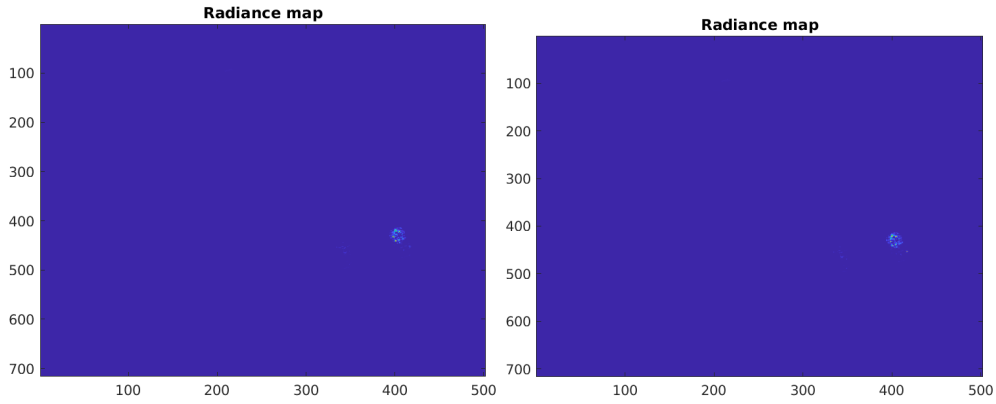
$$lnE_i = \frac{\sum_{j=1}^{P} w(Z_{ij})(g(Z_{ij}) - ln(\Delta t_j))}{\sum_{j=1}^{P} w(Z_{ij})} \tag{1}$$

Where E_i is the radiance field value for pixel i, Z_{ij} is the value of pixel i in image j, $g()$ is the response function obtained previously and Δt_j is the exposure time of the image j.

In fig.3 and fig.4, the different radiance maps obtained using different response functions are shown. It is very interesting how, in this case, the different values of lambda are barely noticeable, while the different weights used are much more evident (contrary to what the look of the functions would lead to believe). Weighting each pixel by how close it is to the center of the intensity range results in a much more smooth radiance field, where only the most bright part is actually noticeable.

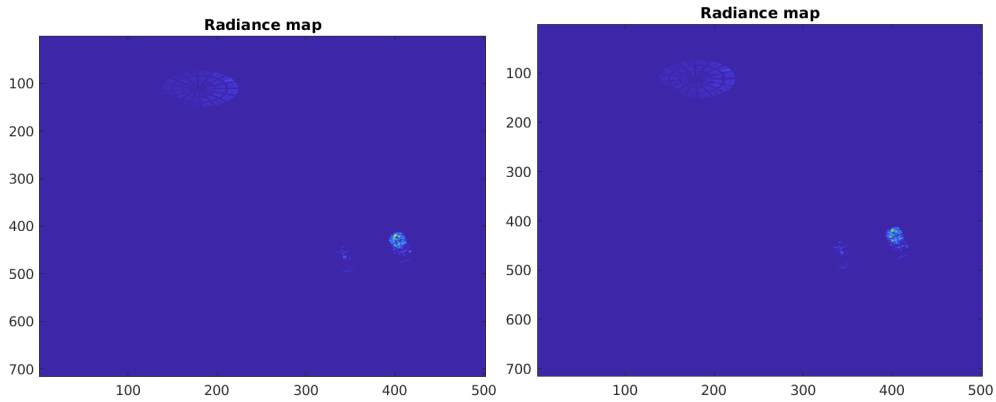
For the rest of this work, the radiance map that has been used is the one in fig.3a

Figure 3: Radiance map with weight schema.



(a) Radiance map with lambda 20. (b) Radiance map with lambda 0.001.

Figure 4: Radiance map without weight schema.



(a) Radiance map with lambda 20. (b) Radiance map with lambda 0.001.

3 Global Tone Mapping

The purpose of the tone mapping step, is to reduce the contrast of the luminance layer of the image, so that all the details, both the most bright and most dark, can be represented in a normal display.

To apply the method described in [**reinhard**], it is necessary to obtain the luminance of the image. There are different approaches to doing this, the ones that we tried are:

- Take each color channel as it's own luminance.
- Use the average of the three channels as the intensity.
- Use the following weighted average: $0.32R + 0.65G + 0.01B$.
- Use the third channel of the hsv color space.
- Use the second channel of the xyz color space.

After some trials we decided to go with the third option, as we believed the end result looked nicer.

Once the intensity is obtained, a contrast reduction operation is performed on it as described on [**reinhard**]. This contrast reduction step takes in three parameters:

- δ: Small amount added to the radiance map to avoid problems with the logarithm if a pixel value is 0.
- a: Relates with the value of the scaled luminance used in the contrast reduction operation.
- L_{white}: Determines what is the minimum value of luminance that will be mapped to a saturated pixel.

In fig.5, fig.6 and fig.7 the effect of varying the parameters is shown. The increase of the δ parameter leads to higher "global luminance" supposition, that in return, leads to a darker image. The increase of a however, leads to a brighter image. Finally, the increase of L_{White}, makes the brighter parts of the image saturate, while leaving the darker parts mostly unaffected, and the lower the value, the more areas are affected by this saturation.

Figure 5: Variation of δ. $a = 0.18$ $L_{white} = \text{inf}$

(a) $\delta = 0.002$ (b) $\delta = 0.2$ (c) $\delta = 1$

Figure 6: Variation of a. $\delta = 0.002$ $L_{white} = \text{inf}$

(a) $a = 0.18$ (b) $a = 0.25$ (c) $a = 0.36$

Figure 7: Variation of L_{White}. $a = 0.18$ $L_{white} = \text{inf}$

(a) $L_{White} = \text{inf}$ (b) $L_{White} = 3$ (c) $L_{White} = 1$

4 Local Tone Mapping

This method is based on separating the luminance in two layers, the base and the detail layer. The base layer is obtained with a bilateral filtering of the log of the luminance, and the detail layer is obtained by subtracting the base layer from the log of the luminance. Then, a contrast reduction operation is performed on the base layer, and the details are added without modifying them, so as to preserve them. This process is illustrated in fig.8. As a contrast, fig.8f, shows the luminance after applying contrast reduction without separating the base and detail layers.

Finally, the result of this tone mapping process after applying the new intensity to the color, can be seen on fig.9b. On fig.9a there is the comparison image where the contrast reduction has been applied to the complete intensity, where it is clear that the fine detail is lost.

Figure 8: Bilateral filtering for local tone mapping. Parameters: $\sigma_s = 20$, $\sigma_r = 0.4$ and $dR = 3$.

(a) Original luminance. (b) Base Layer. (c) Detail Layer.

(d) Corrected base. (e) Tone-mapped luminance. (f) Raw luminance corrected.

Figure 9: Comparison between contrast reduction on the raw luminance vs on the base layer.

(a) Contrast reduction on the raw intensity.

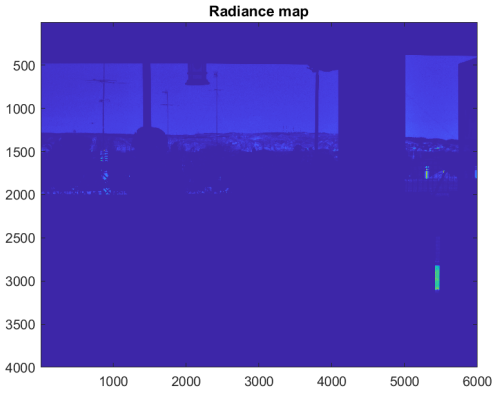
(b) Contrast reduction on the base layer.

5 Try with own images

This has been done using a NIKON D3300 camera, using a tripod to stabilize the camera. In order to be able to process that picture weight, they have been downsampled with a 200:1 ratio. The first HDR image has been created with:

- Obt. Speed = $[1/256, 64/1]$
- ISO = 400
- Focal Aperture = f/32.0

(a) Reference image



(b) Radiance Map

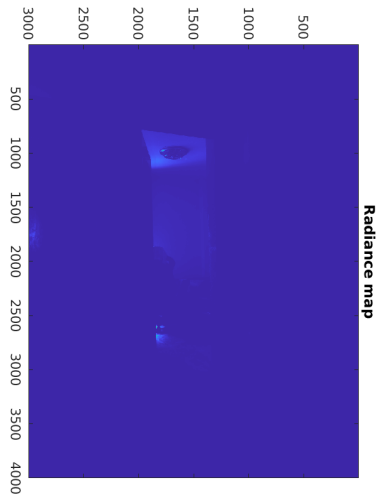
(c) Local Tone Map
$\sigma_s = 3$, $\sigma_r = 0.4$ and $dR = 6$.

(d) Global Tone Map

The second, is done with a Xiaomi Mi 9T Pro camera with the following configuration:

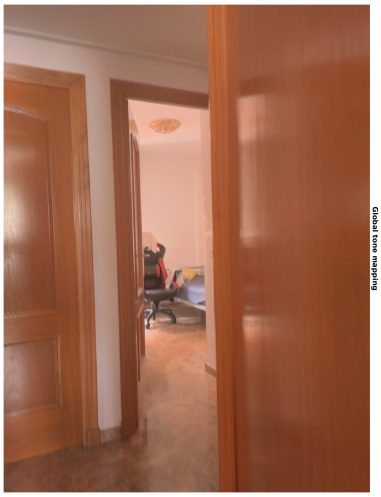
- Obt. Speed = $[1/1024, 64/1]$
- ISO = 100
- Focal Aperture = f/1.8

(a) Reference image



(b) Radiance Map

(c) Local Tone Map
$\sigma_s = 3$, $\sigma_r = 0.4$ and $dR = 6$.



(d) Global Tone Map