CREATING HDR PHOTO BY MANIPULATING DYNAMIC RANGE OF A SINGLE RAW FORMAT PHOTO

Dubravka Maurer[1]

Dr. Sanja Šamanović[1]

Assist. Prof. Dr. Dubravko Gajski[1]

[1]Faculty of Geodesy, University of Zagreb, **Croatia**

ABSTRACT

Contemporary digital cameras enable automated process of creating several photos of the same frame in different exposure (bracketing). By the post processing of the photo, editing it in tone mapping, correctly illuminated parts of individual photos are merged into a new one - High Dynamic Range (HDR) image. The differences between illumination of the parts of the object in direct sunlight and the one in deep shade result in a lack of recognizable details which creates challenges in photogrammetric interpretation. The dynamic range of photo stored in RAW-format reflects the abilities of the sensor to record the intensities of light. Contemporary software packages allow manipulation in the range of illumination to create five photos with different exposure values (-1, -0.5, 0, +0.5, +1) from the single original RAW format. Photos were then merged into one HDR image with uniform illumination in all frame (subject/pattern) without any loss of quality. This method of creating pronounced real textures of the subject enables quality photo interpretation and the creation of orthophoto with significant application in 3D modeling in architecture and cultural heritage. It is also exceptionally practical in creating HDR images from photos taken by drones where there are no possibilities of taking more photos from the same observation point.

Keywords: HDR, RAW, terrestrial photogrammetry, illumination, exposure, drone.

INTRODUCTION

Our environment is presented by the light areas and the dark parts in the shadows whose intensity depends on the stage of illumination of the scene. The dynamic range defines the relationship between the brightest and the darkest parts of the scene. It represents the ratio of maximum and minimum of the luminance [1]. Or simplified, it represents the illumination range from the darkest parts in the shadows to the brightest parts in the sunlit of the scene, and it depends on the amount of the light, the clouds, the reflections and the sky affecting every scene [2]. Average photo taken at the sunny day has the dynamic range 100000:1, which means that the brightest part of the photo is 100000 times lighter than the darkest part of the photo.

The process of creating the photo of High Dynamic Range (HDR) includes a number of techniques to compensate the certain technical limitations of the camera. It combines the technique of merging several differently exposed photos of the same scene.

There are two possible solutions how to manipulate the dynamic range: during the shooting or in the post production. During the shooting, the capturing of the scene is resolved with the significantly wider range of the light that we can capture by the camera by using the bracketing method. The other solution displays the captured scene on the media that has the lower dynamic range which is resulted in postproduction by increasing the dynamic range, respectively maximizing and by local adjustment of the tone range.

The idea of using the differently exposed photos for the purpose of obtaining one HDR photo from differently exposed parts of the scene, in classical photography was presented by the French photographer Gustav LeGray in 1850. LeGray used two negatives, one for the light sky (shortly exposed), and the other for the darker sea (longer exposed), thereby creating the positive by merging the negatives along the horizontal line.

Another way to balance the illumination on the photo was tone mapping by hand and was carried out in the dark room (post-production). The high dynamic range of the negative made it possible to "extract" the tones on the positive. Individual components of the photo were selectively over (burning) or under (dodging) exposed to obtain uniform tones.

Contemporary HDR principles use the approach based on the high dynamic range of the illumination by equal image operations over the whole photo (global – only image operation). The fundament is the mathematical study developed by Steve Mann and Rosalind Picard [3] in 1995.

The most common method today is the method of "bracketing" which allows us during the shooting to capture the same motif with a different exposure value and applies to the static scenes and static point of view only. The bracketing method can be automatic (implemented inside the camera) or manually controlled. The Automated Exposure Bracketing function (AEB) enables automated shooting three or more differently exposed photos. The manual method allows us to define the exposure value of the individual photos. Each photo obtains the different amount of information on the certain parts of the photo which we later merge into a single HDR photo. Increasing the dynamic range in postproduction (tone mapping) is used in case of a capturing the moving motifs, for capturing the motifs when we are not able to use a tripod (aero photogrammetry, biostereometry) or for existing photos.

The appropriate file format of the picture should be able to save all information from the sensor at the moment of taking the photo. Therefore, for the implementation of the method of the high dynamic range, it is recommended to save a photo in RAW file format. The usual image format, such as jpeg or tiff, is not able to store and keep all these information. RAW format presents a format of image files without any loss of information. It contains all information that are captured during the taking a photo, without any compression or processing.

The technique is used in photo processing as in a computer graphics with the intention to transfer one set of colors to the other for displaying the HDR photo on the media with the limited dynamic range [4].

It decreases the overall contrasts of the photo as a whole, giving thus the dynamic space to rise the contrast locally. By that way, the fine details in the photo are much better

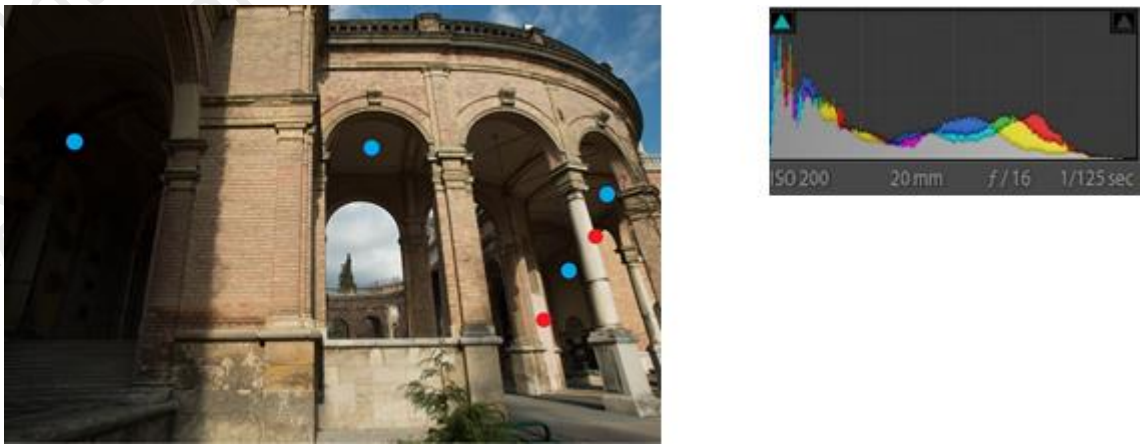
visible, giving the chance to be recognized and interpreted easily and measured with confidence. In some cases, the HDR application creates only the aesthetically acceptable photo, while other applications put the focus on the reproduction of a large number of details or on increasing the contrast. The main goal of the HDR tone mapping is to create a visual matching of the real scene and the photo, even when the device is unable to reproduce the high dynamic range of photos. There are two basic methods of tone mapping:

- Method that applies Linear Scale-Factor Methods
- Method that applies Non-Linear Scale-Factor Methods

The linear scale includes Mean Value Mapping and Interactive Calibration (5). The methods that apply non-linear scale were developed by Tumblin and Rushmeier [6,7], and others.

METHODOLOGY

As the RAW photo format has a high dynamic range, it is possible to create an HDR image using a single photo, thus make it possible to apply HDR technology even if images are taken in dynamic conditions (i.e. drones). Further it is worth noting that the taking of images is a few times faster comparing to the case if one use bracketing technology to take three or five photos of one scenery. This paper investigates the method of creating an HDR using a differently exposed photos derived from a single RAW format photo (simulation of differently exposed photos with the same perspective, apropos photos captured using bracketing). The resulting photo will not be a true HDR since the sensors can record only a certain amount of dynamic range, but it will have a greater dynamic range than the conventional photos. The original photo was taken by the digital camera Nikon D800E equipped with the wide-angle lens SIGMA RF 20/1.8 in RAW format (picture 1). Adverse weather conditions (direct sunlight) resulted in deep shadows which disable high-quality photogrammetric measurements. By manipulating the exposure in Adobe Lightroom software, five images with different exposures were derived from the original one. These images were merged to create one final 32-bit HDR image.(picture 6).

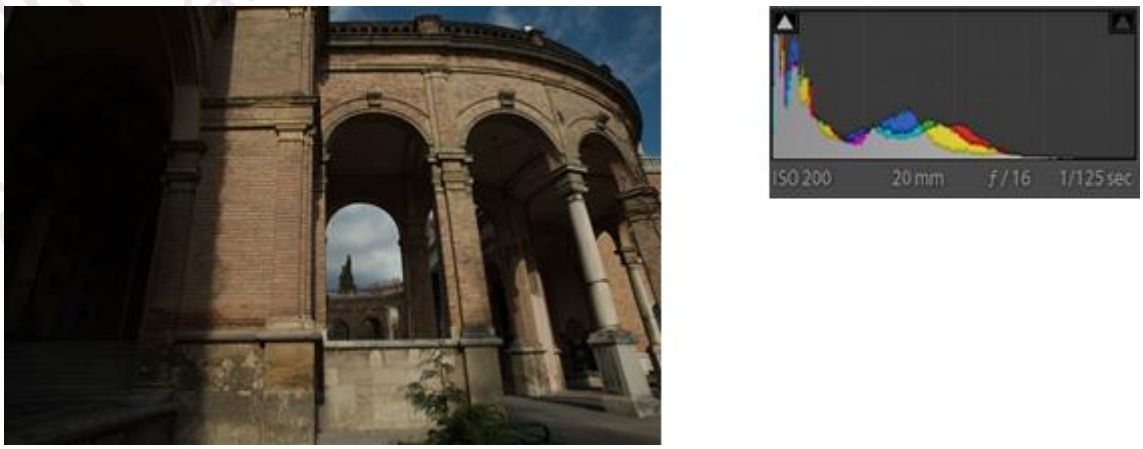


Picture 1. Original photo taken in the RAW format (red circle – over-exposed, blue circle – under-exposed)

The histogram of the original image shows a large number of pixels in the darkest parts of the photo, while on the brightest parts the number of pixels is unsubstantial. In purpose to make the original photo suitable for photogrammetric measurements, we created several images with different exposure values (EV). For the purpose of gaining a better tone alignment of all details on the final image, we have chosen the step of changing the values of exposure of 0,5 EV. By evaluating the exposure of the brightest as well as of the darkest parts of the image we conclude that the range of the exposures from -1 EV to +1 EV gives satisfactory results. Therefore, we derived 5 images from the original one, using the exposure values as follows: -1, -0.5, 0, +0.5, +1. These images are shown in pictures 1-5. The distributions of intensities among the whole visible spectrum are presented in histograms that correspond to each image.

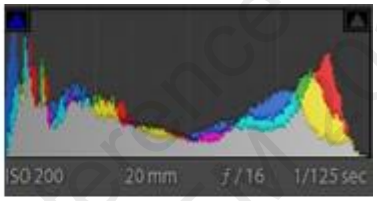
Picture 2. Derived photo - EV-1

In the picture 2. the captured motif is under-exposed. Almost all tonal values reside mainly to the left half of histogram, in the area of low intensities. Just the strongest illuminated parts of the motif are correctly exposed and suitable for photogrammetric measurement. Therefore, during the generation of the HDR image, just these parts of the image were taken into HDR-image.



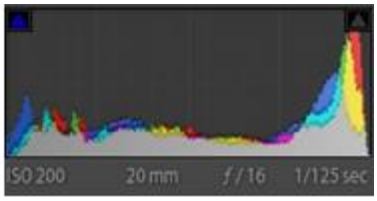
Picture 3. Derived photo - EV-0.5

Picture 3 shows the image, generated from the original one by the lowering of the exposure value (EV) for -0.5 under the original one. Most of the image is still underexposed, although the remarkable part of it resides in the middle part of intensities as shown in the corresponding histogram. The human eye can see the most of the details in the middle part of intensities. Therefore, the part of the image, that resides to central part in the histogram is used to build the HDR-image.



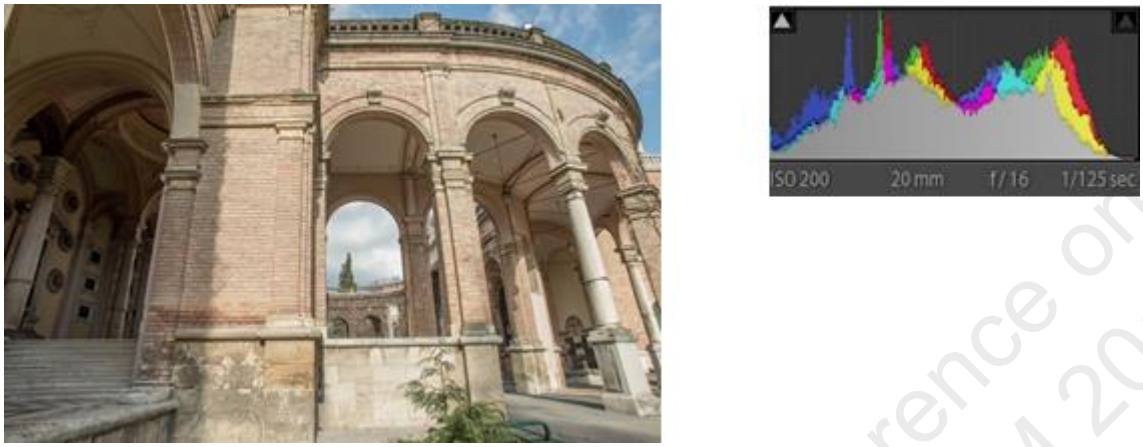
Picture 4. Derived photo - EV +0.5

In picture 4, the motif is slightly over-exposed, and the details in the shadows are beginning to appear. The lightest parts of the image aren't suitable for photogrammetric interpretation anymore, and they cannot be used to generate HDR-image.



Picture 5. Derived photo - EV +1

The image generated by raising the exposure value for +1 stop (picture 5) is generally over-exposed. The biggest amount of pixels resides to the right half of histogram. However, the details in shadows appear clearly visible and suitable for subjective interpretation and photogrammetric compilation. Therefore, these details will be used to generate the HDR image.



Picture 6. HDR image made of five images (picture 1 – picture 5)

Picture 6 shows that the motif is well-balanced. The details throughout the whole motif are clearly interpretable and measurable. The local contrast is highlighted. The histogram follows the normal distribution. Therefore it enables maximum interpretability.

CONCLUSION

Contemporary digital camera sensors reach radiometric dynamics from 10, 12 up to 14 bits. This kind of dynamics applies to RAW photo formats, which records all sensors data without any compression and processing. In most applications, a photo with 8 bite radiometric dynamics per channel (R, G and B) is in use. That is why there is a big potential that enables getting a photo with radiometric uniform motif using the radiometric compression of a single photo. This approach allows us to use a well-known HDR technology if we have only one photo available, as in the case of photos taken from moving platforms (drones, vehicles, vessels, hand, etc.), and/or photos of moving objects and dynamics appearances. Additionally, if the only one photo is sufficient for creating an HDR, the shooting process, especially for photogrammetric purposes, drastically accelerates (3 to 5 times). Using this technology each photo takes approximately normalized histogram (as in picture 6), that significantly facilitates, not only the interpretation and photogrammetric measurement but also the process of creating the orthophoto. While recording the special attention should be put on storing the photos in a RAW format, because only in this way by using the mentioned technology, the optimal result can be achieved. As the first results are encouraging, we are planning to dedicate our further researches to automatization and to optimize the tone leveling of individual photos using the HDR technology.

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