Methodological Creation of HDRI from 360-Degree Camera - Case Study

Maria Peteva(✉)

New Bulgarian University, Ul. "Montevideo" 21, Sofia, Bulgaria
lintch.co@gmail.com

Abstract. Panoramic imagery has been used in a variety of ways in many industries - cinema, architecture, entertainment. With the steady rise of 360-degree images and VR, the creation of realistic environments for industry purposes has come even close to CG artists. 360-degree cameras have enabled users to take even more control of lightning and HDRI in their own hands by creating their own images. This paper focuses on the process of creating an HDRI through a 360-degree camera within a commercial price rate while also investigating artifacts and errors during the process.

Keywords: 360-degree images · HDRI · Cubemap

HDRI has been established in many Medias as a must-have. High Dynamic Range Image (HDRI) is a 360-degree image that is wrapped around an image plane for lighting and background purposes. HDRI are easy to add in an environment and create realistic lightning in computer graphics. They are widely used for 3D visualizations in the entertainment industry - movies, animation, games, and in architecture, interior design and many more. The best way to describe an HDRI in plain terms is as a scene captured not as a two dimensional surface, but a spherical interactive surface, where the viewer is set in the middle of a sphere. The main difference between normal 360-degree pictures and HDRI is that HDRI is a technique where multiple images are taken in the same environment and then combined into a single spherical image. Such an image has a higher dynamic range of luminosity and contains more information about the lighting than a normal photograph. The HDRI than can be used for realistic rendering purposes. Using a 360-degree camera to create an HDRI has proved to be even more easy and effective than creating an HDRI from multiple images. 360-degree cameras have approved over the century and now have the needed specifications for creating a good HDRI. In this paper, we are going to review the process of creating an HDRI using a 360-degree camera.

1 360-Degree Cameras

360 degree cameras have become household objects that consumers could afford. 360-degree cameras did not only come with easy ways to take photographs, but with free software to ensure the images were easy to download, review, edit, stitch and export. 360-degree cameras are easy to carry and use. Manufacturers gave the users and CG artists

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the opportunity to create their own HDRI for multiple purposes be it professional or entertaining. This paper concentrates on the specifics and performance of a commercial 360-degree camera and the creation of HDRI by using the Q00Cam 8K 360-degree camera created by Kandoo.

From 2020 to 2022, the main manufacturers of 360-degree cameras for commercial use have changed the number of cameras, and managed to develop more models with even more characteristics. When a consumer buys the camera, it comes with free apps for easily controlling the camera from your phone. The software for image manipulation still has something to be desired from but it accommodates the basic needs for exporting a good image. The software has a huge limitation in color correction and exposure settings. However the specifications of a 360-degree camera come very close to a professional camera and ideally it is what a user needs for a good HDRI. From 2020 to 2022, GoPro has switched from only two 360-degree cameras to five. Theta has also switched from two cameras produced in 2020 to seven. Insta 360 have not changed the number of cameras they have produced - still at five, but all of their models have improved. Kandoo, which is the manufacturer of the camera used for this process, have not changed the number of cameras they produced, however they also manufacture professional cameras - and they have added one more professional camera to the three they already had. Major companies associated with 360-degree cameras you can see in Table 1 below.

Table 1. 360-degree camera changes of models from 2020 to 2022.

	2020	2022		2020	2022
Go Pro	Go Pro Max	Hero 10 – Creators Edition	Theta	Ricoh Theta V	Theta Z1
	Go Pro Fusion	Hero 10		Ricoh Theta Z1	Theta X
		Hero 9			That V
		Hero 8			Theta SC2
		Max			Theta S
Insta 360	One R	One RS			Theta SC
	One X	One X			Theta m12
	EVO	One X2	Kandoo	QooCam 8K	QooCam 8K
	One	Evo		QuoCam Fun	QooCam Fun
	NanoS	Go 2		QooCam	Qoocam
		Nano S	Kandoo Professional	Obsidian Go	Obsidian Pro
Insta 360 Professional	Pro 2	Pro 2		Obsidian S	Obsidian R

(*continued*)

Table 1. (*continued*)

	2020	2022		2020	2022
	Pro	Pro		Obsidian R	Obsidian S
	Titan	Titan			Obsidian Go
Samsung	Samsung Gear (2017)	Samsung Gear (2017)			
Vuze	Vuze XR	Vuze XR			
	Vuze+	Vuze+			
	Vuze	Vuze			

2 Methodology

HDRI stores the three value colors of RGB scale with floating point precision, which means the brightness is recorded in each color pixel. It contains 32 bits per pixel per channel which is more than the traditional 8-bit image. When we talk about using a 360-degree camera to produce an HDRI image, what we need to accomplish is to take several RAW pictures with different ISO - sensitivity to light and different EV - exposure value or the amount of light radiation in an image. Both of which are available in range even in a low budget 360 camera. The specifications of the Kandoo 8K camera can be viewed on Table 2.

Table 2. Specifications and features in QooCam 8k.

ISO	Shutter			White Balance	EV – Exposure value	
100	1	1/80	1/640	Auto	−2	0
200	1/1.3	1/100	1/800	Underwater	−1.7	0.3
400	1/1.6	1/120	1/1000	Incandescent	−1.3	0.7
800	1/2	1/160	1/1600	Florescent	−1	1
1600	1/2.5	1/200	1/2000	Daylight	−0.7	1.3
3200	1/3	1/250	1/3200	Cloudy	−0.3	1.7
6400	1/10	1/320	1/4000			2
	1/30	1/400	1/5000			
	1/60	1/500	1/6400			

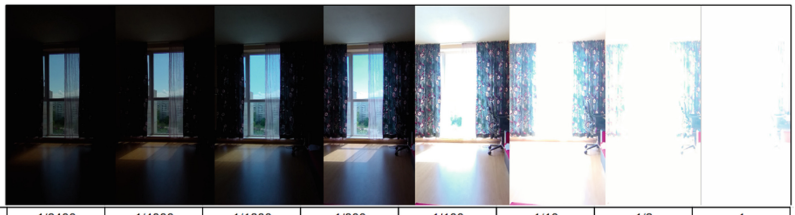
In terms of compression, we can always downscale from an upscale resolution, QuoCam 8k camera provides a 7680 by 3840, 12 bit DNG (RAW), Raw+ photo (16bit). DNG stands for Digital Negative Image. DNG images are easier to edit than Raw images. From the parameters even the quality given from this 360-degree camera is as standart as a professional camera. The various combinations between parameters ensures the

capture of a good HDRI image. The two most important aspects of HDIR are dynamic range of the image and high resolution. Dynamic range is an indication of the contrast in an image - the more contrast there is the better the HDRI would look. To compress a good HDRI you need at least from 5 to 12 images for indoor shooting and 5 do 22 for outdoor shooting. These images are a combination of EV and Shutter speed, however, images with EV = 0 are considered a well-exposed image (Bloch 2012). To start off the process, the first picture we take needs to be almost black with a EV -2 and shutter speed 1/8000. The formula on the dependency between EV and shutter speed you can view on Fig. 1(a). In the equation, F is the relative aperture of the lens and Δt is the exposure time. (Do 2016) and the visual representation of such an image can be viewed below on Fig. 1(b).

(a)

$$EV = log_2 \frac{F^2}{\Delta t}$$

(b)



Shutter	1/6400	1/4000	1/1600	1/800	1/100	1/10	1/2	1
EV	-2	-1.3	0	1	1	1.3	1.7	1/2

Fig. 1. (a) A measurement of exposure value (EV). (b) Images captures with QooCam8K with different EV and shutter speed.

Due to the huge variety of options between the Shutter and the EV presented in the 360-degree camera on Fig. 1(b) only a sample of the different exposure settings are presented. The most important example of this picture taking is the huge difference between EV of 1, taken with different Shutter speeds - 1/100 and 1/10 - the difference is noticeable in Fig. 1(b) above.

3 Stitching Issues

This far we have managed to talk only about the principles of making a good HDRI from a photographer point of view. However there are other problems that could occur when using a 360-degree camera - these problems are mostly motivated by stitching issues, distortion awareness and unwanted artifacts in the image (See and Cheok 2015).

Image stitching and 360-degree stitching is the technology of overlapping images to generate a wider panoramic image. Stitching issues occur because of field of view limitations (FOV limitations). 360-degree cameras use two fisheye lenses, on each side of the device, each capturing a 180-degree angle of view. The two hemispherical images are then stitched together to produce a 360-degree spherical view. To portrait a stitching issue we can view Fig. 2. To eliminate the issues of potential flows in the image and to

extend to the HDRI, a seamless method is endorsed. 360-degree cameras have closed-loop stitching - each image is aligned, deformed and projected onto a spherical surface. The software Kandoo uses to stitch together a 360-degree image is based on optical flow. The best way to describe optical flow is through image motion. In videos or animation, a series of images set one after another create a motion, between frames we have a small time step. Optical flow is a technique that calculates the velocity of points within the different frames – but it calculates the point's direction of motion. It is just one of the many algorithms used for stitching images (Lyu et al. 2019).

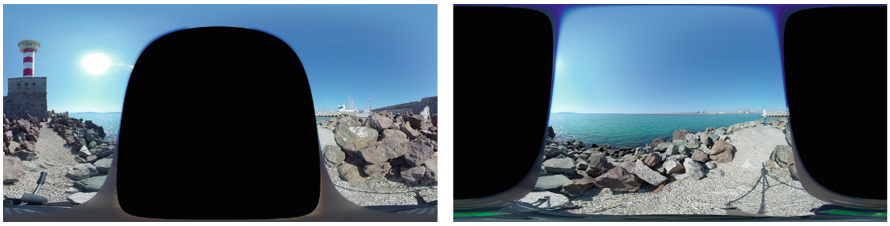


Fig. 2. Unstitched image taken from QooCam 8k.

Because optical flow calculates not only what is inside the image, but also estimates the camera parameters with great accuracy, the issues with stitching, even in a low-budget camera are few and even non-existing. Most issues of stitching occur while taking 360-degree videos.

4 Parallax Errors

Parallax errors are displacements that appear in the image due to different viewing angles. Due to the 180 fish lenses of the camera, these errors occur especially if the 360-degree camera is too close to the ground. As you can see in Fig. 3, on a tile floor, the parallax error is quite visible. This is why 360-degree photographs are taken using a tripod with approximate height next to a human height. HDRI are effectively positioned in the middle of a sphere, the world position set at (0, 0, 0, 0), so the position of the camera will match the world position in a third-party software. Knowing this while taking a 360-degree camera is customary to turn one of the two lenses to any important part of the environment you are taking. A lens being perpendicular to an object minimizes parallax error.

Having gathered a variety of images taken with a range of shutter speed and EV, the images are ready to be compressed into an HDRI. The Kandoo Studio application can retrieve and re-render the information taken from the camera - stitch from separate lens images and use optical flow to stitch them together into one panoramic image, creating a new image. In this step we can choose the size of the new image. High resolution ensures less distortion of the image, precise shadows and crisp and sharp image. To avoid pixilation in the final image, especially since HDRI is visible in the background for rendering purposes. A third-party software is needed to compress the images into

Fig. 3. Parallax error.

one HDRI with a 32-bit channel. This step will not be described in depth in this article but will be set aside for more in depth study in future work.

However the compression of the HDRI and the stitching are two separate steps which can be taken vice-versa. Lens images can be run by a third-party software and compressed into HDRI before being re-rendered as a whole image by the Kandoo software. It is arguable if images that are first re-rendered through Kandoo are not losing some of their quality as a RAW image as any interaction would further take some quality from the original render.

While testing the HDRI in Unity engine by implementing it on a spherical surface a few artifacts on the top and the bottom of the sphere. Figure 4. Increased number of polygons added to the sphere do not clean the artifact and with a VR headset the errors were even easier to spot.

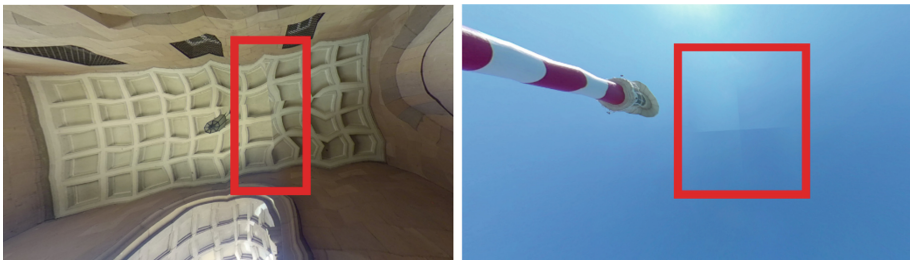


Fig. 4. Artifacts at the top of two HDR images captures in Unity Engine.

5 Results

The best method to cope with these errors is to convert the HDRI into a cubemap, also called skybox. The cubemap method uses six cube faces to fill the whole sphere. Figure 5(a) 360-degree images or HDRI are largely used when the environment needs to be projected onto an object - to stimulate reflections and light. However to make an environment with minimal performance cost and no such errors, developers use the cubemap as a neat solution. Cubemaps are created by six seamless textures with a left, front, right, back, top and bottom texture. Figure 5(b). The illusion of a HDRI stays intact since the center of the engine and the cube remain the same and the cubemap sustains the sharpness of the image without any distortions. Figure 5(c) gives us how a cubemap looks inside the Unity engine. The only part of the image that could occur as an "error" is the shadow the tripod has left on the ground in the HDRI. In a clean HDRI, especially one used as a cubemap. The solution is to clean the image of the shadow using various retouching methods by a third-party application.

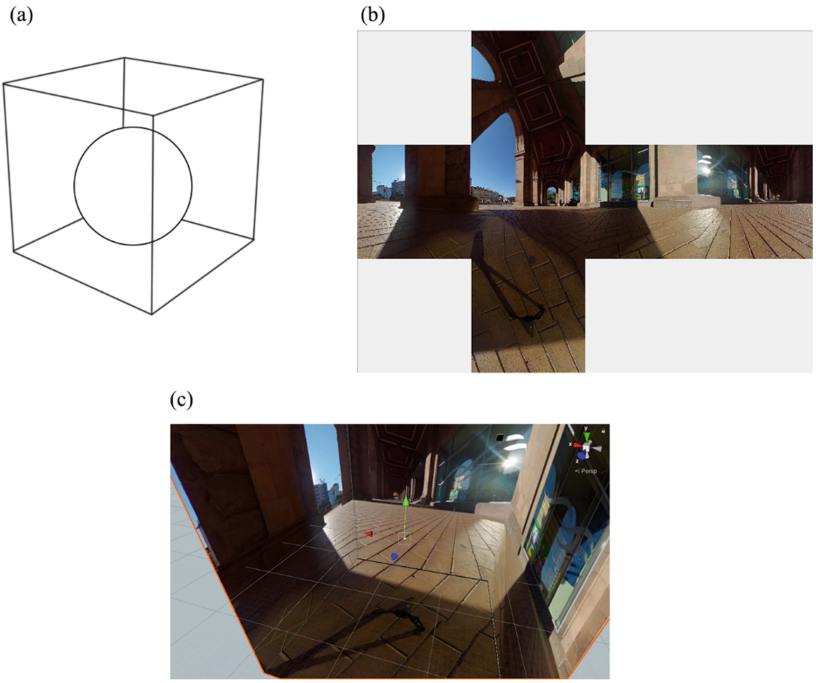


Fig. 5. (a) Cubemap surrounding HDRI. (b) Unfolded cubemap (c) Cubemap as viewed in Unity engine.

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