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High dynamic range photography techniques for exterior scenes

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Abstract:

High Dynamic Range (HDR) imaging plays an important role in daylight research, facilitating the capture of lighting environments with a dedicated focus on human perception and visual comfort.[2] In response to the challenges associated with capturing HDR images from building facades, this research undertook the development of a novel methodology. This methodology addresses aspects such as direct exposure to sunlight known as the "overflow" phenomenon [3], and capturing images from the building facade.

While acknowledging the limitations associated with variable light conditions, the methodology developed shows the effectiveness of the Shadowband tool, a tool conceptualised by Dr. S.W WASILEWSKI to improve HDR imaging. In addition, the work provides a dataset for visual clarity research and in a wider context for daylight research.

Finally, this study highlights the versatile integration of HDR imaging in a variety of fields, from daylight research to architectural design - a user-centered approach to façade design that puts visual and light quality at the forefront.[4]

1. Introduction.

High dynamic range (HDR) images are used to measure the lit environment through sequential imaging. Lighting environment measurement enables researchers to study how people perceive and experience visual comfort in existing environments, in order to determine the components that contribute to positive or problematic lighting characteristics [2][6]. The purpose of HDR is to capture a landscape (a scene in the context of this report) as accurately as possible as we perceive it. We can imagine that capturing HDR images is like a pot of modelling clay. The capture scene is the modelling clay. If we divide the modelling clay into X pieces, we have X pieces that represent a part of the original modelling clay, in this case the original scene being captured. These X pieces are all similar but different in shape. In the example, each of the pieces represents an image at a different exposure time (the speed at which the camera takes the shot). These X pieces are put together and we have, almost, the original modelling clay. This is what happens with HDR images, which are the assembly of X images taken at different exposures to reform the full luminosity range of the original scene. (further down Figure 10)[7].

Until now, there have been very few papers on shooting HDR images outdoors. The literature focuses on shooting indoor scenes with the right methodology or on the accuracy of the measurements captured [1][2][3]. However, in order to understand and simulate interior spaces offering views of the exterior, it is essential to obtain images of the exterior, and more specifically images from a facade. A concrete example of the use of these images would be to understand and optimize the blind system in an office in order to avoid excessive glare that could cause visual fatigue and reduce the quality of the work carried out [5]. It is through the openings that the facade pre-defines the visual comfort and experience within an interior [6]. In order to carry out this type of simulation, it is therefore essential to take HDR images as seen from a building facade. Nevertheless, HDR from a “facade” raises the question of the feasibility of such images. Parameters such as direct exposure to sunlight and shooting HDR from this quasi-fictional space, meaning it is physically hard to be at a “facade”, seem to need to be addressed when it comes to shooting HDR for an outdoor scene.

To address these issues, we therefore undertook to develop a new methodology for capturing HDR images from the facade interface. We measured the effectiveness of this method by building up a dataset of high dynamic range (HDR) images for daylight and view research.

2. Materials.

1. Canon EOS 70D
2. SIGMA 4.5mm 1:2.8 circular fisheye lens
3. Tripod
4. Illuminance meter LMT
5. Lux Meter
6. ND3 filter
7. Tweezer
8. Shadowband

*All the equipment was supplied by the LIPID Laboratory

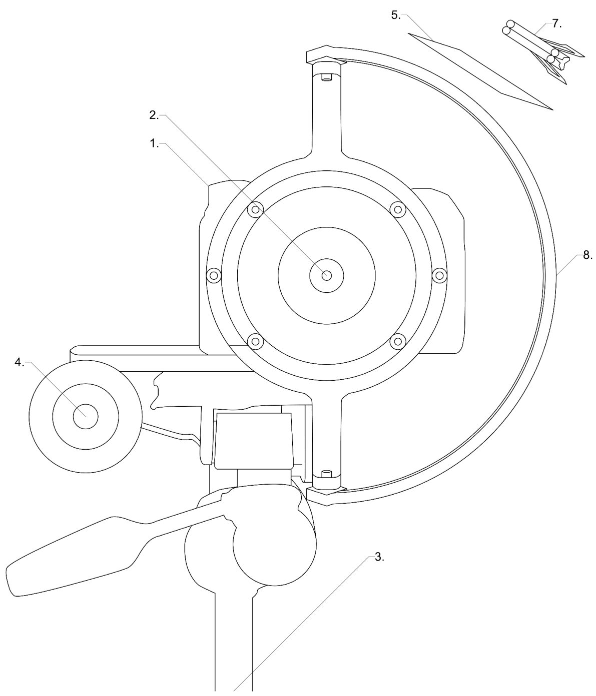


Figure 1. Material and setup

The Canon EOS 70D and its SIGMA 4.5mm 1:2.8 hemispherical fisheye lens are mounted on the tripod. To the left of the camera, in the same plane as the lens, stands the LMT illuminance meter. On the objective the Shadowband tool is aimed. The ND3 filter can be pinched onto the half-circular arc of the Shadowband.

2.1. Shadowband.

1. Rotating half circular arc
2. First rotating ring
3. Second fixed ring
4. Third fixed ring

a. First axis of rotation (90 degrees)

b. Second axis of rotation (more than 180 degrees)

**The tool was developed by Dr. Stephen Wasilewski at the LIPID Laboratory

Figure 2. Shadowband tool

The Shadowband is a new tool in the literature of HDR image capture conceptualised by Dr. S.W. WASILEWSKI. When taking images of a scene with the sun in the field of vision, HDR images underestimate the luminosity of an extremely bright source such as the sun [3]. In practical terms, on the image, this is represented by white pixels from which it is not possible to derive any information, such as their luminosity. In other words, when the sun appears in a scene it is not fully possible to capture the entire range of luminosity. This phenomenon is called "luminous overflow", or more generally it can be thought as the phenomenon of over-exposure. If rays or the sun appear on one of the X pieces of the HDR, the HDR image can be considered as inaccurate.

The Shadowband is designed specifically to address the issue of overflow. The purpose of the shadowband is to block the sun. This tool consists of a half-circular arc (1.) whose axis of rotation is the b-axis (Figure 2). The b-axis of rotation is coplanar with the centre of the lens, so rotation can take place through 180 degrees covering the entire lens. In addition to this 180 degree rotation, there is a 90 degree rotation centered on the first ring (a.), in other words the centre of the lens. This combination of two successive rotations (a.&b.) enables the half-circular arc to be positioned horizontally and vertically. In this way, the sun can be blocked both vertically and horizontally, in order that the shadowband can later be removed from the final image. The thickness of the half-circular arc corresponds to the size of the sun as seen from the earth.

The first rotating part (2.) of the shadowband can be considered as mobile. In fact, this mobile part can be removed and replaced on the fixed part of the tool. The fixed part is composed of the second and third rings (3.&4.), which are fixed directly on the lens.

2.2. ND3 Filter.

An ND3 filter is a neutral density (ND) filter. In other words, it reduces the amount of light reaching the camera's sensor without changing the spectrum of the light.

2.3. LMT Meter.

In order to collect reliable measurements of captured daylight conditions during image collection, illuminance was recorded with an LMT light meter positioned next to the camera in the same plane as the camera lens.

3. Methods.

The present HDR images were taken in the city of Lausanne and the surrounding area between 26 July 2023 and 23 August 2023. Using consistently the same material, detailed in section 2, a large number of images were collected to represent a wide variety of types of environments, image compositions as well as weather conditions. The methodology adopted is divided into three distinct parts:

- Scene Image Collection
- Selection Process and Cataloguing images
- HDR Image Development

3.1. Scene Collection.

3.1.1. In Situ

Potential scenes on site were identified. Although it's not necessarily easy to access the façade from the windows of public or private buildings, we had to pretend to be from a façade. To narrow down the search, locations with strong contrasts in relative heights were chosen. Nearby obstacles were avoided while maintaining a five meter distance from the lens to prevent distortion, which results in an unrealistic fish-eye effect (Figure 3.). Any objects in movement were also avoided such as cars, tree leaves or even flags, which could cause blurs during HDR development. In addition, any coverings (underroofs, sunshades) which do not allow the illuminance of the outdoor scene to be measured correctly were minimised. The feasibility of the diverse locations was taken into account. We recommend having a location where there are no obstacles preventing access to the camera and that there is enough space to place the tripod and camera in a stable position.

		
Direct movement: Road and flag	Under cover	Diform and unrealistic

Figure 3. Examples of inadequate sites

3.1.2. Parameters

ISO	100
Mode	Manual Mode
Kelvin white balance	Daylight 5200K
Image type	RAW
Shutter speed	1/8000; 1/4000; 1/2000; 1/1000; 1/1000; 1/800; 1/400; 1/125; 1/60; 1/30; 1/15; 1/8; 1/4; 0.5';1' [seconds]
Aperture	F11 & F22
Preview Mode	ON
Silent LV Shooting	OFF
Automatic Exposure Bracketing	ON

Figure 4. Canon EOS70D camera settings

The X pieces that compose the HDR image are made up of 14 images ranging from a very short exposure time of 1/8000 to a duration of one second. It is these 14 images that make up the range of images (Figure 5.). This range allows to capture both bright and dark scenes, covering the full range of light that a scene can offer. When shooting these 14 images, we recommend activating the “Automatic Exposure Bracketing” mode, which can take up to 7 images at a time, to increase the speed and regularity of the captures. To sum up, a first sequence of 7 images from 1/8000 to 1/125 and a second sequence from 1/60 to 1' are taken (Figure 5.).

Based on previous studies, a medium aperture size: F11 was chosen.[7][8] As for the largest aperture, meaning the one that lets the most light through, F22, was chosen because of the ND3 filter, which lets less light through.

We recommend activating preview mode. It is useful for cropping and adjusting the sharpness of a scene. Preview mode is also essential with the Shadowband in order to view the sun correctly. This mode effectively blocks out all the sun's rays, without letting through those that might escape by looking only through the lens (Figure 6.). However, it is essential to deactivate the Silent LV Shooting mode in the settings menu. This is to prevent “shutter shock”, which tends to slow down the camera's capture speed when preview mode is on.

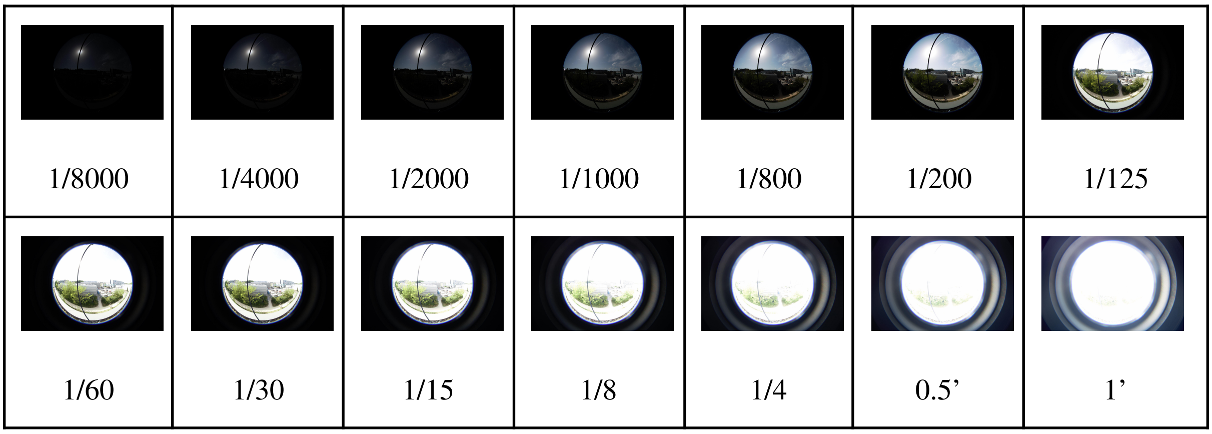


Figure 5. A sequence from 1/8000 to 1 second

Figure 6. Viewed from the camera lens, the horizontal arc of the Shadowband blocks the sun and its rays

3.1.3. Execution Process

When the sun appears in the field of vision, we proceed with the Shadowband in three distinct steps. The first step is to use the ND3 filter and F22 aperture. The second step consists of obtaining the shadowband's half-circular arc vertically, i.e. perpendicular to the lens, with aperture F11. The third step consists of the same operation as the second, but with the half-circular arc horizontally.

We check that the camera is correctly set up with the parameters described in section 3.1.2 above. The camera is set to 1/1000 and the aperture to F22. We also check that the camera is stable and aligned in space. We adjust the frame and sharpness. (Figure 7.)

1. The ND3 filter is pinched onto the vertical half-circular arc. The sun should be in the middle of the filter, forming a point of light.

2. We record the value of the illuminance indicated by the LMT meter before capture.
3. We run a first sequence from 1/8000 to 1/125.
4. Without touching the camera, we change the aperture from F22 to F11 and we block the sun with the half-arc already in the vertical position.
5. We run two sequences consecutively from 1/8000 to 1'.
6. We return to a shutter speed of 1/1000 and position the half-circular arc horizontally, in the same way as we did for the vertical one.
7. We run two sequences consecutively from 1/8000 to 1'.
8. We record the value of the illuminance indicated by the LMT meter after the capture.
9. Using a portable LUX meter, we measure the illuminace again and the x & y values after the captures. We advise to carry out this step at the end. To obtain a measurement comparable to the LMT light meter, it is preferable putting the lens cover on so that we can hold the meter against it.

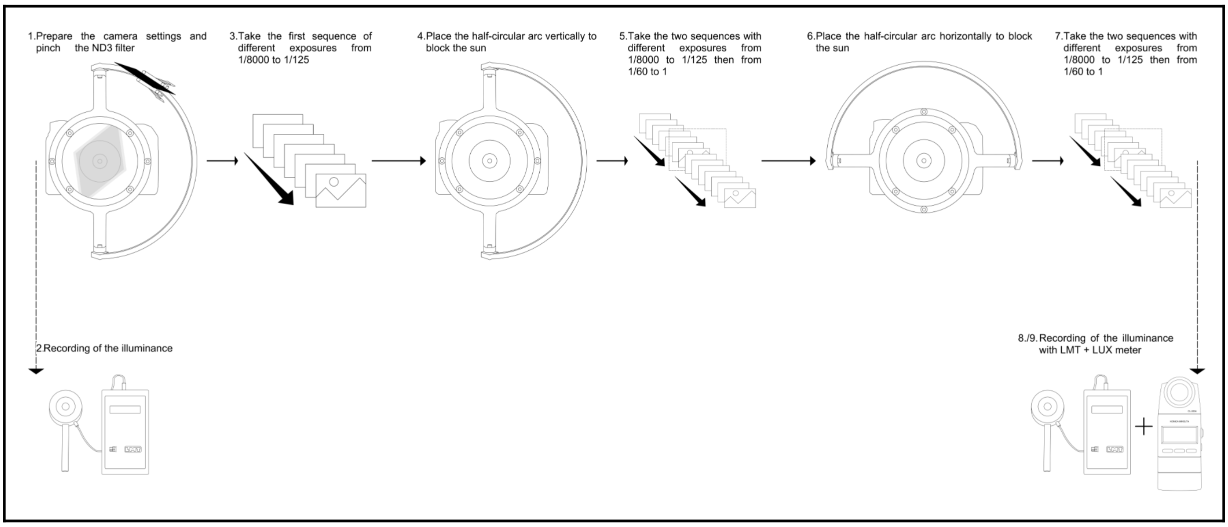


Figure 7. Taking HDR with Shadowband step by step

When the sun does not appear in the field of vision, we proceed with two successive sequences with an aperture of F11.

We check that the camera is correctly set up with the parameters described in section 3.1.2 above. The camera is set to 1/1000 and the aperture to F11. We also check that the camera is stable and aligned in space. We adjust the frame and sharpness.

1. We record the value of the illuminance indicated by the LMT meter before capture.
2. We run two sequences consecutively from 1/8000 to 1'.
3. We record the value of the illuminance indicated by the LMT meter after the capture.
4. Using a portable light meter, we measure the illuminace again and the x & y values after the captures.

3.1.4. Accuracy.

To ensure accuracy, it is important to refer to the values of the LMT meter. The illuminance values are used to check the stability and reliability of the conditions before and after HDR images capture. If the measurement taken after capture is more than 10% higher or lower than the first value recorded, then the image sequence is biased. The images then need to be re-taken.

In the same way, the values indicated by the LMT meter should be relatively stable when recorded. If the values vary too wildly, the measurements are repeated subsequently. We advise to take an image of the measured values with the scene in the background so as to avoid getting lost when processing the data.

In order to make proper use of the Shadowband tool, we strongly recommend that it is joined with Preview Mode. Otherwise it will be difficult to block all the sun's rays just through the lens. For example, we use Preview Mode and our index finger to block out the sun in order to position the ND3 filter correctly. Similarly, in order to block the sun vertically and horizontally, we use the tenfold zoom offered by the preview mode to correctly block the entire sun.

When it comes to image accuracy, time is another key factor. To avoid any movement of the sun or changes in lighting conditions, the three steps of capture with the Shadowband should take no more than a minute. It is a matter of knowing the different parameters and being well organised. For example, having a pouch on the camera to store the ND3 filter or having the LMT meter in sight can help optimize capture timing. When shooting outdoor HDR, and in public spaces, it's important to have the hands free and not be encumbered. Everything must be considered to optimise the reliability of the images and the ability to take measurements.

3.2. Selection Process and Cataloguing images.

The images taken are labelled with the date, a unique number for the scene and the number of times the scene was taken (Figure 8). The values of the LMT meter before and after capture are recorded, as well as the luxmeter. The orientation ; North, North-East, East, South-East, South, Sought-West, West, Nortn-West are entered. The sky description and the presence or absence of the sun in the field of vision are also described. The scenes are then sorted by keywords, enabling them to be grouped by criteria such as: Vegetation, building, park, street, horizontal, vertical, linear, circular, etc.

Name	230823_00159_01	230823_00001_02
Country	Switzerland	Switzerland
City	Ecublens	Ecublens
Location Code	159	1
Capture Number	1	2
Captures at location	1	2
LMT initial [Lx]	65640	76580
LMT final [Lx]	66180	77130
Lux meter [Lx]	67500	78660

x value	3435	3453
y value	3582	3600
Lon. (WGS 84)	6.567188	6.575893
Lat. (WGS 84)	46.521774	46.524442
Orientation	West	West
Direct Sun (0=No, 1=Yes)	1	1
Sky Description (0=Clear, 1=Partly Cloudy, 2=Cloudy)	0	0
Keywords	Building/Street	Building/Vegetations/Interior/Circular

Figure 8. Example of data for the images captured

The selection process mainly involves sorting out over- or under-exposed images. In practice, this is similar to identifying white or black pixels. White or black pixels appear when the RGB (Red Green Blue) values are greater than 228 or less than 27 [7]. In other words, if a pixel crosses one of these two limits, the information it contains is lost, such as its luminance. This can be checked manually by making sure that the darkest exposure has no white pixels. This means that the total luminance of the brightest light source in the field of vision is captured correctly. In our case, the script used, called plylinearhdr, automatically informs us of the presence of black or white pixels.

3.2.1. QGIS.

The data set out in section 3.2 of each scene is imported into QGIS. QGIS is an open source geographic information system (GIS) software designed to manage and analyse geospatial data. With this software, all the information about a scene is associated with a point on the map derived from the geographical coordinates of the captured scene. In this way, each image in the database is stored and can be accessed quickly. As a result, it is possible to provide a visual and global representation of the various scenes. In addition, it is easy to trace the origin of the scene and, if necessary, return to the scene to capture new data.

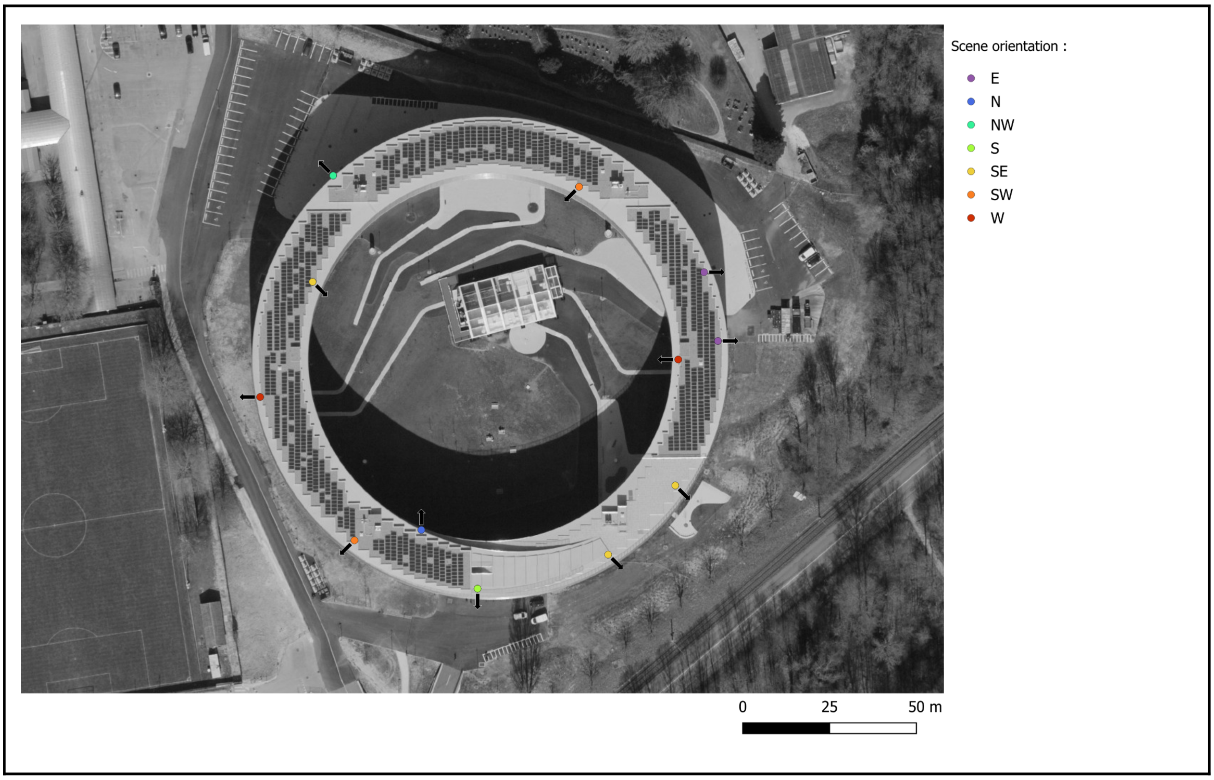


Figure 9. Example of the various scenes captured at the Vortex Center

3.3. HDR Image Development.

The development of the sequences of images for a final HDR image involves several steps. Steps such as selection, calibration and image validity check are essential. The various steps and processes involved are described in Pierson et al (2020) 's paper [8].

The basic idea behind HDR image development is to merge images from different exposures into a single image (Figure 10). Concretely, we have two sequences of 7 images, which combine a total of 14 images. We merge the images using the pylinearhdr script. Pylinearhdr is a script that uses the bash language and allows several programs to be run in order to carry out the various steps presented in the work of Pierson et al, 2020.

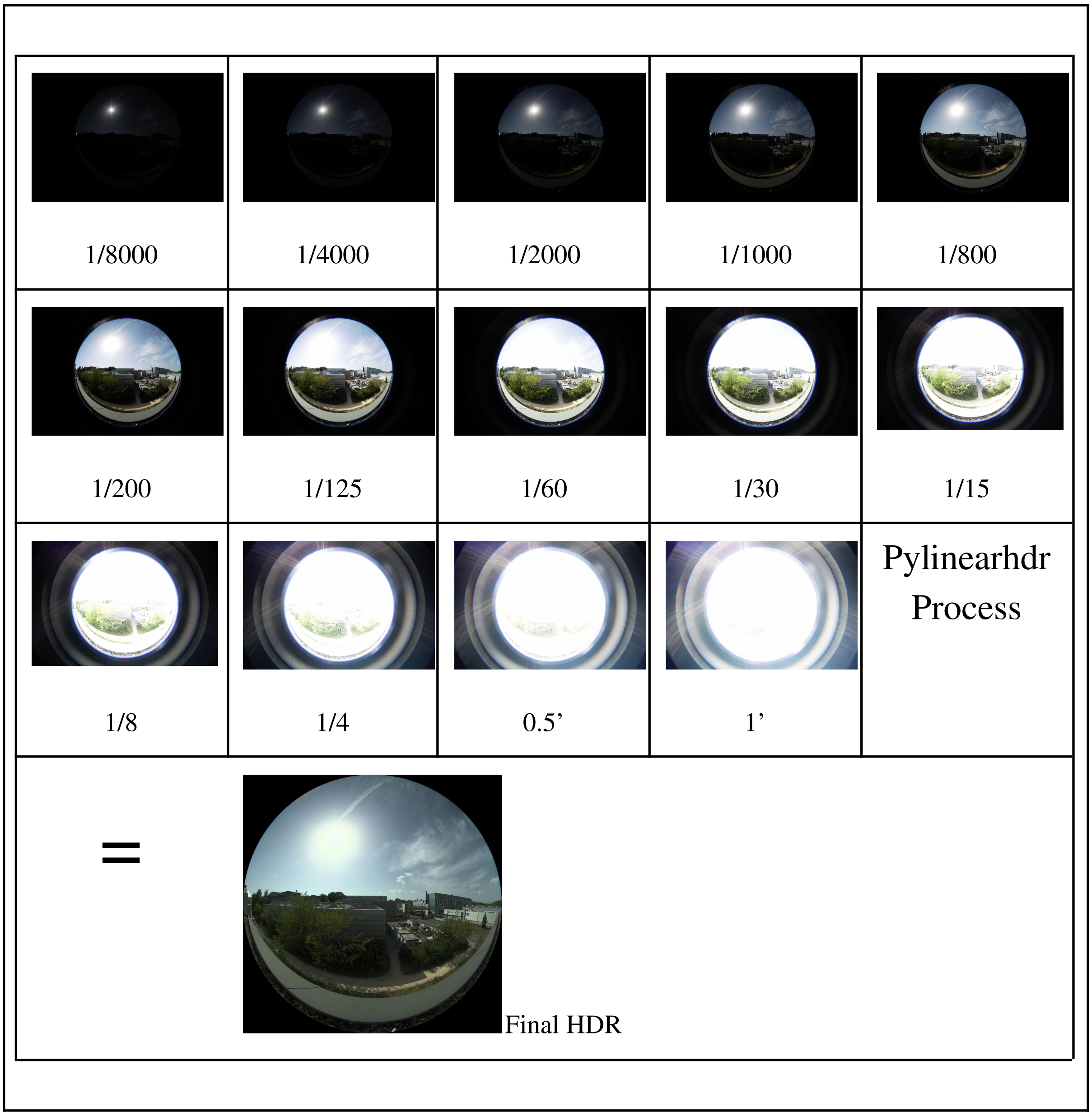


Figure 10. Example of HDR development.

4. Results

After taking the three sequences described in section 3.1.3, Figure 11 shows the three sequences developed as HDR images (the three images starting from the left at the top) and the final HDR (the fourth image at the bottom right). In this way, by combining the 3 HDR images: the one with the ND3 filter, and the half-circular vertical and horizontal arc, we are able to produce a final HDR image with the sun in the field of vision without the phenomenon of overflow.

As shown on the right image of Figure 11, the principle of combining the 3 HDR images into a final HDR is to subtract the black areas, in other words the parts with the half-circular arc, in order to recompose the image without the arc. This means that the non-black parts of the respective vertical and horizontal images are combined to reform the scene. The red parts of the images are used to extract the sun and its mass in order to recompose a sun on the final HDR. This ensures that the image is not saturated, in other words that there is no overflow, resulting in the creation of an HDR image with the sun in the field.

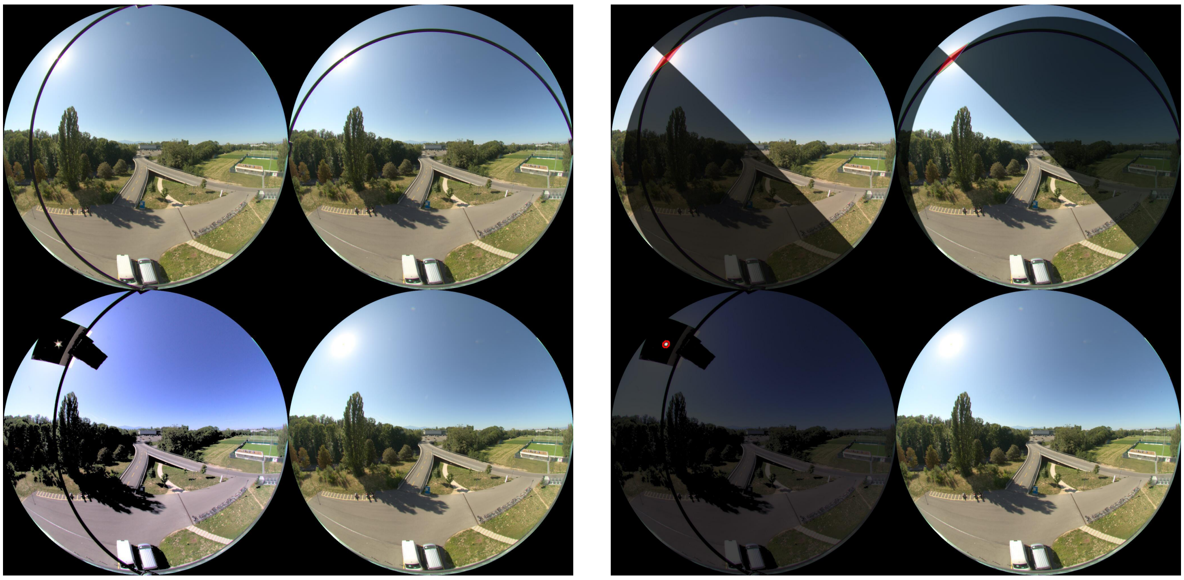


Figure 11. Process and final HDR

As a direct result of the methodology described, a total dataset of 278 captures was taken. Of these 278 captures, more than 152 captures show the sun in the field of vision and are collected using the Shadowband tool. Of these 278 captures, a total of 148 different scenes were collected, covering a wide range of elements and image compositions (Figure 12).

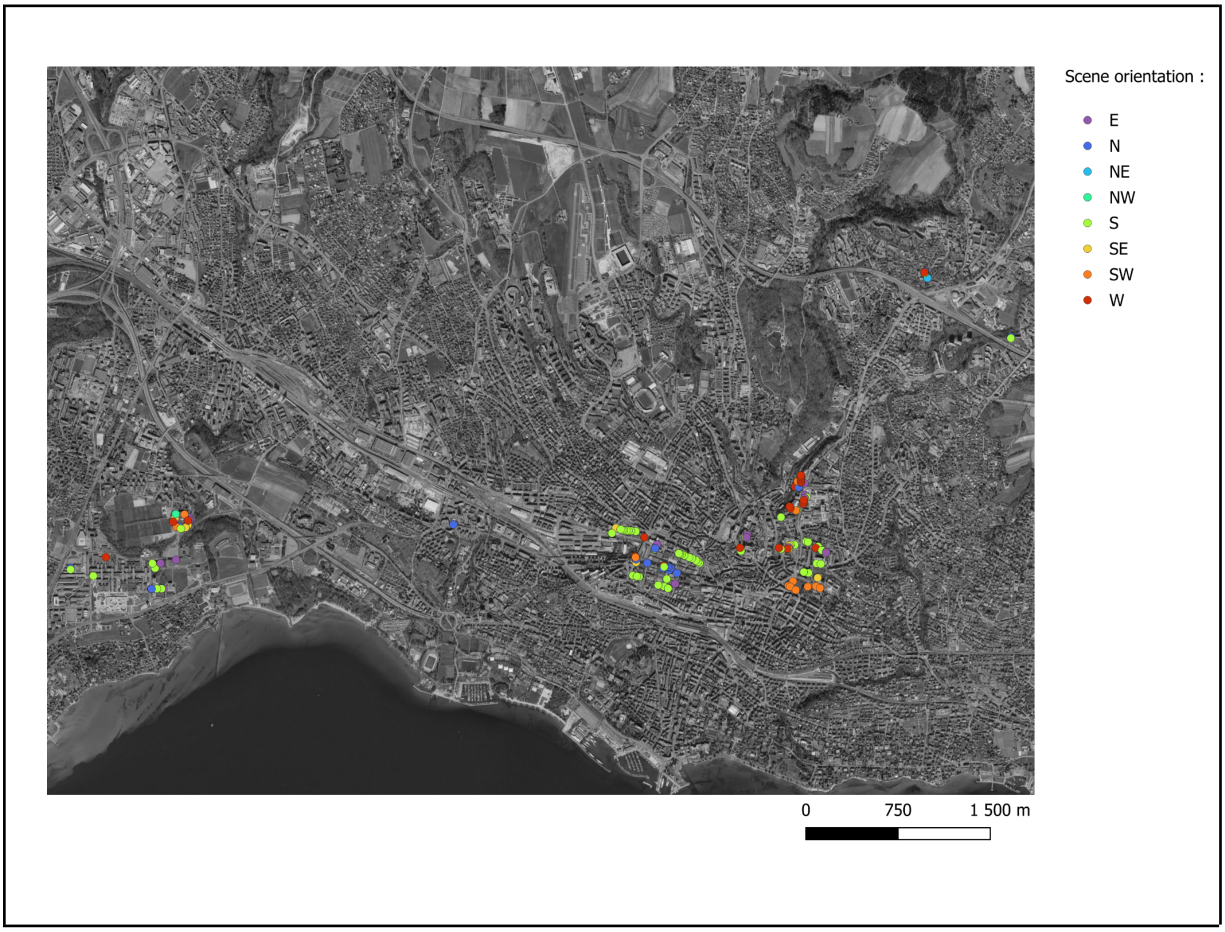
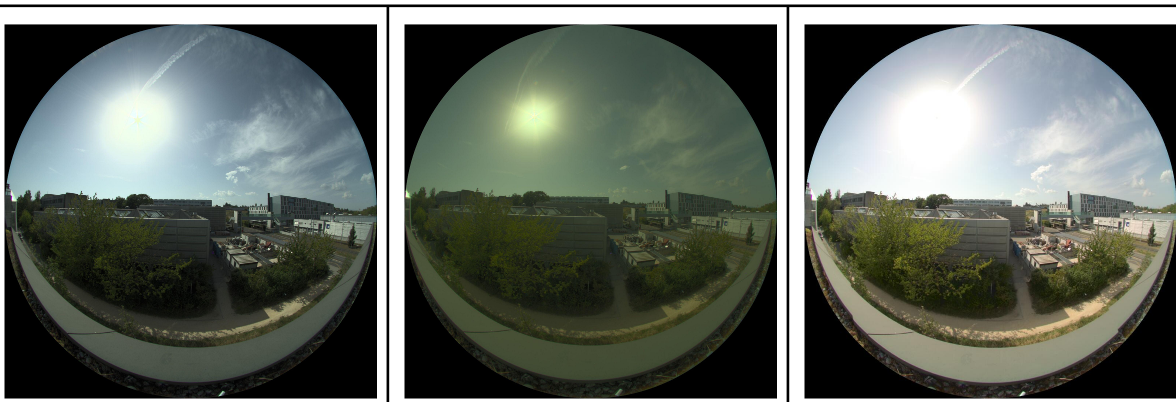


Figure 12. The display of the 148 scenes constituting a dataset using QGIS

Of the 148 different scenes collected, 24 were taken in the Ecublens / Chavannes-près-Renens area, and 124 in the city of Lausanne. This includes the following neighbourhoods: 47 scenes in Flon, 10 in Mousquines/Bellevue, 12 in Sébellion/Malley, 8 in Vennes and 44 in Vallon/Béthusy.

5. Discussion & Conclusion.

This study shows that capturing HDR images using the Shadowband tool and the methodology developed was effective for capturing reliable images. Three approaches are illustrated in the following Figure 13 (a,b,c). The first approach (a.) consists of a classic HDR capture with the sun in the field of view. This method has overflow pixels which do not constitute a reliable image. The second approach (b.) is to apply an ND filter directly to the lens. This filter offers a good alternative to the "overflow" phenomenon, allowing only 10% of the incident light to pass through. It is possible to get the sun at range using an ND filter, but due to the uncharacterised glare of the lens, it is still not possible to know the actual luminance as some of the energy has been scattered onto other pixels. Finally, the third approach (b.), using the Shadowband tool, avoids the two previous problems. The image is closer to the scene as perceived at the time of capture, without the issue of overflow.



a. b. c.

Figure 13. Three approaches when taking a scene with the sun

The advantages of capturing HDR with the Shadowband tool are that it avoids what is described in the literature as filter combinations, such as NF (no filter) + ND3, which is not a very reliable solution. Similarly, correcting overflow post-capture using illuminance measurements may turn out to be unreliable when based on variable measurements [3]. Furthermore, this process can be time-consuming if a large number of images are processed. The Shadowband tool is therefore a practical, accurate and fast response to the problem of overflow. Although this is an early version of the tool, the Shadowband helps to control the risk of overflow and is a reliable way of delivering HDR with the sun in the field.

The limits of this research are mainly the rapid variability of light conditions. It is difficult to obtain consistent results from the values indicated before and after with the LMT meter, particularly due to the capture time and the more or less rapid changes of light conditions. The ratio between time and light conditions is therefore extremely important. An efficient and short capture rate will reduce the risk of obtaining an excessive change in luminosity.

Other limiting factors such as movement during shooting or some dirt spots on the lens mean that the figure of 278 image captures has to be reconsidered. Around 61% of the images in the database do not present one of the 3 problems listed above, making a total of 170 captured. Although the Shadowband tool makes it easier to capture HDR images, it's important to remember that there are other factors that can affect the quality of HDR images.

In the same way, each scene was captured at least once, and other scenes from two to nine times under different time or weather conditions. In other words, slightly less than 54% of the images of the dataset have a second image for comparison. It would have been preferable to capture fewer scenes on a more regular basis in order to obtain a collection of several images of the same scene under different meteorological and temporal conditions.

One part of this research that is not mentioned is calibration when developing HDR images [8]. When it comes to reproducing reality correctly and reliably with cameras, it is necessary to make adjustments to the RGB values taken by the camera, which may vary from one sensor to another. Other calibrations such as the aperture size of the camera, in our example F11 and F22, or the capture speed need to be made to get as close as possible to the conditions in which the original scene was shot.

This research improves the imaging of simulations in daylight research by capturing the sun, as well as providing a usable dataset. A use would be its application in the field of view clarity, which studies the links between daylight and human visual perception and performance in relation to the building envelope. A concrete example would be to analyse and optimise a building's blind system. Another example would be to optimize the introduction of daylight into hospital spaces through the architectural design of the façade, in order to understand what can improve patient recovery.

It is this idea of being able to simulate views which capture the real in-situ image perceived by the human eye, that could provide a proto-tool for façade design for the architect. In other words, how a building will interact with its surroundings through HDR images could be a promising concept. This could make it possible to conceptualise spaces that are no longer exclusively functional but based on the human experience of interiors for their visual and luminous quality, recalling the importance of user-centric design.

With the shadowband tool and the methodology developed, this study shows that we now have a good basis for integrating HDR images not exclusively into daylight research but as an application tool to other fields such as facade design in architecture.

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