

The Possibility of Computer Software and Smart Phone Apps to Help with Lighting Designers ' Daily Jobs

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Abstract

The measurement of light quantity is the main method that many lighting experts rely on when assessing existing spaces. The numerical values are then interpreted and translated into quality terms. As luminance values are more relevant to what we see and experience, to qualify the lighting conditions of any lit environment by measuring luminance is much more important than designing by illuminance values alone.

In order to be able to use luminance as a primary measurement method, we need to measure the luminance value of each point by a luminance meter. This method will not be really feasible due to the need for a light stable condition, it is very time consuming and has the capacity for errors due to measurement uncertainties. Therefore, we need a tool that can capture the luminance values of the whole scene at the same time. A photo realistic HDR photography technique is the answer.

Since the introduction of more advanced digital imaging cameras, some effort has begun to develop physically-based HDR assembly software that produces images in which each pixel contains a realistic luminance value. Such software needs both digital cameras, and computers. However, when a smart phone is used, everything is contained in one device. This also includes GPS navigation units and motion sensors. Thus, we always have a luminance meter, GPS and compass in our hands. So, when dealing with the lighting design of an interior or exterior space, we can use our mobile phone to make a very fast and easy analysis within an acceptable accuracy range. Using such software/apps can help us to find basic statistics values like minimum, maximum, and mean luminance values of any area in the scene. Then, we can quickly and easily calculate the relevant contrast, uniformity, brightness, etc. of the scene.

Therefore, the main topic of this presentation focuses on how, when and where we can or should use luminance-based HDR images in either the already-built or the future-built environment. The tools and methods to create and analyze those images will be discussed. Relevant computer software and, more specifically, smart phone apps that can be used to do such analysis will be introduced and

their advantages and disadvantages of applying each of them in different stages of lighting design process will be briefly discussed.



Figure 1: A photo that is taken by Aftab Luminance iPhone app in Venice Architecture Biennale 2016. Such a photo realistic HDR image can help us to get the luminous information of any environment immediately.

Introduction

As a lighting designer, we generally work with two types of projects; new development or already existing spaces. Within this framework, there are also two types of spaces; interior or exterior. For exterior projects, there are usually external “spill” lights that come from the neighboring spaces and it is crucial to consider them in our design. Spill light is usually emitted from electric light sources, thus they are defined as static light. Since they are not changing rapidly, taking care of such unwanted light is much easier than dynamic lights.

When working with static lighting design projects, we need to measure existing light quantity to assess those spaces. The numerical values are then interpreted and translated into quality terms. Therefore, we need a tool that helps us to measure and estimate the light and daylight level in the specified spaces.

Interior spaces also provide an interesting lighting design challenge because such spaces are not usually isolated from outdoor conditions. The yearly daylight availability of the space is an important factor when creating lighting designs. Regarding the ever-changing characteristics of daylight, such analyses should be considered dynamic.

Since the introduction of the more advanced digital imaging cameras, some effort has begun to develop physically-based HDR assembly software producing images in which each pixel contains a realistic luminance value. Such software needs both digital cameras, and computers. However, when a smart phone is used, everything is contained in one device. This also includes GPS navigation units and motion sensors. Thus, we always have a luminance meter, GPS and compass in our hands. So, when dealing with the lighting design of an interior or exterior space, we can use our mobile phone to make a very fast and easy analysis within an acceptable accuracy range.

As the author of this paper has developed an iPhone app to create physically realistic HDR images, measure sunlight hours, Daylight Autonomy and Continuous Daylight Autonomy together with some other important functions, here the applicability of such mobile apps will be discussed more in detail.

Luminance versus Illuminance Analysis

The easiest, fastest and cheapest way of measuring light level is to measure the lux level with a lux meter. Most of the lighting standards use illuminance and not luminance when specifying their lighting requirements. However, since the luminance values are more directly related to what we see rather than illuminance values, luminance is more relevant when considering the visibility and, indirectly, the appearance of the space. However, for categorizing the space as daylit, partially daylit or non-daylit, illuminance values are more feasible.

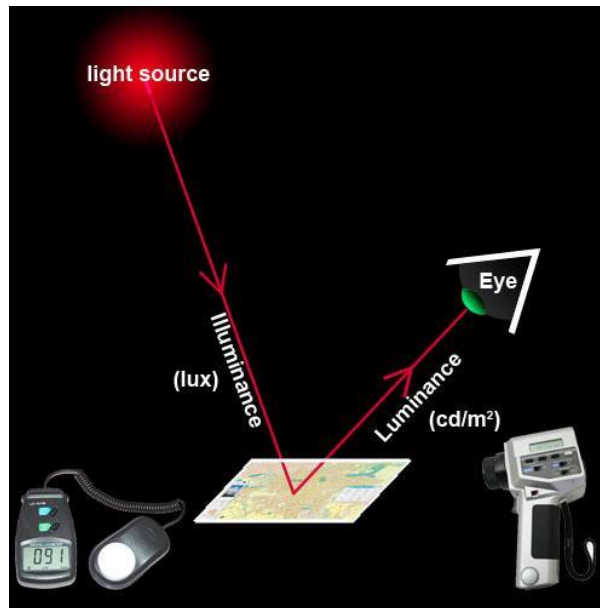


Figure 2: Luminance versus illuminance measurement

Static/Dynamic Light/Daylight Analysis

When analysing the lighting condition of any given space, depending on if it varies with the passage of time or not, it can be defined as a static or dynamic analysis. Since a scene that is lit up solely by electric light is not changing consistently, electric light analysis can be categorized as static.

However, regarding the daylight analysis, depending on whether a single or a series of consecutive sky conditions is considered, it can be divided further into static and dynamic methods. The conventional static daylight simulation is based on a specific date and time. However, as natural daylight is extremely dynamic, static daylight simulations are only of limited usage.

Static

Ignoring the changes of the sky luminances (such as changes in moon phases, and cloudiness of the sky, etc.) we can consider the nighttime as static sky condition and all the analysis that are done during this time period can be categorized as static analysis. Moreover, any analyses for spaces that are lacking enough natural light can be chosen as a static analysis as well.

In any type of exterior lighting design projects, such as façade, park and street lighting design, we need to take into account the surrounding lighting conditions. Therefore, doing a luminance based lighting analysis of the space can be a solution.

In order to be able to use luminance as a primary measurement method, we need to measure the luminance value of each point by a luminance meter. This method

will not be really feasible due to the need for a light stable condition. It is also very time consuming and has the capacity for errors due to measurement uncertainties. Therefore, we need a tool that can capture the luminance values of the whole scene at the same time. A photo realistic HDR photography technique is the answer.

HDR Images

Around a decade ago, more advanced digital imaging cameras were introduced to the market. Since then most of the cameras that are available in the market have limitation to capture a large dynamic range of luminance in a realistic scene. Therefore, we need computer software to assemble a sequence of LDR (low dynamic range) photos taken by them to create a HDR (high dynamic range) image which includes the whole range. In such HDR images, each pixel is corresponding to a realistic luminance value. However, there is another way to create HDR images for virtual spaces by using physically-based rendering tools such as Radiance, Dialux-evo, Relux-pro, etc. Then we can use such an HDR image to assess the lighting condition of any spaces by performing some post-process analysis with per-pixel data analysis techniques.

Available HDR Assembly and HDR/Daylight Analysis Tools

There are some available physically based HDR image assembly tools. Some of them can also analyze HDR images too. Some of them are mentioned in the below table.

	HDR Assembly	HDR Analysis	Operating System	Internet Address
Photosphere	✓	✓	Mac OS X	http://www.anywhere.com/
WebHDR	✓	X	via Internet ¹	http://www.jaloxa.eu/webhdr/
Aftab	✓	✓	MS Windows/IOS ²	http://aftabsoft.net/
Wxfalsecolor	X	✓	MS Windows	http://tbleicher.github.io/wxfalsecolor/
HDRscope	X	✓	MS Windows	http://courses.washington.edu/hdrscope/

Table 1: Comparing the function and operating system of some HDR software

In order to analyze any space with the help of HDR photos, computer software is needed that is able to process HDR image assembly and to be able to compute the analysis. Therefore, to do so, we would need both digital cameras, and computers. On the other hand, all this can be done using mobile phones. When a smart phone is used, everything is contained in one device. So, when dealing with the lighting design of an interior or exterior space, we can use our mobile phone

¹ It uses Photosphere as its assembly engine.

² As the Iphone App is newly developed by the author, at the time of writing this paper it cannot compete other computer software regarding stability and accuracy.

to make a very fast and easy analysis within an acceptable accuracy range. Using such software/apps can help us to find out some basic statistics values like minimum, maximum, and mean luminance values of any area in the scene. Then we can calculate the relevant contrast, uniformity, brightness, etc. of the scene.

Probable Errors, Problems or Mistakes When Taking HDR Photos

While using either DSLR cameras or smartphones, there are some probable errors and mistakes that could happen when creating luminance based HDR images. They are as follows:

- Image mis-alignment due to movement of camera
- Changes in direction and/or level of (natural) light during capturing process
- Lens vignetting effects
- Lens flare effects
- Luminous overflow

Moreover, there are some advantages and disadvantages based on using DSLR cameras or smartphones for HDR assembly. Some of them are listed below:

Advantages, and Disadvantages When Taking HDR Photos with DSLR Cameras:

Advantages:

- The possibility to use different lenses (such as a variety of fisheye lenses, etc.)
- In case of using a full frame sensor DSLR cameras with higher resolution the quality and accuracy can be higher.

Disadvantages:

- Needs to have an external computer software (like Photosphere, Aftab, etc.) to assemble LDR photos and create an HDR image ->
So it is not fast to read the luminance values right after taking photos

Advantages, and Disadvantages When Taking HDR Photos by Smartphones:

Advantages:

- No needs to have a external computer software (like Photosphere, Aftab, etc.) to assemble LDR photos and create an HDR image ->
Easy to read the luminance values right after taking photos

Disadvantages:

- The possibility of using different lenses (such as a variety of fisheye lenses, etc.) is low.
- The quality and accuracy of smart phone camera images sensors is less than DSLR cameras.

The main concern of this paper is to introduce a new iPhone app that is

developed by the author. A discussion of its ability to help lighting designers, professionals, students or even lighting experts, with different types of Per-Pixel Data analysis and luminance based rules and recommendations that can be done with HDR images, and that are available in this app are mentioned in the following:

Per-Pixel Data Analysis

We can use per-pixel luminance data of any photo realistic HDR images to quantify or even qualify the lighting conditions of the space.³ There are different types of analysis of a luminous environment that can be obtained from an HDR image. Those analyses that are possible to do in the Aftab Luminance iPhone app (at the moment) are as follows:

- Single image analysis
 - We can do the following analysis for the whole image or we can do it just for a region or regions of interests like visual field of view.
 - Numerical analysis
 - Visually
 - It shows luminance (or illuminance) distributions and can be demonstrated as false color images with different color pallets.
 - Mathematically/statistically
 - The whole or part of a scene
 - By finding the maximum, minimum, average, and median of the scene, we can calculate the luminance ratios, luminance contrast, or some other statistical analyses.
 - Task to background luminance ratio
 - Find the ratio between a task, and immediately adjacent surrounding or remote (non-adjacent) surfaces.
 - Luminance to brightness conversion
 - The link between brightness and luminance in a scene follows a power law. Its formula is $B=kL^n$ where B is the brightness magnitude, K is a constant, L is the luminance of the stimulus (cd/m^2), and N is an exponent ⁴
 - Although the differences for the value of the exponent between different people are large, “for small targets subtending less than 2° , in dim surrounds, the exponents found by different experimenters range from 0.23 to 0.31.”⁵
 - Human visual sensitivity simulation
 - To approximate the appearance of a high dynamic range image in a low dynamic range image based on the human visual sensitivity properties, a tone-mapping operator can applied.

³ Mehlika Inanici, 2005, p. 4

⁴ Peter Boyce, 2014, p. 198

⁵ Peter Boyce, 2014, p. 198



Figure 3: FalseColor page in Aftab Luminance iPhone app. It shows the falsecolor images with different pallets. It also gives us the minimum, maximum, average and median luminance value of the whole image.

Here, it is worth mentioning that there are some other Per-Pixel Data Analyses that we cannot perform with this app at the moment, but some computer programs that are already introduced here are able to do so. However, as we are able to save the HDR images that created by Aftab Luminance app into our computers, the following analyses that cannot be done directly in this iPhone app, can be easily performed with those computer programs.

Creating iso-counter lines, or iso-counter bands images, histogram diagram of the image, finding the Standard Deviation of the whole or part of the HDR images (i.e. Standard Deviation of the window luminance⁶), Mean Luminance of 40° Horizontal Band⁷ are some examples of what the computer software can do but this app cannot.

Moreover, those programs can also help us with Glare/Sparkle analyses as well as Masking analyses. HDR images combination, subtraction, or multiplication that are useful in a test lighting with a limited number of fixtures by creating an HDR image that includes all the fixtures in all positions are other examples of applications that this iPhone app is unable to do, but computer programs can.

⁶ M Inanici, KVD Wymelenberg, 2015, p. 11

⁷ M Inanici, KVD Wymelenberg, 2015, p. 11

HDR Image Base Daylight Coefficient⁸, HDR Image Based Rendering⁹ (that is based on including realistic sky with surrounding conditions by importing an 180° fisheye HDR image into the simulation), and finally Spatial Contrast¹⁰ are some more advanced analyses that can not be done in this app.

Rules and Recommendations

Some of the regulations and recommendations that can be handled by measuring luminance values in this app are as follows:

- Measuring the minimum acceptable and preferable background luminance (surrounding walls and ceilings) for the offices (30 cd/m² for the former and between 60 cd/m² and 100 cd/m² for the latter^{11, 12, 13})
- Measuring the following luminance ratios for offices:
 - o Between a paper task and an adjacent Visual Display Terminal (VDT) screen: 3:1 or 1:3.
 - o Between a task and immediately adjacent surroundings: 3:1 or 1:3.
 - o Between a task and remote (non-adjacent) surfaces: 10:1 or 1:10¹⁴.
- Measuring obtrusive light permitted for exterior lighting installation based on the CIE 150:2003 or other standards such as EN-12464-2
- Measuring average road luminance and longitudinal uniformity of road surface luminance in regard to the road lighting standard like EN-13201

Dynamic

Since we cannot make a valuable assessment, especially for an interior space, without including daylight in our analysis and it is not easy for any electric light to compete daylight in any daylit spaces, there should be a different lighting design for a daylit or non daylit zone.

In contrast to static daylight metrics, dynamic daylight performance metrics are based on a full or a specific period of yearly analysis rather than snapshot of specific condition at a specific instant. Such analyses consider hourly, daily and seasonal daylight variation for the specified interior or exterior space. Therefore, dynamic daylight simulation methods yield the time development of indoor or outdoor luminance, illuminances or irradiances under multiple sky conditions usually by including the weather data file of the place.¹⁵

⁸ Mehlika Inanici, 2013,, p. 3392

⁹ Mehlika Inanici, 2009, p. 369

¹⁰ Andersen M, Rockcastle S, 2014, p. 320-333

¹¹ W. Dau, G., et al., 2012, p. 8

¹² Sheedy et.al., 2005, p. 1127

¹³ Goven. et. al., 2007

¹⁴ W. Dau, G., et al., 2012, p. 8

¹⁵ C.F. Reinhart, J Mardaljevic & Z Rogers, 2006, p. 13

When dealing with daylight condition in the interior spaces, the easiest way to categorize the space based on the daylight access is to use computer simulation and measure dynamic daylight metrics such as Daylight Autonomy, Useful daylight Illuminance, etc. From all types of dynamic daylight metrics, Daylight Autonomy and Continuous Daylight Autonomy that can be measured in this app is shortly explained here. Doing a Daylight Autonomy analysis can help us to define each point of the space as daylit, partially daylit or non-daylit.

Daylight Autonomy (DA)

The Daylight Autonomy is a dynamic daylight performance measured at a certain point in the building. It is defined as the percentage of occupied hours per year, when the minimum illuminance level can be maintained by daylight alone. Similarly, it can also infer how many hours per year we can switch off electrical lights. To calculate Daylight Autonomy, all sky conditions throughout the year are considered. Finally by doing Daylight Autonomy analysis, we can assess the design when considering both visual quality and energy usage in the building.

Continues Daylight Autonomy (DA_{con})

In contrast to daylight autonomy, in addition to those hours that fulfil the required daylight illuminance level, partial credit is counted for those hours of the year that the daylight illuminance becomes below that minimum acceptable level. For example, when we need 300 lux as a minimum for office lighting, but we received around 200 lux from daylight alone for a specific hour of year on a specific point in the space, a partial credit of $200/300=0.67$ is given to that point and hour. Therefore, instead of having hard border compliance and non-compliance, the transition between them becomes softer. This means that DA_{con} is always higher than DA for any point in any spaces.

Possibility of Daylight Analysis in Smartphones

Generally all smartphones have GPS navigation units, accelerometers/ gyroscope sensors, and cameras together with touch-screen displays, and good CPUs and internal memories. Thus it makes it possible for us to always have a luminance meter, GPS and compass in our hands.

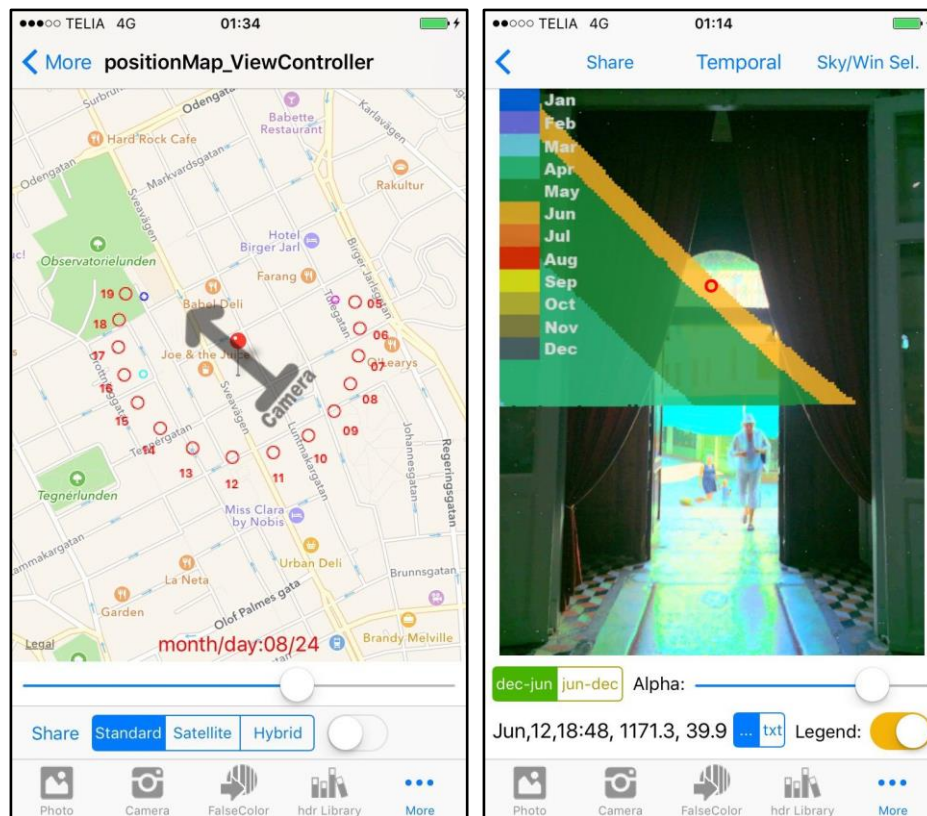


Figure 4: Left image: Horizontal Sun Position Map page; Right image: Sunpath Diagram for the period between 21st of December and 21st of June in the SunPath Diagram page.

By knowing geographical specification of the space, obstructions, the size, position and orientation of all fenestrations that are visible from camera point, and the windows glass visible light transmission and the average reflection factor of all internal surfaces, we can guess the temporal daylight illuminance variation of each point in the space in every hour of a year. Therefore this method that has some similarities with Lumen Method¹⁶ is applied by the Aftab Luminance iPhone app. So, we can measure the daylight level of any points in a space for every hour of a year with this app. Accordingly we can measure Daylight Autonomy (DA) and Continuous Daylight Autonomy of that specified point too.

¹⁶ Lumen method is a simplified method that helps to measure the light level in a room.

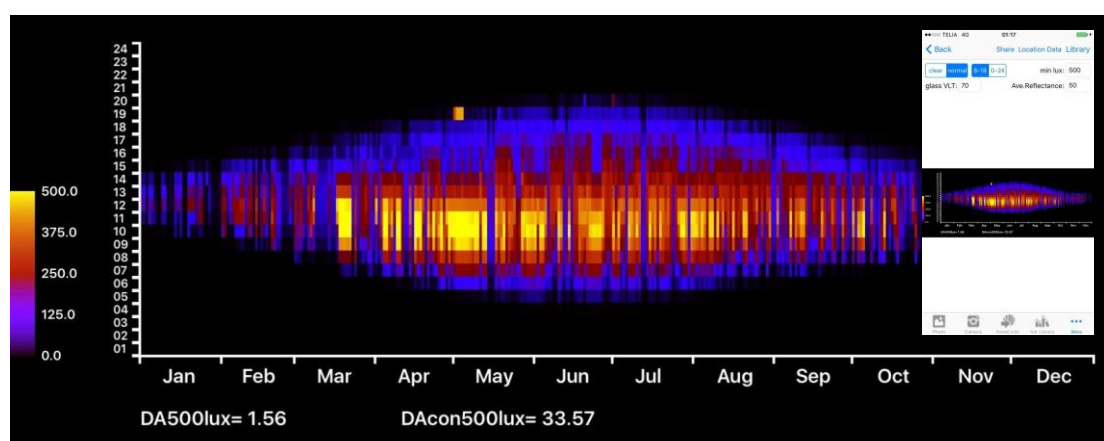


Figure 5: Temporal mapping diagram created in the Temporal Mapping page in the Aftab Luminance iPhone app. In this page, we can also estimate DA, DA_{con} , and sunlight hours for the camera point in the space.

Daylight Analysis Applications in Real Lighting Design Projects

Regarding IES LM-83-12 recommendations and other studies measuring daylight Autonomy and Continuous Daylight Autonomy, we can define any points in a space as daylit, partially daylit, or non-daylit. Such an analysis can help us for better understanding and evaluating the space and also to make a base for our lighting design concept, and grouping the lighting fixtures to control.

Smartphone Apps in Lighting Design Process

At first, we should define the most relevant spots and views in the space (step A). Then regarding if it is exterior or interior (step B), we can divide our analysis based on static (usually with artificial light) or dynamic (mostly with natural light) (step C). If we are dealing with an exterior space, and regarding daylight condition of the space what we can do with this app is to create a daily sunpath diagram that shows horizontal position of the sun for every day of a year. However, regarding electric light for exterior projects, by taking photo realistic HDR photos, we can evaluate the space by considering each of these three factors: Functions (obtrusive light or glare, step D2), Environment (light pollution, step D3), and Aesthetics (Unwanted light on the surfaces, and assessing highlights and contrasts, step D5). For the first two, measuring luminance works well, however, for the Aesthetic, if we convert the luminance values to brightness values and assessing the highlights and contrasts, our assessment will be more relevant.

When working with interior spaces, to achieve a more holistic lighting design, we need to take into account both electric and natural light together by measuring Daylight Autonomy (DA), Continuous Daylight Autonomy (DA_{con}), or sunlight hours. Then we can categorize any points of the space as daylit, partially daylit, non daylit, or with excessive daylit (step D7). Similarly to steps D2, D4, and D5,

measuring luminance or brightness can help us in functional (step D9) or aesthetical lighting design (steps D10 and D11). Moreover, wherever that we measure luminance, it can help us to educate ourselves with a better understanding of luminance values and its relationship with brightness, glare, sparkles and dull spaces (step D6 and D12).

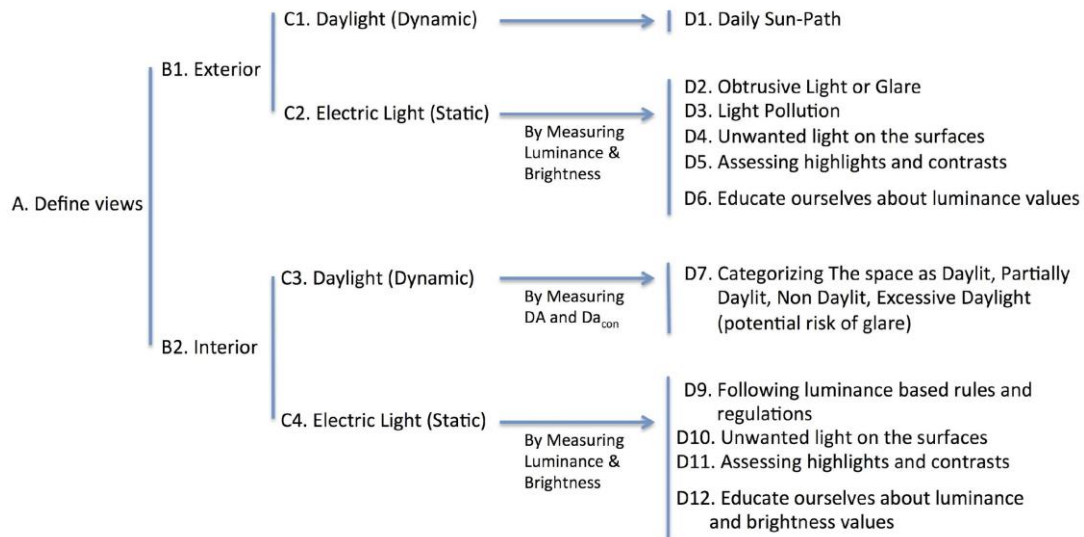


Diagram 1: Using Aftab Luminance iPhone app during a lighting design process

Conclusion

Using smartphones apps can help us in different ways in our daily lighting design work. Some of the most useful areas are as follows:

- Checking if the spaces are compliant with luminance based rules and recommendations immediately on site
- How luminance-based analysis (by measuring luminance and brightness) can help us to understand the lighting condition of the space.
- To educate ourselves with a better understanding of luminance values (points value, maximum, minimum, mean and median value of a scene) and its relationship with brightness, glare, sparkles and dull spaces (the relationship between luminance based false color images and the quality of the space at the same time that we are in the space).
- Finding out and highlighting the problematic areas of each space regarding the light distribution or inconsistency in color of light by taking HDR photos of any scene.
- By measuring DA, DA_{con} , and sunlight hours, we can categorize the camera point and accordingly the whole or some part of the space as daylit, partially daylit and non-daylit. It can help us when doing light planning for that space.
- By creating sunpath diagrams for each specific camera point and direction in the space, we can estimate the probability of disability glare for the whole year on that given camera point.

References

- Majid Miri, Luminance-based HDR photos to help lighting designers in their everyday work, PLDC conference, 2015
- Van den Wymelenberg K and Inanici, M. Evaluating a New Suite of Luminance-Based Design Metrics for Predicting Human Visual Comfort in Offices with Daylight, *Leukos: The Journal of the Illuminating Engineering Society of North America*, 2015.
- Siobhan Rockcastle, Marilynne Andersen, Measuring the dynamics of contrast & daylight variability in architecture: A proof-of-concept methodology, *Building and Environment*, 2014, page 320-333
- Christoph F. Reinhart, John Mardaljevic, and Zack Rogers, Dynamic Daylight Performance Metrics for Sustainable Building Design, *LEUKOS*, v. 3, no. 1, 2006, page 1-25