Topic 6 - Optics – Depth of Field and Circle Of Confusion

Learning Outcomes

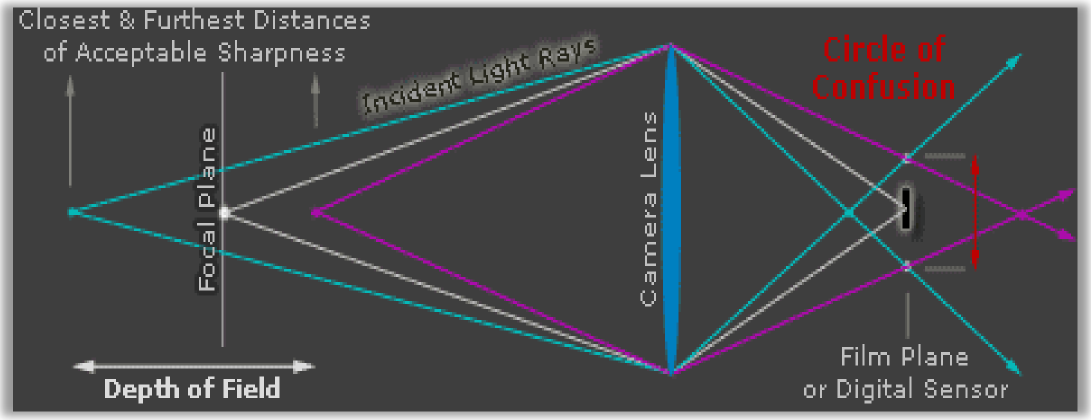
In this lesson, we will learn all about depth of field and a concept known as the Circle of Confusion. By the end of this lesson, you will have a much better understanding of what each of these terms mean and how they impact your photography.

Advanced Photography

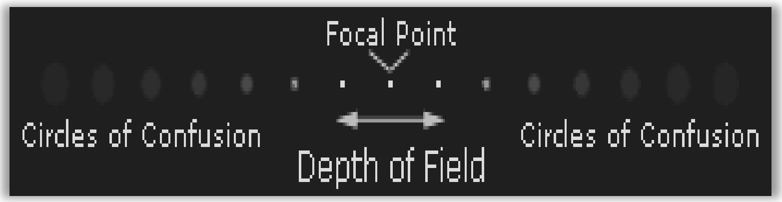
Depth of Field

Depth of field refers to the range of distance that appears acceptably sharp. It varies depending on camera type, aperture and focusing distance. The depth of field isn't something that abruptly changes from sharp to unsharp/soft. It happens as a gradual transition. Everything immediately in front of or behind the focusing distance begins to lose sharpness, even if this is not perceived by our eyes or by the resolution of the camera.

Circle of Confusion (CoF)



The term called the "**circle of confusion**" is used to define how much a point needs to be blurred in order to be perceived as unsharp, due to the fact that there is no obvious sharp point in transition. When the circle of confusion becomes perceptible to our eyes, this region is said to be outside the depth of field and thus no longer "acceptably sharp." The circle of confusion in this example has been exaggerated for clarity; in reality this would only be a tiny portion of the camera sensor's area.



When does this circle of confusion become perceptible to our eyes? Well, an acceptably sharp circle of confusion is loosely defined as one which would go unnoticed when enlarged to a standard 8x10 inch print, and observed from a standard viewing distance of about 1 foot.

At this viewing distance and print size, camera manufacturers assume a circle of confusion is negligible if no larger than 0.01 inches, when enlarged. As a result, camera manufacturers use the 0.01 inch standard when providing lens depth of field markers. In reality, a person with 20/20 vision or better can distinguish features 1/3 this size, and so the circle of confusion has to be even smaller than this to achieve acceptable sharpness throughout.

A different maximum circle of confusion also applies for each print size and viewing distance combination. In the earlier example of blurred dots, the circle of confusion is actually smaller than the resolution of your screen for the two dots on either side of the focal point, and so these are considered within the depth of field. Alternatively, the depth of field can be based on when the circle of confusion becomes larger than the size of your digital camera's pixels.

Bokeh

The depth of field only sets a maximum value for the circle of confusion, and does not describe what happens to regions once they become out of focus. These regions are called “bokeh”. Two images with identical depth of field may have significantly different bokeh, as this depends on the shape of the lens diaphragm. In reality, the circle of confusion is usually not actually a circle, but is only approximated as such, when it is very small. When it becomes large, most lenses will render it as a polygonal shape with 5-8 sides.

Controlling Depth of Filed

Although print size and viewing distance influence how large the circle of confusion appears to our eyes, aperture and focusing distance are the two main factors that determine how big the circle of confusion will be on your camera's sensor. Larger apertures, with smaller F-stop number, and closer focusing distances create a shallower depth of field.

Focal Length vs Depth of Field

You will have noticed that the focal length has not been listed as influencing depth of field, contrary to what you might think. Even though telephoto lenses appear to create a much shallower depth of field, this is mostly because they are often used to magnify the subject when one is unable to get closer. If the subject occupies the same fraction of the image (constant magnification) for both a telephoto and a wide angle lens, the total depth of field is practically constant with focal length. However, this would require you to either get much closer with a wide angle lens or much farther with a telephoto lens.

Limitations

There is a limitation with the traditional DoF concept in that it only accounts for the total DoF and not its distribution around the focal plane, even though both may contribute to the perception of sharpness. A wide angle lens provides a more gradually fading DoF behind the focal plane than in front, which is important for traditional landscape photographers. Longer focal lengths may also appear to have a shallower depth of field because they enlarge the background relative to the foreground (due to their narrower angle of view). This can make an out of focus background look even more out of focus because its blur has become enlarged.

However, this is another concept entirely, since depth of field only describes the sharp region of a photo and not the blurred regions. On the other hand, when standing in the same place and focusing on a subject at the same distance, a longer focal length lens will have a shallower depth of field. This is more representative of everyday use, but is an effect due to higher magnification, and not the focal length. Depth of field also appears shallower for SLR cameras than for compact digital cameras, because SLR cameras require a longer focal length to achieve the same field of view. We describe depth of field as being *practically* constant, due to the fact that there are such few cases where this does not hold true.

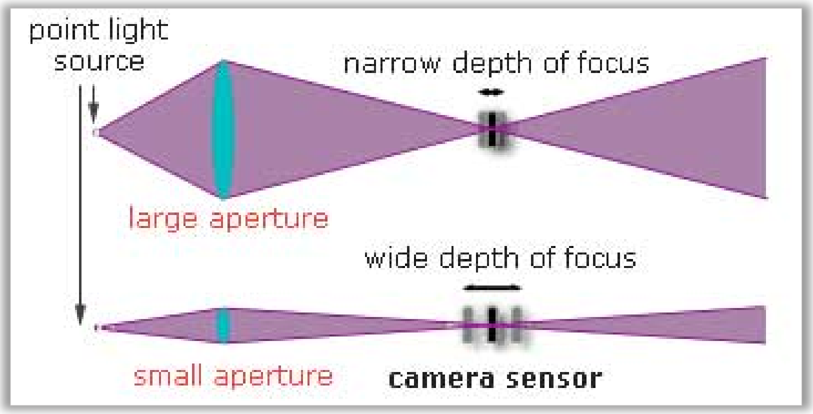
For focal distances resulting in high magnification, or very near the hyperfocal distance, wide angle lenses may provide a greater DoF than telephoto lenses. On the other hand, at high magnification, the traditional DoF calculation becomes inaccurate due to another factor: pupil magnification. This reduces the DoF advantage for most wide angle lenses, and increases it for telephoto and macro lenses. At the other limiting case, near the hyperfocal distance, the increase in DoF arises because the wide angle lens has a greater rear DoF, and can thus more easily attain critical sharpness at infinity.

Calculating Depth of Field

In order to calculate the depth of field, one needs to first decide on an appropriate value for the maximum allowable circle of confusion. This is based on both the camera type (DSLR or film size), and on the viewing distance / print size combination. Naturally, it's very difficult to know this information ahead of time.

Depth of Focus and Apertur Visualization

Another implication of the circle of confusion is the concept of depth of focus. Some know it as 'focus spread'. It differs from depth of field because it describes the distance over which light is focused at the camera's sensor, as opposed to the subject.



Source: cambridgeincolour.com

This diagram shows the depth of focus versus camera aperture. The purple lines comprising the edge of each shaded region represent the extreme angles at which light could potentially enter the aperture. The interior of the purple shaded regions represents all other possible angles.

The key concept is this: when an object is in focus, light rays originating from that point converge at a point on the camera's sensor. If the light rays hit the sensor at slightly different locations (arriving at a disc instead of a point), then this object will be rendered as out of focus — and increasingly so depending on how far apart the light rays are.

Conclusion

Why not just use the smallest aperture (largest number) to achieve the best possible depth of field? This may require prohibitively long shutter speeds without a camera tripod and too small of an aperture softens the image by creating a larger circle of confusion (or "Airy disk") due to an effect called diffraction — even within the plane of focus. Diffraction quickly becomes more of a limiting factor than depth of field as the aperture gets smaller.

For **macro photography** (high magnification), the depth of field is actually influenced by another factor: pupil magnification. This is equal to one for lenses which are internally symmetric, although for wide angle and telephoto lenses this is greater or less than one, respectively. A greater depth of field is achieved for a pupil magnification less than one, whereas the pupil magnification does not change the calculation when it is equal to one. The problem is that the pupil magnification is usually not provided by lens manufacturers, and one can only roughly estimate it visually.

What have we learned in this lesson? A Summary

We have learned about how depth of field and the circle of confusion work in photography. We have also learned about an effect known as the bokeh technique, something which is popular among photographers and occurs as a result of the Circle of Confusion.