DEPTH OF FIELD IN PHOTOGRAPHY

Handout for Photography Students
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WHAT IS DEPTH OF FIELD? Photographers generally have to deal with one of two main optical issues for any given photograph:

Motion (relative to the film plane) and Depth of Field. This handout is about Depth of Field. But what is it?

Depth of Field is a major compositional tool used by photographers to direct attention to specific areas of a print or, at the other extreme, to allow the viewer's eye to travel in focus over the entire print's surface, as it appears to do in reality. Here are two example images.

Depth of Field Examples

Shallow Depth of Field
using wide aperture
and close focal distance

Deep Depth of Field
using small aperture
and greater focal distance

SURPRISE! IT'S ALL AN ILLUSION

The first image (the garden flowers on the left) was shot with a wide aperture and is focused on the flower closest to the viewer. The second image (on the right) was shot with a smaller aperture and is focused on a yellow flower near the rear of that group of flowers.

Though it *looks* as if we are really increasing the area that is in focus from the first image to the second, that apparent increase is actually an optical illusion. In the second image there is still only one plane where the lens is critically focused.

Everywhere else — in front of or behind that plane of critical focus — is actually *out* of focus, increasingly so the further away it is from that point of focus. So why does it look sharp if it isn't?

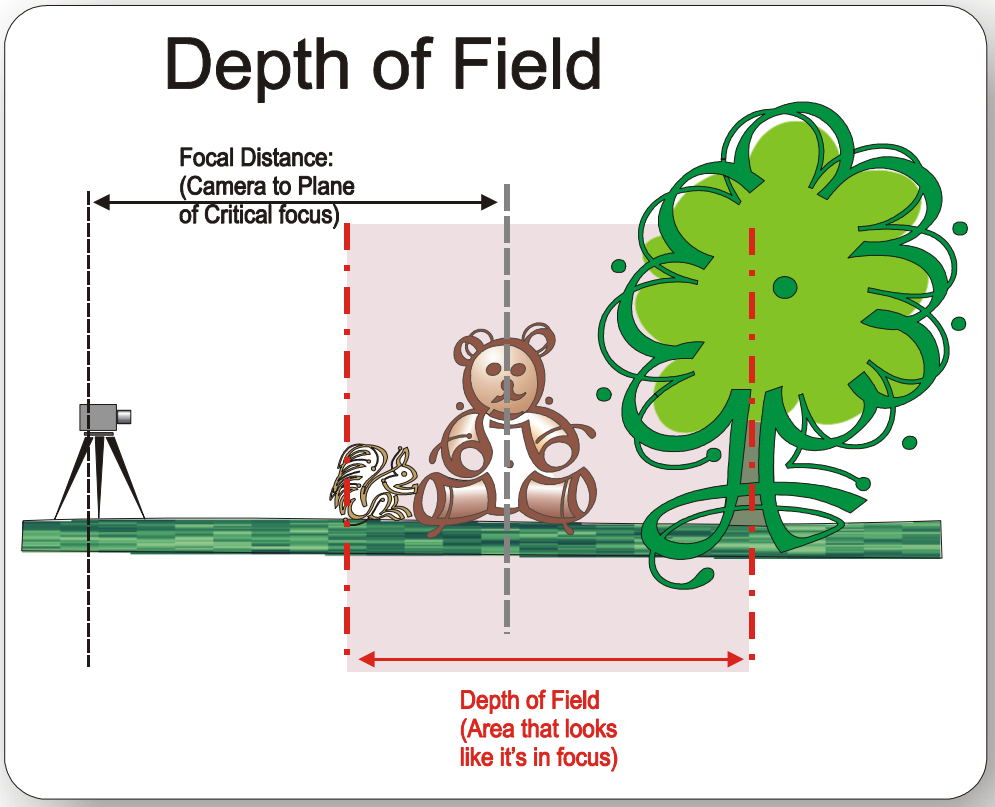
This illusion of sharpness happens because of a nearly universal limitation in the resolution of the human eye. **Typically we humans cannot resolve detail smaller than about 1/200th of an inch.**

That means, for example, if you looked at an area created by lines and spaces where both the lines and the spaces between the lines that were less than 1/200th of an inch you would see it as a solid block; if the lines and spaces were larger than 1/200th of an inch you could see the individual lines and spaces.

WHAT AND WHERE IS THE DEPTH OF FIELD?

That area from *in front of* the point or plane of critical focus to *behind* the point of critical focus that *appears* to be focused on the print is called the "Depth of Field." It is often called the "range of acceptable sharpness."

It extends about twice as far behind the point of critical focus as it does in front of it. Following is an illustration showing this



But how can all this have an effect on a photograph when the grains of silver in the emulsion or the photosites on a sensor are microscopic in size? Well, it's the lens' fault.

CIRCLES OF CONFUSION

When an image is transmitted through a camera lens, each point of light reflecting from the subject is projected on the film plane[1] as a circle. Those circles of projected light are called "Circles of Confusion" … an apt name and not to be confused with confused people standing in a circle.

If those circles, when enlarged *on a print*, are 1/200th of an inch or smaller, most of us will see that part of the image as sharply focused. If they are larger than 1/200th of an inch it will appear out of focus. The larger the

[1] The Film Plane is also known as The Focal Plane or now in the digital age, the Image Plane..

circle, the more out of focus the image will look.

"Fascinating… but so what?" you ask.

WHAT IS SO SPECIAL ABOUT DEPTH OF FIELD

Depth of Field is an optically created phenomenon. Consequently photography is the only art medium that can render selected areas as either sharply focused, apparently in focus, or out of focus. This ability gives photographers a powerful visual tool to guide the viewer's eyes and attention to the desired subject.

Painters's eyes refocus instantly so their perception is that everything is in focus so that is what they paint. So this is an exclusively photographic tool.[2]

WHY DON'T OUR EYES SEE DEPTH OF FIELD?

So, if our eye is actually a sort of lens, why don't we see this Depth of Field? Why don't we see only one thing in focus and the rest of the world blurry?

Well, actually we do.

Like a camera lens, our eye can only focus on one plane in space at a time. You can prove this by focusing on something close then letting your peripheral vision become aware of the things at greater distance without changing focus. Those things at greater distance will be obviously blurry.

But we humans have something the camera doesn't have: a brain.

Well some of us do, anyway. And for those that do, the brain directs an amazing function. As we scan a scene from front to back, say a landscape, our brain causes our eyes to nearly instantly refocus as they pay attention to various areas. The effect is we think we see everything in focus because no matter where we look it IS in focus. But it is our brain that accomplishes it.

For a lens without a brain, we need to try something very different in order to accomplish the same "sense" of how we see a print as how we see the original.

[2] A school of painting called "Photo-Realistic" painting attempts to replicate this by painting from photographs and copying the out of focus areas, but it is nearly impossible to actually paint something out of focus based on human vision alone.

WHAT EFFECTS DEPTH OF FIELD?

Well, it turns out that there are several things that effect how large those circles of light are going to be on the final image.

By controlling those variables we can control how much something looks like it is in focus. And by doing that, we can direct viewer attention to various parts of the image since it is literally painful for the optic nerve when it tries to focus something on a print that cannot be focused since it is already OUT of focus.

By controlling the size of those confusing circles we can create an illusion of sharpness, that is, we can make it look like an area is in focus when in fact it is not.

There are basically four things that can have an effect on the Depth of Field of a given photographic print. They are…

1. **The Focal Length of the lens being used.**
2. **The Focal distance (in simple terms, the distance from the camera to the subject).**
3. **The Aperture (f-stop) of the lens being used. And**
4. **The degree of enlargement of the final print.**

Let's examine these influences one at a time.

EFFECT OF LENS FOCAL LENGTH

The focal length of the taking lens has a major impact on the Depth of Field of the final photograph. The basic rule is straightforward:

The SHORTER the Focal Length of the lens, the DEEPER the Depth of Field.

Wide-angle lenses, in small format terms, lenses with focal lengths of approximately 35mm or wider, show deep Depth of Field, especially compared to their telephoto brethren. Telephotos, those focal lengths of approximately 80mm and longer show shallow Depth of Field.

That is why landscapes with wide lenses generally show nearly everything in focus while animal shots taken with long telephoto lenses have such shallow Depth of Field

with all but the animal out of focus.

NOTE: It is important to note that the Depth of Field is based on lens focal length and not on the angle of view of a lens. A "Normal" lens on a 4x5" view camera is approximately 135mm. It has about the same angle of view as a 50mm lens for small format, but it has the same Depth of Field as a 135mm light telephoto would have when used on that small format camera.

EFFECT OF FOCAL DISTANCE

The distance the camera is from the subject also greatly influences Depth of Field[3]. The rule for this influence is:

The GREATER the Focal Distance, the DEEPER the Depth of Field.

That means that when you are photographing something where you are focusing at a distance, the Depth of Field extends deeply into the scene. It also explains why macro photography — the photography of images with about a 1:1 image to subject relationship — has such a shallow Depth of Field.

USING APERTURE TO CONTROL DEPTH OF FIELD

The third influence upon Depth of Field is the one most often used creatively by the photographer so it requires a more in-depth explanation.

The rule itself sounds simple enough:

The SMALLER the Aperture, the DEEPER the Depth of Field.

Rephrased to incorporate f-Stops, the rule would read:

The LARGER the f-stop number, the DEEPER the Depth of Field.

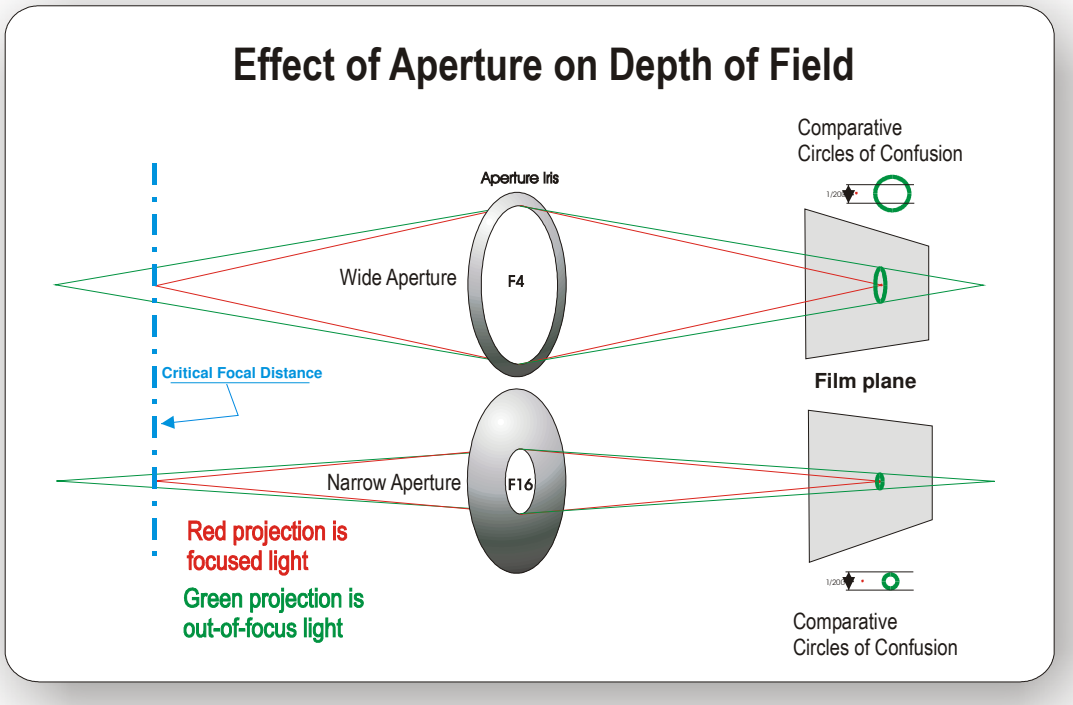
But why would changing the aperture of a lens have any effect whatsoever on the illusion of focus on a photographic print? Doesn't that just cut down on the

[3] The "Focal Distance" is technically the distance from the film plane (also called the focal–plane or the plane where the image is being focused by the lens) to the plane of critical focus. Note the illustration describing Depth of Field.

intensity of light falling on the photosensitive surface?

The answer is that changing the aperture size forces the light passing through the lens-set to change its angles and that has an effect on the size of the Circles of Confusion.

Look closely at the following illustration.



Remember, at the very first of this discussion we explained how the size of the Circle of Confusion projected by the lens will have an effect on what appears to be sharp on the image? It turns out that smaller apertures reduce the size of the Circles of Confusion being projected on the film's emulsion.

In the illustration above, the red lines are from a point of light at the Focal Distance. No matter what size the aperture is, it always is projected as a point of light on the film or chip.

But the green lines represent a point of light reflecting from something farther away from the lens than the Focal Distance. It then ends up being focused behind the Focal

Plane.

As the cone of light passes through the film it forms the Circle of Confusion for that point of light. By making the aperture smaller one constricts the diameter of the cone and the resulting circle. You can see this effect clearly in the illustration.

If, when those circles are enlarged on the print, they become larger than 1/200th of an inch that area will look as if it is out of focus (top portion of illustration).

However, closing down the aperture changed the angles of the light thereby creating smaller Circles of Confusion. If they remain smaller than 1/200th of an inch on the final print, it will look like they were in focus (bottom portion of illustration).

EFFECT OF IMAGE ENLARGEMENT

Despite the ease photographers enjoy of changing print size by simply sliding the enlarger up and down, the size of the print can greatly change the Depth of Field on a print and with it the whole composition. This sometimes catches the photography by surprise.

But the photograph was made in the camera. How can the enlargement of a print in the darkroom effect the Depth of Field? It's obvious once you think about the process of enlargement. In fact the *word* "enlargement" is the clue.

The actual Circles of Confusion on the film itself are measured not in hundredths but in thousandths of an inch. That is why contact prints always look so good and sharp and it is in the enlarged print that things start to fall apart.

As the image itself is enlarged, so are those circles of confusion. Depth of Field tables and charts, as well as the Depth of Field scale printed on some lenses, are all based on the making of an 8x10 inch print from the negative.

Smaller prints with minimal enalrgement, such as contact prints or even wallet prints, have smaller Circles of Confusion, but by the same token, larger prints have

larger Circles of Confusion.

So for an image where the Circles of Confusion were, say, 1/250th of an inch on an 8x10 print, and therefore appearing sharp and focused, the same circles might be 1/175th of an inch on an 11x14 and now starting to look soft. Increase the enlargement to 16x20 and they start to look *very* soft indeed.

That means that the expected or intended size of your desired final print needs to be taken into consideration when you adjust the variables to establish a given Depth of Field when you are taking the shot. It is as important to previsualization as are the tonalities of the image.

ACTUALLY THERE IS ONLY ONE MAJOR CONTRIBUTOR

Although we use a number of variables to control depth of field, the major influence is magnification of the subject at the image plane. Except for aperture issues of angles of light waves, all of the other factors boil down to the enlargement of the subject. Focal distance (camera to subject) effects depth of field the most followed by Focal Length of lens, Both of these effect Depth of Field because they make the subject larger or smaller on the film or sensor.

IF ALL THAT IS TRUE, WHY DO LARGE FORMAT PHOTOS OFTEN HAVE EXTRAORDINARY DEPTH OF FIELD?

Wait a minute, isn't there a problem here? If a large format camera is taking a normal view but with a lens that has the focal length of a telephoto on a small format, and it might be focused close-up for small product work, how can it create a photo with the extraordinary Depth of Field required by that kind of shooting?

Simple… it cheats.

Large format lenses have Depth of Field appropriate to their focal lengths but large format cameras have something small format cameras generally do not: they have the ability to tilt the plane of Depth of Field using the optical movements of the lens and film standards following something called the "Scheimpflug Effect."

But you'll have to wait for the large format class to learn how to do that.

THEN WHY DO DIGITAL POINT AND SHOOT CAMERAS SEEM TO HAVE GREATER DEPTH OF FIELD?

Digital images seem often to have much greater Depth of Field than film-based images, especially in the point and shoot type of cameras. But unlike large format view cameras, they don't have optical movements to tilt the plane of Depth of Field.

The reason is that the imaging chip is much smaller than the frame of film even in small format photography. A 135 frame is roughly an inch and one-half wide by an inch tall. But many chips are only 2/3rd of an inch, and sometimes smaller.

The lens that will achieve the same angle of view as a 50mm lens for small format film may actually only be 10mm or so. It will therefore have about the same Depth of Field as a 10mm extreme wide-angle or fisheye lens on the film format.

On the SLR-Type Nikon 5700, for example, the zoom lens's maximum lens focal length is actually only 75mm, but the angle of view is the same as a 300mm on a small format film camera.

CONCLUSION

Depth of Field is a powerful compositional tool that allows the photographer to isolate areas in a photograph or to give the viewer the same impression they have when viewing an actual scene. Few tools allow a greater amount of aesthetic flexibility and power.

When the photographer takes advantage of all of the influences available, and, for example, selects the shooting distance, the focal length of the lens, the aperture size, and also plans specifically for a given enlargement size, he or she has virtually unlimited variation in the Depth of Field they can achieve.

RELATED TOPICS

Related to this discussion of Depth of field are the following topics:

- Optical "Infinity" Point.
- Hyperfocal Distance
- "Zone" Focusing

INFINITY / INFINITY POINT

"Infinity" does not mean the same to a photographer as it does to a physicist (or even a theologian. For us, "infinity" as that distance in front of the camera which, if IT is in focus or within the depth of field, everything beyond it will also be acceptable sharp, i.e. within the depth of field.

Camera lens distance scales mark this using the icon for infinity which looks like the numeral "8" laid on its side:

"∞"

What is important to remember is that if the lens's infinity distance (or infinity point) is at the far edge of the depth of field, then it and everything beyond it will also be within the depth of field.

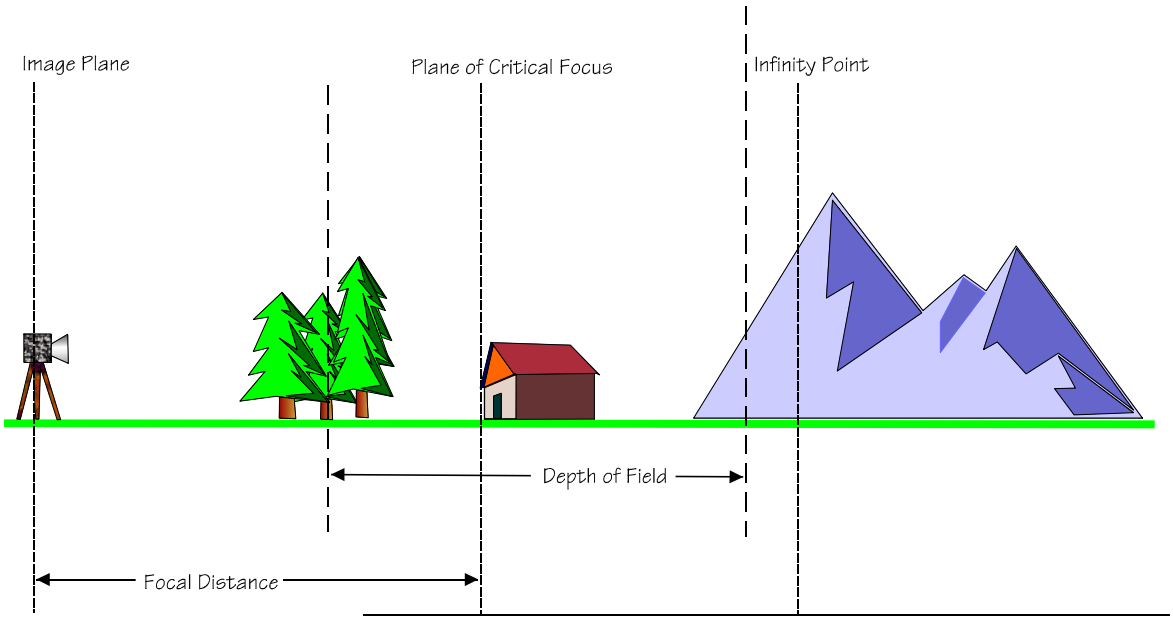
HYPERFOCAL DISTANCE

DEFINITION:

The "**Hyperfocal Distance**" is that focal distance (the distance from image plane to the plane of critical focus) at which, for a given *f*-stop, the far edge of the depth of field is at the infinity distance. It is the focal distance which, therefore, yields the greatest depth of field possible for a given lens focal length at specified *f*-stop.

So first a quick review of Depth of Field. In the illustration below, The plane of critical focus is the face of the structure. Using our hypothetical lens and aperture setting, the depth of field extends from the middle of the group of trees to the start of the mountain range.

The infinity point of the lens is just a little bit further into the mountains.



HYPERFOCAL DISTANCE, CONTINUED

HOW TO FIND IT:

In the "old days" of mechanical lens operation, each small and medium format lens contained a "Depth of Field" indicator. These were markings on either side of the central focus line indicating the depth of field near and far points for each potential aperture setting. These not only allowed you to see the near and far points of acceptable sharpness at any focal distance, when adjusted so that the far indicator line up with the infinity mark, that was the setting for the hyperfocal distance. It was simple and clear.

But now, with auto focus lenses and electronic aperture settings, those indicators are rarely marked on the lens barrel. It is a major loss although the usual response is that with good auto focus, who cares? Well, anyone who needs to know with some precision what is in focus or not cares.

Cameras still have a "depth of field preview" function but those are very difficult to see, especially with small sensor DSLRs. And they still do not indicate hyperfocal distance which, for landscapes and those shots needing maximum depth of field is still an issue.

In the film world, the only issue was focal length and so one 50mm lens could be seen as having the same depth of field as any other 50mm lens and therefore the same hyperfocal distance as well. Digital has thrown a small

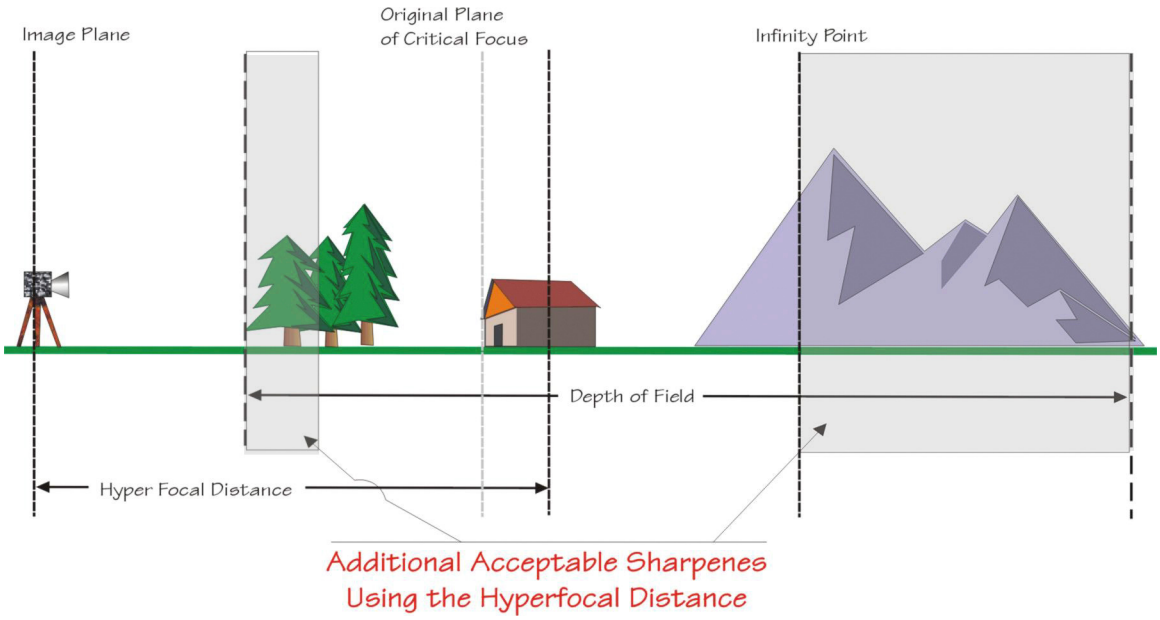
glitch into the mix since unlike film with a continuous emulsion, its photo sites are set up in a tabular array on the sensor and are of a fixed and finite size. If the circle of confusion for a given lens and aperture is larger than the photosite, then it changes the depth of field and hyperfocal distance… usually for the worse.

Unfortunately there are no simple, elegant, or easy solutions, but there are some ways to deal with it mostly thanks to the internet. You can download tables for each lens focal length and for specific digital camera bodies (which accommodates the circle of confusion issues without your having to know that data for your sensor or lenses. Some sites such as " www.dofmaster.com " offer online calculators and even apps to download to your smart phone or iPad/iPod Touch/Palm device to use in the field.

They tell you what the proper hyperfocal distance is for a specific lens and a specified aperture. But that still leaves an issue: if the hyperfocal distance is, say, 184 yards, can you look out onto your scene and know where that is?

The older lenses with distance scales were pretty good since you simply set the distance . Modern lenses are pretty worthless for this and I've seen photographers in the field using rangefinding devices as focusing aides.

For our example, we have found that the hyperfocal distance is found farther from the image plane and about halfway into the structure itself. Depending on our angle of view we might not actually be able to see it on the structure so auto focus would not help us. However by increasing the focal distance we have increased the depth of field to where it covers the trees in front and overlaps the infinity point of the lens and therefore extends beyond optical infinity behind the point of focus.



HYPERFOCAL DISTANCE, CONTINUED

HOW TO USE IT:

Once you know where you need to focus, then you simply focus there and your shot will have acceptable sharpness from infinity (and beyond) down to about half the distance from the focus point to the camera. You then need to crop the shot before it comes too far forward and out of the depth of field range.

ZONE FOCUSING

Once a staple technique of sports photographers and photo-journalists, Zone Focusing has given way in importance due to fast and accurate auto-focusing lenses. If the only important thing in the shot is the primary subject, then auto focus is fast and easy but the image is limited by the inherent depth of field based on the lens focal length, the focal distance, and the aperture being used.