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Tuesday, 23 June 2009

Depth of Field Hell—The Sequel

By **Ctein**

I don't know why this myth about the depth of field being utterly independent of focal length (for constant magnification) keeps on going, because it's easy to prove that it's wrong and sometimes it really matters that it's wrong.

Nonetheless, it is a myth and it is wrong.

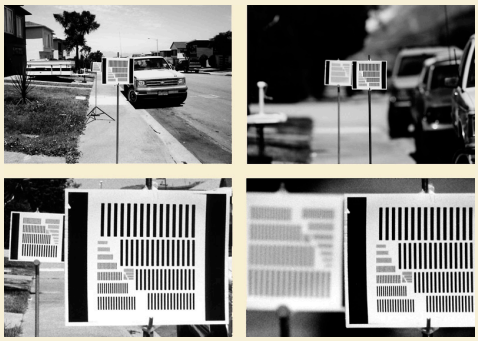
Here's the real skinny. At close working distances, depth of field is nearly independent of focal length. In fact here's a handy *approximate* equation for depth of field that depends solely on circle of confusion (c), aperture (f), and on-film (or sensor) magnification (M):

DoF (on either side of the subject) = c*f*(M+1)/(M*M)

As you decrease the magnification, lens focal length starts to become more important. As you get close to the hyperfocal distance, to maintain comparable total depth of field, the magnification becomes inversely proportional to the focal length of the lens rather than being independent of it!

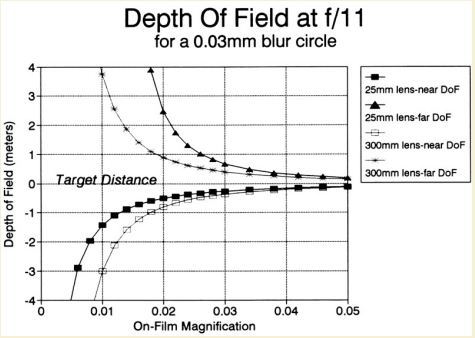
A good rule of thumb is that for just about any photography you do indoors, depth of field isn't going to be affected by focal length, just on-film magnification. But as you start photographic more distant subjects, the effect of focal length increases and eventually becomes as important as aperture.

At intermediate distances, the total depth of field (in front of and behind the subject combined) decreases as the focal length of the lens increases, for the same on-film magnification (and same aperture and circle of confusion). The distribution also changes. The shorter focal length lens will always have less depth of field in front of the subject than the longer focal length lens, but it will have more depth of field behind the subject than the longer focal length lens. In other words, for the shorter lens the depth of field is not only greater but more asymmetric.



These comparison photos illustrate how changing the focal length of the lens can change depth of field even when the on-film magnification stays the same. The photograph in the upper left was made with a 25mm lens and the one in the upper right with a 300mm lens. The lower photographs are enlargements of the ones directly above them.

I moved the camera to keep the on-film magnification 0.02X, but the distance between the targets didn't change and both photographs were made at *f*/11. The front target is equally sharp in both photographs, but the far target is much blurrier in the 300mm photograph than in the 25mm photograph.



This graph shows how depth of field changes with on-film magnification for the 25mm and 300mm lenses. At closer distances (greater magnifications) focal length has

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minimal effect on depth of field; it becomes increasingly important as the distance increases. Notice that the total depth of field is always greater for the shorter lens, but the shorter lens has less depth of field in front of the subject and more depth of field behind it than the longer lens does.

Assuming you don't want to take my word for any of this, you can prove it yourself any one of several ways:

1. **Mathematically**—if depth of field really depends upon magnification and not lens focal length, you should be able to recast the depth of field equations using magnification as one of the variables so that focal length drops out entirely. Give it a try! Good luck!

2. **Numerically**—set up a spreadsheet with the depth of field equations that computes depth of field in front of and behind the subject as a function of on-film magnification (for a given f-stop and circle of confusion, of course). Try it out on a bunch of cases.

3. **Pragmatically**—pull out some of your lenses that still have depth of field markings on them. Compare the depth of field of markings between, oh say, your 50mm lens and a 300mm lens at distances that would correspond to the same on-film magnification (about six times further for the 300mm lens).

4. **Logically**—consider two extremes. First hyperfocal distance. Go to your textbook and pull out the standard equation for hyperfocal distance. Figure out what on-film magnification it corresponds to. You'll see that the magnification varies inversely with the focal length of the lens. No, that's not an artifact of having the far distance go to infinity. You could pick a far depth of field that was huge but finite, like say, 1 km, and plug that into the full depth of field equations and you'd get the same result as close as matters.

5. ***Reductio ad absurdum***—consider the depth of field in front of the subject for any particular lens and situation you choose. It'll be some finite number. Now imagine swapping that lens for a lens of shorter focal length; to keep the on-film magnification the same (which, according to myth, will keep the depth of field the same) you will have to move proportionately closer to the subject. Keep making the lens shorter and shorter. At some point the total distance from the shorter lens to the subject is going to be less than the near-side depth of field you calculated for the longer lens.

Ctein

Posted on Tuesday, 23 June 2009 at 01:46 PM in Ctein, Photo-tech | Permalink

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Comments

It would help to indicate at least one major example of the myth (i.e., the source of it)... in absence of which, the article risks being labeled as a straw-man argument.

Posted by: Slobodan Blagojevic | Tuesday, 23 June 2009 at 01:58 PM

Your experiment - thank you very much for it, and its results and conclusion are in complete opposite of conclusion from Michael Reichmann's article at:
http://luminous-landscape.com/tutorials/dof2.shtml

Just wanted to mention it - my conclusion is much closer to yours then Michael Reichmann's.

Sincerely yours
Bojan

Posted by: Bojan Volcansek | Tuesday, 23 June 2009 at 02:11 PM

I think a lot of people get confused between fstop and the physical aperture of the lens. It is true to state that DOF does not change with the same physical aperture and focus distance, regardless of what lens is used. Of course, holding the aperture constant while changing the focal length necessarily changes the fstop. Since we all deal with fstops, not aperture size, it's important to remember what you've written. I do have to say that since reading "The Ins and Outs of Focus" all those years ago, I do think about my aperture size first when dealing with DOF. Of course, I'm usually only worried about DOF with LF photography and I have the time to think like that...

Posted by: isaac | Tuesday, 23 June 2009 at 02:12 PM

Oh lordy, and I thought I understood it enough for my purposes....

Posted by: Patrick Dodds | Tuesday, 23 June 2009 at 02:13 PM

When photography gets mathematical the photographers get going....

Posted by: Lars K. Christensen | Tuesday, 23 June 2009 at 02:18 PM

Anyone who's been using medium or (even better) large format must have learned this. In today's digital world, people don't know about DoF so much, to the point that I was mocked for having bought a full frame DSLR, which is "more expensive and less in focus" !

Posted by: Lou | Tuesday, 23 June 2009 at 02:37 PM

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Thanks. I'll be forwarding this on to a photography professor I had recently that kept insisting that total depth of field was distributed such that 1/3 fell in front of the focus point and 2/3 behind it.

Posted by: Andre | Tuesday, 23 June 2009 at 02:43 PM

Mike, that's even more confusing than the ZONE SYSTEM (an excellent systen to know and understand, but so complicated in practice that even St. Ansel occasionally messed up the calculations).
The best way to determine Depth of Field is still (as always) to just stop down the aperture and look at the viewing screen. It's even easier with Live View on the latest DSLRs which magnify the image.

Posted by: Wilhelm | Tuesday, 23 June 2009 at 02:49 PM

"this myth about the depth of field being utterly independent of focal length".

Independent of focal length if you do not do a fixation on magnification, but only care about the field of view. If you take pictures with different lenses, but showing the same field. In other word, step back with your 300mm to get the same field of view than in the picture taken with the 25mm, from the house to the left to the other side of the street to the right, and you will have the same depth of field. Maybe you arguing people are talking about different things?

Posted by: Luc Novovitch | Tuesday, 23 June 2009 at 03:01 PM

I'm trying to get my head around the apparent conflict between this and the LL article. The best I can come up with is that they are talking about two different things. Obviously the rear card in the left-hand image is sharper. But is there actually more information there? Our eyes read it as sharper, but if there's no more information, then it's doesn't actually gain anything, even if we consider it "in focus".

Posted by: MikeWebkist | Tuesday, 23 June 2009 at 03:14 PM

@Slobodan Blagojevic,
I actually saw this myth stated as fact in a forum post last week. I guess that's not a "major" example, but it is an example.

I've been meaning to check it out, but now Ctein has done it for me. Now I just have to go through the equations a couple more times until I actually understand them....

Posted by: Brian R | Tuesday, 23 June 2009 at 03:16 PM

The thing is that if the focal length is different enough there are many occasions where it is simply not possible (in practical terms certainly, and probably not even mathematically under some circumstances) to get the same field of view.

Sure it's easy enough to do when comparing a 200mm lens to a 300mm lens, but just try it comparing a 12mm to a 500mm. Not possible.

The problem with the myth is that it doesn't take into account subject distance when that is significantly closer than the hyperfocal distance. When close to or past the hyperfocal distance and using lenses of similar focal length it's easy enough to get them looking very similar.

But the thing that intrigues me, and perhaps Ctein or Mike might comment is not simply DOF but the degree to which the OOF areas are blurred. And that I think depends on the physical size of the aperture, on shorter focal lengths with subject close to the lens you may have most of the picture blurred but still recognisable. On a longer focal length with nominally the same DOF the areas that are OOF can be completely unrecognisable.

Posted by: Craig Arnold | Tuesday, 23 June 2009 at 03:37 PM

Oh believe me, this is no straw man argument. All you have to do is google "depth of field" to find an unlimited string of arguments back and forth about what DOF is and isnt, and what does and does not affect it.

THANK YOU, Ctein for explaining this issue so clearly, both visually and mathematically. I really think it will make it "click" for a lot of people.

But here's a brain-twister for you. What if you compare the DOF of two cameras in different formats, with lenses of equal FOV? For example, comparing a 40mm lens on 135 to a 300mm lens on 8x10. The distance to the chart is the same in both cases, and the size of the chart on the film relative to the total frame is the same (say 10% of the frame width). What are the differences in DOF?

Posted by: ben | Tuesday, 23 June 2009 at 03:38 PM

Oh my, Oh Lordy, sigh.

Circles 3 times and lays down.

Posted by: Bron Janulis | Tuesday, 23 June 2009 at 03:39 PM

I enjoyed #5...thanks Ctein!

Posted by: David Bostedo | Tuesday, 23 June 2009 at 03:56 PM

Bron, I'll join you. I'm happy just knowing that, in practice, big lens/big hole = small DoF; small lens/small hole = big DoF.

I'm not a subtle enough photographer to need more precision than that.

Posted by: Rana | Tuesday, 23 June 2009 at 04:42 PM

"Oh lordy, and I thought I understood it enough for my purposes.... "

I'm sure you do. So long as you understand that DOF exists, and you understand how to manipulate it with regards to opening & closing your aperture and moving closer & further away from your subject, you'll do just fine.

Closer = less DOF.
Larger aperture (smaller number) = less DOF.
Longer lens = less DOF.

Everything else is just minutiae.

Posted by: Jayson Merryfield | Tuesday, 23 June 2009 at 04:50 PM

Dear Slobodan,

Ummm, sorry, but no. For one, I don't waste my columns on straw men, and you'll just have to trust that. For two, I NEVER give a pointer to erroneous information. Too often, the pointer and memory of the errors persist where the correct info doesn't.

Dear Bojan,

The LL page has been noted and discredited in several recent columns.

Dear Luc,

No, we're not talking about two different things. (Almost) everyone else simply is getting it wrong.

Dear Mike,

What you're asking is whether you can recast the DoF equations so that they refer to the real-world subject detail rather than the in-print/on-screen detail.

Answer is "Yes," but it proves to be not very useful except for scientific data collection; it does not correlate with what we see when we look at a print.

It also doesn't make the "focal length independent" claim correct, because in terms of subject detail, that assertion blows up badly for the closer working distances.

There simply is not a good universal rule of this sort. It doesn't exist.

pax / Ctein

Posted by: ctein | Tuesday, 23 June 2009 at 04:54 PM

I think Luc has put his finger on an important point. The LL examples used *cropped* images to demonstrate the "depth of field." It also evaluates the amount of blur of an OOF object compared to the size of the object itself. But DoF depends on the amount of blur of an object relative to the *whole image*. Thus DoF calculations rely on assumptions about the final image (print) size and the magnification necessary to achieve that size. If you crop the original image heavily, you have to recast the assumptions.

For example, the chart above specifies a 0.03-mm blur circle. That's an appropriate value if you are starting from a 35-mm frame. But if you crop that frame to a fraction of its original size, you need to use a smaller blur circle and recalculate.

Unless you hold the assumptions constant, DoF comparisons are problematic. The LL article does not hold the examples constant and is thus flawed.

Posted by: Jon Bloom | Tuesday, 23 June 2009 at 05:00 PM

Dear Craig,

Absolutely! I just made a similar email comment to Mike:

"And, y'know, all of this SOOOO doesn't matter in practice! Depth of Field Hell, indeed! All anyone really needs to know is, 'Stop down to get more depth of field. But don't stop ALL the way down, or diffraction may steal back the sharpness you gained. Now go make photos, dammit.'

It's a cart/horse thing. If you're photographing a 'scene' (as opposed to 'subjects') you don't pick your focal length by depth of field. You look at the scene. You frame a composition that pleases you. You choose a lens focal length that gives you the appropriate crop. You stop down to (*hopefully*) get adequate depth of field, but you can't changes lenses, because it's the composition that drives the lens choice. So who cares about this sh*t?!

OK, sometimes it's about subjects, like getting the flower in the foreground and the mountain in the background both sharp. THEN, it's worth knowing that a wider-angle lens will get you more depth of field behind the flower. So you pick the focal length that'll make the picture adequately sharp, and try to find a composition you like with that crop. But that ain't the norm."

I don't know the answer about the characteristics of the OOF areas. I agree it looks different in a long lens than short, but I don't know if that's just because it's so much blurrier. It's a great question!

pax / Ctein

Posted by: ctein | Tuesday, 23 June 2009 at 05:05 PM

What is it going to take for MR to correct that page? TOP vs LL! Rumble on the web...

Posted by: Cameron | Tuesday, 23 June 2009 at 05:08 PM

"Obviously the rear card in the left-hand image is sharper. But is there actually more information there?"

Exactly. When you reduce the right-hand image so the rear card is the same size as the rear-card in the left-hand image, the blurring is essentially the same. The size differential has to do with the ratios of camera-to-cards difference.

So, essentially, yes, it is still true that focal-length doesn't matter. Focal-length ONLY affects angle-of-view.

Posted by: Ken N | Tuesday, 23 June 2009 at 05:14 PM

Dear Ben,

OK, your question is one I know the answer to! It turns out that a *crude* rule of thumb is that stopping down the lens in proportion to the size of the format gets you ROUGHLY the same depth of field.

E.g., using your case, the 40mm lens at f/4 on 35mm film produces about the same DoF as the 300mm lens at f/32 on 8x10 film, when you're aiming for prints of the same size and sharpness.

Works in the other direction, too. So, for example, my Fuji S100fs, with its 1/4-scale sensor gets me about the same DoF at f/2.8 that I'd get at f/11 in 35mm size.

Which is why diffraction-freakazoids who complain about being unable to stop down (sharply) to f/11 with those tiny, tiny pixels are whining about nothing. That's going for DoF like you'd get at f/45 in 35mm-- you hardly ever need it, and if you try it in 35mm, you'll find your pictures won't be tack-sharp there, either!

It's also why the shallow-DoF fans are right about small-sensor cameras making their lives difficult. They're wrong about thinking they're anything but a small minority, but that's a forgivable delusion of grandeur, not of fact [grin].

pax / Ctein

Posted by: ctein | Tuesday, 23 June 2009 at 05:17 PM

Hi Ctein, hi folks,
great article, but maybe its time also to tell the truth about d.o.f.: it is not simple.
There is no way of understanding it in theory except using math in one or the other way. And even with math it is not really simple.
So if you want to be sure about it without math, use trial and error.
Approximations are fine, but you will always need to make sure that they are still valid...
Regards, Jan

Posted by: Jan | Tuesday, 23 June 2009 at 05:40 PM

How would one derive *c* above? Also, what is the equation before the approximation was made, and what are the units of each term?

Sorry if these questions are related to basic optics, but it would help understand the mathematical approach.

Posted by: Jared Lynem | Tuesday, 23 June 2009 at 05:44 PM

Ahhh, if ONLY enough people would complain so that lens manufacturers would start putting DOF scales on lenses again! I'm not holding my breath, though.

Posted by: Roger Engle | Tuesday, 23 June 2009 at 05:51 PM

Dear Ken,

No, not so much.

First of all, if you saw the original photos, instead of highly-reduced-in-size JPEGs, you'd discover there's a lot more detail in the WA background target. You're seeing lines down to the single-pixel level in the JPEG-- what makes you think it stops there?

Second, you're attempting to recast the issue in a useless way.

This is about PHOTOGRAPHS, not about how one can construct a debate so as to win.

Depth of Field is useful to photographers because it addresses this, and only this, question: "What parts of my scene will look sharp in my print?"

It has nothing to do with external-real-world resolutions, either spatial or angular. Those matter for scientific data collection; they do not matter for pictorial photography.

DoF concerns itself with line pairs per millimeter on print or on screen. It does not and should not be construed to deal with anything else, because it is not useful to do so.

In summary, my examples do not, in fact, prove your point, and your point is not the point.

pax / Ctein
==========
-- Ctein's Online Gallery http://ctein.com
-- Digital Restorations http://photo-repair.com
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Posted by: ctein | Tuesday, 23 June 2009 at 05:53 PM

It seems like maybe you could always perhaps just move the cards a little bit closer together.

Posted by: Robert P | Tuesday, 23 June 2009 at 05:59 PM

Hey Ctein,

First, let me say that I'm perfectly happy to have my mistake corrected on this, and will be glad to change my tune, if I ever get the time to think seriously about it again.

I first read that DOF is dependent on image mag and aperture only -- and independent of focal length -- in a book called Applied Depth of Field by a man named Alfred Blaker who was, as you probably know, a prominent author of technical photography books for many decades. I happen to have a photocopy of the relevant chapters which I'll reread (and scan and send to you if you'd like). (The book contains a ton of cool drawings, which showed me what physically causes sharpness falloff from front to back and why DOF varies with aperture. Still remember the aha! of that.)

I tested this claim fairly informally when I first read it (early 1990s) because I didn't believe it, but my tests showed it to be correct. I may now be learning that my tests were flawed :-)

I then saw the same claim in a primer on photography published by Kodak a few years back (which I don't have), but maybe Blaker wrote that, too :-)

I really actually don't have time to investigate this myself right now, but I'll stop repeating the claim out of respect for your knowledge on such matters, Ctein. But until I can figure out what's wrong with Blaker's lovely diagrams and equations (he's got lots of 'em!), I'm going to remain quietly neutral ...

Posted by: Eamon Hickey | Tuesday, 23 June 2009 at 06:00 PM

Did you bother to read Mike's rant about DoF. Mike was right on the button for me. This is another confusing article, and in the end does anyone end up wiser, or more confused?

Whenever the subject really gets going, great reams of material are spewed forth "explaining" it [...] Assuming any given reader engages with said great mass of verbal matter, he comes out the other side usually no more enlightened, and possibly considerably more confused.
Finally, add to those conditions the simple fact that a technical understanding of DoF is not required for the successful practice of photography... .

So in summary, for very close up photography, for example macro photography, the impact on DoF of a change in focal length is trivial if you are keeping the subject the same size in the viewfinder. So pick your macro lens to set your working distance from the subject.

For photographing more distant subjects, the choice of focal length plays a part in DoF performance, with the general rule being, the shorter the focal length the greater the DoF.

But with Depth of field, go out and get a feel for how it varies. Do not let the maths blind you, instead learn to enjoy and use the properties of the lenses you have.

Is that not a simpler way to put it?

Posted by: John | Tuesday, 23 June 2009 at 06:40 PM

For those looking for a more detailed mathematical treatment of the subject, and support for Ctein's claims, take a look at Depth of Field in Depth, in particular, page 9. The author of this article points out the assumption used for cases where DoF is independent (approximately) of focal length.

Posted by: Daniel F | Tuesday, 23 June 2009 at 06:45 PM

Nevermind, I get it (thanks Wikipedia). All these "rules of thumb" just get in the way of the mathematics behind it, which are fairly clear.

So the correct answer is that it relies on all four variables (focal length, subject distance, aperture, and magnification- *c* in this case is a constant, based on whatever your subjective criteria of "good enough" may be), though the relationship between the first two determines how either will affect the near and far depths of field.

If you're mathematically inclined I suggest Wikipedia's derivation of these formulas:
http://en.wikipedia.org/wiki/Depth_of_field#Derivation_of_the_

Posted by: Jared Lynem | Tuesday, 23 June 2009 at 07:03 PM

Oh my.

I'm starting to think that, instead of trying to figure these things out, I should just take photos and then look at them.

Posted by: Matthew Robertson | Tuesday, 23 June 2009 at 07:04 PM

Here be dragons, indeed.

Here's a question. Take a picture with a camera and print it. Keep aperture constant. Keep final print size constant. Double the focal length, sensor size, and scale the size of the world outside to Brobdingnagian proportions by 2x with the camera at the same spot. Take another picture and print it at the same size. Will the two prints be indistinguishable in terms of in focus and out-of-focus elements, with the prints viewed at the same distance from the eye?

What's this got to do with taking pictures with my Leica or Nikon D100? I dunno, but the question has its own (non-photographic) charm to me...

Posted by: Mani Sitaraman | Tuesday, 23 June 2009 at 07:07 PM

All these beautiful explanations about DoF in one week, us the readers have hit gold here!

In succession to my comment on Mike's DoF Hell post, I am still in deep thought about the gap that exists between the perfectly logical, scientific, positivistic and true arguments put forth by Ctein and Mike, and the numbheaded masses who just wish their

digicam to start putting out pictures like the camera they knew for decades. This includes taking a picture from a certain distance with a certain aperture and a certain apparent perspective just like they did in the old days, and with the same results as far as apparent bokeh/DoF go. As argued by me before, the solution to a gut feeling is not necessarily a theoretical and logical explanation.

My question: given all the much appreciated and crystal-clear info on DoF here, and a certain John Doe's wish to get exactly the same perspective and DoF as he had with his 35mm camera, should he or should he not buy the E-P1 and 17/2.8?

My internet educated numbheaded guess whould be no, and wait until they put a 35mm sensor into these cams so the deviation from a decades-long framework is eliminated and they can enjoy again where they left off ten years ago.
You may just have to deal with the fact that the masses want to create depth in their photos with a quick effect, and not necessarily through real artistry.

Posted by: georgec | Tuesday, 23 June 2009 at 07:51 PM

I am so glad you get a kick out of good ol' fashioned straight forward step by step reason (clearly illustrated) as it reminds me of how happy I am when I figure out what's going on by looking at the results of what *I've* just tripped over, if I'm so lucky. Pax to you too brother.

Posted by: Robert Howell | Tuesday, 23 June 2009 at 09:17 PM

Har! This one again.

Focal length affects magnification. That is a 100mm lens has twice the magnification as a 50mm lens. Move the camera back to twice the distance from the subject (so the subject is the same size) and the DOF does not change at the same aperture.

F-stop affects aperture diameter. A 100mm lens has the same diameter aperture at f4.0 as a 50mm does at f2.0. So you also have to stop the 100mm down two stops.

The problem is definition. People think of aperture and f-stop as the same thing. They are not aperture is the diameter of the lens opening. F-stop is the focal length divided by the aperture which gives us a very useful light transmission value.

The confusion comes from us misusing the terminology.

BTW, did anyone get the impression that DOF also is affected by the size and viewing distance of your image? It is. Magnification is a function of focal length, subject distance, final image size, and viewing distance.

Posted by: Graywolf | Tuesday, 23 June 2009 at 09:20 PM

"I first read that DOF is dependent on image mag and aperture only -- and independent of focal length -- in a book called Applied Depth of Field by a man named Alfred Blaker"

Eamon, check chapter 5 of Blaker for the hyperfocal distance formula and chapter 6 for the near- and far-limit formulas, and you'll see that focal length is very much in the picture, so to speak. If you reread chapter 3 closely you'll see that the generalization that you're remembering from there is actually qualified in several respects and wasn't intended as a universal statement.

Posted by: Oren Grad | Tuesday, 23 June 2009 at 10:06 PM

Ctein: "It's also why the shallow-DoF fans are right about small-sensor cameras making their lives difficult. They're wrong about thinking they're anything but a small minority, but that's a forgivable delusion of grandeur, not of fact [grin]."

I like my delusions. They keep me company. And I appreciate the vote of confidence, I think....

Posted by: Ken Bennett | Tuesday, 23 June 2009 at 10:29 PM

When first learning photography in the early 70's I think this was "gut knowledge" to some of the photographers I talked to. I read books that showed me how to set exposure and read the DOF scales on the lens, set hyperfocal distance, etc. When I showed one photographer I knew how to read and use the DOF scale he just remarked "forget it", but, stammered I, look right here, pointing at the scale. His comment? "Lies! If you want to use the scale, read two stops more than you set. If you want infinity to be sharp, focus on infinity." But then they had been shooting and printing for a few years and liked correctly focused, sharp prints. Even so, I too have often repeated just what I've read years ago, that DOF is controlled by object-image ratio and f stop regardless of focal length. After reading your post I travelled over to Bob Atkins online DOF caculator and the figures It spit out agrees with your information.

Posted by: john robison | Tuesday, 23 June 2009 at 10:31 PM

Look, I just twist the twisty thing on the lens barrel until the bits I want not blurry aren't blurry. Don't make my head hurt with calculus.

Posted by: James McDermott | Tuesday, 23 June 2009 at 11:09 PM

I'll bet the standard reference tables used by cinematographers produced correct results. They frequently need to plan days or weeks in advance how to achieve particular effects, at a wide range of distances, and had to KNOW they had it right in the can, without waiting for the dailies to come back. Sometimes in time to tell people what size to build various aspects of the set. (These days video assist or actual video masters give them the same ability most of us have to "chimp", but the guides will still be around, probably still in the current editions even.)

Posted by: David Dyer-Bennet | Tuesday, 23 June 2009 at 11:42 PM

The LL exercise proves only that for a range of focal lengths, when magnification of a nearby focus target is kept constant, a tower a mile away is out of focus. Nothing more and nothing less. It does not prove LL's thesis. To do that, one would need to test a variety of focus target distances and for each of those actually try to determine the effective DOF.

But wait:

This could be just the beer talking, but I think it's easy to see where the myth might come from:

I seem to be reading in Ctein's reply to Ben, above, that an X mm aperture gives the same DOF as an X mm aperture regardless of focal length. Which seems to agree with Blaker (as long as both parties are talking diameters).

But Ben posits the same field of view in different sensor sizes, which does entail a change in magnification.

That's the tricky part, I think. There's no explicit mention of focal length in Ctein's equation, but it is implicit in the ratio "f". It is implicit as well in "M", which AFAIK is a function of distance to subject and focal length. It's clear enough once you start plugging in numbers, but the take-away rules of thumb, for me, and I assume for some others, were obscured a bit by the terminology.

Am I right? Or is the beer wrong?

Posted by: robert e | Wednesday, 24 June 2009 at 12:45 AM

Dear Jan,

I agree. When I started to get into the math of all this (with the helpful support of Al Blaker, author of "Applied Depth of Field") I quickly discovered that the math was only poorly approximated by qualitative rules.

Indeed, it is not simple.

Dear Jared,

"c"'s kind of arbitrary; it's not derived from anything, but rather it's an assumption about what the acceptable blur circle is. For 8x10 prints from 35mm, it's typically set at 1/30th-1/35th mm, but many photographers like me are hyper-picky about sharpness and use a blur circle more like 1/50th mm. Similarly, for medium format, 1/20th is the canonical number, but I personally prefer to stay near 1/30th.

The aperture (the f/#, really) and the magnification are both dimensionless, so the DoF comes out in the same units as the blur circle (mm, for the numbers I give here).

I have an exact equation at home, but I'm on vacation in Minneapolis this week, and I don't trust myself to re-derive it correctly. Email me in a week and I'll be glad to look it up for you. It's mathematically interesting, but not all that useful, since casting the DoF equations in terms of magnification doesn't have a lot of practical value for non-closeup work.

Dear Eamon,

Al is a long-time colleague and friend of mine! In fact, when I first stumbled on this peculiar truth, I had him double-check my results, and he confirmed I was correct. He was a little surprised he'd never noticed himself that DoF was not focal-length-independent, but he agreed it wasn't.

Can't point you to what's right or wrong in his wonderful book, which is a fabulously useful practical guide to the subject, as I don't have a copy at hand. But if you're willing to trust my word, I'll tell you he said I got it right.

Keep in mind that Al's predominant interest was macro and micro work, where the 'no-focal-length' approximation works well.

BTW, if anyone cares, Al is alive and well, albeit retired, and living with his daughter (I think that's the right relative) in Arizona.

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Posted by: ctein | Wednesday, 24 June 2009 at 12:57 AM

Dear John,

"Did you bother to read Mike's rant about DoF."

Truth? I wrote my column in response to the myriad mistaken comments that followed Mike's rant. I delayed an already-written column to run this one. I sent it to him under the subject line: "Possible replacement column? Please ACK"

Mike's reaction to that new column?

"Beyooteeful."

Personally, I think your shorthand, verbal rules are utterly great and nothing more should have to be said.

Unfortunately...

Mike and I know from long, sad experience that the gearheads do not willingly let go of misconceptions. So this article is intentional intellectual overkill, showing FIVE different ways to demonstrate the misconception is wrong.

Observe that we're still getting arguments.

Sigh. Not unexpected, but still... sigh.

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Posted by: ctein | Wednesday, 24 June 2009 at 01:13 AM

Dear Graywolf,

"Focal length affects magnification. That is a 100mm lens has twice the magnification as a 50mm lens. Move the camera back to twice the distance from the subject (so the subject is the same size) and the DOF does not change at the same aperture."

No, that is precisely what I demonstrated was wrong, and my article shows you five different ways to demonstrate that.

Please read it again.

Your second assertion, that keeping the absolute aperture (as opposed to the f/#) constant produces a constant DoF is also false.

Set up the equations, do the math, run the spreadsheet, whatever. You'll easily confirm this.

It's not a definitional problem. It's just wrong.

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Posted by: ctein | Wednesday, 24 June 2009 at 01:32 AM

As has been said above, the DOF depends on a range of variables.

If one somehow latches on to a mantra like "variable X is not important" it is possible, by jumping through enough hoops (see the LL article), to contrive a couple of photos whereby you change the other variables in order to compensate for the change in the one you have decided doesn't matter.

I can't for the life of me imagine why anyone would want to do that. But there you go...

I think I have seen examples of pretty much every variable being singled out as the one that isn't relevant. We have the CoC sub-variables of print size, print resolution and viewing distance. We have the DOF equation variables of focal length, aperture and distance. I have in one place or other seen claims where each of those variables is claimed to not affect DOF, and with some great ingenuity some photos taken where that variable does differ but other variables have been adjusted to more-or-less compensate.

The root of the problem is that when we are trying to operate on an intuitive level, as we often must with photography, our brains are incapable of using even mildly complex (sic) mathematics. So we have to approximate and reduce the complexity, and the DOF equations really aren't that easy to make intuitive.

Posted by: Craig Arnold | Wednesday, 24 June 2009 at 01:45 AM

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has anyone mentioned this site
http://www.dofmaster.com/

It has a handy do it youself calculator for those of us that can't handle the maths

Keith

Posted by: Keith Smith | Wednesday, 24 June 2009 at 02:00 AM

I don't see how this article is in conflict with the dof2 article at LL. They just address the issue from different perspectives. If you magnify the chart in the back it will show that they resolve exactly the same(in a perfect example with a perfect focal plane und so weiter...). Right?

Slightly OT but how many of the truly great pictures in the history of photography has relied on really shallow dof? I'd be inclind to say close to nil.

Posted by: Anton | Wednesday, 24 June 2009 at 02:12 AM

For anyone still in doubt, I strongly recommend the reading of http://toothwalker.org/optics/dof.html and I thank the person who signaled it.
It answered all my questions and let me clearly understand why Ctein is right while many other professionals can make mistakes over such a complex topic.
The author really knows what is speaking about and how to communicate in an accessible, plain but not over-simplified way.
Thanks also to Mike and Ctein for enlightening me about such an obscure topic that (erroneously) I previously thought to master.
The reading of T.O.P. really improves my photography knowledge and I'm going to subscribe to thank you in a tangible way.

Posted by: Filippo Mugnaini | Wednesday, 24 June 2009 at 02:33 AM

[irony:ON]
hey ctein, why did you spoil that nice first photo of a suburban neighbourhood with some akward tripods and technical charts??
[irony:OFF]

i never understood all the DoF talk anyway. and still dont. maybe because i just shoot enough photos to FEEL what my gear is doing at what setting, so i can use it appropriatly. the moment i have to start pulling out a calculator i am done. and will never be hired again.

good explanations, though. keep 'em coming.

Posted by: grubernd | Wednesday, 24 June 2009 at 03:41 AM

I don't care about the math. I'm an engineer, and I get enough math at work.

When I use a longer focal length there is less stuff in the background, and it looks blurrier. That's all I need to know.

Posted by: scott_h | Wednesday, 24 June 2009 at 06:02 AM

Firstly, the LL article makes a big boo boo by enlarging the images. If you look at the full mathematical formula for DoF you'll find that DoF depends on focal length, aperture, and the CoC, which translates to final image size.

Secondly, I really don't get this hoo-ha over DoF in digital. If you can wrap your head around DoF estimations in 35mm once, you can do the same with new digital sensors. Ballyhooing on DoF over reduced frame sensors is really like complaining we need to stop breathing to help save the environment: It's pointless and counterproductive.

Posted by: YS | Wednesday, 24 June 2009 at 06:22 AM

Thanks Ctein - this is something I'd understood by experience but been unsuccessful in explaining to others in the past.

The photos also illustrate something else I've found it hard to get through to people - that blowing up an image is NOT the same as using a telephoto. The difference in the size relationship between the two targets is constant no matter how much you enlarge the wide angle version.

Cheers,

Colin

Posted by: Colin Work | Wednesday, 24 June 2009 at 07:08 AM

Ctein,
Thanks for the informative article. A lot of it I knew before but the fact that depth of field in front of and behind the subject becomes more asymmetric with shorter focal lengths was news to me, and useful news at that.

Posted by: Mark Roberts | Wednesday, 24 June 2009 at 07:46 AM

@Graywolf: no, the problem isn't one of definition. You can't reframe the issue so that the myth becomes true. The myth fundamentally rests on an attempt to use an assumption to simply the complex polynomials in a way that is only an acceptable approximation if the object distance is much less than the hyperfocal distance.

The best thing to do is work through the equations from the top, the PDF linked by Daniel F is pretty good.

Posted by: Charles | Wednesday, 24 June 2009 at 08:19 AM

Hi,

it has been said above, but let me repeat it. The problem with a statement like "DOF does not depend on focal length" is not whether it is correct, the problem is that it is not well-defined. Let me state something which is well-defined (and, I think, even true):

If you change your distance to the objects, keep the same object in focus, change the focal length in such a way that the size of the object in focus in the picture does not change and do not change the f-stop (absolute aperture will therefore change), then if the circles of confusion of two points on an out of focus object touched before, their new circles of confusion will still touch.

(This can easily be derived mathematically, of course assuming a simplified lens. And assuming the absence of errors in my calculation.)

Of course, these points will have a different distance in the picture now. The illustrating pictures on LL indicate that this was meant there: If the tower in the 17mm picture is enlarged to be of the same size as the tower in the 100mm picture it is equally sharp. (Of course only if we pretend that we have infinitely small pixels, otherwise it will only work in the other direction, shrinking the tower of the 100mm picture.) It can now be claimed that this means that it was sharper before enlarging it. The latter seems to be a matter of the definition of the term sharpness and the source of the confusion here.

Posted by: Carsten S | Wednesday, 24 June 2009 at 10:07 AM

"Thanks for the informative article. A lot of it I knew before but the fact that depth of field in front of and behind the subject becomes more asymmetric with shorter focal lengths was news to me, and useful news at that."

Oh, and I should second what Mark says here. I didn't know that either.

Mike

Posted by: Mike Johnston | Wednesday, 24 June 2009 at 10:20 AM

Well, once again, there are some confusions in the comments, and I'm afraid that I helped that along.

Earlier, I said that physical aperture and focus distance were the only things that determined DOF. That isn't true. What I should have said is that the size of the detail being recorded is determined my physical aperture and focus distance only. That really isn't the same thing as DOF. In other words, if I set things up so that everything with a diameter of 10mm and larger are recorded, that will be fine for things at a distance, but things that are closer may end up not looking as sharp. That's really what DOF is, it is the amount of "stuff" in the picture that is acceptably sharp. The physical aperture and focus distance determine the absolute (within the confines of what the lens can do) level of detail that will be recorded.

For my stye of photography, or at least the style I use when I actually think about DOF, that distinction isn't important to me. It becomes very important when dealing with close up photography. Landscape photography, not so much.

Posted by: isaac | Wednesday, 24 June 2009 at 11:35 AM

Ctein,

Thanks for the effort, and I've learned something because of this post. Because of it I looked up the math on DOF and saw that focal length is indeed a variable in the calculation. I'm still not sure how I missed it all these years amidst the online din and furor surrounding DOF arguments.

However (correct me if I'm wrong), I don't think you've actually proven what you intended to with your experiment if I'm understanding it correctly. From the sample photos and your description, you changed both focal length *and* distance, right? If so, all you have shown is that at least one of those two affects DOF, not necessarily which or whether they both do. To really prove that focal length matters, you must keep all other relevant variables constant (aperture, distance, and circle of confusion) and only change focal length. Let me know if I'm missing something though; it's entirely possible.

But if you simply intended to show that focal length matters in practice in how photographers actually take photos where focal length and distance are never independent of one another due to compositional considerations, then you've certainly done that. It shows that if you want to keep a subject the same size in the frame--a very common goal of simple portraiture, for instance--if you change distance you must change focal length and vice versa, and doing so will change the resulting DOF.

It's easy to fall too far on one side or the other--ignore the theory and math, or get too wrapped up in the theory to bother with practice--but I think we're richer for understanding both sides of the coin. This level of understanding of DOF isn't necessary to create amazing photos, but we shouldn't make pantomime villains out of those who desire to have more than a passing understanding of how our tools actually work.

Posted by: Yohan Pamudji | Wednesday, 24 June 2009 at 11:46 AM

Dear robert e,

Partly right, slightly the beer, [smile].

In my answer to Ben, he and I are talking about changing formats, so not only is the focal length changing, the blur circle (c) is changing in concert. It's the combination of blur circle, focal length and f/# scaling that VERY CRUDELY cancels out.

And it is rough; it's useful as a rule of thumb only because one doesn't really use it to make photos. It's just a way to get a sense of what apertures work similarly with different formats.

My equation at the beginning of the column is a truncated approximation which works very well for close work. There's a missing term of the form c*FL/f#, where FL is the dreaded focal length. That's the FL you can't make go away with a variable substitution, even when the whole rest of the equation talks about magnification.

When c*FL/f# is small compared to the magnification, it can be ignored. It's always small for closeup work; it's usually small for any kind of indoor work. It's usually not small for outdoor work. As M shrinks, this term becomes increasingly important. When M = c*FL/f#, the equation blows up!

This is the famed hyperfocal distance, H. So, in fact, the magnification that produces H is not independent of focal length, it's exactly inversely proportional to it.

Which may be the ONLY short statement one can make about the DoF equations that is truly correct, for whatever good it does us.

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Posted by: ctein | Wednesday, 24 June 2009 at 11:49 AM

Dear Craig,

Yes, yes, yes!

And furthermore... yes!

Dear Anton,

No, that's wrong. I addressed that in my comment to Ken N, above, so I won't repeat it, but please read it; it applies to your comment as well.

Dear Carsten,

If I understand you correctly, you've just restated the false assertion in slightly different words. Unless I've misread you (possible!), this is precisely the case I'm talking about: changing focal length while holding the target size constant. It doesn't yield the same depth of field. That's a myth.

So, yeah, I think you did your calculations wrong.

See my early comment to Mike and my later one to Ken N, for more elaboration. We're not having a problem with defining our terms or conditions; there are some folks who are trying to do that in a vain attempt to make the myth work (which it still doesn't even if you play with the definitions).

Dear Mark and Mike,

Yeah, once I'd figured out my math was right (which took months of convincing myself) that asymmetry was what most intrigued me.

I think it also helps explain why photojournalists tend to gravitate toward semi-wide lenses (aside from field of view, of course). Most news photos have the primary subject in the foreground, with the background being important for establishing context. Rarely is it important the stuff in front of the main subject be sharp, but the stuff behind often matters.

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Posted by: ctein | Wednesday, 24 June 2009 at 12:10 PM

Dear Yohan,

Everyone agrees that focal length matters. What is usually, nearly universally, claimed, though, is that so long as you hold the target magnification constant, you can change focal length without altering the depth of field.

Almost every tutorial out there that purports to explain depth of field invokes this 'handy' rule of thumb. (Like you, I'd question how handy this really is, since holding magnification constant when you change lenses means repositioning yourself, which alters the composition, etc. But, whatever-- it's the rule that gets repeated ad nauseum.)

All I'm doing here is correcting that misinformation. I have no higher aspirations.

What may be causing some confusion in this thread is that a number of correspondents are trying to find a way to reformulate the myth (in terms of subject detail, angular resolution, print magnification, etc.) so that it works.

Aside from the important fact that those reformulations are pretty well irrelevant to pictorial photography, they simply don't work mathematically. They all fail badly, and usually in a more serious way than the original myth.

Folks, you're dealing with a polynomial here that's got quadratic terms in the numerator and denominator. It is not particularly amenable to simplistic manipulation. Just give it up and accept the reality; you'll waste a lot less time.

pax / Ctein

Posted by: ctein | Wednesday, 24 June 2009 at 01:47 PM

Dear Ctein,

I did not claim that it does not change the depth of field, because I am not even sure what that means. I said something different and very specific, and I still think that it is true. In short, what I claimed is that if you take second chart in your photo on the right hand side and scale it down to the size which it has in the photo of the left hand side, they will both look the same.

In formulas, in the above setup, with the two charts at distances d_0 and d_1 and the chart at distance d_0 being in focus, a point on the chart at distance d_1 will have a circle of confusion (or whatever the correct term is) of a radius proportional to $d_0(d_1-d_0)/d_1$. Since we assume d_1-d_0 to be constant, we can also say that the radius is proportional to d_0/d_1. This shows that your claim is right in the sense that if we approach the subject, the radius becomes smaller. On the other hand, d_0/d_1 is exactly the ratio by which the chart at distance d_1 appears smaller (to be exact, larger, but you understand what I mean) than the chart at distance d_0. So would we measure the radius not in the film plane or the plane in focus, but in the plane of the object itself, the size of the radius would not change.

Again, I repeat what has been said above: When we get nearer and the focal length gets shorter, the chart at distance d_1 gets into the region that is considered in focus (again, excuse my possibly wrong or inexact terminology), but we still resolve exactly the same amount of detail of it (in practice of course less, because our film/sensor has limited resolution).

So I do not disagree with you at all. I just try to describe one

So I do not disagree with you at all, I just try to describe one aspect of the situation more fully and to find out which of the statements at LL are true.

Best,

Carsten

Posted by: Carsten S | Wednesday, 24 June 2009 at 01:49 PM

I thought the asymmetry was well-known from the old rule of thumb (which was presumably developed by landscape photographers using wide angle lenses and which, based on the above, seems to be a gross over-simplification) that one third of the depth-of-field is in front of your focal point, and two-thirds is behind.

Regards,
Adam

Posted by: mcananeya | Wednesday, 24 June 2009 at 01:56 PM

Dear Isaac,

Nicely summed up!

There's lots of 'technical' photography where what one cares about is how much real-world detail is collected, e.g., astronomy, microscopy, and photomacrography. Then we concern ourselves primarily with subject resolution, and it drives everything else: "I want to record 50 micron features over a distance range of 2 cm. What focal length, aperture and recording medium will achieve that?" Print sharpness and recorded lp/mm are secondary (whereas they're primary in pictorial work).

There are equations that help us with that, but they're cast differently from the familiar DoF equations, and they're of little value to pictorial photography.

pax / Ctein

Posted by: ctein | Wednesday, 24 June 2009 at 01:59 PM

"I thought the asymmetry was well-known from the old rule of thumb (which was presumably developed by landscape photographers using wide angle lenses and which, based on the above, seems to be a gross over-simplification) that one third of the depth-of-field is in front of your focal point, and two-thirds is behind."

Adam,
I knew that (in fact I used to *teach* that--may the gods of accuracy forgive me) but what was news to me is that DoF gets *more* asymmetric as focal length decreases.

Mike

Posted by: Mike Johnston | Wednesday, 24 June 2009 at 02:26 PM

"The root of the problem is that when we are trying to operate on an intuitive level, as we often must with photography, our brains are incapable of using even mildly complex (sic) mathematics."

I know a lot of people who can throw a rock at a moving object and hit it who wouldn't be able to do calculus involved. If you are going to try and hit something with a projectile miles away, you will probably want to do the math.

For studio work ranging from tabletop to portraiture, being able to imagine an image, pick a camera and lens, then arrange some people and or things plus the camera and the lights to get the image I want, basing everything on image size comes close enough. You can internalize it to the extent that something "looks like 5.6".

Posted by: hugh crawford | Wednesday, 24 June 2009 at 02:59 PM

"There's lots of 'technical' photography where what one cares about is how much real-world detail is collected, e.g., astronomy, microscopy, and photomacrography. Then we concern ourselves primarily with subject resolution, and it drives everything else: "I want to record 50 micron features over a distance range of 2 cm. What focal length, aperture and recording medium will achieve that?" Print sharpness and recorded lp/mm are secondary (whereas they're primary in pictorial work).

There are equations that help us with that, but they're cast differently from the familiar DoF equations, and they're of little value to pictorial photography."

I agree that the formulas aren't all that helpful, but I will slightly disagree and claim that their conclusions can be very useful. In particular, the insight that when focused at infinity, the lower limit of resolution throughout the picture is equal to the physical size of your aperture is very useful I think. Contrast that with using "hyperfocal distances" where the diameter of the smallest detail that can be recorded gets larger and larger as the distance increases from the point of focus, especially behind the subject. By knowing this fact, it is often MUCH simpler to focus at infinity and stop down a tad in order to guarantee the maximum depth of field in landscape photography instead of fiddling with charts and worrying about how accurate your DOF scale is.

So yeah, the actual formulas aren't all that useful when taking a picture, but it is certainly nice to know how things work!

Posted by: isaac | Wednesday, 24 June 2009 at 03:02 PM

I'm thinking about Ctein's response to my comment and I understand now where he is coming from. However, I see a flaw in the visual photography tests used to illustrate the point.

The two test charts are set with one in focus and the other out of focus. For this calculation we are not concerned with what something looks like OUT of focus, we want to see both charts IN focus.

A calculated DoF for a 100mm lens at F16 on a FF 35mm camera focused at 10m distance gives us an in-focus depth of just under 7m to 19m.

A calculated DoF for a 50mm lens at F16 on a FF 35mm camera focused at 5m distance (to maintain subject size) gives us an in-focus depth of 2.5m to 100m.

Oh wait, did this just confirm that he's right?

Old saws die hard.

Posted by: Ken N | Wednesday, 24 June 2009 at 05:21 PM

Dear Carsten,

Thank you for the clarification. Now I understand what you mean. I don't believe it's true, though.

In my original photos, the far targets don't have the same amount of detail when scaled to the same size. It may look here like they do, but you're not seeing the limiting sharpness in the wide angle photo in a mere 800-pixel-wide screen shot. There's a lot more fine detail not resolved in the illo.

Also, if you try to recast the DoF equations in terms of subject detail, you'll find that the 'no focal length' approximation is working better for the low magnifications, but now it fails badly at high magnifications. The problem's just been flipped around.

I don't know of any recasting of the DoF equations that produces a useful 'no focal length' approximation over the full range of magnifications. I can't say it's impossible, not having thought of all possible recastings, I'm sure, but I consider it extremely unlikely that one exists.

pax / Ctein

Posted by: ctein | Wednesday, 24 June 2009 at 08:18 PM

I'll admit that the article is waaaay above me, but I trust in Ctein--however, this comment made me pause.

"The photos also illustrate something else I've found it hard to get through to people - that blowing up an image is NOT the same as using a telephoto. The difference in the size relationship between the two targets is constant no matter how much you enlarge the wide angle version."

I thought that cropping is absolutely equivalent to using a telephoto--only moving where you take the shot changes the perspective. If you take two pictures of the same subject using a wide angle and a tele, keeping it the same size in the frame, then of course everything shifts. But take a picture with a 35mm lens and then a 90mm lens at the exact same spot and the photo with the 90mm lens would be the same as a crop (forgetting about resolution) from the 35mm one--right?

Posted by: Craig | Wednesday, 24 June 2009 at 10:49 PM

Dear Ken N,

To me, it looks like both test charts are pretty well in focus in the w.a. photograph. 'Course they're not going to be in the tele photograph.

Unfortunately, compositional constraints kept me from showing much of the same distant background in both photographs. But one can see bits -- the tree above the far target and edges of lawn and sidewalk below and to the left of the far target. Even the enlarged w.a. photograph, which ought to look much degraded in resolution, is sharper in those areas than the un-enlarged tele photograph.

pax / Ctein

Posted by: ctein | Wednesday, 24 June 2009 at 11:22 PM

Dear Craig,

Yer right; Colin's comment slipped past me.

Yes, the two photographs were not made from the same location. I had to move back about a dozen meters to get the same target magnification with the telephoto lens as I'd gotten with the wide angle. So you'd expect the composition to change.

Had I stayed in one place and made photos with two different lenses, the composition would have stayed the same. I could have blown up the wide angle photo and gotten the same composition as the telephoto picture.

BUT...

... and this is most curious ...

The two photographs would NOT exhibit the same DoF. The photo created with the wider-angle lens will exhibit more DoF both in front of and behind the target.

Bizarre, huh? Definitely counter-intuitive.

So cropping and enlarging a photo does not produce the same photograph as changing lenses, although it does produce the same composition.

This one makes my head hurt.

pax / Ctein

Posted by: ctein | Thursday, 25 June 2009 at 01:01 AM

Dear Ctein,

thank you for your answer. Let me detail my calculation to see if we can find out why they do not agree with your experimental findings.

The method (model?) I was using was that described in this Wikipedia article. Let me switch to their notation and use S1, S2 for the distances (I had used d0, d1 before). They give

c = A m |S2-S1| / S2

as an equation for the diameter of the circle of confusion, which means that for our setup (and with A=f/N)

c*S2/f = m*|S2-S1|/N

is constant. Above I had claimed that c*S2/S1 is constant. That claim relied on my assumption that m=f/S1, which I now realize is an approximation, because actually m=f/(S1-f). But is it not a good enough approximation for the distances that we are considering?

What is your take on this?

And regarding your last message to Craig: "So cropping and enlarging a photo does not produce the same photograph as changing lenses, although it does produce the same composition." It definitely does not produce the same photograph if you keep the f-stop fixed. Do you claim that it also does not produce the same photograph if you keep A=f/N fixed? That would indeed be surprising.

Best,

Carsten

Posted by: Carsten S | Thursday, 25 June 2009 at 04:38 AM

Ctein: "The two photographs would NOT exhibit the same DoF. The photo created with the wider-angle lens will exhibit more DoF both in front of and behind the target."

You have to take two things into account: 1st) the circle of confusion is changed by the cropping and 2nd) the f-stop for the two lenses does not refer to the same absolute aperture.

For your example, if you open the wide lens by 2 stops and crop by a factor of 2, the resulting DoF is indeed identical to the long lens.

I enjoyed reading your column,
Thanks, Stefan

Posted by: Stefan | Thursday, 25 June 2009 at 04:56 AM

"So cropping and enlarging a photo does not produce the same photograph as changing lenses, although it does produce the same composition."

This echoes another internet «truism» that pops up in many discussions of APS-C/43rd lenses, and goes like this: «17mm f/2.8 on four-third is equivalent to 35mm f/5.6 on full-frame» (or similar f.l. combinations).

I've always felt that this was complete nonsense at least in terms of exposure.

Your article and the discussion so far also suggests that it may be wrong in terms on d.o.f. as well, as the d.o.f. will be (slightly) more asymmetric on the 17mm than on the 35mm, if I get it correctly.

I'd be curious to read what people who really understand d.o.f. think of this internet «rule» anyway...

Posted by: Cyril | Thursday, 25 June 2009 at 05:59 AM

"So cropping and enlarging a photo does not produce the same photograph as changing lenses, although it does produce the same composition."

Really? I'm just a newbie at this but somehow this doesn't seem right. Don't different focal lengths introduce distortions from normal, or at least relative proportions of objects change w.r.t. each other within the photo? If so, how can a simple change of magnification (+/-) introduce those same distortions? I would like to test this myself but I only have a Canon 40D and not another camera with a different crop factor for comparison.

Posted by: Daniel F | Thursday, 25 June 2009 at 07:02 AM

Hugh,

It's true that people can't do the calculus to hit a baseball in anything like the required time, but we have brains that have evolved to allow us to approximate those calculations very well indeed.

Perhaps if we all keep on photographing like maniacs (I think we're on the right track) and can introduce some reproductive penalty for those who cannot get it right. Summary sterilization or execution for those who misfocus?? Then in only a few hundred generations we will all be able to get just the depth of field we want without hardly thinking about it at all. :-)

Posted by: Craig Arnold | Thursday, 25 June 2009 at 02:42 PM

Daniel - Assuming that you don't have any drastic distortions (like a fisheye), all longer focal length lenses do is show you a narrower angle of view. So if you captured two objects in one photo with an 85 mm lens and the same two with a 200 mm lens, their relative sizes in the images would be exactly the same. The lenses don't change the relationship between objects. When people talk about telephotos "compressing" a scene or "flattening" it, they're just talking about the psychological effect of the DOF and narrow angle of view - no actual difference in the image components.

Now if you take a single image and change the size of the sensor, all you're doing is capturing less of the image that comes through the lens. As far as composition and angle of view go, that's the same as using a longer focal length.

So when Ctein said it would be the same composition, that what he meant - all the relative sizes and locations of objects will be the same. The DOF, however, will probably not be the same - so the two photos may not be identical.

(As an aside, using a cropped sensor isn't changing magnification. The image produced inside the camera is the same no matter what size the sensor is, and that defines the magnification.)

Posted by: David Bostedo | Thursday, 25 June 2009 at 04:03 PM

Dear Carsten,

"... m=f/S1, which I now realize is an approximation, because actually m=f/(S1-f). But is it not a good enough approximation for the distances that we are considering? ..."

Well, y'see, that's the big fly in the ointment. It's not a good approximation when M gets large. And as M gets larger, your DoF gets shallower and shallower, so poor approximations are more dangerous.

As I said, there are useful approximations that work for near distances. There are simple approximations that work for very far distances (large fractions of the hyperfocal distance). In between, it all goes to hell, and an approximation that works well for one end of the range (like the one I started my column with) turns into crap at the other.

Dear Stefan,

I did take the change in CoC into account.

My math agrees with yours-- change the magnification, change the CoC *and* change the f/stop in concert, and all the effects cancel out.

Ummm, but who cares? That wasn't really the question. It was whether cropping worked exactly the same as changing focal lengths, and the counter-intuitive answer is that it doesn't.

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-- Ctein's Online Gallery http://ctein.com
-- Digital Restorations http://photo-repair.com
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Posted by: ctein | Thursday, 25 June 2009 at 09:26 PM

Dear Cyril,

It's not an 'internet "truism";' it's a well-known rule of thumb from way before the Internet. I quoted it much earlier in this thread in my answers to ben and robert e. Where I point out it's a ROUGH rule of thumb that's good enough.

And, so long as people are quoting it in the context of DoF, it does work well enough. It is handy for me to know my Fuji S100fs, operating at, say, f/2.8 is getting me about the same DoF as I'd get with my 35mm Pentax at f/11 and my 6x7 Pentax at f/22.

IF you can find someone quoting it in the context of exposure, yes that would be nonsense. f/2.8, in exposure terms, is f/2.8 regardless of format. If they're talking DoF, it's not.

Regarding the distribution of DoF...

Something I hadn't mentioned, and possibly should have sooner, is that trying to nuance this too far is pointless, because real-world lenses NEVER have the same DoF that the equations predict. The precise shape of the light 'cone' near the point of focus has a big effect on where the diameter of the envelope hits the CoC limit, and the shape of that envelope is very sensitive to lens designs and residual aberrations. There have even been lenses with a floating element that tweaked the mix of aberrations so as to let the photographer alter the balance between near and far DoFs!

So, you never want to take this to too many decimal places. It doesn't match reality all that well.

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Posted by: ctein | Thursday, 25 June 2009 at 09:29 PM

Dear Craig,

I'm afraid I'm childless by choice (and surgery), so your grand eugenics program is already hopelessly messed up.

If only you'd let me know what you had in mind about 35 years back, I'd have planned my life differently! [vbg]

pax / highly-singular Ctein

Posted by: ctein | Thursday, 25 June 2009 at 09:32 PM

"The precise shape of the light 'cone' near the point of focus has a big effect on where the diameter of the envelope hits the CoC limit, and the shape of that envelope is very sensitive to lens designs and residual aberrations."

At the risk of tugging a little more on the lid of a certain container, perceived DOF can be strongly affected by bokeh - the smoother the OOF rendering, and the further away from the plane of focus that recognizable form is retained, the more powerful the illusion of depth. OTOH, overtly frizzy OOF renderings work strongly against that effect.

This just underscores Mike's point - the only way to understand the DOF characteristics of a lens for practical purposes is to use it and study the results. The formulas help you make sense of your observations, but are not sufficient in themselves. You can't tell how much apparent depth a picture made with a real lens will have just by feeding the lens parameters, CoC criterion and subject distance into a DOF calculator that assumes an idealized lens.

Posted by: Oren Grad | Friday, 26 June 2009 at 12:28 AM

Dear Oren,

Absolutamente!

Many threads back, I commented on this... but I had trouble finding my own comment, so I'm gonna repeat it here:

"the issue here is not DoF, it's the need for some photographs (-ers) to keep the unimportant parts of the photo from taking your attention away from the important parts. That's all about suppressing high spatial frequencies; that's what distracts the eye.

"It doesn't matter where those frequencies come from: it they're there, they distract (e.g., artifacts in a very high-compression JPEG).

"The boke characteristics of a lens *radically* change that high frequency power spectrum. The difference in high frequency strength between 'harsh boke' and 'smooth boke'is much bigger than the difference introduced by 1, or even 2, aperture changes.

"A lens with really 'jangly' out of focus rendition is going to produce more distracting backgrounds at f/2 than a 'smooth' lens will at f/5.6. Yes, the f/2 lens will have much shallower DoF... but that shallow DoF will not translate into the visual effect that's desired!

"Declaring that some hypothetical f/2 lens will give you better DoF control (in the way that MATTERS) than an f/2.8 lens, absent any knowledge of the real imaging characteristics of the lens, is concentrating on the chihuahua and ignoring the mastiff."

pax / Ctein

Posted by: ctein | Friday, 26 June 2009 at 12:53 PM

Thanks for your interesting view on this subject! I have been thinking about this some times and - in practical work - used the "myth" á la Reichmann and others. And it has worked out OK for me. One comment here: In your sample picture, taken with a long lens, the scale for the main (sharp) subject is the same as in the picture taken with a short lens. But for the unsharp subject, the scale is not the same at all! Now, what would happen if you would require that the unsharp subject should have the same size in both pictures? Or, in other terms: Is it true to say that the "sharpness" of the distant subject is so bad in the picture taken with the long lens? I don´t think it is! In your example, the distant subject shows roughly the same definition of the lines in both pictures but since it is so much bigger in one case, it looks more unsharp. One can actually count the number of lines equally well in both pictures! So in one respect, they are equally "sharp". The whole discussion may be different if we talk about the resolution of details in the picture or if we talk about resolution of details in the subject!

Posted by: Staffan Johansson | Friday, 03 July 2009 at 11:36 AM

The comments to this entry are closed.