

Focus Stacking: the Quest for Depth of Field

By Dennis Goulet, HonNEC

One limitation we all struggle with is the shallow depth of field we must live with when photographing close up and macro subjects, and the depth of field becomes razor thin as we increase magnification greater than 1:1, an example being optical microscopy. Focus stacking techniques and specialized software provide the ability to combine the areas of sharp detail from multiple captures into a single image with extended sharpness.



Why Focus Stack?

We already know that focus stacking can help us increase depth of field with macro lenses when making close up images. DoF is very shallow for close up photography; a typical 100mm macro lens set at F/16 focused on a subject 18 inches away has a depth of field of .62 inches. If that lens is moved closer to a 12 inch distance, the DoF drops to .24 inches. For those cases where a shallow DoF meets your creative needs of selective focus, then you are in luck. However, if you want to show more of your subject in focus, then there are some ways you may be able to take advantage of the huge number of pixels in today's modern cameras. By increasing the focus distance between the camera and the subject and



keeping the same aperture, the DoF increases. The subject may be smaller in the frame, but the image can be cropped substantially to get the image you envision. A similar result can be accomplished by using a wider angle focal length lens then cropping.

Unfortunately, these increases in DoF are incremental at best. With focus stacking techniques, if the subject has a depth of one inch and the DoF of the camera/lens setup is only a tenth of an inch, then 13 to 15 images, to ensure sufficient overlap of in-focus areas, can be stacked together to accomplish the end result of a completely in-focus subject.

Macro and micro photography are certainly the driving force that resulted in focus stacking techniques, but there are other instances where we may benefit from the technique. We may have too little DoF by choice. For instance, occasionally I will use

a larger aperture to increase shutter speed without resorting to high ISO setting, and the image noise that results, and still want a subject or the entire view in focus. A higher shutter speed may be required to capture the subject without motion blur.

The image of the spider is four captures at f/8 which provided sufficient shutter speed to stop the movement of the spider on the web in the slight breeze and render the nearby vegetation in softer rendition.

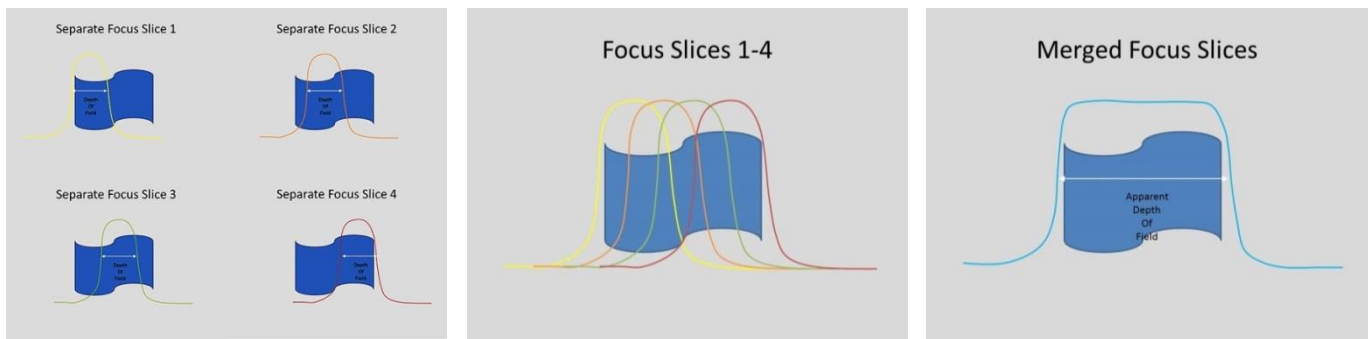
It may be desirable on occasion to use the sweet spot of a particular lens for the sharpest capture, avoiding the diffraction effects of small apertures. And my personal favorite rationale for using focus stacking techniques is isolating a subject from the background. I use focus stacking to isolate a single flower in sharp detail from front to back while keeping the background soft. This is accomplished by capturing multiple images at a wide aperture, which leaves the background soft. The images are first aligned in software then merged to keep the sharp sections of each capture.

The image of the pink lady's slipper on the left is a single capture at f/16. It's a nice image but I wanted the nearby flowers to be softer and less prominent in the image. I could have used software tools to soften the background but I find it is very difficult to do especially when the main subject has tiny hair like structures on all the plant parts. The second image is a focus stack of twelve captures taken at f5.6. This aperture was selected to get the background look that I wanted.



How Does Focus Stacking Work?

A series of images is captured at slightly different focus distances. Each image is a “slice” of focused area adjacent to focused areas in other slices. In-focus areas of each “slice” are selected manually or automatically (using edge detection or Fourier analysis) and combined into a single image. A graphic representation of the process is shown here. In this case four slices are captured. Each time the focus is adjusted to move the focus point forward for each capture. The images are then manipulated in software to align the images, select the in-focus sections, and merge them into a composite image.



Capturing Image Slices

There are several methods for capturing the individual slices. The most common is to set the camera on a tripod and change the focus distance of the lens by rotating the focus ring. The distance between the camera and subject do not change, but the point on the subject which is targeted for focus is changed. This method requires no additional equipment to capture focus stacking slices.

The second method is to fix the focus of the lens at a point on the subject and change the position of the camera/lens. This method moves the camera in small increments to place the point of focus on different parts of the subject. The best way to accomplish this is by use of a macro slider. These are readily available at camera stores and online stores. Some of the low cost macro sliders available online are low quality and require some “tweaking” to make them easier to use. The top slider below is typical of those available in camera stores and are functional as is. The two separate rails can be easily separated since both rails are not required for focus stacking. The bottom rail was purchased online for about \$12 but needed some work; I added a thin piece of plastic between the slider and rail to remove some of the play, and used a small file to etch a thin marker above triangle to have better resolution on the position of the slider compared to the rail.



There are more costly focusing rails with very precise control, and electrically driven rails are also available for computer control of very fine movement of the rail and to trigger the camera. This is typically used for macro and micro image capture where hundreds of slices may be needed.

One effect of changing the focus distance by either method described above is a shift in perspective. As the focus is moved forward, the subject gets bigger in the frame. With close up subjects the difference in subject size is considerable. The two images below are the first and last images of a 52 image set of a flower approximately two inches from front to back. In the first image, the focus is on the closest part of the subject to the lens. The first image has been resized so that the flower is the same size in both

images. For this reason, it is important to frame the subject with the focus on the subject element closest to the camera.



Perspective shift is generally not a problem as the software used for stacking resizes each image so that elements in each image slice line up with others in the stack. It is more complex than just reducing image size; the software will distort the image in an attempt to match subject elements if the subject moves a little in an image slice. The perspective shift problem can be eliminated by using a bellows to fix the lens in place, and move the camera body back and forth to change the point of focus on the subject. However, this method introduces a shift in magnification which can also be problematic. I've only started using a bellows and haven't much experience with it so I'll save that technique for another article once I know more about it.

Capture Considerations

You will find that there are many circumstances that will result in your image stack giving an unsatisfactory result. Some of these can be fixed in post-processing; others will need a new set of captures.

Camera movement and subject movement are both bothersome for focus stacking as the software can only do so much to align subject elements before the stack. Camera movement is easily controlled with a sturdy tripod or other mechanical mount coupled with good capture technique. Use a cable release or the camera's self-timer. Longer exposure times may warrant mirror lockup to reduce camera vibration during exposure. Using live view in manual mode may be a good option as the mirror is in the up position. Live view also includes the capability of magnifying a section of the subject so that focus point can be moved forward more effectively. Also, by using the DoF button on the camera, the effect of the aperture can be seen and help in deciding how much to move the focus point forward.



Subject movement can show up in the resulting image of a stack and is often easily corrected in cases where the subject, such as a flower has moved slightly. For an insect, the movement is more complex with legs, head body and other body parts all moving in different directions. In the example above, a breeze caused the subject to move in one of the captures, causing a ghosting effect of the subject. By reviewing the individual images in the stack, I found the image in which the subject was not aligned, removed that image from the stack, and reprocessed it. This effect generally does not show up in stacks processed with Photoshop because of the way that

PS stacks the image slices. More on that later.

Some software does not handle variances in image brightness and changes in lighting among images in the stack. While it is not as big a problem in Photoshop occasionally some programs will display a warning that the variations are too extreme to stack properly. A similar warning may also be displayed for those cases where the steps between the slices are inconsistent. These phenomena are more readily addressed by using good capture planning and techniques. Insufficient focus overlap can be prevented by calculating the number of captures required to fully cover the subject. First we must decide how much subject is to be rendered in sharp detail.



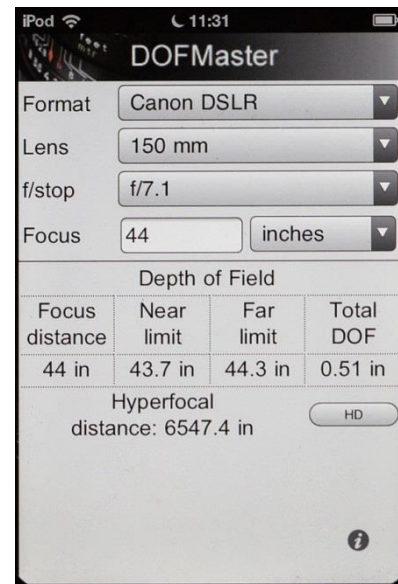
In this example, the depth of the subject is 2½ inches deep and the camera is 44 inches from the subject which is determined after setting the camera to get the desired framing. Using a DoF calculator tool such as DOFMaster or PhotoPills, we can enter the camera and lens used, the distance to the subject, and the selected aperture to calculate the amount of DoF for that combination. I select the aperture to provide the softness of the background I wanted.

With an aperture of f/7.1 the calculated DoF is ½ inch. Since the subject is 2½, it would reason that five slices would cover the subject. However, I typically add a few slices and often double the number so that there is sufficient overlap of the in-focus sections.

With enough overlap, if one slice is “bad” it can be removed with no loss of sharpness in the processed image.

Another technique that I use with a focusing rail if I don’t have a DoF calculator with me is to move the rail to the point where I have the closest point focused and note the marking on the rail’s scale, and do the same for the far end of the subject. Based on the starting and end points on the rail I can make consistently spaced slices by moving the rail the same amount for each capture, such as 3mm. This is somewhat arbitrary, but if I use smaller increments I can always use every other slice, or every third slice, if I find I have too many. In general, you can’t have too many slices.

If you have a mirrorless camera with an electronic viewfinder, another tool is available. Most of these cameras have a focus peaking display for use with manual focus. The sharp edges of the image in the viewfinder are highlighted in a contrasting color so that you know what will be sharp in the image. After making a



capture, you can look at the viewfinder or rear display to see how much the focus area moves forward as you rotate the focus ring to ensure you move just enough. It only shows the sharp areas at the wide open aperture, so the actual DoF will be larger if a smaller aperture is used, providing overlap.

Simple Two Image Stack



I wanted to make an image of three pink lady's slippers in my yard. Two of the flowers were in the same plane, but one was forward of the others. They were close enough that I could have used a aperture of f/16 or f/22, but to keep the background softly out-of-focus I chose to stack two images at f/8. I merged the two images with Photoshop.

The line around the flower on the left indicates where Photoshop selected the sections from one image and merged it with the second image. You can see that Photoshop does not do a great job of selecting the edges of the sharp portion of a slice to merge with the other slices.

Image Stacking Software Choices

Rather than include the chart of available software, a comprehensive list of available focus stacking software, some of it free, can be found on Wikipedia at

http://en.wikipedia.org/wiki/Focus_stacking

I generally use Photoshop and Helicon Focus, each having some benefits and liabilities. **Photoshop** uses a very basic cut and paste technique for merging sharp areas of slices into a composite image. Unfortunately, the selection algorithm of sharp areas is not refined; it will often include some of the image on that slice that is not in focus. While this can be a problem in some cases, there are ways to fine tune an image after the Photoshop merge. The Photoshop merger results in a patchwork of selected sections from each slice, showing only the sharp items in the final image. Adjustments to the layer mask could be made but it is laborious because when one layer mask is modified to block an out-of-focus reveal, an equivalent area must be masked out from another layer. However, when an image is auto-blended, the layer masks can be modified by



painting black into the mask, but not white. So changes can be made to remove part of the image, there is no means to replace it on another layer. Photoshop does a very good job of handling color and brightness changes in the background, but not so well in defining the edges of sharp areas. This stack example shows the smooth areas of the out-of-focus lateral sepal adjacent to the petal. The Photoshop algorithm cannot closely mask fine hairs on the petal to reveal the sharp detail of the sepal behind it. The image is a stack of 15 slices taken at f/7.1.



Helicon Focus is designed for focus stacking and does an excellent job of detecting and merging fine details of multiple slices. It occasionally has problems with variations in exposure, and cannot resolve an image element that has moved a considerable amount from the other slices. It considers those elements sharp and merges them into the final composite. Helicon Focus has three algorithms, which they call methods, available but I seem to always have success with method C. There is a retouching tool that facilitates cloning a section from any of the layers into the composite image in a side by side window. The cursor displays in both views so that the source and destination can be seen at the same time. Included with the merging software is Helicon Remote, which allows tethered photography with Canon and Nikon DSLR cameras to automate focus (DoF) bracketing, exposure bracketing (HDR) and time-lapse shooting, even combined if needed.

The same image stack of 15 slices for the previous images was processed with Helicon Focus. The results are much better with all the detail of the lateral sepal shown.

As can be seen in the Wikipedia list of focus stacking software there are many alternatives available. Helicon Focus is one of the more popular, with an online forum and tutorials. Many offer free trials, and some are freeware, but some of these products are not as well supported and may be more difficult to learn. Another product that many photographers use is Zerene Stacker. Similar to Helicon Focus it also offers multiple stacking methods and online tutorials.

Using Photoshop for Focus Stacking

I find it is best to organize images stacks so they are easily found, as well as their stacked results. It is important to organize your images so that the images that belong to a stack can be identified for import and processing.

1. In Photoshop, open Bridge.
2. Select all the image slices of a stack
3. Select Tools/Photoshop/Load Files into Photoshop Layers

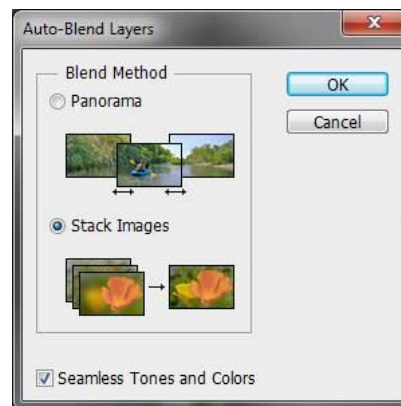
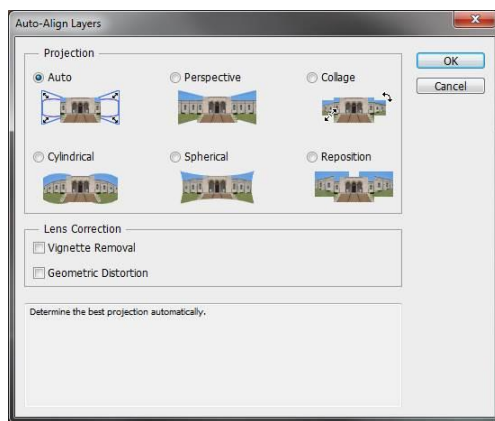
4. All the captures will be loaded into one workspace as layers

If you use Lightroom to manage your images

1. In Library view, select slices to be stacked
2. Right click on one image
3. Select Edit In/Open as Layers in Photoshop
4. Photoshop opens all images as layers in one workspace.

After the image slices are loaded as layers in Photoshop

1. Highlight all the layers
2. Select Edit/Auto-Align, leave the selection on Auto, click OK.
3. Select Edit/Auto-Blend. This will open a selection, leave on Stack Images, click OK.

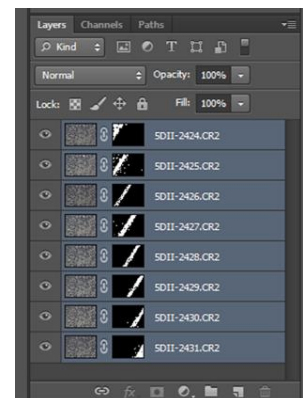


After the auto-blend operation, a layer mask for each layer (slice) is created to reveal the sharp areas, with consideration of where it adjoins other sharp areas from other layers.

In this example, an image of water drops from melted frost on a window was made from eight slices. Due to the camera location it was impossible to place the camera parallel to the window. You can see from the layer panel how Photoshop selected bands of in-focus area from each successive layer for the merge.



Some additional processing such as curves adjustments were made on the composite image.



Using Helicon Focus for Focus Stacking

With the plugin provided, images can be loaded into Helicon Focus directly from Lightroom.

1. In Library View, select slices to be stacked.
2. Right click on one image.
3. Select Export/Helicon Focus
4. Helicon Focus will open
5. All images will be shown in right hand panel.
6. Below the source image panel are the selections for Rendering Method. I always start with Method C.
7. Click on the Render button.

You can also bring in a set of images directly into Helicon Focus.

1. Open Helicon Focus
2. In File/Open Images select the files to be stacked. This works best if the image slices are in their own folder.
3. Proceed as described above.

Fixing Stacked Images

After initial merging of an image stack, often some post processing will be required. With Helicon Focus, a retouching tool is provided that facilitates cloning a section of one of the slices into the final image. A similar technique can be done for an image stacked in Photoshop by manual manipulation.

First open the flattened stacked image into Photoshop. Look at the images slices that were used to make the stack and select the one that has the detail you will to insert into the final image. Open that into Photoshop. Now there are two images opened separately in Photoshop.

1. Select the composite image with the Rectangular Marquee Tool
2. Use the Move Tool, click and hold on the composite image and move the tool over the repair source image title. When that image opens move the tool over the image.
3. The composite image will now be a layer over the repair image.
4. Create a layer mask on the top image (composite image).
5. Using the Brush Tool paint black on the out-of-focus area to reveal the in-focus detail in the composite image.
6. You may need to do this several times as the out-of-focus portions may cover in-focus areas of more than one slice.

The left top image is the merged composite image and the left bottom image is the repair source slice that has the in-focus detail of the lateral sepal above the left petal. The larger image is the repaired

merged composite now showing detail in the sepal. Additional steps would be required to add detail from a different slice below the sepal since it is further back.



A Few Stacking Examples

This wolf spider was found in my wood pile early one morning on a piece of split wood. Since he wasn't moving much due to the very cold temperature that morning, I got my macro gear and went to work. It took several attempts to get enough images to stack; occasionally the spider would move a little and I would have to start over. For this stack I started the first capture with the top of the head in focus and worked my way forward with the final image having the most forward leg in focus. The twenty slices took



a total of 12 minutes 25 seconds to capture, each being a five second exposure at f/22. Helicon Focus was used to assemble the stack as the fine hairs on the legs and body would cause problems with merging in Photoshop.

Focus stacking can also be used for “big picture” images. By that I mean landscape and other compositions which are a long way from close-up or macro/micro images. When photographing shorebirds in Cape May, NJ, I was presented with the view of hundreds of semipalmated sandpipers and dunlins in the shallow water near the edge of an impoundment. Using a 500mm lens with a 1.4X converter set at f/16 aimed at a downward angle to the birds, I did not get much of the field of view in focus. Only a thin strip of across of the image was in focus and using the DoF preview on the camera I was able to determine that six slices would be sufficient to capture all the birds in focus on one slice or another. Using the Photoshop stacking technique or Helicon Focus would have been futile as some of the birds moved between captures; a raised wing here, a head tucked in there, a the occasional head turn. A trial stack merger in Photoshop was attempted and bird parts were merged with other parts, and parts were missing. The only way to merge the slices was to do it manually.

I use two slightly different methods for hand merging multiple slices in Photoshop. I'm certain there is a more elegant way to merge these images in Photoshop, but I am a brute force user. I loaded the first two images in the stack as layers into Photoshop with the closet image below the second image. Then I added a layer mask on the top layer. What is seen on the image is a strip of out of focus birds below a strip of in-focus birds. Using the Brush Tool, I painted black on the layer over the out-of-focus birds in the bottom section of the image below the in-focus birds to reveal the in-focus birds below. I work with small sections at a time, in this case a few birds so that if I go too far, I can undo the last set of brush strokes and rework that area. Once all the sharp areas are revealed from the bottom layer, I flatten the layers and save this file.



Then I add the next layer, put it on top of this layer which now shows the third band of sharp birds from the bottom with two rows of out-of-focus birds. I use the same technique above to reveal the in-focus sections. One thing that is different from the first two layers is that I don't use the brush to paint the entire lower section of the top layer mask. I use the brush along the boundary between the in-focus and out-of-focus areas, then using the Rectangular Marquee Tool mark the area from the bottom edge into the brush painted area and fill it (Edit/Fill) with black. To make identifying where the painted area is in the layer, I hide the bottom layers, which leaves only those areas of the top layer that will be seen in the composite image. Then I save this image file with a unique name, flatten the layers, then add the next layer and repeat.

While this is not very elegant, the second method I have used is similar but preserves all the layers in one image file

I open all the slices as layers in Photoshop. Making certain that the closet image slice is the bottom layer, I add a mask to the second layer. Just to keep things simple visually, I hide the layers above this layer showing only the two layers I'm working with. Once I get the mask completed, I just make the next layer visible and hide the lower layer since I don't need to see it. After masking the boundary between the two layers, I mark and fill the rectangular section to completely mask the area below the slice merger.

You can read a few blog posts on focus stacking at www.dennisgoulet.us

Larger copies of the images in this text can be found [here](#).

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A member of Photographic Society of Rhode Island, Dennis Goulet concentrates his photographic endeavors on nature and landscape subjects. He is also a member of the Massachusetts Camera Naturalists and is currently chairman of the board of the New England Camera Club Council (NECCC). He gives presentations on photographic technique at camera clubs, has presented five times at the NECCC annual photography conference, and was the General Chairman of the NECCC 2013 and 2014 annual photography conferences.

Dennis' images have appeared in several magazines including Audubon, Nature's Best Photography, Wild Bird, Birder's World, Rhode Island Monthly, Outdoor Photographer, and Sierra, as well as on the websites of Audubon and National Wildlife magazine. His image of a Green-breasted Mango was selected Grand Prize Winner of Audubon Magazine's 2010 Birds-In-Focus photography contest. www.dennisgoulet.us