

# **Image Stitching for Panoramas**

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# Panoramic Image Stitching

Panoramic stitching involves combining two or more overlapping images into a single image that covers a wider field of view than any of the individual images. This technique is most commonly used in landscape photography where the subject is horizontal and is significantly wider than it is tall.



While you could capture a similar image in a single shot with a wide angle lens, after cropping it to panoramic proportions you would be discarding a lot of pixels and the resulting image quality would suffer.

In addition to creating panoramas, image stitching is also a way to create higher resolution images than your camera would otherwise be able to take. This is a great way to get very sharp, high resolution images from a relatively low-resolution camera. It also has the side effect of narrowing the depth of field since the individual images are taken with a longer focal length compared to what you would use to get an equivalent field of view in a single photograph.

Image stitching is best performed using specialized software, but for best results it is also important to photograph the subject properly and to pre-process the images before attempting to stitch them together.

# Taking the photographs

## Equipment

While you don't need any special equipment to take panoramas, if you are going to make a lot of them, a leveling base in combination with a tripod head that can do horizontal panning is a big help.



Ball Head with Panning

## Leveling Base

The leveling base mounts between the tripod base plate and the bottom of your ball head. It provides a quick and easy way to level the base of your ball head so that when you pan, the camera stays level and tracks the horizon. If you don't level the base of the ball head, the strip of images can drift upward or downward as you pan and you will end up having to crop the stitched image more than you may want. You can take panoramas without a leveling base by adjusting the lengths of the tripod legs until the ball head base is level, but that takes a lot of time is not very accurate.

Many different leveling bases are available, but make sure the one you get is rated for the weight of the equipment it needs to support, and make sure the base of your ball head does not extend beyond and thereby obscure the level on the leveling base.



## Basic Procedure

The basic procedure for a single row horizontal panorama using a leveling base and ball head is as follows:

- 1) Set up the tripod.
- 2) Use the leveling base to level the ball head base.
- 3) Mount the camera on the ball head.
- 4) Use the ball head to level the camera and adjust the elevation depending on the composition.
- 5) Set the camera to manual focus and manual exposure. Make sure you are not using a polarizer.
- 6) Focus the camera manually.
- 7) Select an f-stop that gives you enough depth of field for the scene.
- 8) Review the scene, panning through the range of angles you want to capture and determine the panning angle increment you need to get good overlap between images.
- 9) Select an exposure time that avoids clipping highlights in any of the images.
- 10) Using a remote shutter release, take an overlapping series of images using the panning degree scale to space the images evenly.

## Nodal Slide

You can use a panoramic tripod head or nodal slide that lets you rotate the camera around the lens's nodal point to avoid parallax errors. The nodal point is generally located somewhere in the middle of the lens – rotating the camera about this point keeps the foreground and background aligned. The nodal point of each lens is different and needs to be determined by trial and error. This item is largely unnecessary unless you are photographing subjects relatively close to the camera. However, if you are using a wide angle lens and capturing foreground close to the camera as part of your panorama, parallax can cause the stitched foreground to be distorted. In this case, you may need to use a panoramic head or nodal slide rail such as these:



## Panning Base

An alternative to using a leveling base is to use a panning base:



This attaches on top of your ball head, and instead of using a leveling base to level the ball head, you use the ball head to level the panning base. The advantage of this solution is that a panning base is usually a little lighter than a leveling base and it can be easily removed when you don't need it. However, it works differently from a leveling base if you angle the camera up or down from the horizon. The panning base does not keep the camera at the same elevation above the horizon as you pan, but moves the camera in a great circle so that for a 360 degree panorama, half the images are above and half are below the horizon. A leveling base keeps the camera at the same elevation to the horizon as you pan, but the images will not be in a straight line, so the stitched panorama will have an odd shape.

## Automated tripod head

There are also fully automated panoramic tripod heads such as the Gigapan that can be programmed to take a complete set of panoramic images in one operation.



## Use a rectilinear lens

Avoid using fisheye or other special purpose lenses that distort images – this will make it impossible to stitch the images later.

## Use the same camera settings for all the images

Use the same focal length for all the images and turn off autofocus.

If the scene brightness does not vary too much, putting the camera in manual mode and selecting a compromise exposure that works for all the images is generally the best approach. If the exposure varies a lot across the scene, you can use autoexposure, overlap the images

heavily and hope the stitching software can smooth out the seams. Or, you can bracket each image and use HDR to merge the bracketed exposures before or during stitching.

Similarly, if you need to use focus stacking to get the entire image sharp, focus bracket each image and stack each one before stitching them together.

While you could do both HDR and focus bracketing, it can get very complicated to keep track of all the images. The more complicated you make the process, the more likely one or more of the images will be taken incorrectly and spoil the entire shot. If you are using HDR and/or focus stacking, it is a good idea to repeat the entire process several times so you have a better chance of success.

## **Image overlap**

Allow a substantial overlap between images as this will make the stitching software's job easier and give it more options to deghost and blend the multiple images smoothly. Try for at least a 1/3 overlap between frames. To maintain a consistent overlap between images you can use the degree scale on the panning part of your ball head and move the camera by the same number of degrees between each shot.

## **Camera orientation**

The general rule is to shoot in portrait mode for horizontal panoramas and in landscape mode for vertical panoramas. While this requires more images to cover a given panning angle, it gives you a wider field of view perpendicular to the panning direction.

## **Allow for cropping**

The boundary of a stitched panorama is generally uneven, depending on the projection you select in the stitching software, so you will always need to crop the final image to make it rectangular. Therefore, when you take the pictures, leave a generous margin around your subject to allow room to crop at the end of the process. This is particularly important if you are using a wide angle lens or if you shoot with the camera angled either up or down.

## **Avoid using filters**

The effects of a polarizer change as you reposition the camera, so you can get inconsistent illumination if you try to shoot panoramas with a polarizer attached. You can use a regular neutral density filter if you need to slow the exposure. You might also be able to get away with using a graduated neutral density filter if you are making a single row panorama and the split is parallel to the panning direction.

## **Single- and Multi-row panoramas**

Single row panoramas are usually horizontal or sometimes vertical and consist of a single strip of images resulting from panning the camera in one direction between shots. This is the most common type of panorama. Before you start, use the ball head to level the camera and compose the shot, running through the angles you want to capture and adjust the exposure if necessary to work with all the images.

When you need to cover a wide area both horizontally and vertically or if you simply want a very high resolution image, you may want to create a multi-row panorama. This involves shooting a series of single row panoramas, moving the camera in the other direction between rows. Try to maintain as much overlap between rows and you have between images. Multi-row panoramas are trickier to stitch but can be very effective. To make a multi-row panorama, note the starting and ending panning angle and angle increment between images from the first row so you can position the other rows directly above and/or below the first row.

### **Mark the beginning of each series of images**

When you get home and look at your files, it is much easier to identify a series of images that make up a panorama if you mark the beginning and possibly the end by taking a frame with the lens cap on or with your hand in front of the lens.

### **Limitations**

To stitch images, the subject must not move too much between images or you will get ghosts. Ghosts occur when a subject appears in some images but not others and is then rendered semitransparent. Good stitching software can help reduce ghosting, and some subjects such as moving water can be automatically de-ghosted surprisingly well. Wind, moving subjects and changing light all create problems for any image stitching program. If you need to shoot under these conditions, taking several sets of exposures will let you select the one that works best.

# **Pre-processing the images**

## **Correct for vignetting, lens distortion and chromatic aberration**

When processing raw files for stitching, enable corrections for lens vignetting, distortion and chromatic aberration if your raw converter supports it. This makes the job of the stitching software much easier and produces higher quality results.

## **Remove lens hot spot**

If you are shooting infrared, remove any central hot spot from each image before stitching or else you will get multiple hot spots in the final image.

## **HDR or Focus Stacking**

If you shot bracketed exposures, merge them before stitching, making sure you process each image with the same HDR settings. If you try to HDR merge after stitching, the images may not align perfectly. Some stitching software can perform HDR during the stitching process if you supply overlapping images with different exposures.

If you used focus bracketing, merge each group of images before stitching.

## **Speck Removal**

If you notice distracting spots from dust on your sensor, remove them from each image before stitching or they will get replicated across the panorama.



# Stitching the images

## Software

Panorama stitching is built into some image editing programs such as Adobe Lightroom and Photoshop, but you have more control over the results by using specialized commercial software designed expressly for stitching images. Lightroom, for example, stitches horizontal panoramas quite well but makes a mess of vertical panoramas.

Stitching is a complicated process. To get a high quality result involves accurately aligning the images in the presence of unknown lens characteristics and distortion, projecting all the images onto a common surface, blending the images smoothly where they overlap, and deghosting. There are quite a few stitching programs available. Here are four I have tested – two commercial and two free.

### **PTGui (commercial)**

A good commercial panorama stitching program with a lot of features. The program is expensive and the interface is confusing and complicated, but it is capable of professional quality results. PTGui Pro (the more expensive premium version) can merge HDR images automatically. This is the best currently available package. A beta version that uses a novel blending algorithm is also available.

### **Hugin (free)**

A free panorama stitching program that is fairly easy to use and works well. I have not used it extensively but it performed well on the set of test images I tried it with.

### **Microsoft Image Composite Editor (free)**

Another free panorama stitching program. It is relatively easy to use, but I have seen reviews that claim the stitching quality is not as quite good as PTGui. One major shortcoming is that it produces 24-bit color panoramas even when you start with 48-bit color images. This program appears not to have been updated recently.

## Projections

To map a 3-dimensional scene to a 2-dimensional image, stitching software uses a projection, like map projections for reproducing a globe as a flat sheet of paper. Each type of projection has its own advantages and disadvantages. The three main projections you are likely to use are rectilinear, cylindrical and spherical, although some stitching programs support others. It can be worthwhile to try each of them on a given image and then decide which look you prefer.

### **Rectilinear (sometimes call Perspective)**

A rectilinear projection is like using a rectilinear wide angle lens to capture the original scene in a single image. The advantage of rectilinear projections is that they keep all straight lines straight, so this can be a good choice for architectural photography. There are several disadvantages, however. First, as you approach a 180 degree field of view, the projected image becomes infinitely wide, and beyond 180 degrees, this projection does not work at all. Second, the edges of the image tend to get very distorted and blurry

as the field of view increases. Nevertheless, for panoramas that are not too wide, this can be a good choice.

### **Cylindrical**

A cylindrical projection (equivalent to a Mercator map projection) is a good choice for single row, horizontal or vertical panoramas. It keeps lines perpendicular to the panning direction (for example trees and buildings) straight and can produce a full 360 degree panorama. As the field of view perpendicular to the panning direction approaches 180 degrees, the cylindrical projection runs into the same problem as a rectilinear projection as the image height becomes infinite. The same way a Mercator projection exaggerates the size of Greenland and Antarctica, objects near the top and bottom of the image are elongated vertically.

### **Spherical**

A spherical projection does not preserve straight lines, but it deals with panoramas that have a wide field of view both horizontally and vertically better than cylindrical.