

Image Stitching for Panoramas

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Introduction

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 the 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 and 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 check that the base of your ball head does not extend beyond and 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, or just judge the overlap by eye.

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. There are a number of videos available on the internet that describe the procedure for locating the nodal point of a lens should you decide to go this route.

A nodal slide 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 panning the base of the tripod head if you angle the camera up or down from the horizon. Panning from the top of the tripod head 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° panorama, half the images are above and half are below the horizon. Panning from the base of the tripod head 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 fully automated panoramic tripod heads such as the Gigapan (now discontinued) and Nodal Ninja Mecha that can be programmed to take a complete set of panoramic images in one operation. While these tripod heads tend to be heavy, bulky and expensive, they may be justified if you are creating panoramas on a regular basis, especially multirow panoramas.



Use a rectilinear lens

While some systems for capturing 360° virtual reality cylindrical or spherical panoramas are designed to work with fisheye lenses, normally it is best to use a regular rectilinear lens since they capture detail more uniformly across their field of view.

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 auto-exposure, 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 image data to align, deghost and blend 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. Or, use distinctive features in the image and track their position in the viewfinder as you pan the camera.

Camera orientation

The general rule of thumb 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 and produces a higher resolution result image.

Composition

The boundary of a stitched panorama is generally irregular, depending on the projection you select in the stitching software, so you will nearly 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.

Since you can't see the final stitched image in the camera's viewfinder, it takes some practice to learn to pre-visualize panoramas. Be prepared to experiment a lot when you are starting out to discover what works and what doesn't. When in doubt, shoot several variations and include plenty of extra background around your subject to leave yourself as many framing options as possible in post-processing. For example, more sky and less foreground may work better than more foreground and less sky.

Avoid polarizing filters

The effects of a polarizer change as you pan 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.

Avoid cutting off the corners of the frame

Especially if you are using a wide angle lens, avoid using any filters or anything else that cuts off the corners of your images. Otherwise you will have trouble stitching them together later.

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 with normal proportions, 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 as 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. An indexing head with adjustable click stops can help you pan in equal overlapping steps without any gaps.

If you cover a wide field of view with a large number of narrow field of view images, while increasing the amount of detail you can capture, you will be using a longer focal length and consequently depth of field will be reduced considerably. Unless the entire subject is far from the camera, this can make it impossible to get everything in focus without focus stacking each sub-image.

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. You can also make a card to carry with you that is, for example, green on one side and red on the other and photograph it to mark the beginning and end of a series.

Night Photography

Aside from the obvious difficulty of finding your way around after dark, taking photographs at night presents special problems when trying to focus accurately on faint objects. Autofocus is unreliable at night and even if your camera has a distance scale, it is probably not accurate enough to focus blind, especially if you are using a wide aperture to gather more light. Here are several methods for focusing at night:

- 1) Bring a flashlight and use it to temporarily illuminate your subject while you focus.

- 2) Pre-focus manually before it gets dark and tape the focus ring of your camera to keep it from moving.
- 3) For astrophotography, try to find a bright star, the moon, or some distant light to establish infinity focus. There are also specialized filters available to help you focus accurately such as a [Bhatinov Mask](#) as well as filters designed to reduce light pollution.
- 4) Take some test shots and check that they look sharp when you magnify them.

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, while 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.

Note: if you plan to use PTGui (see below) to stitch your images, do not correct for lens distortion during raw file processing since PTGui performs this correction during the stitching process. This is particularly an issue if you are creating a large, multi-row panorama.

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 bracketed exposures, merge them before stitching, making sure you process each group of images with the same HDR settings. If you try to merge after stitching, the images may not align perfectly. PTGui Pro can perform HDR during the stitching process which saves you from having to merge the bracketed exposures separately.

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

Although panorama stitching is built into various image editing programs such as Lightroom, Photoshop, Affinity Photo, ON1, and Luminar, you will have more control over the results if you use specialized software designed expressly for stitching images. You are also less likely to encounter stitching artifacts such as ghosting or areas where adjacent images are misaligned or are not smoothly blended.

Stitching is complicated. Getting high quality results involves accurately aligning the images in the presence of unknown lens characteristics and distortion, projecting all the images onto a common surface, and blending and de-ghosting the images smoothly where they overlap. While some older programs such as Image Assembler and Microsoft Image Composite Editor have been discontinued, there are still a few good stitching programs available. Here are three currently available programs I have tested – one commercial and two free.

PTGui and PTGui Pro (commercial)

An excellent commercial panorama stitching program with lots of features. The program is expensive and the interface is complicated and can be confusing, but it is capable of professional quality results. PTGui Pro (the more expensive premium version) can merge HDR images automatically while it is stitching. This is the best currently available package. See below for streamlined instructions on how to use its basic functions.

<https://ptgui.com>

Hugin (free)

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

<https://hugin.sourceforge.io>

Kolor AutoPano (free)

Before migrating to PTGui, AutoPano was my primary panorama stitching program. While this excellent commercial program was unfortunately discontinued in 2018, they have since made a free version available, but it may take a little effort to get it to run on newer computers.

First download and install the program via the following link:

https://download.hdrmaps.com/AutopanoGiga_x64_442_2018-09-10.exe

Next, locate a recent copy of the open source file *libeay32.dll* and copy it to the folder in which AutoPano was installed (typically *C:\Program Files\Kolor\AutoPano Giga 4.4*), replacing the obsolete version already there. I was able to find a newer copy of *libeay32.dll* included with Adobe Acrobat Reader which worked fine (located at *C:\Program Files\Adobe\Acrobat DC\Acrobat\RdrTools\libeay32.dll*), but many other programs install and use this file. Or, you can download a copy from:

<https://www.dll-files.com/libeay32.dll.html>

You can now launch AutoPano by double-clicking its icon on the desktop, and use the following credentials to register your free copy:

User: *freecopy@kolor.com*

Registration code: *KAPG7-K3A9X-IZJHX-FIIT7-C5IM8-MQF2N*

Although the on-line help function for the program is no longer maintained, here is a link to a copy of a mostly complete manual in PDF form:

<https://www.dl-c.com//Documents/AutoPano.pdf>

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 other variations. It can be worthwhile to try each of them on a given image and then decide which look you prefer.

Rectilinear (sometimes called 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° field of view, the projected image becomes infinitely wide, and beyond 180°, 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 (similar 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° panorama. As the field of view perpendicular to the panning direction approaches 180°, 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. Not all stitching software can create good vertical cylindrical panoramas.

Spherical

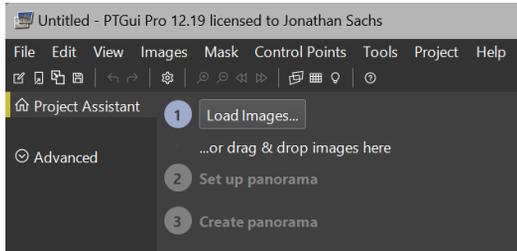
A spherical projection does not preserve straight lines in any direction, but it can handle panoramas that have a wide field of view both horizontally and vertically better than cylindrical.

Getting Started with PTGui

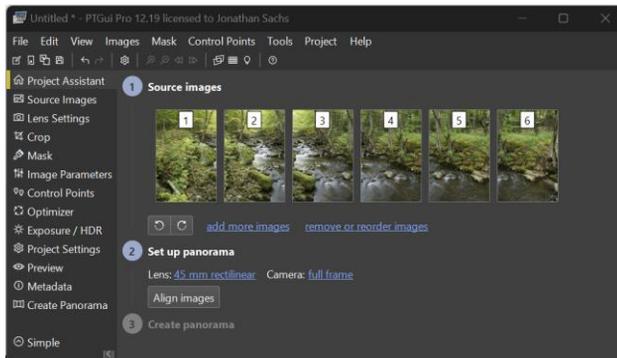
PTGui's user interface can be a little intimidating, so here is a streamlined procedure to help you get started with the program's basic functions. Once you get familiar with how it works, you can start to explore its advanced features.

Step 1 – Select the images you want to stitch.

When PTGui starts up, it displays its *Project Assistant*:

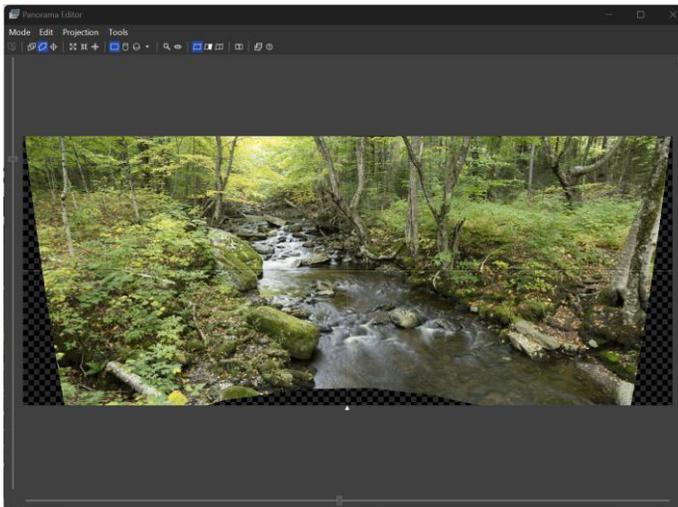


The first step is to click the *Load Images...* button and then select the images you want to stitch, ideally in order and click the *Open* button. Or you can just drag and drop the images on the PTGui window. PTGui will then open the files and display thumbnails of the images you selected. Check to make sure you selected the correct set of images before continuing.



Step 2 – Align the Images

Next, click the *Align images* button at which point PTGui will attempt to assemble and project the selected images. If successful, it will display the resulting panoramic image in its *Panorama Editor* window.



Selecting the Projection

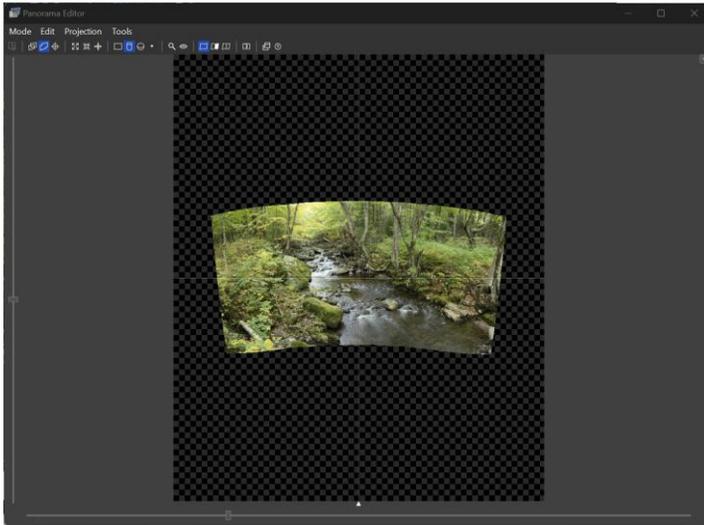
If the field of view of your panorama is not too great, a rectilinear projection may work well. This projection has the advantage that straight lines in the scene are rendered as straight lines in the panorama. As the field of view gets wider however, the edge of the panorama become increasingly distorted, and as the field of view approaches 180 degrees, the rectilinear projection breaks down completely.

As an alternative, consider using a cylindrical projection. Note that if you are creating a vertically-stacked panorama, you need to select Transverse Cylindrical instead of Cylindrical. This option is available via the drop-down menu. The advantage of a cylindrical projection is that distortion is reduced at the edges of the image. While lines in the scene perpendicular to the direction of camera sweep remain straight, parallel lines are rendered as curves, so for architectural photography this can produce unnatural results.

For panoramas that have a wide field of view both horizontally and vertically, a spherical projection may be the best choice.

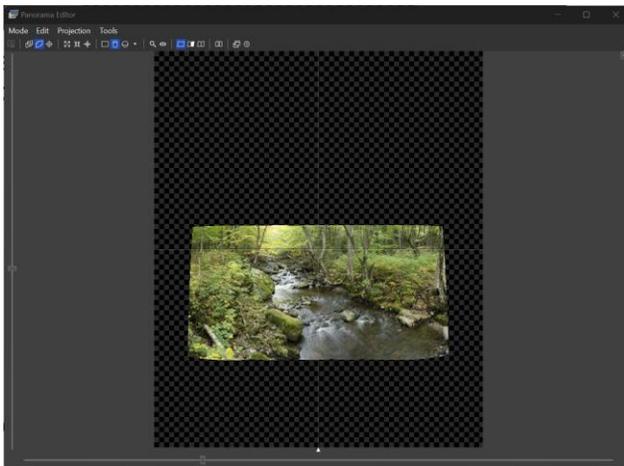
You can select the projection using the tool bar at the top of the editor window. In this example, a cylindrical projection was used. Since the camera was angled up a little, the outline of the resulting panorama is curved and the top part is cut off.

To zoom the image in or out, use the horizontal and vertical sliders to the left of and below the image. In this example, the projection was set to cylindrical and the image was zoomed out to make room for subsequent operations.

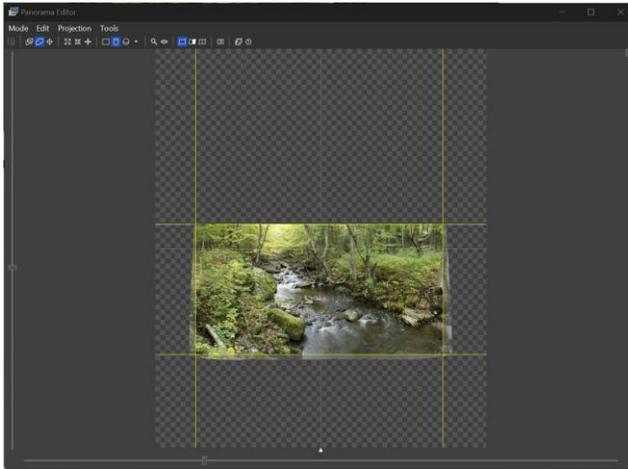


If you photographed the original images with the camera angled up or down the panorama boundary will be curved – you can make it more or less rectangular and thereby straighten the horizon by dragging it upward or downward until it evens out.

You can also rotate the image if necessary by dragging it using the right mouse button. This might be required, for example, if the base of the tripod head was not quite level.



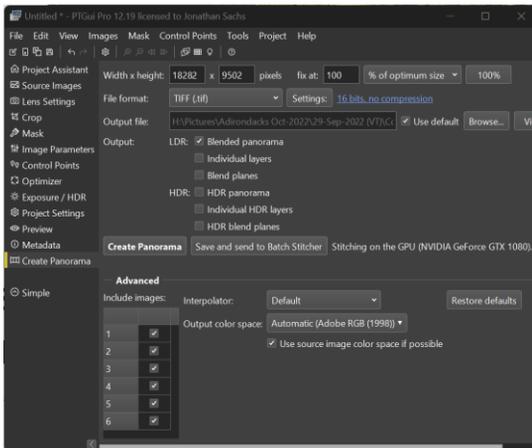
Lastly, you need to trim the unnecessary background around the image – otherwise it will have a large, black border. You accomplish this by dragging the edges of the image background (the checkerboard area) inwards. It can be a little tricky locating the edges, so watch carefully for the cursor to change shape as you pass over each edge.



You are now ready to save the image.

Step 3 – Create the Panorama

To create the final panorama and save it as a TIFF file, return to the main PTGui window and click the *Create panorama...* button. This brings up the *Create Panorama* screen.



Next, set the *File format* to *TIFF* and select the desired TIFF options. You can assign a custom pathname to the output file or just use the default. Generally there is no need to include an alpha layer in the output file. Finally, click the *Create Panorama* button and PTGui will finish stitching the images and save the result as an image file.

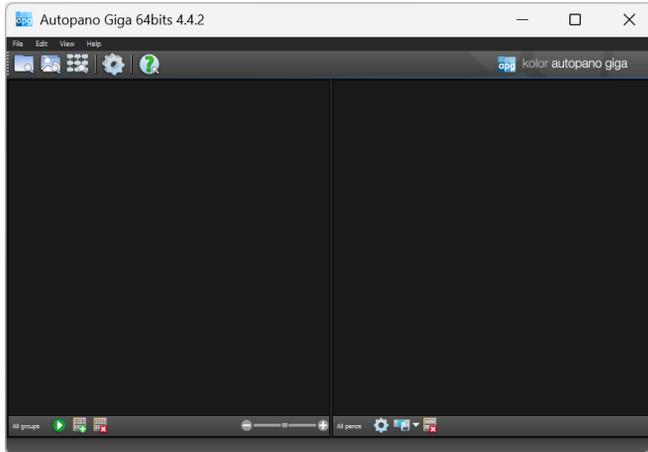
To make your file format and other settings the default so you don't have to re-enter them every time you use the program, select the *File/Make Default* command from the main menu.

Here is the final panorama image:

Getting Started with Kolor AutoPano

Step 1 – Start AutoPano

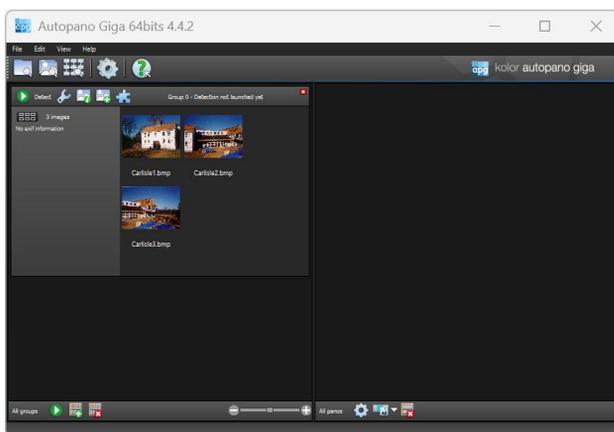
When AutoPano starts up, it displays its main screen:



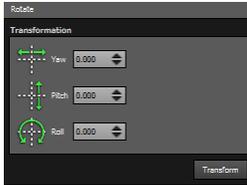
If this is the first time you are using it you will probably want to change the default settings. To do this, select Edit/Settings from the main menu to display the Settings dialog box. First click the Panorama tab and select the projection you want to use by default. I typically set this to Cylinder. For more details on selecting a Projection see the quick start for PTGui above. Next click the Render tab and set the file type you want to save as (under Format). I recommend setting this to 16-bit uncompressed TIFF. I also set the Output Folder to %i and Output Filename to %a. Click OK to close the Settings dialog box. You can always override any of these settings later but it saves a lot of time if you start with the right defaults.

Step 2 – Select the images you want to stitch.

Select File/Select Images from the main menu and then select the images you want to stitch, ideally in order and click the *Open* button. AutoPano will then open the files and display thumbnails of the images you selected. Check to make sure you selected the correct set of images before continuing.



To adjust the rotation angle of the pitch of the image, click the  button. This brings up the Yaw/Pitch/Roll settings:



To change any of the settings, you need to enter numeric values and click the Transform button. Any changes you make are cumulative. Yaw scrolls the image left or right, Pitch scrolls the image up or down, and Roll rotates the image. Pitch is what you change to compensate to shooting a horizontal panorama with the camera aimed up or down. Roll is what you change to compensate for the horizon not being level.

To crop the image, click the  button. This displays a crop box on the panorama that you can drag. Click the  button when you are done adjusting the crop box.

To create the final panorama, click the  button on the Editor tool bar. Review the Render settings and click the Render button when you are ready to proceed. This launches a background process that creates the stitched panorama. It will notify you when the file has been created.