Panoramic Photography

Stitching with Hugin



A Tutorial

by Daniel K L Oi

website: www.dkloi.co.uk email: info@dkloi.co.uk

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Preface

- Panoramic photography has been around since nearly its very beginnings, digital technology has made it widely accessible, both to produce and and to view
- This tutorial is meant so show the mechanics of how panoramic photos are taken and assembled
- The use of Hugin (https://hugin.sourceforge.io/) is to demonstrate the underlying principle of aligning and optimising panoramas, hence the manual process described
- For streamlined workflows, a commercial alternative (e.g. PTGUI https://ptgui.com/) may be more efficient as it effectively automates many of the steps shown in this tutorial
- Hugin also provides automatic functions such as control point generation, optimisation, and output, though they may not be as effective as PTGUI
- However, in expert mode and with manual control, Hugin is able to produce professional results with some practice and experience
- The information and advice is provided without guarantee or warranty and should be used at your own risk. Any mention of products does not constitute an endorsement.

Introduction

- This tutorial goes through the steps I use to create panoramas
- It covers the basic techniques of creating a spherical panorama
- It does not include advanced techniques such as exposure fusion, high dynamic range imagery, coping with shadows, moving scene elements, or compensation of differing white balance or exposures
- The main steps are:
    a) Adjusting the panoramic rig, ensuring the no-parallax point is set
    b) Taking the source imagery
    c) Assembling the pano, optimising alignment and exposure
    d) Editing the exported panorama
    e) Displaying the final panorama
- We will concentrate on Steps b) & c). There are many other resources available explaining a). Step d) is similar to editing a normal photo, though there are some subtleties to be mindful of, a future tutorial may cover this is more detail. Step e) is dependent on the final usage.

Preliminaries

- Equipment
- Panohead setting up and camera mounting
- An explanation of the No-Parallax Point and Entrance Pupil



In My Bag

I use a typical set-up for taking a 6-shot panorama. The main elements are: Interchangeable lens camera; Diagonal fisheye lens; panoramic head; tripod with ballhead. The ballhead and tripod have been chosen to produce a small nadir footprint to minimise the nadir hole that has to be patched.

1. Sony A7m3 Camera. Good image quality, decent resolution (24MP), good selection of lenses, versatile system. Any relatively recent large sensor camera (M4/3rds or up) can give good results paired with a decent lens. The main considerations are sensor size, pixel pitch (resolution for a given sensor size), sensitivity, and dynamic range.
2. Samyang 12mm/2.8 Fisheye Lens. Good sharpness, “stereographic” fisheye projection, “fullframe fisheye” (180° diagonal field of view), manual focus and aperture
3. Nodal Ninja 3 Mk III with Nadir Adapter and Rotator Mini v2. There are several inexpensive options for panoramic head that will do the job. It should have sufficient adjustment range to allow the camera+lens to rotate around the entrance pupil that is the location of the no-parallax point (mistakenly called “nodal point”)
4. Tripod. A fairly sturdy one is good to reduce any possible blurriness from vibration or wind. It should be tall enough to put the point of perspective at the appropriate height, usually eye-level. The size of the head should be considered as this can intrude into the nadir footprint. A ballhead is typical.
5. Remote Release. Eliminated camera shake when triggering shutter. Avoids blurry images. Not essential but highly advised.
6. Blower. Helps remove dust from lens. Also, sensor cleaning system, e.g. Gel Stick
7. Spare Battery. It’s good to be prepared.
8. Padded bag insert. Fits into an ordinary backpack easily, inconspicuous. Also holds a 28-75mm/2.8 and 85mm/1.8 lens as my travel setup.



Panohead Setup

1. Nodal Ninja 3 Mk III. Good quality multirow panohead. Reasonably compact but sturdy. By adjusting the lower and upper rail positions, the entrance pupil of the camera can be placed at the intersection of the rotation axes so as to avoid parallax between images.

2. Upper Arm. Camera attached to the upper arm which can rotate up and down, i.e. in elevation.

3. Vertical Arm. Joins the lower and upper arms. Needs to be long enough so that the camera can clear the lower arm as the upper arm rotates towards vertical

4. Nadir Adapter. Allows the vertical arm to be rotated 180 degrees so that the camera can be pointed directly down for an uninterrupted view of the ground. Useful for taking the nadir down-shot for patching the nadie hole

5. Lower Arm. Connect upper arm with the rotator.

6. Rotator Mini v2, 24 clicks (15°). Allows consistent and rapid yaw rotation of panohead to shooting positions.

7. Ballhead. I have chosen one without a QR clamp in order to minimise the Nadir patch. I have also adjusted the knob to point down when clamped, this also reduces the intrusion into the Nadir region.

8. Tripod. Nothing special, should be reasonably sturdy. Its shoulders may appear in the Nadir area so find one that isn’t too wide.



Camera Mounting

1. Nadir Adapter. Allows taking a Nadir shot easily by rotating the upper arm and moving it to the end of the lower rail so that the lens can be pointed straight down when the tripod is shifted to match the camera position of the other shots

2. Arca Swiss Clamp. Makes it quick and simple to attach and detach the camera. The stock mounting plate with the NN3MkIII is satisfactory, but is slower to mount onto the panohead. The additional thickness of the Arca Swiss clamp also helps move the vertical arm further away from the shooting axis so less of it appears in the frame. This is a dual clamp that attaches to upper arm of the NN3MkIII.

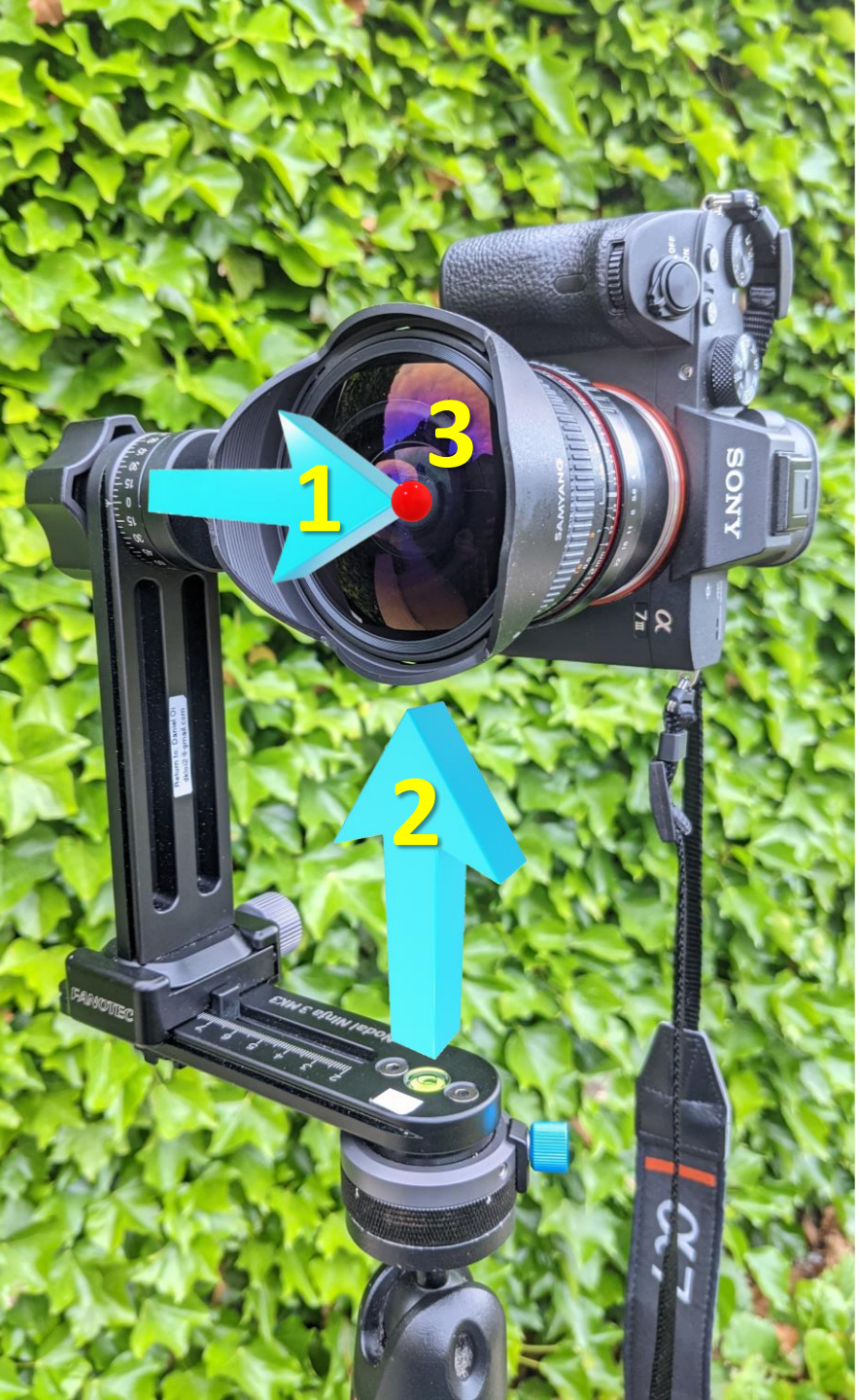
3. Slim Arca Swiss Plate. Adds very little bulk of weight to the camera

4. Upper arm locking knob. The upper arm can move in elevation. Here, it is in the +90° position, pointing straight up

5. Lower arm setting. The vertical arm can be moved along the lower arm so to align the entrance pupil with the vertical axis of the rotator.

6. Upper arm setting. The camera can be moved back and forth on the upper arm to place the entrance pupil in line with the upper arm rotation axis.

7. Samyang 12mm f/2.8 Diagonal Fisheye Lens. Provides a field of view of ~ 106° x 157° (180° on the diagonal)



No-Parallax Point

(Not the "Nodal Point"!)

1. Upper arm rotation axis

2. Rotator vertical axis

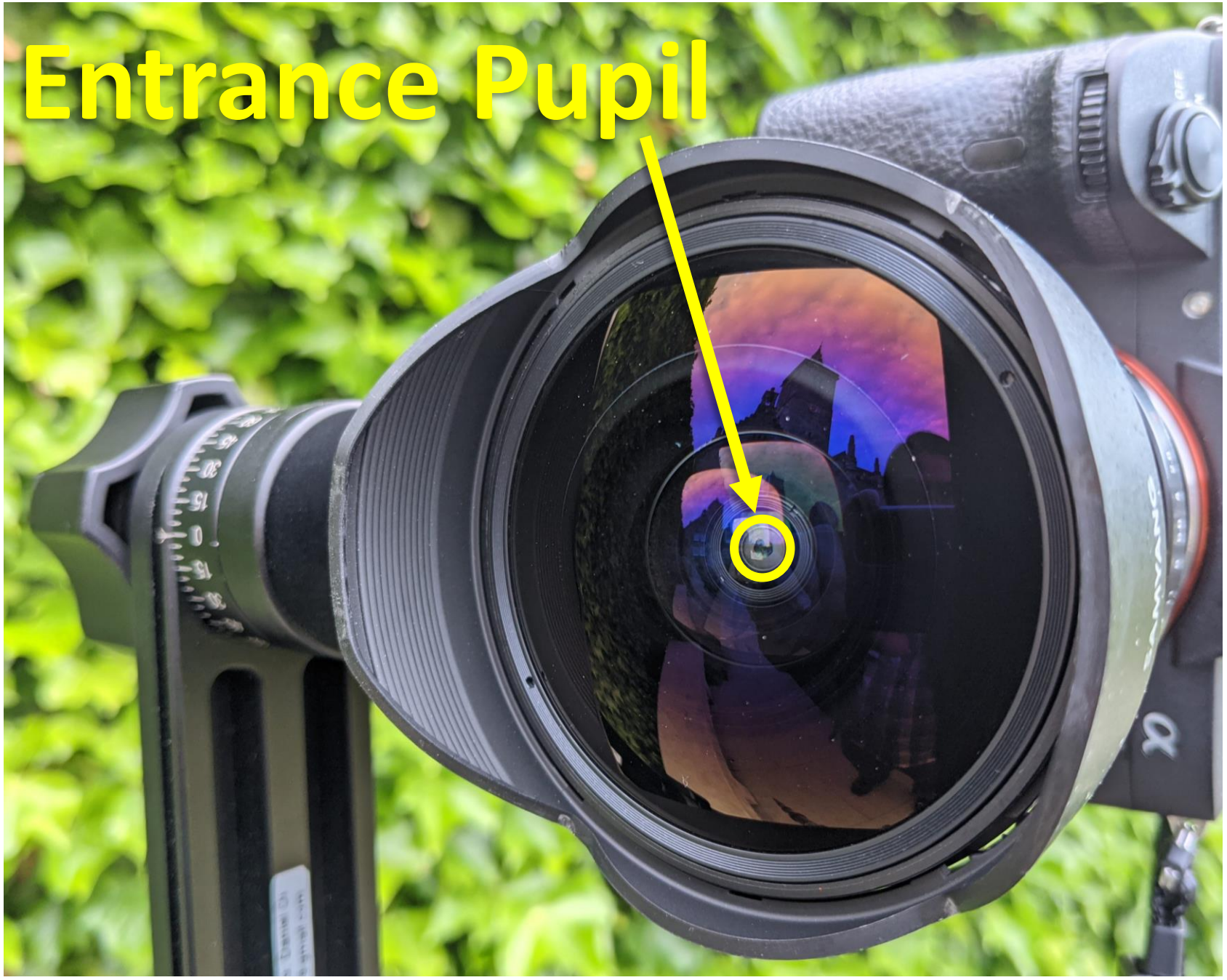
3. Entrance Pupil or No-Parallax Point. This is point of viewing perspective. The camera needs to be rotated around the entrance pupil to avoid parallax. NB The Entrance Pupil is **not** one of the two nodal points of a lens (front and rear) that have entirely different meaning. See https://en.wikipedia.org/wiki/Entrance_pupil "*Panoramic photographers often incorrectly refer to the entrance pupil as a nodal point, which is a different concept.*"

4. Rotator Mini v2, 24 clicks (15°). The blue knob allows the rotator to be locked into position. Otherwise, there are detents that allow shots to be taken at set rotational intervals. A 24 click detent allows shooting patterns with 2, 3, 4, 6, 8, 12, and 24 shots in the yaw direction. I have added a triangle to the top part and white paint to the bottom part to indicate 90° intervals.

5. Bubble Level. Not essential since you will be levelling the assembled panorama in any case. But useful to get an approximately level shooting setup. No need to spend too much time or effort with trying to get an exact level panohead.

6. White Tape. Helps provide a visual reference in the dark for tilting down the camera to minimise the Nadir patch. It is also useful for getting ad hoc white balance.





Entrance Pupil

1. The Entrance Pupil is the location of the no-parallax point
2. It is the apparent position of the aperture stop of the lens when looking into the front element
3. In general, the Entrance Pupil position will change depending on the angle away from the optical axis that the lens is viewed
4. In fisheye lenses, the Entrance Pupil will move forward as this angle increases, this is the reason why a fisheye lens can have an extremely wide angle of view.
5. Since the position of the Entrance Pupil changes with the angle away from the optical axis, the setting up of the panohead and the upper-arm setting will depend on the number of shots to be taken when rotating the camera horizontally.
6. When determining the no-parallax position, rotate the camera by the same angle as when shooting and adjust so that there is no parallax at the midpoint of the overlapping frames

The Shoot

- Setting up the shot
- Taking the source images
- Handling the Nadir Hole



Shot Set-Up

1. Narrow stance of tripod, reduces the size of the nadir hole. The legs are brought in so that they are not as visible in the frame.

2. First set aperture to aperture to help focus

3. Using magnified live view to set my focus distance. This should balance depth of field between the closest object (usually the floor directly underneath) and the furthest point (could be less than infinity if indoors)

4. After focus distance has been set, close down aperture to taking aperture, here it is f/8. This may depend on the lens and the situation, e.g. balancing depth of field, optimum sharpness, and exposure time







Taking the Pano

1. The camera is tilted down slightly until the top of the panohead is just in view at the bottom of the frame

2. The ISO is set to the base value (here ISO100), aperture priority (aperture set on lens, shutter speed determined by autoexposure system)

3. Each shot is triggered with a remote release to avoid shake. Electronic first curtain shutter eliminated any vibration from the beginning of the exposure.

4. After each shot, the panohead is rotated 90 deg (depends on camera+lens) to capture 4 shots horizontally around

5. Take care to make sure straps, hands, or other bits of your body not in the shot. Also take note if any moving objects cross the overlap between adjacent shots as this can cause stitching problems.

6. The zenith shot is captured by rotating the panohead directly upwards

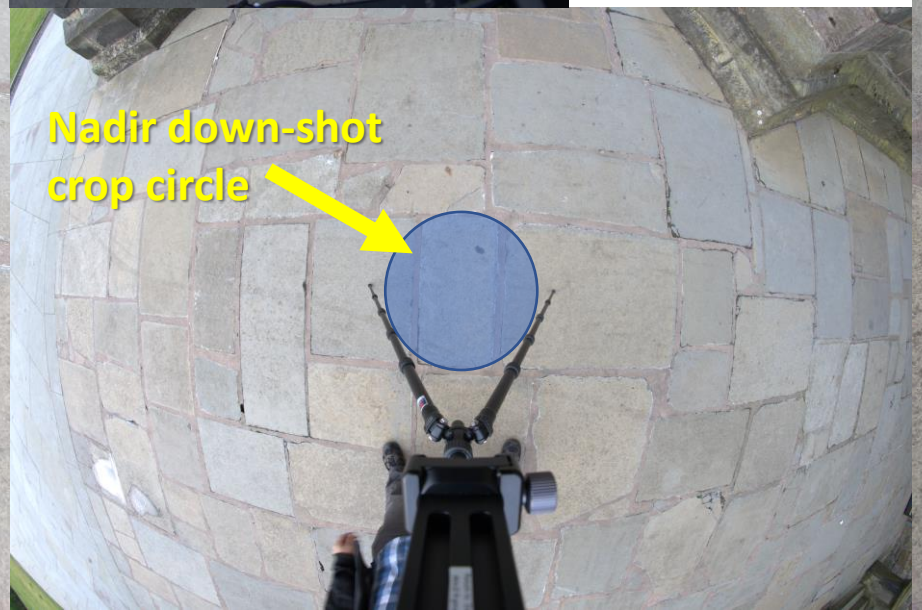


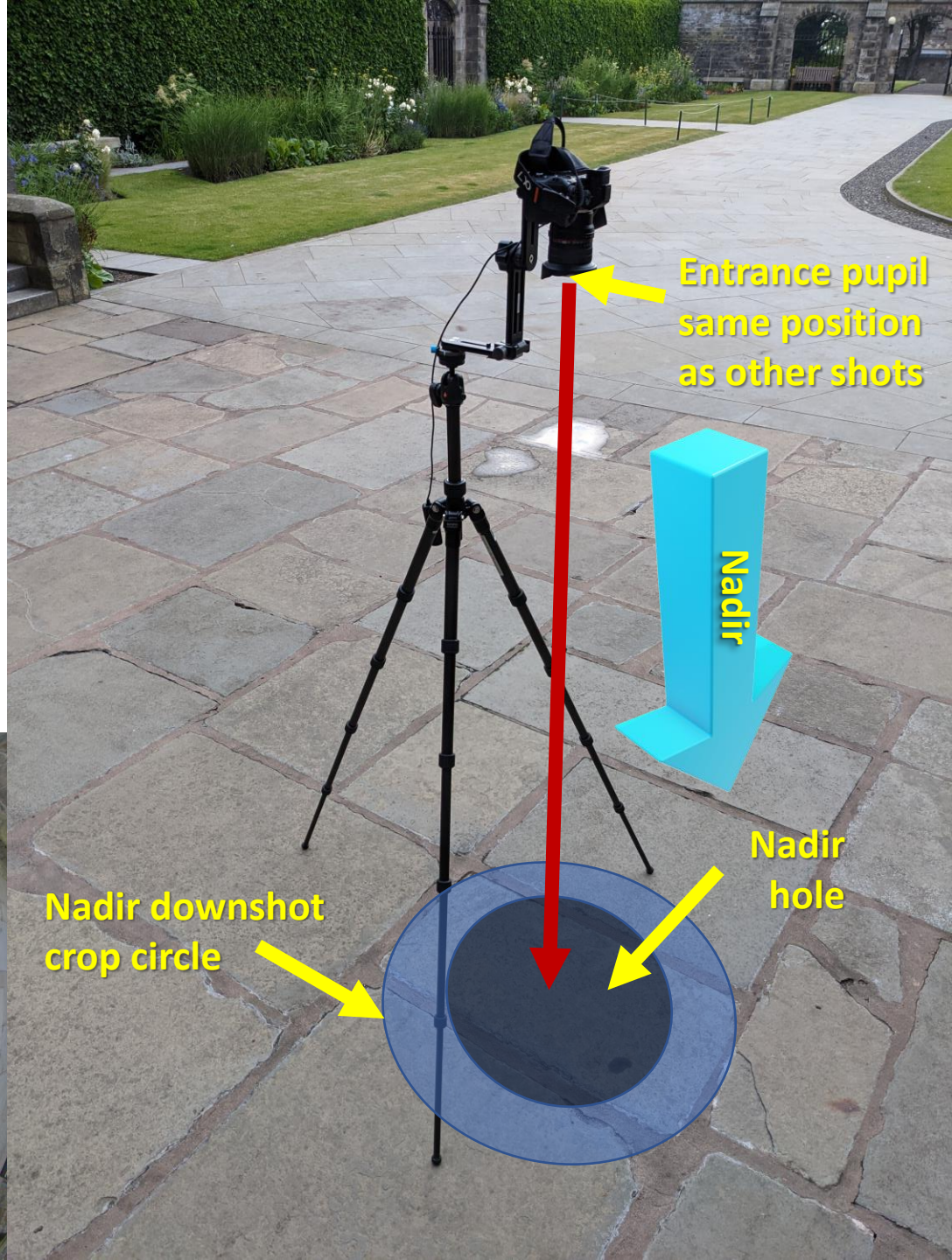
Nadir Shot

1. Minimise the size of the nadir hole by narrowing the stance of the tripod and tilt down the camera
2. Use a Nadir Adapter to allow the down-shot to be directly over the nadir
3. Ensure the down-shot has clear coverage of the obscured part of the nadir to allow easy patching









Preparing the Source Images

- Raw file development
- Optimisation of raw file export







Standard Export of Raw Files

1. Shoot raw files to maximise sensor data capture
2. Set the white balance (colour temperature as well as Green-Magenta shift) to be the same for all the shots
3. Remove chromatic aberration and purple fringing
4. Apply noise reduction to taste, trying to match the appearance of noise in overlapping regions
5. Usual advice is to keep exposure settings and export consistent across all frames, this is outdated advice.



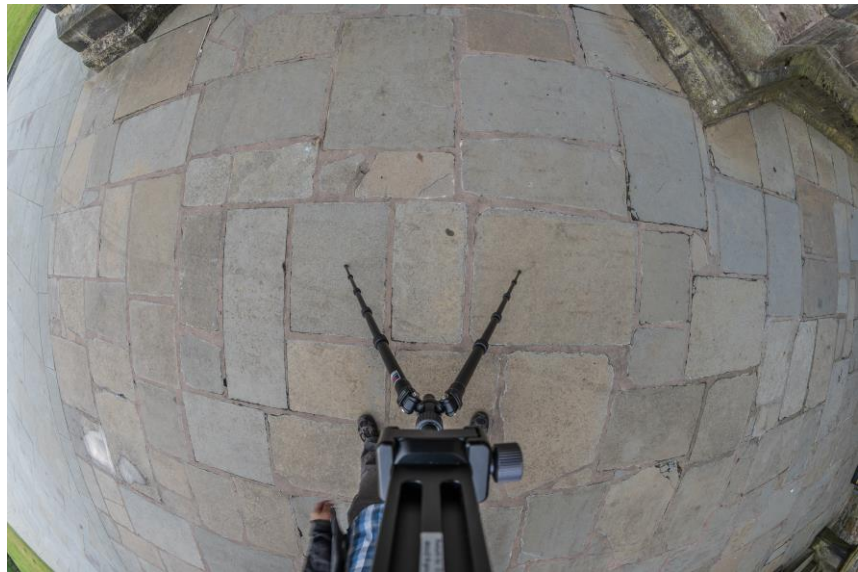






Optimised Export of Raw Files

1. Modern panostitching software can easily deal with photometrically matching different exposures.
2. When taking the source images, you should expose each frame optimally (contrast permitting) to capture the full brightness range.
3. When developing the raw files, you can use the highlight and shadow recovery sliders to bring in brightness extremes. You can also use Clarity and Presence sliders to add extra “pop” at this stage
4. Export in a high bit-depth/HDR file format, e.g. 16-bit TIFF or EXR



Stitching in Hugin

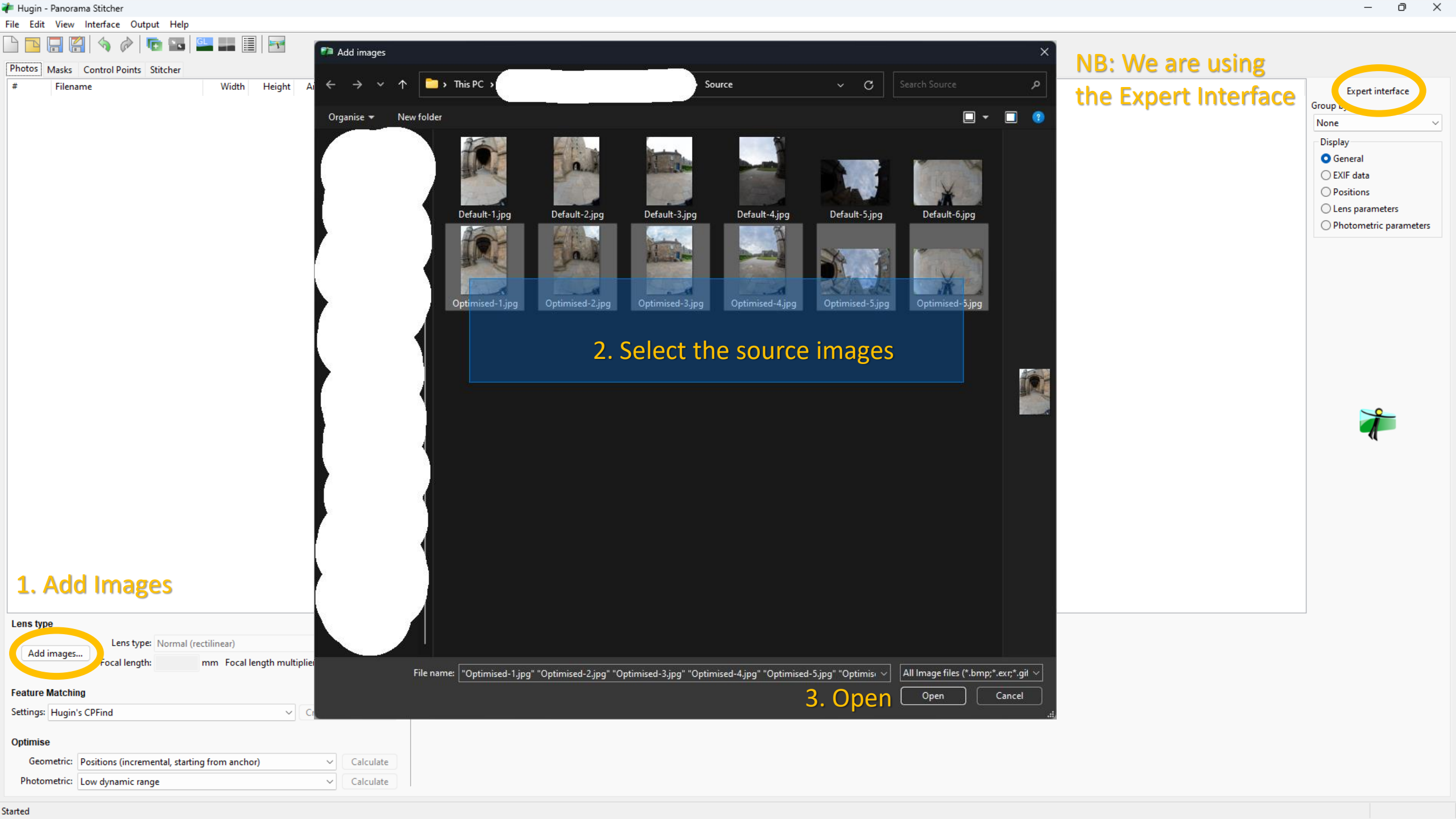
The main steps to assembling, aligning, and optimising a panorama are:

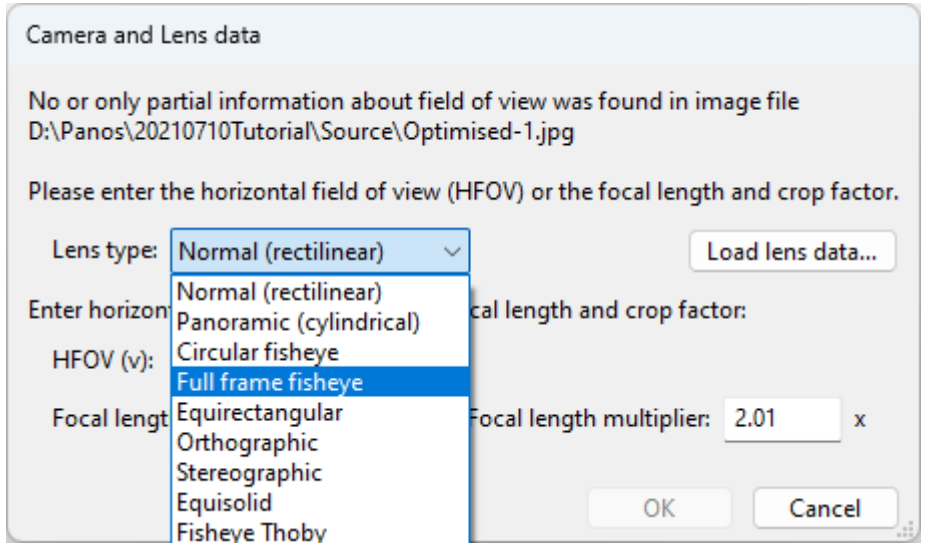
1. Setting up the pano project
    I. Import images
    II. Assign lenses to each image
2. Create masks and crops
3. Control point creation
    I. Create control point pairs on overlapping images
    II. Set Vertical Control points
4. Optimisation
    I. Alignment optimisation
    II. Photometric optimisation
5. Refinement
    I. Export test stitch
    II. Check for alignment errors and exposure problems
    III. Refine control points, alignment, and individual image brightness
6. Perform Final Export

NB: For the purposes of the tutorial, we will be using JPG images as a space saving measure. In practice, the same procedures apply when using TIFFs, except that there is greater flexibility in editing the final stitch when using TIFFs.

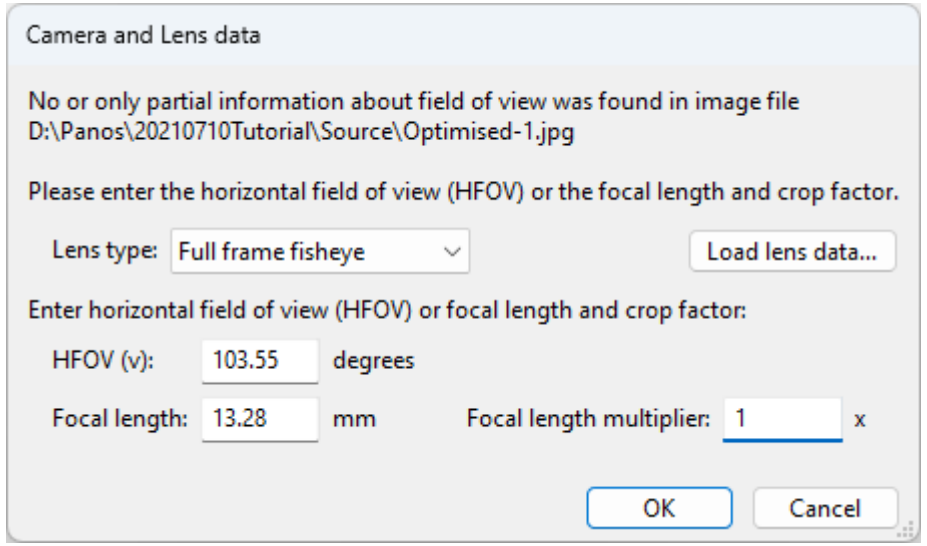
Setting up the Panorama Project

- Importing files
- Assigning lenses

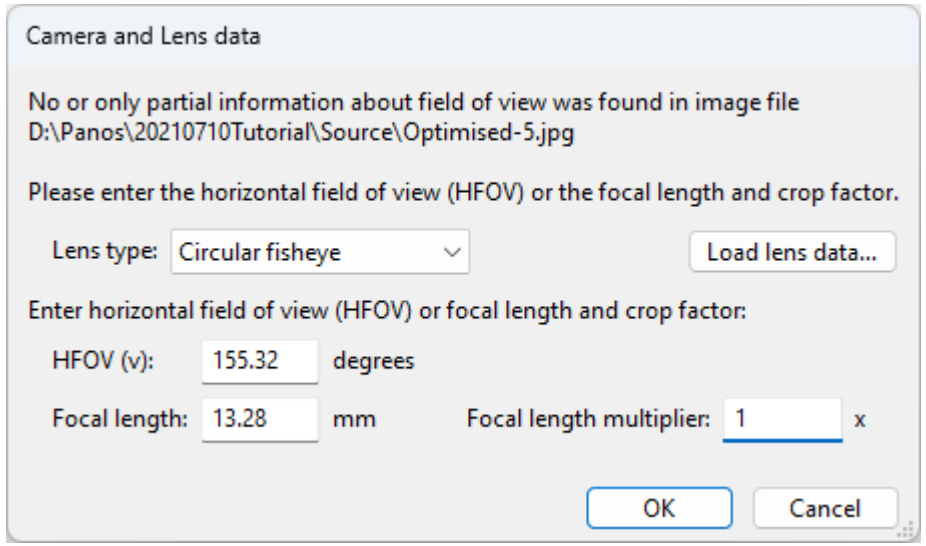

Hugin - Panorama Stitcher
File Edit View Interface Output Help
Photos Masks Control Points Stitcher
Filename Width Height
Add images
This PC
Source
Search Source
Organise
New folder
Default-1.jpg
Default-2.jpg
Default-3.jpg
Default-4.jpg
Default-5.jpg
Default-6.jpg
Optimised-1.jpg
Optimised-2.jpg
Optimised-3.jpg
Optimised-4.jpg
Optimised-5.jpg
Optimised-6.jpg
2. Select the source images
File name: "Optimised-1.jpg" "Optimised-2.jpg" "Optimised-3.jpg" "Optimised-4.jpg" "Optimised-5.jpg" "Optimis
All Image files (*.bmp;*.exr;*.gif
3. Open
Open
Cancel
NB: We are using the Expert Interface
Expert interface
Group by:
None
Display
General
EXIF data
Positions
Lens parameters
Photometric parameters
1. Add Images
Lens type
Add images...
Lens type: Normal (rectilinear)
Focal length: mm Focal length multiplier
Feature Matching
Settings: Hugin's CPFind
Optimise
Geometric: Positions (incremental, starting from anchor) Calculate
Photometric: Low dynamic range Calculate
Started



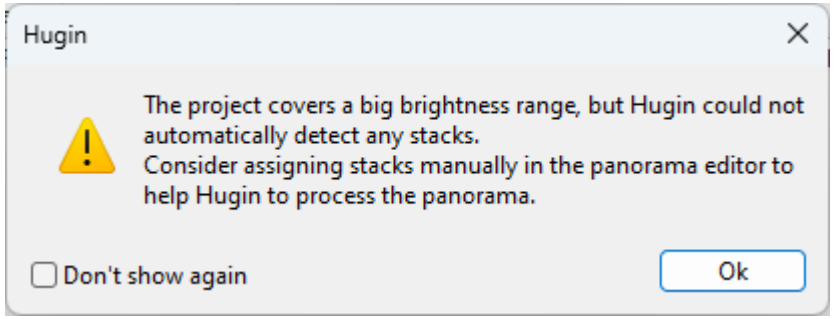
1. Select the lens type



2. If the lens data is not automatically populated, enter your own values



3. For the Zenith and Nadir shots, a Circular Fisheye lens type will allow a circular crop



4. Ignore this warning.

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

Save your project

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	0	0	0
1	Optimised-2.jpg	2000	3000	--	0	0	1
2	Optimised-3.jpg	2000	3000	--	0	0	2
3	Optimised-4.jpg	2000	3000	--	0	0	3
4	Optimised-5.jpg	3000	2000	--	0	1	4
5	Optimised-6.jpg	3000	2000	--	0	1	5

Image parameters

Source Images

Click on the image filename to bring up its lens type and preview

Expert interface

Group by: None

Display

- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.28 mm Focal length multiplier: 1 x

We will use manual control point placement

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Optimisation will occur after control point placement

Geometric: Positions (incremental, starting from anchor) | Calculate

Photometric: Low dynamic range | Calculate

Selected Image



Small image preview

saved project D:\Panos\20210710Tutorial\Source\Optimised-1 - Optimised-6.pto

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	0	0	0
1	Optimised-2.jpg	2000	3000	--	0	0	1
2	Optimised-3.jpg	2000	3000	--	0	0	2
3	Optimised-4.jpg	2000	3000	--	0	0	3
4	Optimised-5.jpg	3000	2000	--	0	1	4
5	Optimised-6.jpg	3000	2000	--	0	1	5

Edit image variables...

Add individual images...
Add time-series of images...
Remove selected image(s)
Anchor this image for position
Anchor this image for exposure
Manipulate image variables...
Lens
Stacks
Reset

New lens
Change lens...
Load lens from ini file
Load lens from lens database
Save lens to ini file
Save lens parameters to lens database

1. Right click on an image to bring up a menu
2. Select, “Lens”, “New lens”

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

Lens type

Add images...

Lens type: Circular fisheye

Focal length: 6.597 mm Focal length multiplier: 2.013 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Geometric: Positions (incremental, starting from anchor) | Calculate

Photometric: Low dynamic range | Calculate

Selected Image



Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	0	0	0
1	Optimised-2.jpg	2000	3000	--	0	0	1
2	Optimised-3.jpg	2000	3000	--	0	0	2
3	Optimised-4.jpg	2000	3000	--	0	0	3
4	Optimised-5.jpg	3000	2000	--	0	1	4
5	Optimised-6.jpg	3000	2000	--	0	2	5

New lens created

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

If needed, adjust lens parameters

Lens type

Add images...

Lens type: Circular fisheye

Focal length: 6.597 mm Focal length multiplier: 2.013 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Geometric: Positions (incremental, starting from anchor) | Calculate

Photometric: Low dynamic range | Calculate

Selected Image



saved project D:\Panos\20210710Tutorial\Source\Optimised-1 - Optimised-6.pto

Masking & Cropping

- Masking out the panohead and tripod
- Setting the crop circles

Optimised-1 - Optimised-6.pto - Hugin - Panorama Stitcher

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

1. Mask Tab

#	Filename	Number of masks	Crop
0	Optimised-1.jpg	1	-
1	Optimised-2.jpg	-	-
2	Optimised-3.jpg	-	-
3	Optimised-4.jpg	-	-
4	Optimised-5.jpg	-	-
5	Optimised-6.jpg	-	-

2. Filename

Masks Crop

3. Add new Mask

Add new mask | Delete mask

#	Mask type
0	Exclude region

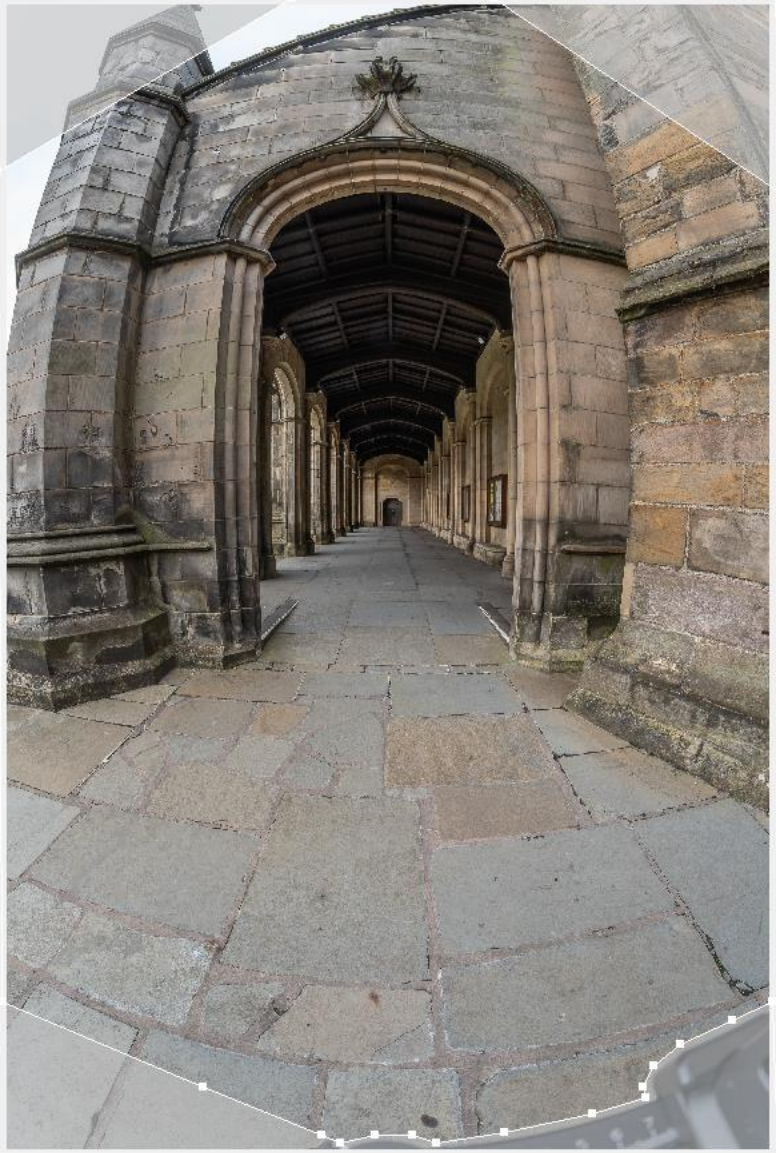
7. Masks can be copied and pasted on other images

Mask type: Exclude region

Import/Export Colour Options

Export | Import

Copy | Paste



4. Mask out panohead and tripod legs. Left click to start adding node

5. Right click to add final node

6. Masks can be refined by clicking on nodes and moving them. New nodes can be added by Control-Clicking on an edge, nodes can be deleted by selecting and pressing the delete key

Zoom: fit to window

Optimised-1 - Optimised-6.pto - Hugin - Panorama Stitcher

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

#	Filename	Number of masks	Crop
0	Optimised-1.jpg	1	-
1	Optimised-2.jpg	1	-
2	Optimised-3.jpg	1	-
3	Optimised-4.jpg	1	-
4	Optimised-5.jpg	-	-
5	Optimised-6.jpg	-	-

1. Mask copied to other images taken in the horizontal plane

Masks Crop

Add new mask | Delete mask

#	Mask type
0	Exclude region

Mask type: Exclude region

Import/Export Colour Options

Export | Import

Copy | Paste



Zoom: 100%

Optimised-1 - Optimised-6.pto - Hugin - Panorama Stitcher

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

#	Filename	Number of masks	Crop
0	Optimised-1.jpg	1	-
1	Optimised-2.jpg	1	-
2	Optimised-3.jpg	1	-
3	Optimised-4.jpg	1	-
4	Optimised-5.jpg	-	453,2547,0,2000
5	Optimised-6.jpg	-	-

1. For Zenith and Nadir shots, set circular crops using the Crop tab

Masks Crop

All images of selected lens

Top: 0

Left: 453 Right: 2547

Bottom: 2000

Always centre Crop on d,e

Reset

3. Untick this box so that the crop region down not change when optimising the lens distortion parameters



Zoom: fit to window

Optimised-1 - Optimised-6.pto - Hugin - Panorama Stitcher

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Number of masks	Crop
0	Optimised-1.jpg	1	-
1	Optimised-2.jpg	1	-
2	Optimised-3.jpg	1	-
3	Optimised-4.jpg	1	-
4	Optimised-5.jpg	-	453,2547,0,2000
5	Optimised-6.jpg	-	1254,1759,691,1196

Masks | Crop

All images of selected lens

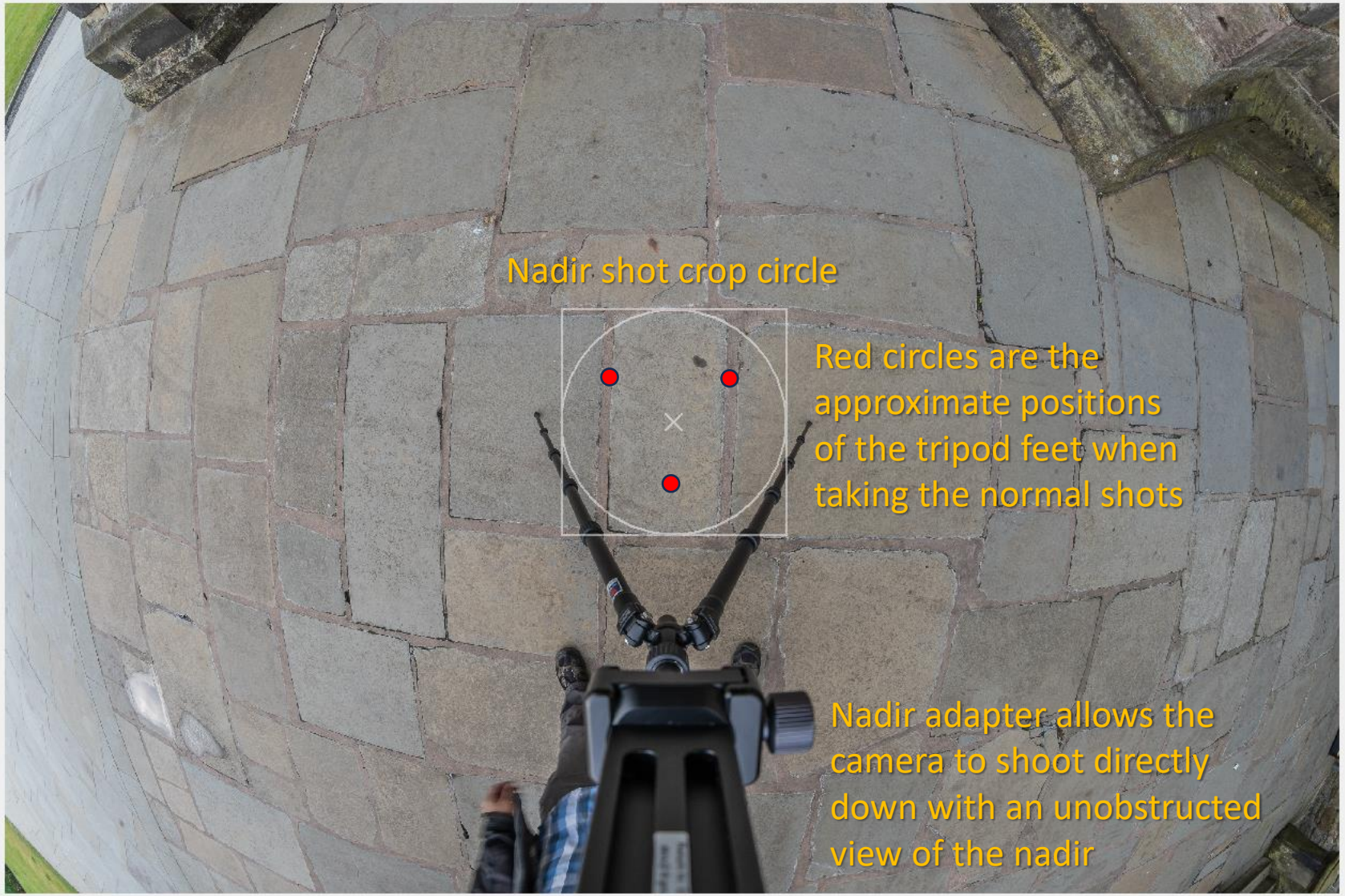
Top: 691

Left: 1254 Right: 1759

Bottom: 1196

Always centre Crop on d,e

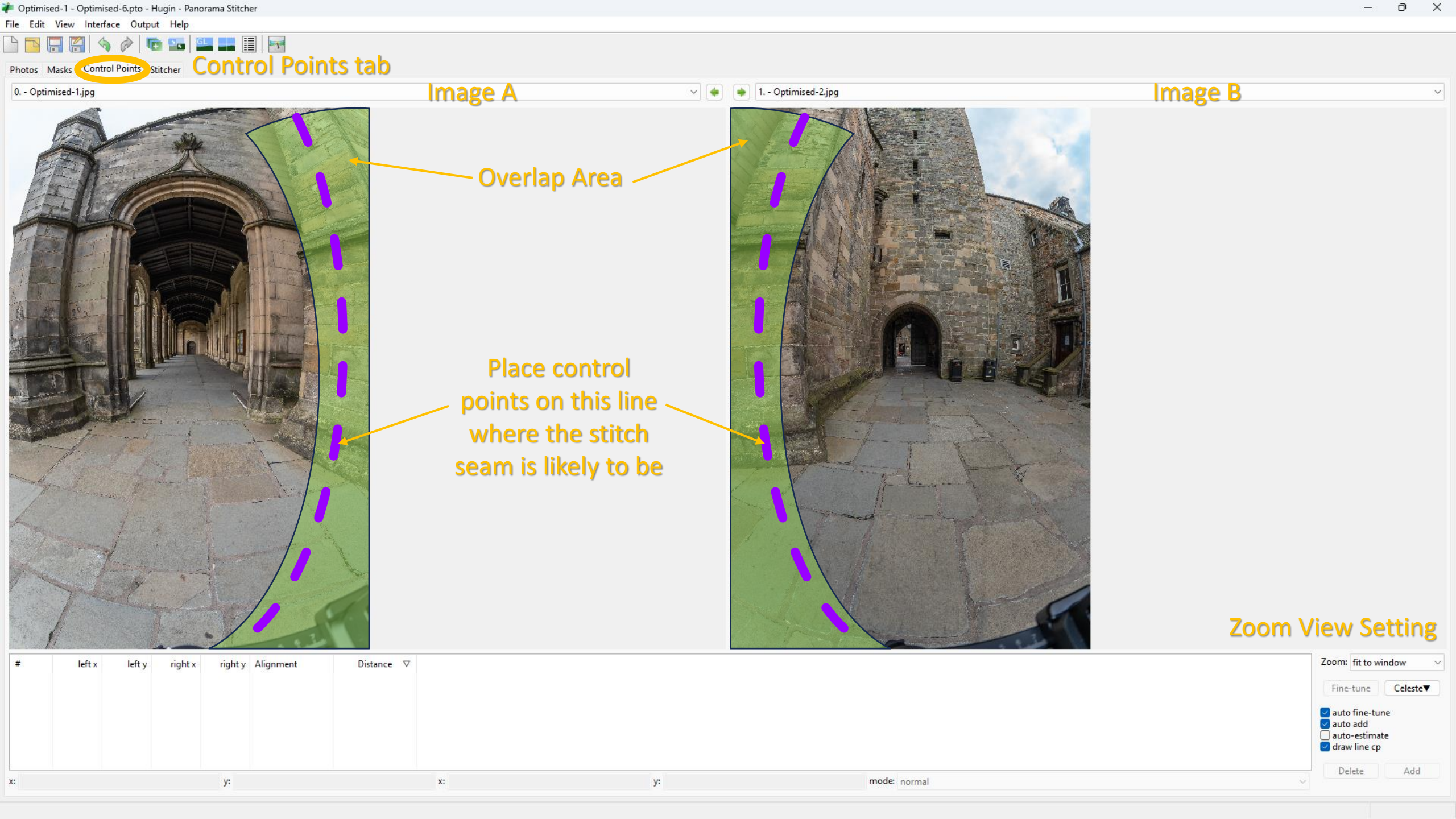
Reset

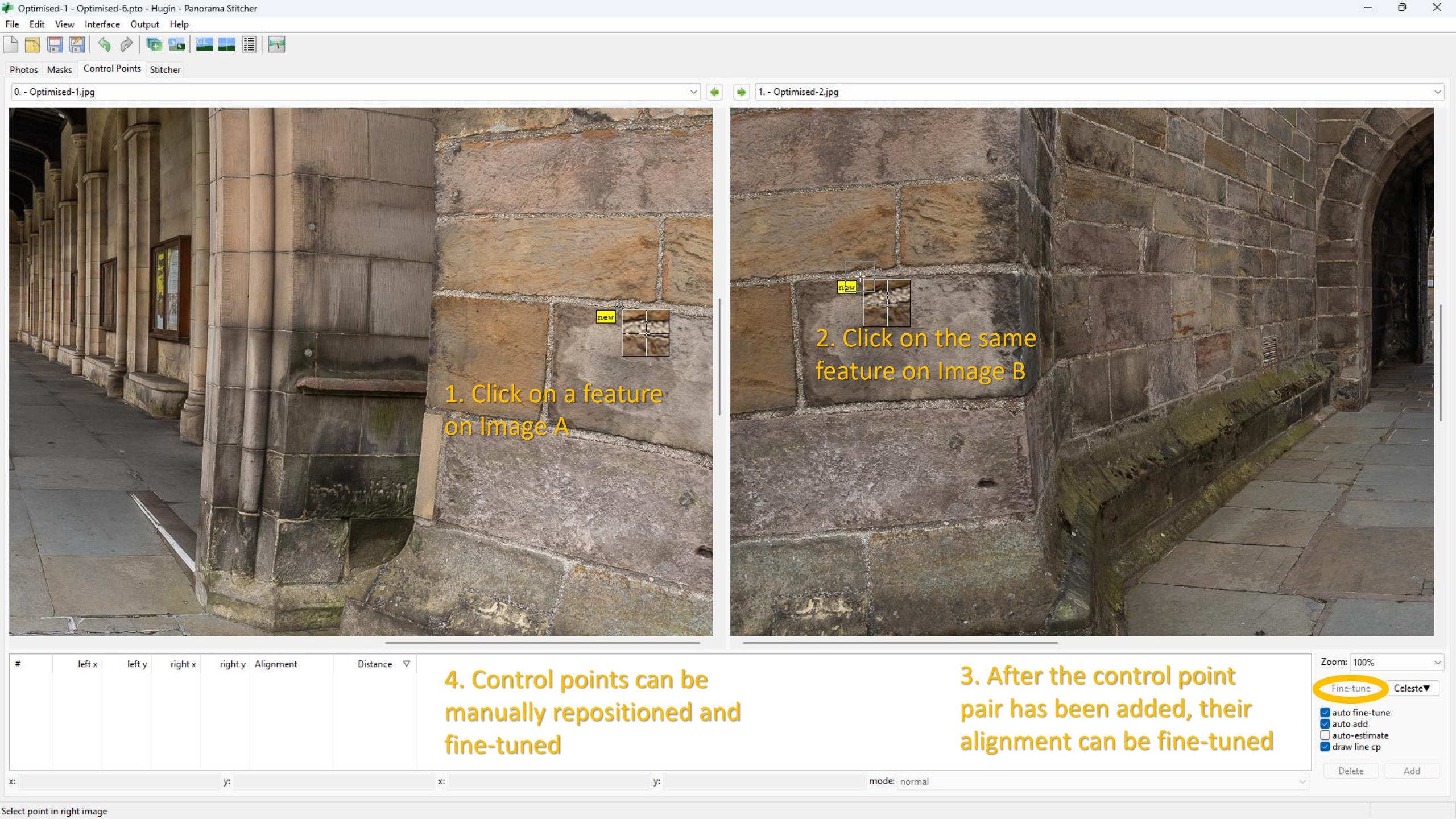


Zoom: fit to window

Control Points

- Adding control points to link adjacent images
- Adding vertical control points


Optimised-1 - Optimised-6.pto - Hugin - Panorama Stitcher
File Edit View Interface Output Help
Photos Masks Control Points Stitcher
Control Points tab
0. - Optimised-1.jpg
Image A
1. - Optimised-2.jpg
Image B
Overlap Area
Place control points on this line where the stitch seam is likely to be
Zoom View Setting
left x left y right x right y Alignment Distance
Zoom: fit to window
Fine-tune Celeste▼
auto fine-tune
auto add
auto-estimate
draw line cp
Delete Add
x: y: x: y: mode: normal


Optimised-1 - Optimised-6.pto - Hugin - Panorama Stitcher
File Edit View Interface Output Help
Photos Masks Control Points Stitcher
0. - Optimised-1.jpg
1. - Optimised-2.jpg
new
new
1. Click on a feature on Image A
2. Click on the same feature on Image B
left x left y right x right y Alignment Distance
4. Control points can be manually repositioned and fine-tuned
3. After the control point pair has been added, their alignment can be fine-tuned
Zoom: 100%
Fine-tune
Celeste▼
auto fine-tune
auto add
auto-estimate
draw line cp
Delete
Add
x: y: x: y:
mode: normal
Select point in right image

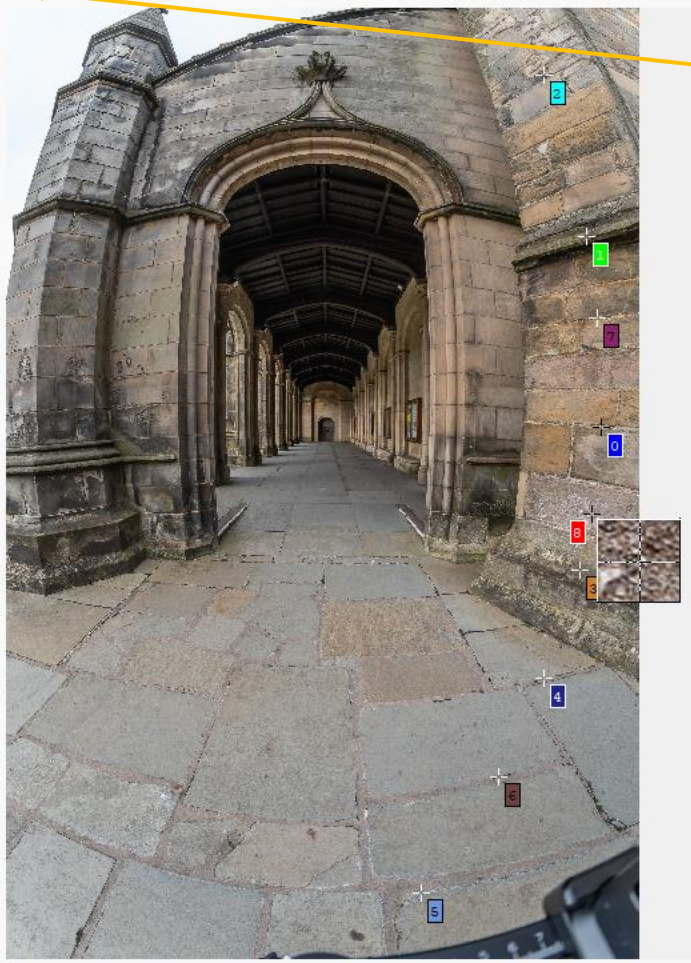
Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

0. - Optimised-1.jpg 9

1. - Optimised-2.jpg 9





1. Repeat the process of adding control point pairs, ensuring a good spread across the stitching seam

2. Add control point pairs between all overlapping images: 0-1; 1-2; 2-3; 3-0; 0-4; 1-4; 2-4; 3-4; 0-5; 1-5; 2-5; 3-5

#	left x	left y	right x	right y	Alignment	Distance
0	1876.46	1320.42	171.08	1319.54	normal	731.55
8	1848.48	1593.56	193.50	1587.94	normal	713.00
7	1865.00	977.00	176.15	983.04	normal	694.71
3	1807.43	1771.52	216.92	1766.32	normal	677.73
1	1831.73	718.43	214.59	730.50	normal	629.13
4	1696.00	2111.00	302.16	2109.04	normal	566.12
2	1696.00	210.00	382.16	243.43	normal	436.84

x: 1848.48 y: 1593.56 x: 193.50 y: 1587.94 mode: normal

Zoom: fit to window

Fine-tune Celeste▼

auto fine-tune
auto add
auto-estimate
draw line cp

Delete Add

saved project D:\Panos\20210710Tutorial\Source\Optimised-1 - Optimised-6.pto

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

4. - Optimised-5.jpg 8



0. - Optimised-1.jpg 8



Image 4 (Zenith) should be connected to Images 0, 1, 2, and 3. Ensure a good spread of points across the area of overlap

#	left x	left y	right x	right y	Alignment	Distance
1	1031.41	1477.51	1659.88	149.26	normal	922.66
4	892.00	1207.00	1270.75	198.05	normal	730.10
7	734.00	1260.00	898.00	198.00	normal	687.18
0	896.00	991.00	994.89	168.94	normal	596.28
5	613.51	984.44	991.30	481.44	normal	534.54
6	706.47	839.56	827.92	395.45	normal	447.67
3	828.00	752.00	705.97	280.96	normal	417.17

x: 1031.41 y: 1477.51 x: 1659.88 y: 149.26 mode: normal

Zoom: fit to window

Fine-tune Celeste▼

auto fine-tune
auto add
auto-estimate
draw line cp

Delete Add

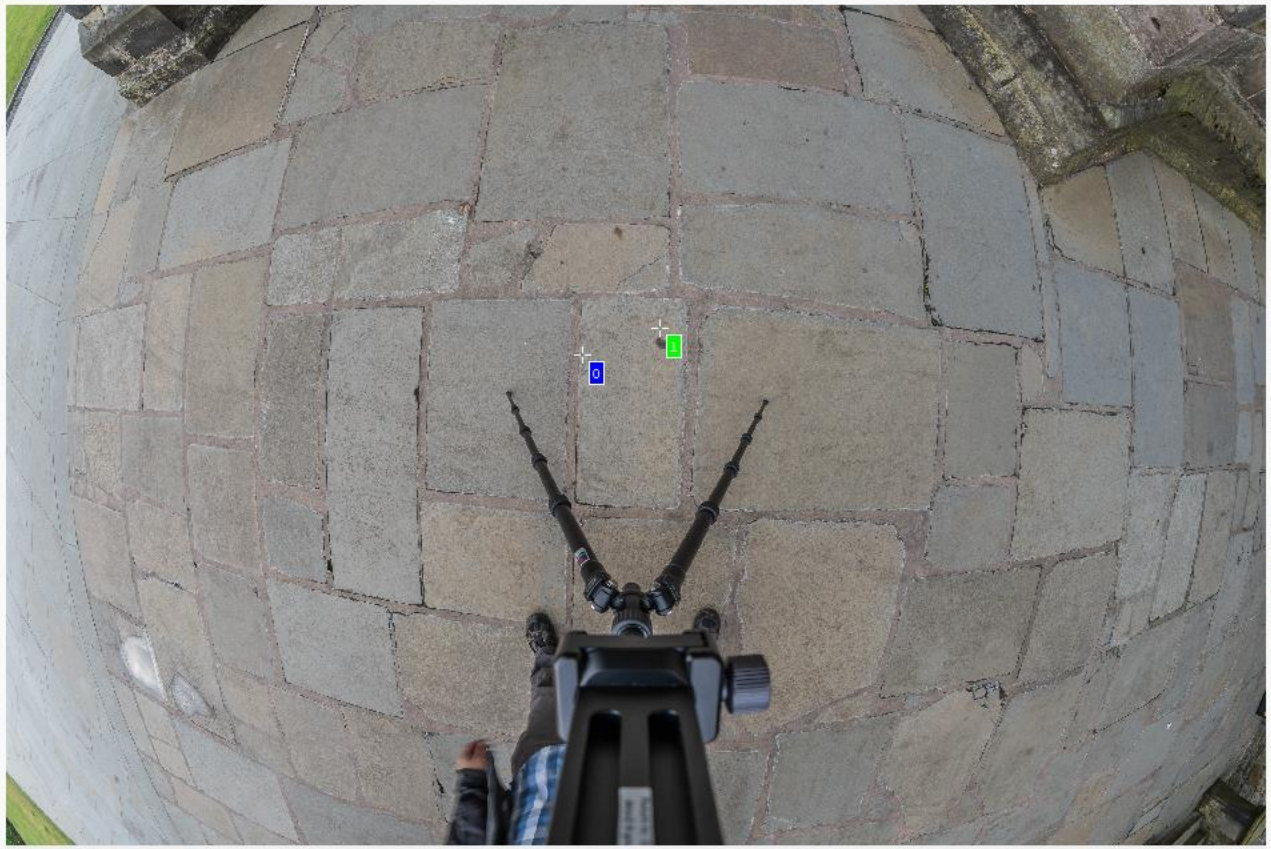
Point fine-tuned, angle: -87 deg, correlation coefficient: 0.620, curvature: 1.239 0.794

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

5. - Optimised-6.jpg 2



0. - Optimised-1.jpg 2



Image 5 (Nadir) should be connected to Images 0, 1, 2, and 3. As the Nadir Patch is small, only 2 control point pairs are required between each pair of images.

#	left x	left y	right x	right y	Alignment	Distance
1	1557.00	769.00	1098.16	2879.82	normal	694.74
0	1370.00	831.00	834.02	2892.98	normal	672.14

x: y: x: y: mode: normal

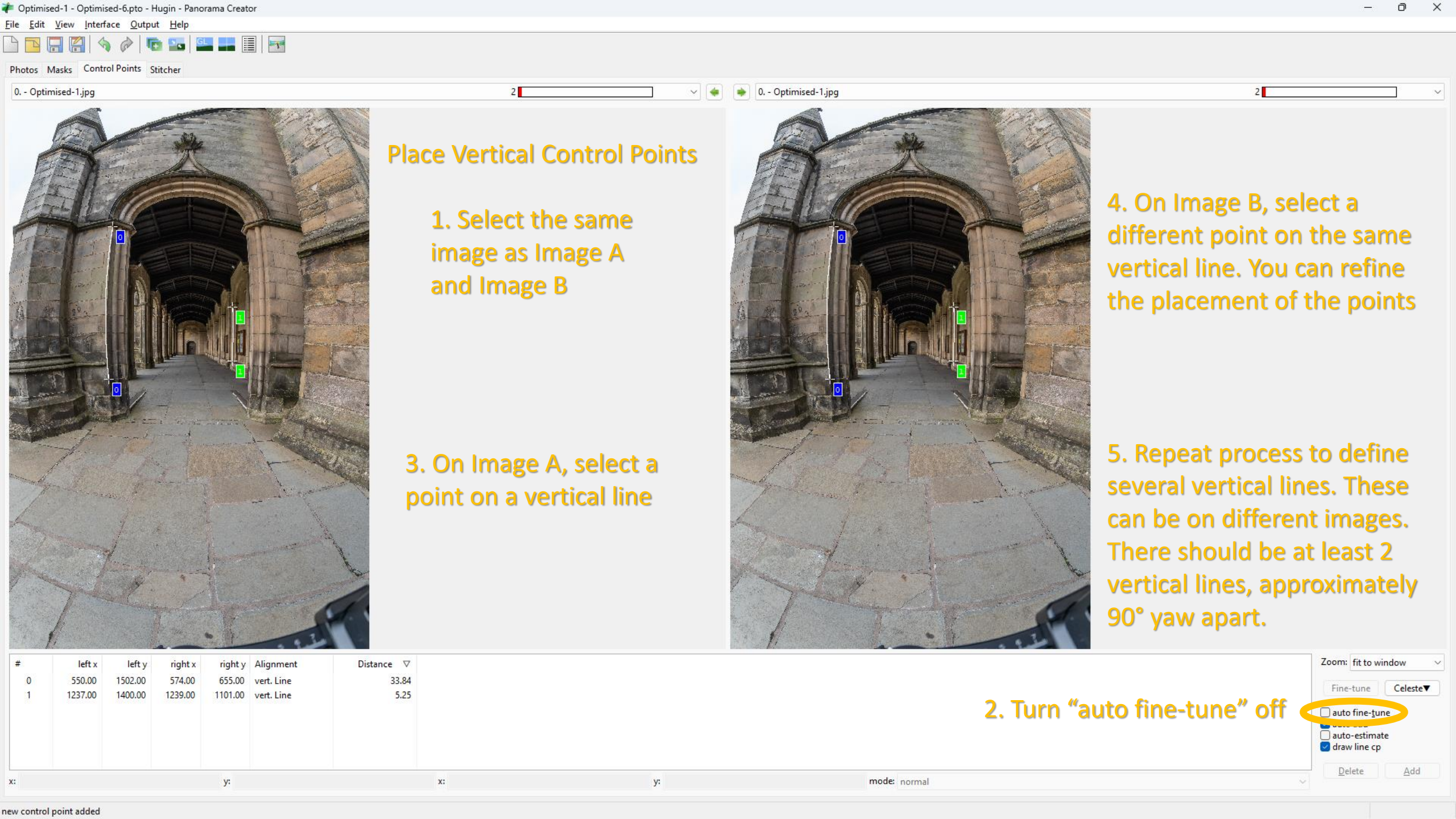
Zoom: fit to window

Fine-tune Celeste▼

auto fine-tune
auto add
auto-estimate
draw line cp

Delete Add

saved project D:\Panos\20210710Tutorial\Source\Optimised-1 - Optimised-6.pto


Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator
File Edit View Interface Output Help
Photos Masks Control Points Stitcher
0. - Optimised-1.jpg
0. - Optimised-1.jpg
Place Vertical Control Points
1. Select the same image as Image A and Image B
3. On Image A, select a point on a vertical line
4. On Image B, select a different point on the same vertical line. You can refine the placement of the points
5. Repeat process to define several vertical lines. These can be on different images. There should be at least 2 vertical lines, approximately 90° yaw apart.
left x left y right x right y Alignment Distance
0 550.00 1502.00 574.00 655.00 vert. Line 33.84
1 1237.00 1400.00 1239.00 1101.00 vert. Line 5.25
2. Turn “auto fine-tune” off
Zoom: fit to window
Fine-tune Celeste▼
auto fine-tune
auto-estimate
draw line cp
Delete Add
x: y: x: y: mode: normal
new control point added

Geometric Optimisation

- Performing initial rough alignment
- Setting the export image size
- Fixing wrongly placed control points
- Fully optimising image placement and lens parameters
- Previewing assembled images

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	30	0	0
1	Optimised-2.jpg	2000	3000	--	30	0	1
2	Optimised-3.jpg	2000	3000	--	29	0	2
3	Optimised-4.jpg	2000	3000	--	23	0	3
4	Optimised-5.jpg	3000	2000	--	27	1	4
5	Optimised-6.jpg	3000	2000	--	8	2	5

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

Optimisation result

Optimiser run finished.
Results:
average control point distance: 13.066184
standard deviation: 16.604319
maximum: 139.776137

Apply the changes?

Yes No

3. Results of the optimisation are displayed. These will not be very good at this stage. Press “Yes”

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.28 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Geometric: Positions (incremental, starting from anchor) | Calculate

Photometric: Low dynamic range | Calculate

Selected Image

1. Optimise “Positions (incremental, starting from anchor)”

2. Press “Calculate



new control point added

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	30	0	0
1	Optimised-2.jpg	2000	3000	--	30	0	1
2	Optimised-3.jpg	2000	3000	--	29	0	2
3	Optimised-4.jpg	2000	3000	--	23	0	3
4	Optimised-5.jpg	3000	2000	--	27	1	4
5	Optimised-6.jpg	3000	2000	--	8	2	5

Expert interface

Group by: None

Display
- (•) General
- ( ) EXIF data
- ( ) Positions
- ( ) Lens parameters
- ( ) Photometric parameters

Optimisation result

Optimiser run finished.
Results:
average control point distance: 7.042785
standard deviation: 16.448944
maximum: 141.447438

Apply the changes?

Yes | No

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.28 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Geometric: Positions, View and Barrel (y,p,r,v,b) | Calculate

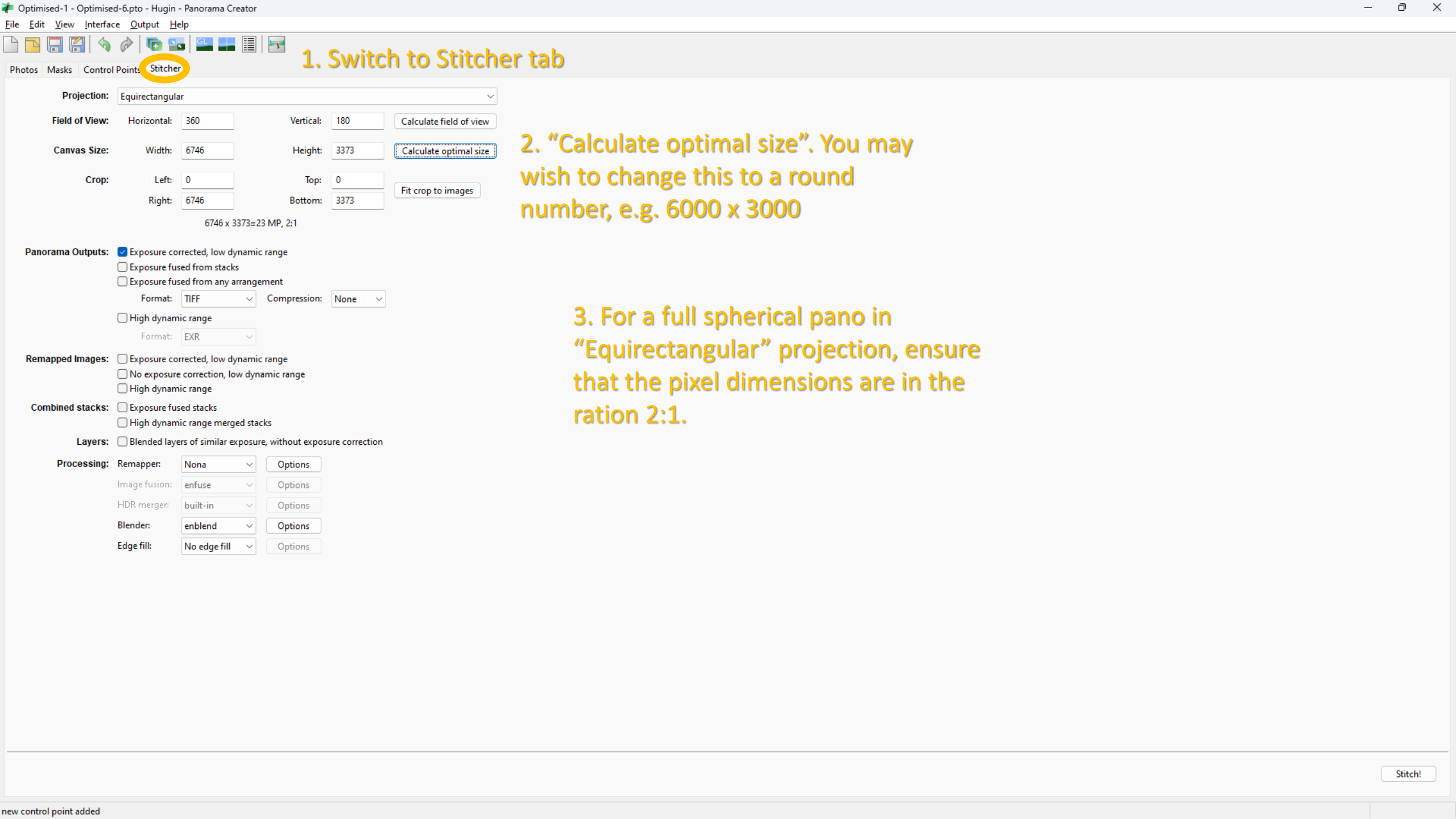
Photometric: Low dynamic range | Calculate

Selected Image



Repeat with “Popsition, View and Barrel (y,p,r,v,b)”

new control point added


Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator
File Edit View Interface Output Help
Photos Masks Control Points Stitcher
1. Switch to Stitcher tab
Projection: Equirectangular
Field of View: Horizontal: 360 Vertical: 180 Calculate field of view
Canvas Size: Width: 6746 Height: 3373 Calculate optimal size
Crop: Left: 0 Top: 0 Right: 6746 Bottom: 3373 Fit crop to images
6746 x 3373=23 MP, 2:1
2. “Calculate optimal size”. You may wish to change this to a round number, e.g. 6000 x 3000
Panorama Outputs: Exposure corrected, low dynamic range
Exposure fused from stacks
Exposure fused from any arrangement
Format: TIFF Compression: None
High dynamic range
Format: EXR
Remapped Images: Exposure corrected, low dynamic range
No exposure correction, low dynamic range
High dynamic range
Combined stacks: Exposure fused stacks
High dynamic range merged stacks
Layers: Blended layers of similar exposure, without exposure correction
Processing: Remapper: Nona Options
Image fusion: enfuse Options
HDR merger: built-in Options
Blender: enblend Options
Edge fill: No edge fill Options
3. For a full spherical pano in “Equirectangular” projection, ensure that the pixel dimensions are in the ration 2:1.
Stitch!
new control point added

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

1. Switch back to Photos tab

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	30	0	0
1	Optimised-2.jpg	2000	3000	--	30	0	1
2	Optimised-3.jpg	2000	3000	--	29	0	2
3	Optimised-4.jpg	2000	3000	--	23	0	3
4	Optimised-5.jpg	3000	2000	--	27	1	4
5	Optimised-6.jpg	3000	2000	--	8	2	5

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

Optimisation result

Optimiser run finished.
Results:
average control point distance: 14.085570
standard deviation: 32.897888
maximum: 282.894876

Apply the changes?

Yes No

3. The errors will be larger than before because the output dimensions have increased. Errors are quoted with respect to the output image

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.107 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind Create control points

Optimise

Geometric: Positions, View and Barrel (y,p,r,v,b) Calculate

Photometric: Low dynamic range Calculate

Selected Image



2. Re-run the Geometric optimisation

new control point added

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Full Screen F11
Control point table F3
Panorama preview window Ctrl+P
Fast panorama preview window Ctrl+Shift+P
Photos Shift+F1
Masks Shift+F2
Control Points Shift+F3
Optimizer Shift+F4
Exposure Shift+F5
Stitcher Shift+F6

1. Open up the Control point Table

Photos

#	Anchor	# Ctrl P...	Lens no.	Stack no.
0	AC	30	0	0
1	--	30	0	1
2	--	29	0	2
3	--	23	0	3
4	--	27	1	4
5	--	8	2	5

Expert interface
Group by: None
Display
General
EXIF data
Positions
Lens parameters
Photometric parameters

2. Click on the control point with the greatest distance. This will take you to the “Control Points Tab” and show you the location of the control point

Control Points

G CP#	Left Img.	Right Img.	P CP#	Alignment	Dista...
43	0	4	7	normal	282.89
48	1	4	4	normal	62.82
63	0	5	0	normal	34.65
40	0	4	4	normal	29.88
37	0	4	1	normal	29.69
41	0	4	5	normal	29.59
42	0	4	6	normal	28.80
36	0	4	0	normal	28.25
39	0	4	3	normal	27.33
38	0	4	2	normal	24.81
47	1	4	3	normal	24.26
52	1	4	8	normal	21.82
49	1	4	5	normal	20.26
44	1	4	0	normal	17.25
73	1	1	0	vert. Line	16.02
62	3	4	1	normal	15.50
64	0	5	1	normal	15.48

Delete
Select by Distance

Lens type

Add images...
Lens type: Full frame fisheye
Focal length: 13.107 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind
Create control points

Optimise

Geometric: Positions, View and Barrel (y,p,r,v,b) Calculate
Photometric: Low dynamic range Calculate

Selected Image



Shows all control point distances

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

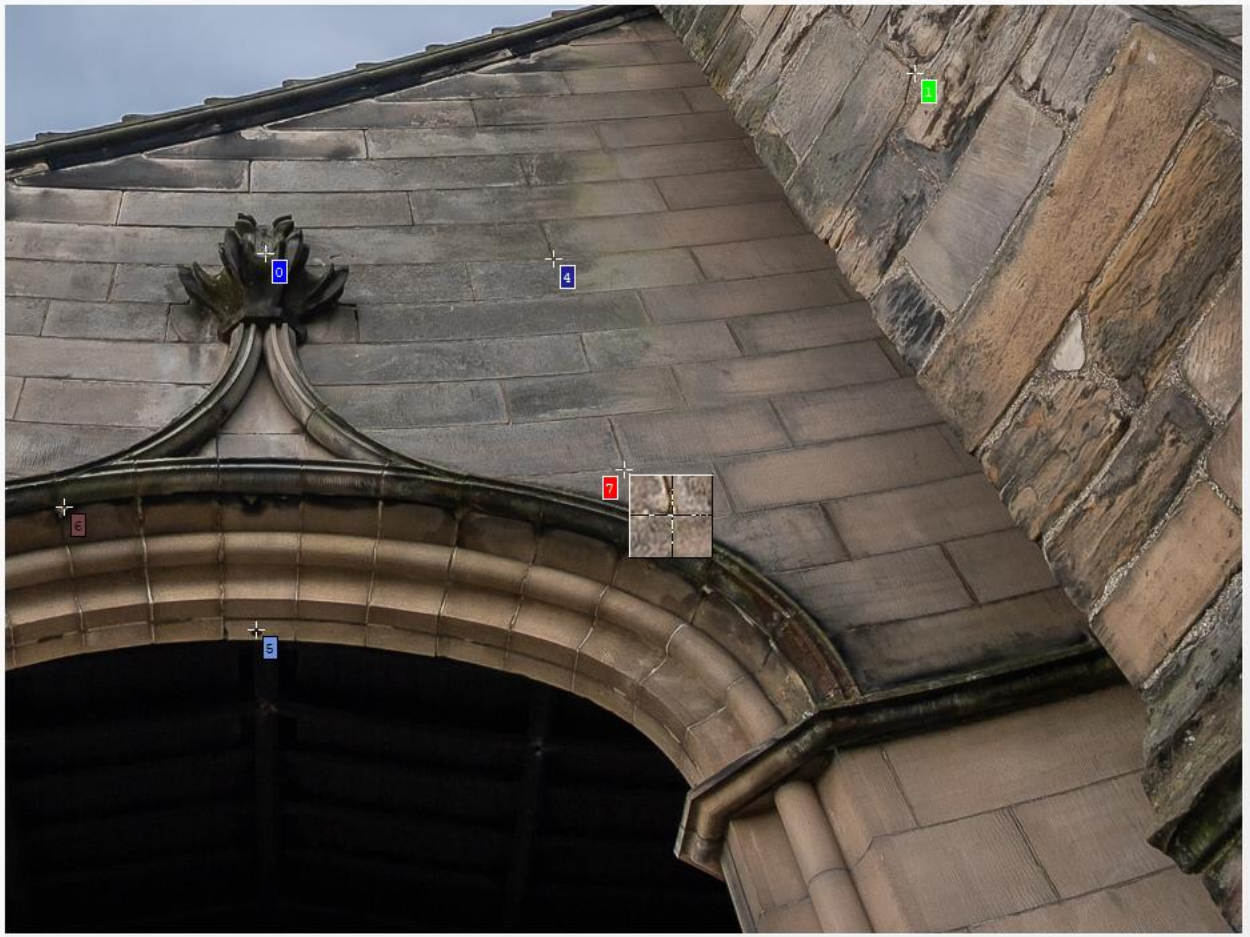
File Edit View Interface Output Help

Photos Masks Control Points Stitcher

0. - Optimised-1.jpg 8

4. - Optimised-5.jpg 8





#						Distance
7	898.00	198.00	734.00	1260.00	normal	282.89
4						29.88
1	1659.88	149.26	1031.41	1477.51	normal	29.69
5	991.30	481.44	613.51	984.44	normal	29.59
6	827.92	395.45	706.47	839.56	normal	28.80
0	994.89	168.94	896.00	991.00	normal	28.25
3	705.97	280.96	828.00	752.00	normal	27.33

Control Point pair #7 is obviously wrong. Drag one of the the control points so that they now are on the same feature

Zoom: 100%

Fine-tune Celeste▼

auto fine-tune
auto add
auto-estimate
draw line cp

Delete Add

x: 898.00 y: 198.00 x: 734.00 y: 1260.00 mode: normal

new control point added

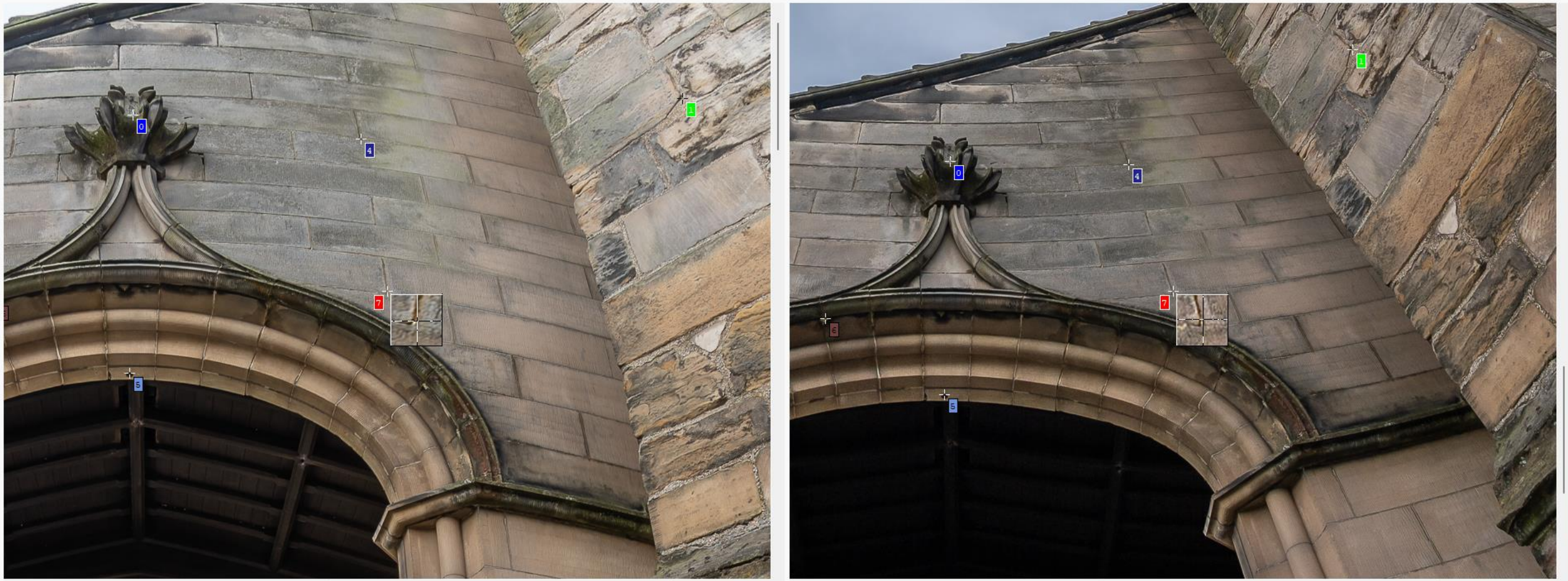
Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos Masks Control Points Stitcher

0. - Optimised-1.jpg 8

4. - Optimised-5.jpg 8



#	left x	left y	right x	right y	Alignment	Distance
7	1303.41	382.40	738.77	1260.53	normal	31.23
4	1270.75	198.05	892.00	1207.00	normal	29.88
1	1659.88	149.26	1031.41	1477.51	normal	29.69
5	991.30	481.44	613.51	984.44	normal	29.59
6	827.92	395.45	706.47	839.56	normal	28.80
0	994.89	168.94	896.00	991.00	normal	28.25
3	705.97	280.96	828.00	752.00	normal	27.33

Control Point pair #7 now is correct. The distance is much smaller than before

Zoom: 100%

Fine-tune Celeste▼

auto fine-tune
auto add
auto-estimate
draw line cp

Delete Add

x: 1303.41 y: 382.40 x: 738.77 y: 1260.53 mode: normal

Point fine-tuned, angle: 67 deg, correlation coefficient: 0.828, curvature: 0.352 1.046

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	30	0	0
1	Optimised-2.jpg	2000	3000	--	30	0	1
2	Optimised-3.jpg	2000	3000	--	29	0	2
3	Optimised-4.jpg	2000	3000	--	23	0	3
4	Optimised-5.jpg	3000	2000	--	27	1	4
5	Optimised-6.jpg	3000	2000	--	8	2	5

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

2. Re-check if any control point distances remain large

Optimisation result

Optimiser run finished.
Results:
average control point distance: 2.345130
standard deviation: 1.407178
maximum: 5.886082

Apply the changes?

Yes | No

Control Points

G CP#	Left Img.	Right Img.	P CP#	Alignment	Dista...
2	0	1	2	normal	5.89
17	1	2	8	normal	5.57
30	0	3	3	normal	5.53
37	0	4	1	normal	5.29
35	0	3	8	normal	4.95
5	0	1	5	normal	4.94
11	1	2	2	normal	4.85
6	0	1	6	normal	4.63
16	1	2	7	normal	4.60
33	0	3	6	normal	4.38
25	2	3	7	normal	4.24
29	0	3	2	normal	4.13
24	2	3	6	normal	3.86
1	0	1	1	normal	3.58
10	1	2	1	normal	3.39
19	2	3	1	normal	3.30
22	2	3	4	normal	3.27

Delete

Select by Distance

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.119 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Geometric: Positions, View and Barrel (y,p,r,v,b) | Calculate

Photometric: Low dynamic range | Calculate

Selected Image

1. After adjusting any erroneous control points, repeat geometric optimisation



3. Repeat process of optimisation and checking for control point errors. Once all the control points are correct, move onto full optimisation

Point fine-tuned, angle: -15 deg, correlation coefficient: 0.611, curvature: 0.805 0.166

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	30	0	0
1	Optimised-2.jpg	2000	3000	--	30	0	1
2	Optimised-3.jpg	2000	3000	--	29	0	2
3	Optimised-4.jpg	2000	3000	--	23	0	3
4	Optimised-5.jpg	3000	2000	--	27	1	4
5	Optimised-6.jpg	3000	2000	--	8	2	5

2. Maximum distances of ~1 pixel or below will generally result in a good stitch

Optimisation result

Optimiser run finished.
Results:
average control point distance: 0.367668
standard deviation: 0.253609
maximum: 1.298861

Apply the changes?

Yes No

Control Points

G CP#	Left Img.	Right Img.	P CP#	Alignment	Dista...
63	0	5	0	normal	1.30
37	0	4	1	normal	1.11
61	3	4	0	normal	1.11
64	0	5	1	normal	0.88
69	3	5	0	normal	0.77
41	0	4	5	normal	0.75
18	2	3	0	normal	0.65
71	0	0	0	vert. Line	0.64
57	2	4	4	normal	0.62
56	2	4	3	normal	0.61
53	2	4	0	normal	0.60
24	2	3	6	normal	0.59
15	1	2	6	normal	0.59
67	2	5	0	normal	0.55
74	2	2	0	vert. Line	0.54
47	1	4	3	normal	0.53
22	2	3	4	normal	0.52

Delete

Select by Distance

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.081 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Geometric: Everything without translation | Calculate

Photometric: Low dynamic range | Calculate

Selected Image

1. Optimisation with “Everything without translation” should give low distances



Point fine-tuned, angle: -15 deg, correlation coefficient: 0.611, curvature: 0.805 0.166

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

Preview panorama

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	30	0	0
1	Optimised-2.jpg	2000	3000	--	30	0	1
2	Optimised-3.jpg	2000	3000	--	29	0	2
3	Optimised-4.jpg	2000	3000	--	23	0	3
4	Optimised-5.jpg	3000	2000	--	27	1	4
5	Optimised-6.jpg	3000	2000	--	8	2	5

Press “Preview Panorama” icon to bring up a separate window to see how the stitch looks so far

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.081 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

Geometric: Everything without translation | Calculate

Photometric: Low dynamic range | Calculate

Selected Image



Show the preview window

Panorama preview

Centre | Fit | Straighten | Num. Transf. | Auto | Update | All | None

displayed images

0 1 2 3 4 5

Each source image can be toggled on and off



Preview Options

projection (f): Equirectangular | Blend mode: normal | Output: LDR | EV: 6.2 | Range compression: 0

Left click to define new centre point, right click to move point to horizon.

172.7 -89.5

360.0 x 180.0

Photometric Optimisation

- Optimising exposures
- Optimising colour balance
- Optimising lens vignetting
- Adjusting the export Exposure and Range Compression

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Stitcher

#	Filename	Width	Height	Anchor	# Ctrl P...	Lens no.	Stack no.
0	Optimised-1.jpg	2000	3000	AC	30	0	0
1	Optimised-2.jpg	2000	3000	--	30	0	1
2	Optimised-3.jpg	2000	3000	--	29	0	2
3	Optimised-4.jpg	2000	3000	--	23	0	3
4	Optimised-5.jpg	3000	2000	--	27	1	4
5	Optimised-6.jpg	3000	2000	--	8	2	5

Expert interface

Group by: None

Display
- General
- EXIF data
- Positions
- Lens parameters
- Photometric parameters

Lens type

Add images...

Lens type: Full frame fisheye

Focal length: 13.081 mm Focal length multiplier: 1 x

Feature Matching

Settings: Hugin's CPFind | Create control points

Optimise

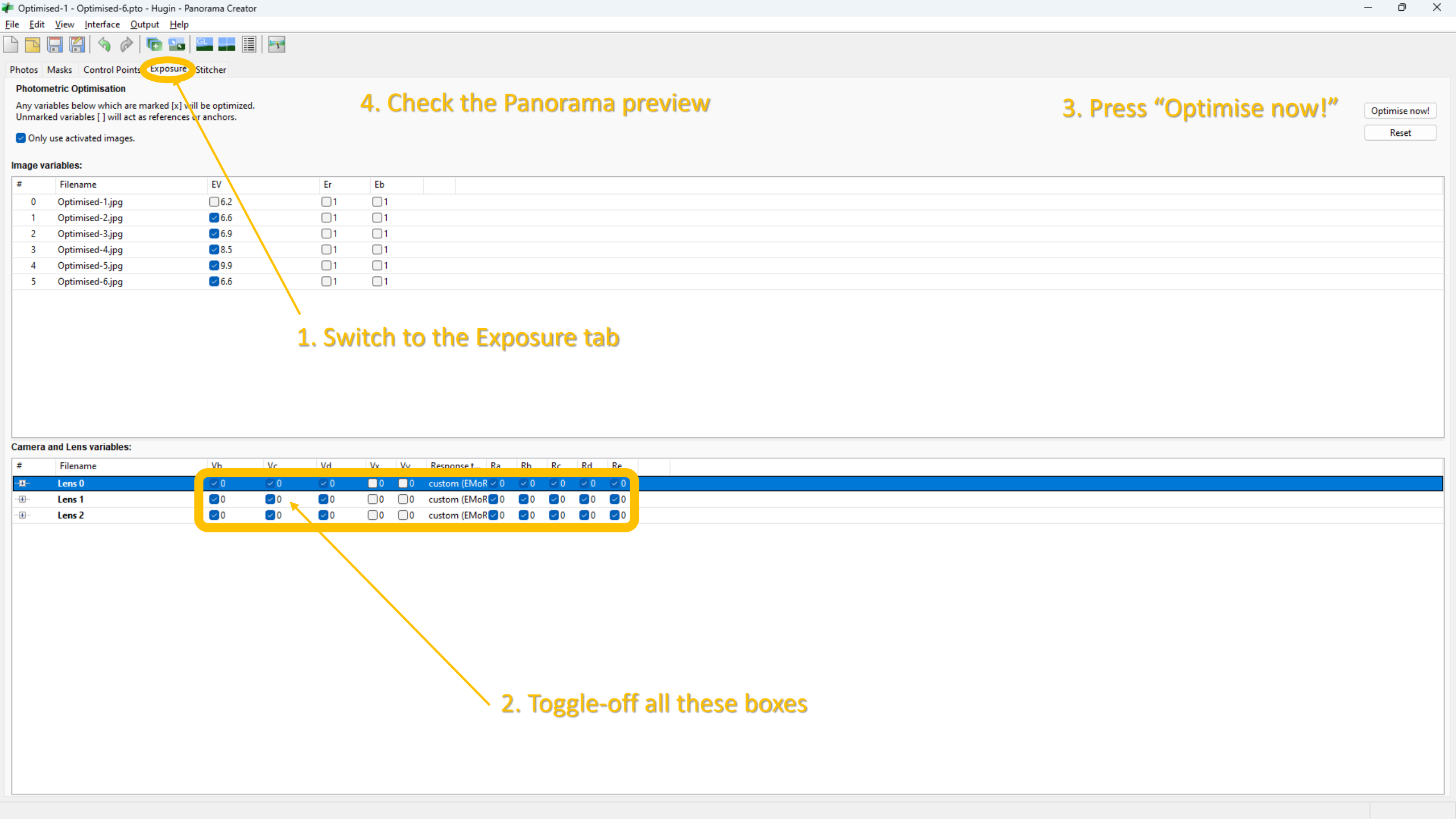
Geometric: [illegible] | Calculate

Photometric: Low dynamic range | Calculate

Selected Image



Change this to “Custom parameters”. A new tab will appear, “Exposure”


Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator
File Edit View Interface Output Help
Photos Masks Control Points Exposure Stitcher
Photometric Optimisation
Any variables below which are marked [x] will be optimized.
Unmarked variables [ ] will act as references or anchors.
Only use activated images.
4. Check the Panorama preview
3. Press “Optimise now!”
Optimise now!
Reset
Image variables:
Filename EV Er Eb
0 Optimised-1.jpg 6.2 1 1
1 Optimised-2.jpg 6.6 1 1
2 Optimised-3.jpg 6.9 1 1
3 Optimised-4.jpg 8.5 1 1
4 Optimised-5.jpg 9.9 1 1
5 Optimised-6.jpg 6.6 1 1
1. Switch to the Exposure tab
Camera and Lens variables:
Filename Vb Vc Vd Vx Vy Response t... Ra Rb Rc Rd Re
Lens 0 0 0 0 0 0 custom (EMoR 0 0 0 0 0
Lens 1 0 0 0 0 0 custom (EMoR 0 0 0 0 0
Lens 2 0 0 0 0 0 custom (EMoR 0 0 0 0 0
2. Toggle-off all these boxes

Panorama preview

Centre | Fit | Straighten | Num. Transf. | Auto | Update | All | None

displayed images

0 1 2 3 4 5



Preview Options

projection (f): Equirectangular | Blend mode: normal | Output: LDR | EV: 7.47 | Range compression: 0

130.9 -67.8 | 360.0 x 180.0

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos Masks Control Points Exposure Stitcher

Photometric Optimisation

Any variables below which are marked [x] will be optimized.
Unmarked variables [ ] will act as references or anchors.

Only use activated images.

4. Check the Panorama preview

3. Press "Optimise now!"

Optimise now!

Reset

Image variables:

#	Filename	EV	Er	Eb
0	Optimised-1.jpg	6.2	1	1
1	Optimised-2.jpg	6.8	1	1
2	Optimised-3.jpg	6.5	1	1
3	Optimised-4.jpg	7	1	1
4	Optimised-5.jpg	7.4	1	1
5	Optimised-6.jpg	6.4	1	1

1. Toggle on these boxes

Camera and Lens variables:

#	Filename	Vb	Vc	Vd	Vx	Vy	Response t...	Ra	Rb	Rc	Rd	Re
	Lens 0	0	0	0	0	0	custom (EMoR	0	0	0	0	0
	Lens 1	0	0	0	0	0	custom (EMoR	0	0	0	0	0
	Lens 2	0	0	0	0	0	custom (EMoR	0	0	0	0	0

2. Toggle on all these boxes

Panorama preview

Centre | Fit | Straighten | Num. Transf. | Auto | Update | All | None

displayed images

0 1 2 3 4 5



Preview Options

projection (f): Equirectangular | Blend mode: normal | Output: LDR | EV: 6.73 | Range compression: 0

130.9 -67.8 | 360.0 x 180.0

Panorama preview

Centre | Fit | Straighten | Num. Transf. | Auto | Update | All | None

displayed images

0 1 2 3 4 5



1. Click twice on the up-arrow

2. Click once on the up-arrow

Preview Options

projection (f): Equirectangular | Blend mode: normal | Output: LDR | EV: 7.4 | Range compression: 1

Left click to define new centre point, right click to move point to horizon.

142.3 -89.8

360.0 x 180.0

Export & Refinement

- Exporting remapped and blended images into panoramic image
- Viewing in a panoramic viewer
- Refining stitching errors or exposure discrepancies

Optimised-1 - Optimised-6.pto - Hugin - Panorama Creator

File Edit View Interface Output Help

Photos | Masks | Control Points | Exposure | Stitcher

Projection: Equirectangular

Field of View: Horizontal: 360 Vertical: 180 Calculate field of view

Canvas Size: Width: 6000 Height: 3000 Calculate optimal size

Crop: Left: 0 Top: 0 Right: 6000 Bottom: 3000 Fit crop to images

6000 x 3000=18.0 MP, 2:1

Panorama Outputs:
- [x] Exposure corrected, low dynamic range
- [ ] Exposure fused from stacks
- [ ] Exposure fused from any arrangement

Format: TIFF Compression: None

- [ ] High dynamic range

Format: EXR

Remapped Images:
- [ ] Exposure corrected, low dynamic range
- [ ] No exposure correction, low dynamic range
- [ ] High dynamic range

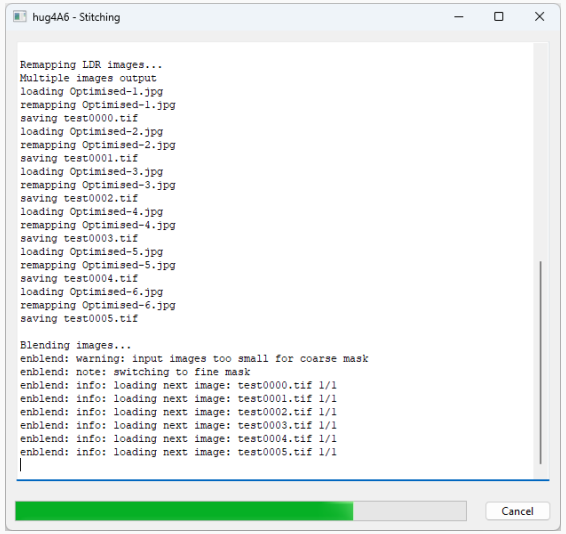
Combined stacks:
- [ ] Exposure fused stacks
- [ ] High dynamic range merged stacks

Layers:
- [ ] Blended layers of similar exposure, without exposure correction

Processing:

Remapper:	Nona	Options
Image fusion:	enfuse	Options
HDR merger:	built-in	Options
Blender:	enblend	Options
Edge fill:	No edge fill	Options

2. Save “test” pano



3. Hugin will remap and blend the images together

1. Click “Stitch!”

Stitch!



The equirectangular image can be examined with a local panorama viewer, such as FSP Viewer https://www.fsoft.it/FSPViewer/
The pano stitching looks fine, but we can refine the sky slightly.

Masked off blown out sky

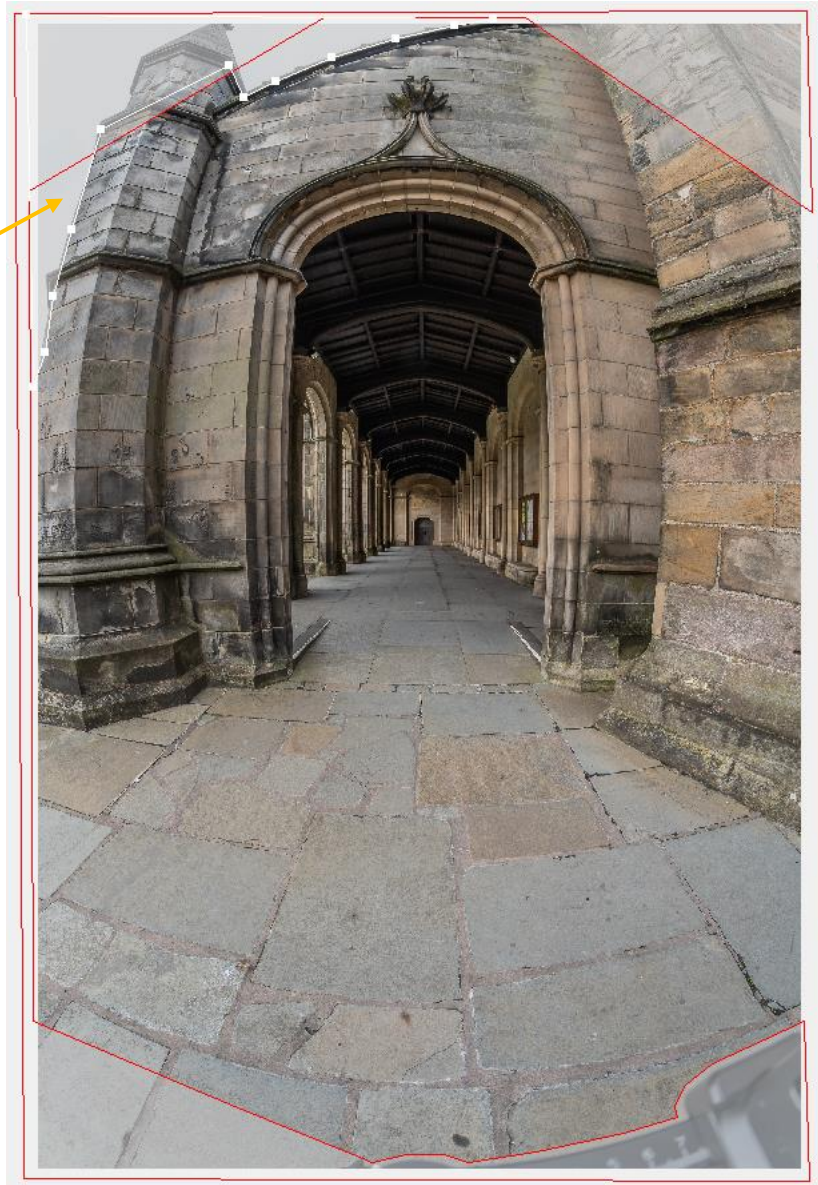


Image 0



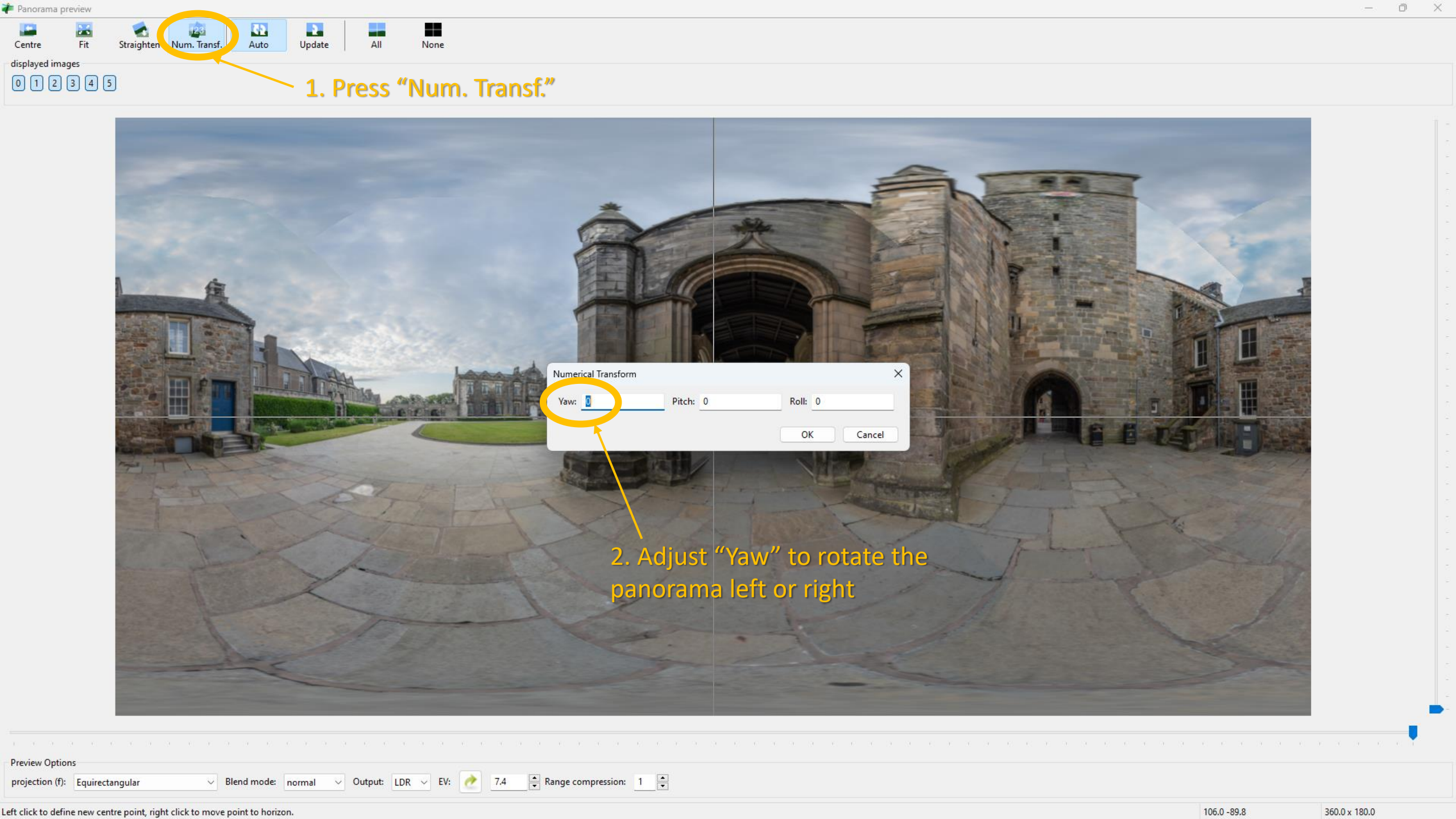
Image 2

Masked off blown out clouds


This area improved by masking out blown-out source image region

Final Export and Editing

- Adjust yaw of the pano (rotate pano left or right to adjust “framing”)
- Post-process exported stitched panorama


Panorama preview
Centre
Fit
Straighten
Num. Transf.
Auto
Update
All
None
displayed images
0 1 2 3 4 5
1. Press “Num. Transf.”
Numerical Transform
Yaw: 0
Pitch: 0
Roll: 0
OK
Cancel
2. Adjust “Yaw” to rotate the panorama left or right
Preview Options
projection (f): Equirectangular
Blend mode: normal
Output: LDR
EV: 7.4
Range compression: 1
Left click to define new centre point, right click to move point to horizon.
106.0 -89.8
360.0 x 180.0

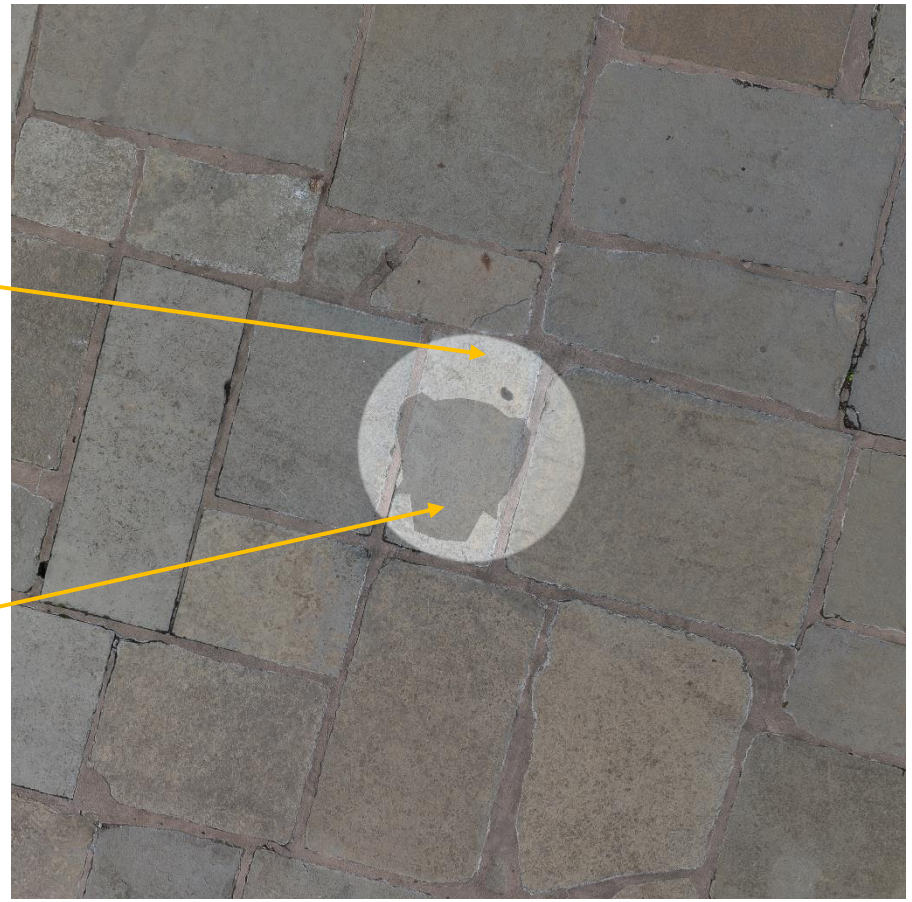


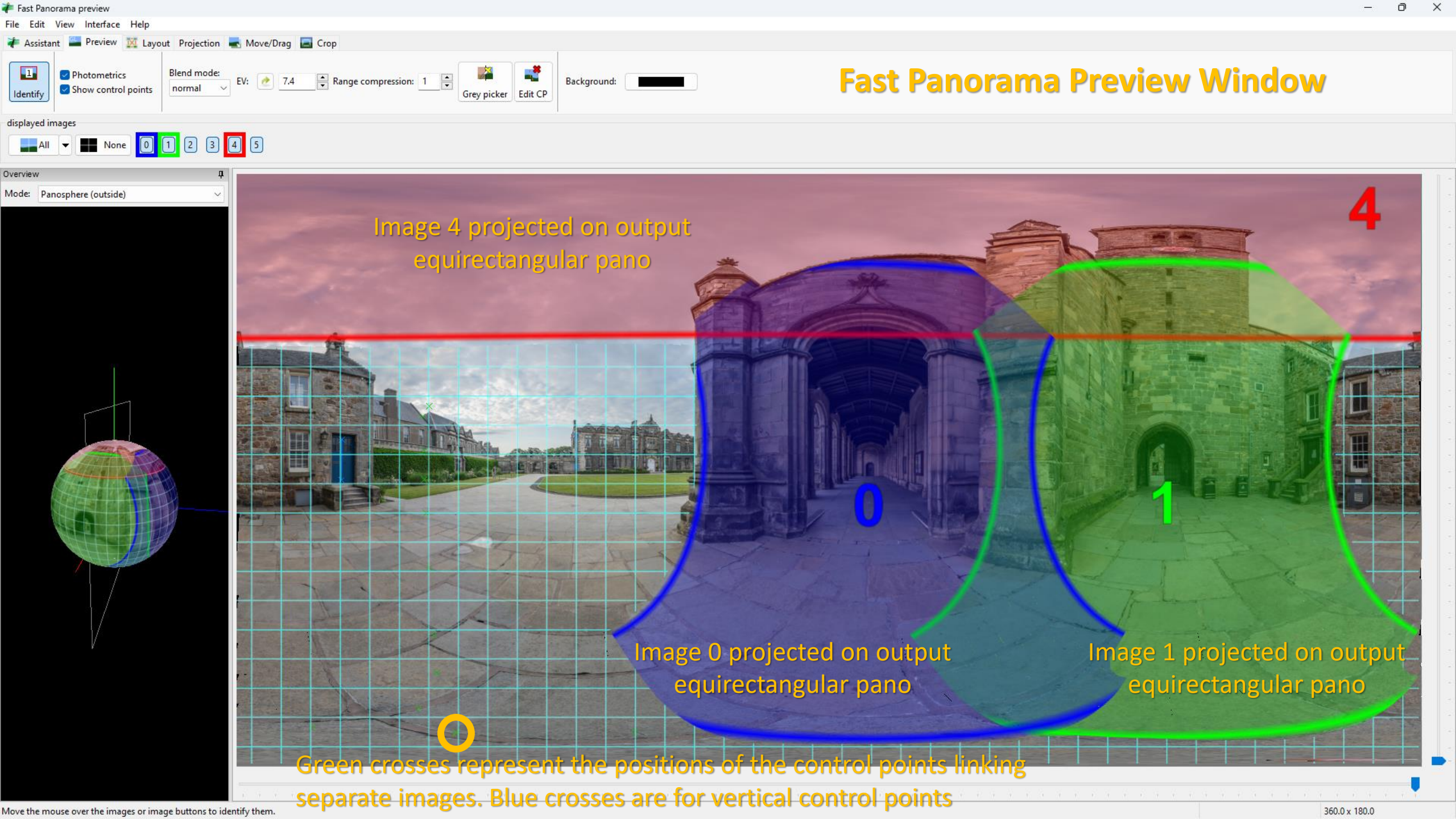
Panorama has been rotated right slightly. Some editing has been performed, mainly some curve adjustments, sharpening, and a boost in saturation

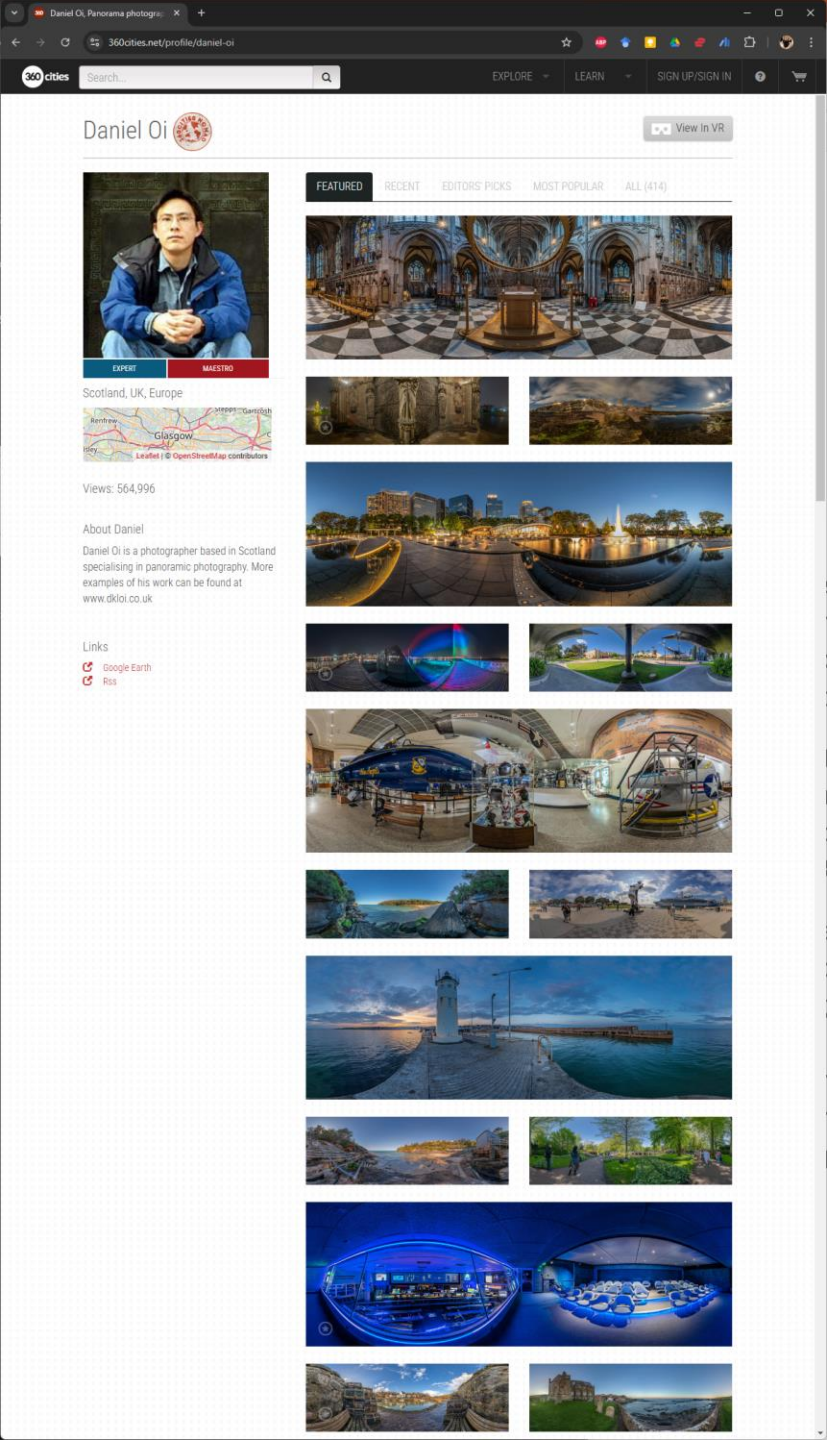
Appendix

- Nadir Hole
- Fast Panorama Viewer Visualisation
- Resources
- Pano/Photo Myths
- To Do

Nadir Hole


Nadir patch downshot
(brightened for clarity)
Nadir hole from
panohead tripod
90° Field of View
90° Field of View


Fast Panorama preview
File Edit View Interface Help
Assistant Preview Layout Projection Move/Drag Crop
Identify
Photometrics
Show control points
Blend mode:
normal
EV:
7.4
Range compression:
1
Grey picker
Edit CP
Background:
Fast Panorama Preview Window
displayed images
All
None
0 1 2 3 4 5
Overview
Mode:
Panosphere (outside)
Image 4 projected on output equirectangular pano
4
0
1
Image 0 projected on output equirectangular pano
Image 1 projected on output equirectangular pano
Green crosses represent the positions of the control points linking separate images. Blue crosses are for vertical control points
Move the mouse over the images or image buttons to identify them.
360.0 x 180.0



Resources

- My work can be seen at 360Cities https://www.360cities.net/profile/daniel-oi
- My personal website https://www.dkloi.co.uk/ has a few articles on panoramic photography techniques and other example Hugin projects for download
- The Facebook group https://www.facebook.com/groups/panoramicphotographers is a useful forum for discussion of panoramic photography
- The Google discussion group https://groups.google.com/g/hugin-ptx is for specific discussion of Hugin and related software

Pano/Photo Myths

- “Nodal Point”: The actual nodal points of a lens have nothing to do with the no-parallax point or entrance pupil
- Fixed Exposure: Early panoramic software could not easily blend together source images taken with different exposures, hence the advice was to fix the aperture, shutter speed, and ISO when taking the source images. However, modern panoramic software can easily perform photometric optimisation on source images taken at different shutter speeds. To maximise image quality, it is better to optimally expose each frame individually. In cases with high inter-frame contrast but low intra-frame contrast, this can avoid having to perform extensive bracketing around a fixed base exposure.
- “HDR” or “HDR Look”: What many people call “HDR” is actually the result of the process of Tone Mapping. HDR in itself is just the capture of the full brightness distribution of a scene and representing it in a scene-referred file format, such as EXR. HDR capture is often used for environmental light maps in computer graphics imagery. For normal display, HDR image files are converted to low dynamic range (LDR) images through a process called tone mapping. Some extreme forms of tone mapping give rise to the characteristic “HDR look”, though it is not intrinsic to HDR image capture itself.
- Focal Length Perspective: It is often said that the perspective of a photo is governed by the focal length of the lens, for example a wide-angle lens gives a different perspective than a telephoto (the latter producing a compressed perspective). This is not strictly correct, the perspective is a function of the positional relationship of the camera to the subject/scene. The focal length of the lens (for a given sensor/film format) governs the field of view captured by the camera. For the same positioning of camera and subject, a wide angle lens cropped down to the same angle of view as a telephoto would provide exactly the same perspective. Conversely, a stitched panorama using a telephoto given the same final angle of view as a wide angle lens would provide identical perspective. When you choose a focal length, to get the desired amount of the subject in the frame, this dictates the distance of the camera to the subject, hence the perspective. The perspective is only round-about determined by the focal length, it is a side-effect of the framing and the positioning required to achieve this.

To Do

- Add section on determining the no-parallax point
- Add section on using different lenses
- Add section on aperture/depth of field
- Add section on common problems/pitfalls when taking source images
- Add section on where to take panoramas, positioning, placement
- Add section on exposure challenges in panoramic photography
- Add section on troubleshooting pano assembly
- Add section on Hugin blend options
- Add section on post-processing