Making Die Photo by Hugin

Shutter Remote Provides No Contact Smooth Shuttering

High Definition (1920 x 1080) Monitor and SLR Digital Camera Connected by HDMI Cable

Screen Division Indices are Attached on Monitor TV to Clearly Define the Captured Area to be Overlapped

Hugin requires sufficient amount of overlap (at least 30% Horizontally & 35% Vertically) to generate effective control points automatically.

The overlap between diagonal adjacent stacks tends to be smaller and will affect stitch processing result so much.

See example below.

Four Adjacent Stacks ((1,1), (2,1), (1,2), & (2,2)) Overlapped 30% Horizontally & 35% Vertically

Six Cases of Overlapping Areas (Gray) (Especially, Overlap between Diagonal Stacks is smaller and decisive)

Hugin self-determines the location of stacks (images) verifying control points generated to all stacks (The origin is defined as "Anchor", stack #0 in default). Therefore, the sequence of control point generation becomes so important to define the mutual location between stacks.

First, determine how many images must be taken by camera.

In this example, 6 x 9 images (had to be increased to 6 x 10 images at final stage due to weird pattern concatenation observation) are needed to achieve sufficient overlap when using 20x magnification.

All the coordinates (X, Y) applied in this case are shown below.

(1,9)	(2,9)	(3,9)	(4,9)	(5,9)	(6,9)
(1,8)	(2,8)	(3,8)	(4,8)	(5,8)	(6,8)
(1,7)	(2,7)	(3,7)	(4,7)	(5,7)	(6,7)
(1,6)	(2,6)	(3,6)	(4,6)	(5,6)	(6,6)
(1,5)	(2,5)	(3,5)	(4,5)	(5,5)	(6,5)
(1,4)	(2,4)	(3,4)	(4,4)	(5,4)	(6,4)
(1,3)	(2,3)	(3,3)	(4,3)	(5,3)	(6,3)
(1,2)	(2,2)	(3,2)	(4,2)	(5,2)	(6,2)
(1,1)	(2,1)	(3,1)	(4,1)	(5,1)	(6,1)

Before taking images of die, precisely verify the following.

(1) Die and object lens must be parallel to get focused on any locations. Alternatively, get focus on every shot.

(2) Both horizontal & vertical edge of die image must be in parallel with each edge in any locations, "rectangle, not trapezoid". This is essential.

When scanning the die (the camera position is fixed and the die on the stage of metallurgical microscope moves), shot and scan from (1,1) to (6,1), move back to (1,1), move up to (1,2), shot and scan from (1,2) to (6,2).

Repeat this sequence until the shot and scan ends at (6,9).

The scan becomes easier and more stable by putting both horizontal and vertical boundary markers (For example, Winded rubber bands on monitor TV screen).

Rename JPEG file sequential numbering to coordinate basis (11 = (X=1, Y=1), 69 = (X=6, Y=9)).
 Example : "IMG_4505.JPG" to "11.JPG", "IMG_4506.JPG" to "21.JPG",,,,,,

8 19	17 29	26 39	35 49	44 59	53 69
7 18	16 28	25 38	34 48	43 58	52 68
6 17	15 27	24 37	33 47	42 57	51 67
5 16	14 26	23 36	32 46	41 56	50 66
4 15	13 25	22 35	31 45	40 55	49 65
3 14	12 24	21 34	30 44	39 54	48 64
2 13	11 23	20 33	29 43	38 53	47 63
1 12	10 22	19 32	28 42	37 52	46 62
0 11	9 21	18 31	27 41	36 51	45 61
Stack# vs. Coordinate					

Run Hugin.

Under "Photos" tab,
 - Load all image files.
 - Select all image files.
 - Select "Equirectangular" as "Lens type" of "Lens type".
 - Select "Custom parameters" as "Geometric" of "Optimize". "Optimizer" tab appears.

Photos	Masks	Control Points	Optimizer	Stitcher				
#	Filename	Width	Height	Anchor	# Ctrl Pnts	Lens no.	Stack no.	
40	55.JPG	5184	3456	--	0	0	40	
41	56.JPG	5184	3456	--	0	0	41	
42	57.JPG	5184	3456	--	0	0	42	
43	58.JPG	5184	3456	--	0	0	43	
44	59.JPG	5184	3456	--	0	0	44	
45	61.JPG	5184	3456	--	0	0	45	
46	62.JPG	5184	3456	--	0	0	46	
47	63.JPG	5184	3456	--	0	0	47	
48	64.JPG	5184	3456	--	0	0	48	
49	65.JPG	5184	3456	--	0	0	49	
50	66.JPG	5184	3456	--	0	0	50	
51	67.JPG	5184	3456	--	0	0	51	
52	68.JPG	5184	3456	--	0	0	52	
53	69.JPG	5184	3456	--	0	0	53	

Lens type

Add images...

Lens type: Equirectangular

Focal length: 81.062 mm Focal length multiplier: 1.573 x

Feature Matching

Settings: Hugin's CPFind   Create control points

Optimize

Geometric: Custom parameters   Calculate

Referring to table below, select four adjacent stacks and click "Create control points" of "Feature Matching" 40 ((9 − 1) * (6 − 1)) times changing the four adjacent stack combination ((0, 1, 9, 10), (1, 2, 10, 11),,,, (43, 44, 52, 53)).

8	17	26	35	44	53
7	16	25	34	43	52
6	15	24	33	42	51
5	14	23	32	41	50
4	13	22	31	40	49
3	12	21	30	39	48
2	11	20	29	38	47
1	10	19	28	37	46
0	9	18	27	36	45
Adjacent Stack #					

Example : Choosing four adjacent stacks of (0, 1, 9, 10)

Photos	Masks	Control Points	Optimizer	Stitcher				

#	Filename	Width	Height	Anchor	# Ctrl Pnts	Lens no.	Stack no.	
0	11.JPG	5184	3456	AC	0	0	0	
1	12.JPG	5184	3456	--	0	0	1	
2	13.JPG	5184	3456	--	0	0	2	
3	14.JPG	5184	3456	--	0	0	3	
4	15.JPG	5184	3456	--	0	0	4	
5	16.JPG	5184	3456	--	0	0	5	
6	17.JPG	5184	3456	--	0	0	6	
7	18.JPG	5184	3456	--	0	0	7	
8	19.JPG	5184	3456	--	0	0	8	
9	21.JPG	5184	3456	--	0	0	9	
10	22.JPG	5184	3456	--	0	0	10	
11	23.JPG	5184	3456	--	0	0	11	
12	24.JPG	5184	3456	--	0	0	12	
13	25.JPG	5184	3456	--	0	0	13	
14	26.JPG	5184	3456	--	0	0	14	

Lens type

Add images...

Lens type: Equirectangular

Focal length: 1311.488 mm   Focal length multiplier: 1.573   x

Feature Matching

Settings: Hugin's CPFind   Create control points

(Procedure of "Control Points" tab below is applied for verification purpose and can be skipped in normal cases. Simply look at control points Hugin made by "View" > "Control point table". If control points with bigger numbers than others were listed, verify if they are actually bogus control points comparing left and right image. If they are bogus, delete them on the control point table. The efforts of creating manual control points (any of normal, vertical & horizontal line) do not contribute effectively although it takes time.)

Under "Control Points" tab,
 - Check all the adjacent images have control points generated checking from Stack #0 to #53, one by one.

Example : 54 metallurgical photo images (6 (X) x 9 (Y)) to be combined into one die photo

8	17	26	35	44	53
7	16	25	34	43	52
6	15	24	33	42	51
5	14	23	32	41	50
4	13	22	31	40	49
3	12	21	30	39	48
2	11	20	29	38	47
1	10	19	28	37	46
0	9	18	27	36	45
Adjacent Stack #					

#15 (2,7)		#24 (3,7)		#47 (4,7)
#14 (2,6)		#23 (3,6)		#46 (4,6)
#13 (2,5)		#22 (3,5)		#45 (4,5)

Stack #23 should have control points with surrounding 8 stacks (#13, #14, #15, #22, #24, #31, #32, and #33) theoretically as above.

Hugin certifies whether control points were properly generated with all surrounding eight stacks or not, as below.

48 (24 x 2) control points were successfully generated in this case.
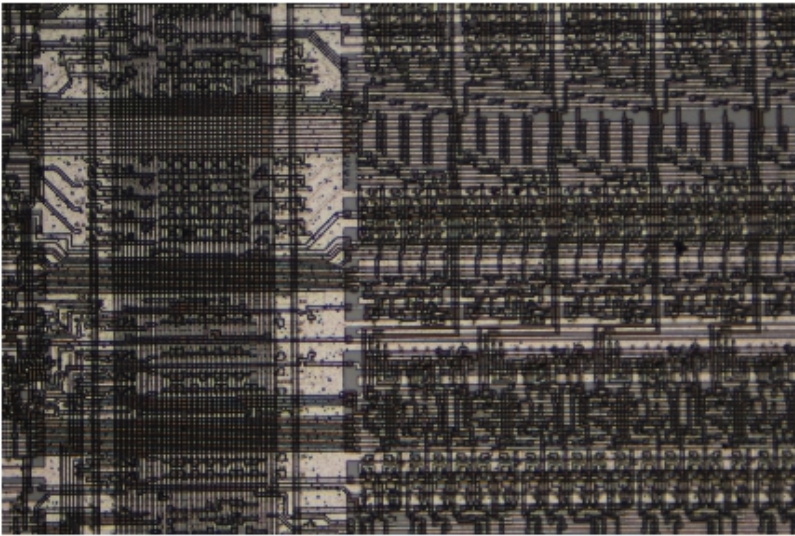
When Hugin was unable to generate control points due to similar patterns overlapped as below, list up the combination of two stacks failed, and make control points manually one by one (It is fate).

Example : Stack #32 does not have control points with #40, #41, and #42.

#24 (3,7)		#33 (4,7)		#42 (5,7)
#23 (3,6)		#32 (4,6)		#41 (5,6)
#22 (3,5)		#31 (4,5)		#40 (5,5)

Photos | Masks | Control Points | Optimizer | Stitcher

32. - 46.JPG   41. - 56.JPG

22. - 35.JPG	18
23. - 36.JPG	48
24. - 37.JPG	19
25. - 38.JPG	
26. - 39.JPG	
27. - 41.JPG	
28. - 42.JPG	
29. - 43.JPG	
30. - 44.JPG	
31. - 45.JPG	44
32. - 46.JPG	
33. - 47.JPG	48
34. - 48.JPG	
35. - 49.JPG	
36. - 51.JPG	
37. - 52.JPG	
38. - 53.JPG	
39. - 54.JPG	
40. - 55.JPG	
41. - 56.JPG	
42. - 57.JPG	
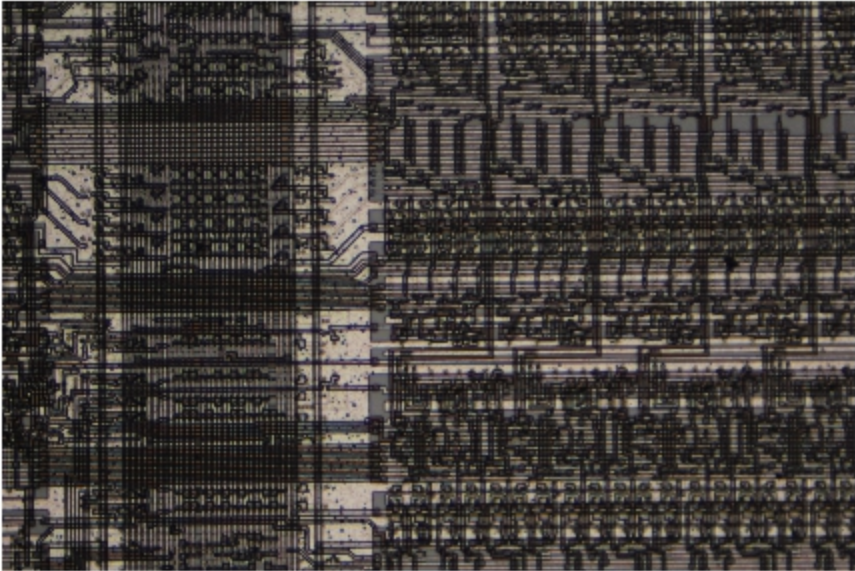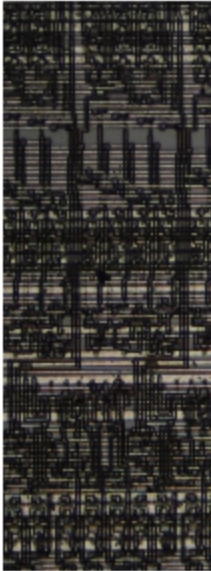
No control points were generated because similar pattern existed in between (Functional limitation of Hugin).

Photos | Masks | Control Points | Optimizer | Stitcher

32. - 46.JPG   41. - 56.JPG

Verify if the "Distance" of all control points is similar (4.23 or 4.22 in this example). If not, delete the control point verifying the control number on the graphics. This is bogus control point generated by Hugin. Minimize the consequence of strange stitch result beyond comprehension.

Good example :

#	left x	left y	right x	right y	Alignment	Distance ▽
23	5018.01	531.13	5086.13	3163.68	normal	4.23
21	4914.74	287.75	4980.99	2914.98	normal	4.22
24	4869.65	641.18	4938.87	3268.25	normal	4.22
5	1225.06	163.00	1294.99	2787.10	normal	4.22
0	827.04	163.19	896.04	2787.04	normal	4.22
4	916.84	658.08	979.27	3280.80	normal	4.22
1	1030 08	264 54	1096 82	2887 02	normal	4 22

Bad example :

#	left x	left y	right x	right y	Alignment	Distance ▽
3	4605.92	704.56	784.87	3321.57	normal	7.44
4	4873.79	718.00	1053.64	3336.11	normal	7.44
1	4509.66	146.45	691.19	2763.73	normal	7.44
2	4598.00	161.66	779.84	2779.01	normal	7.44
0	3923.85	1185.50	4567.48	1048.67	normal	1.06

In this case, graphics result exhibited that the control #0 was plotted at different place. The control #0 must be deleted not to get side effect.
The bogus control point occurs on stack combination which has small number of control point each other.

Check the distance for all stacks one by one. This step is essential.
Viewing "Control point table" by "View > Control point table" is for tendency observation.

Under "Optimizer" tab,

 - Select all image files.
 - Right click on "Roll" of "Image Orientation", click "Unselect all".
 - Click "Reset", Reset all – OK.
 - Right click on "Lens 0" of "Lens Parameters", click "Edit image variables…", type "1" on "degrees of view (v)" of "Lens", click OK, check "Hfov (v)" of "Lens Parameters".
 - Right click Yaw (y) & Pitch (p), Click "Select all".

| Photos | Masks | Control Points | Optimizer | Stitcher |

Geometric optimizer

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

☑ Only use control points between activated images.
☐ Ignore line control points

Image Orientation

#	Filename	Yaw (y)	Pitch (p)	Roll (r)	X (TrX)	Y (TrY)	Z (TrZ)	Plane y...	Plane p...	Camera tran...
0	11.JPG	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
1	12.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
2	13.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
3	14.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
4	15.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
5	16.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
6	17.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
7	18.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
8	21.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
9	22.JPG	☑ 0	☑ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active

Lens Parameters

#	Filename	Lens type (f)	Hfov (v)	a	b	c	d	e	g	t	
⊞	Lens 0	Equirectangular	☑ 1	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	

- Click "Optimize now!".
- Verify the result.

Photos | Masks | Control Points | Optimizer | Stitcher

Geometric optimizer

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

☑ Only use control points between activated images.
☐ Ignore line control points

Image Orientation

#	Filename	Yaw (y)	Pitch (p)	Roll (r)	X (TrX)	Y (TrY)	Z (TrZ)	Plane y...	Plane p...	Camera tran...
0	11.JPG	☐ 0	☑ -1	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
1	12.JPG	☑ -0.1	☑ -0.6	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
2	13.JPG	☑ -0	☑ -0.2	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
3	14.JPG	☑ -0	☑ 0.2	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
4	15.JPG	☑ -0	☑ 0.6	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
5	16.JPG	☑ -0	☑ 1	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
6	17.JPG	☑ -0	☑ 1.3	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
7	18.JPG	☑ -0	☑ 1.7	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
8	19.JPG	☑ -0	☑ 2.1	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active
9	21.JPG	☑ 0.5	☑ -1	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ not active

Lens Parameters

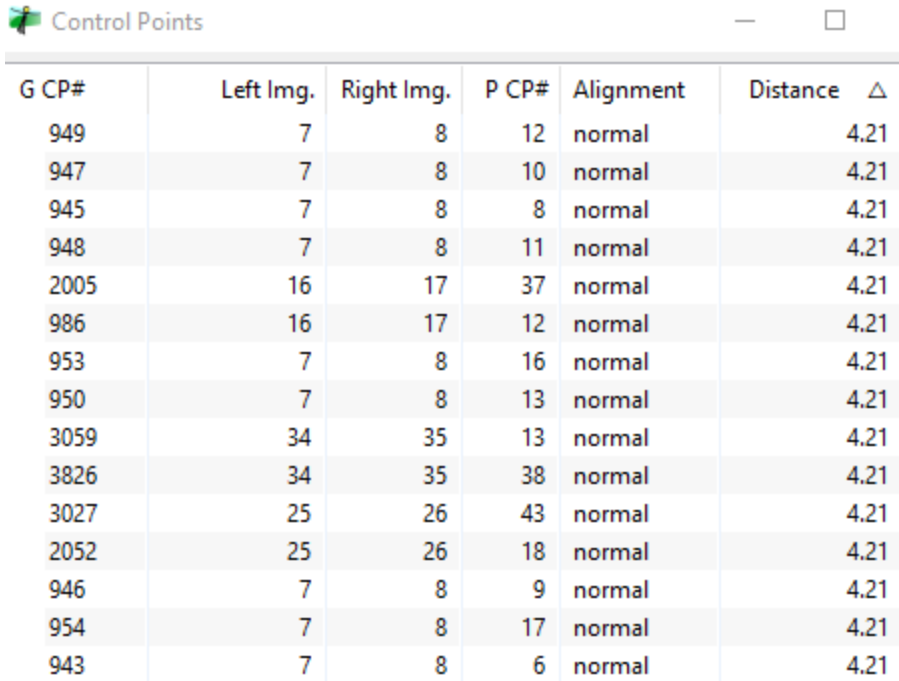| #	Filename	Lens type (f)	Hfov (v)	a	b	c	d	e	g	t	
⊞	**Lens 0**	Equirectangular	☑ 0.7	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	

Definition of Yaw, Pitch, and Roll
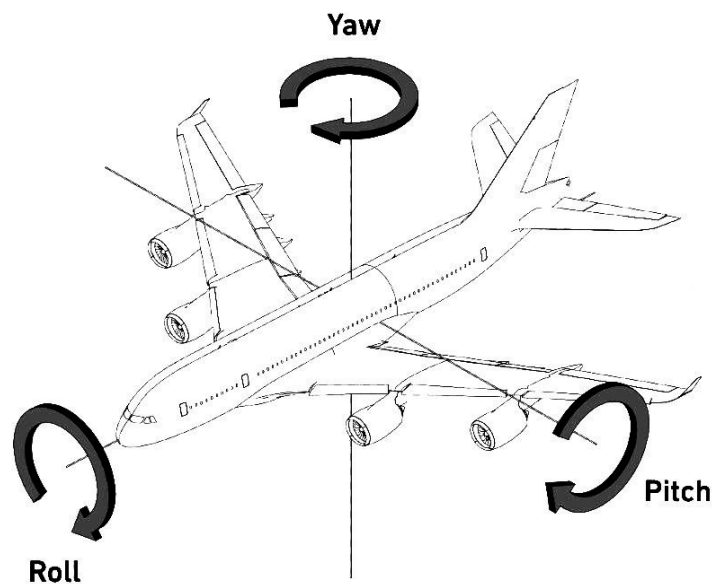
"View" > "Control point table" to open control point table as below.
Click "Distance" and delete all control points over 50 which are bogus. Normally, this never happens if sufficient overlaps between adjacent images are properly made.

If bogus control points are found, it is better to take images once more making sufficient overlaps. It take time to make control points manually. Simply delete bogus control points detected (Rely on Hugin automatic processing although it is not perfect).

Control Points

| G CP#	Left Img.	Right Img.	P CP#	Alignment	Distance △
949	7	8	12	normal	4.21
947	7	8	10	normal	4.21
945	7	8	8	normal	4.21
948	7	8	11	normal	4.21
2005	16	17	37	normal	4.21
986	16	17	12	normal	4.21
953	7	8	16	normal	4.21
950	7	8	13	normal	4.21
3059	34	35	13	normal	4.21
3826	34	35	38	normal	4.21
3027	25	26	43	normal	4.21
2052	25	26	18	normal	4.21
946	7	8	9	normal	4.21
954	7	8	17	normal	4.21
943	7	8	6	normal	4.21

Under "Control Points", compare adjacent two image combinations to see if any bogus control points exist. If the number of control points is 0 through 3, manually add control point(s) until getting 4 control points.

Repeat optimization process again until getting satisfactory result.

"View" > "Fast Panorama preview window"
- Click "Align". It takes time (over one hour) to get aligned all images which should be organized as rectangle die.
- Click "Center", Slide vertical & horizontal bars to get image, Click "Move/Drag" to display cross hair cursor, Move an image to center.
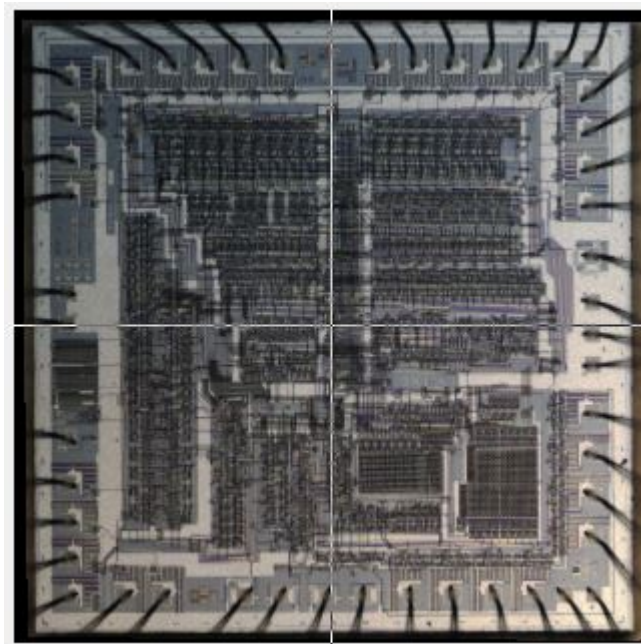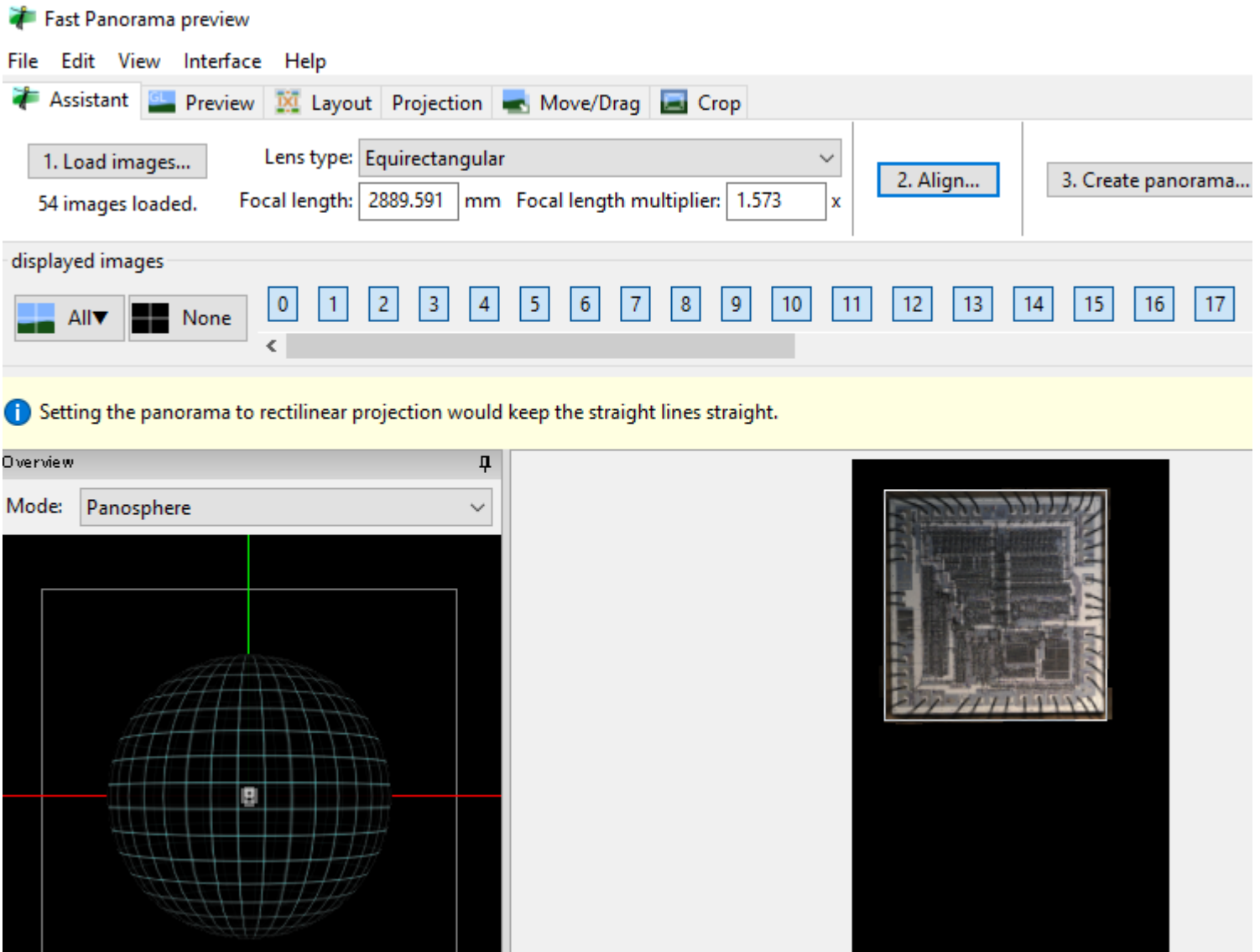
Under "Stitcher" tab,
- Select "Equirectangular" as "Projection".
- Click "Calculate field of view".
- Click "Calculate optimal size".
- Precisely adjust "Field of View" under "Stitcher" tab previewing display of "Panorama preview".

Photos	Masks	Control Points	Optimizer	Stitcher	

Projection: Equirectangular

Field of View: Horizontal: 3   Vertical: 5   [Calculate field of view]

Canvas Size: Width: 34136   Height: 56894   [Calculate optimal size]

Crop: Left: 3465   Top: 3372
Right: 27178   Bottom: 27859   [Fit crop to images]

23713 x 24487= 581 MP, 1:1.03

Photos	Masks	Control Points	Optimizer	Stitcher	

Projection: Equirectangular

Field of View: Horizontal: 0.6   Vertical: 0.6

**Canvas Size:** Width: 24488   Height: 24487

- Click "Stitch!".

Procedure of making micrograph PDF file (Example of µPD8086D)

Output file name	Utility	Function & Contents
"Page 1.pdf"	Open Office Writer	LSI photo, Pin connection, Photo table with the co-ordinates
"8086D.jpg"	Hugin Stitcher	Stitch 104 photos aligned
"8086D_cut_s.jpg"	Gimp	Crop and file size reduction of "8086D.jpg"
"8086D_footer.pdf"	PDFill PDF Tools	Embed "8086D_cut_s.jpg" and footer comment
"8086D_20x Micrograph.pdf"		Combine "Page 1.pdf" and "8086D_footer.pdf"

Open Office Writer is sometimes(?) unable to load a large image file on the document file.

Stitching Errors & Correction
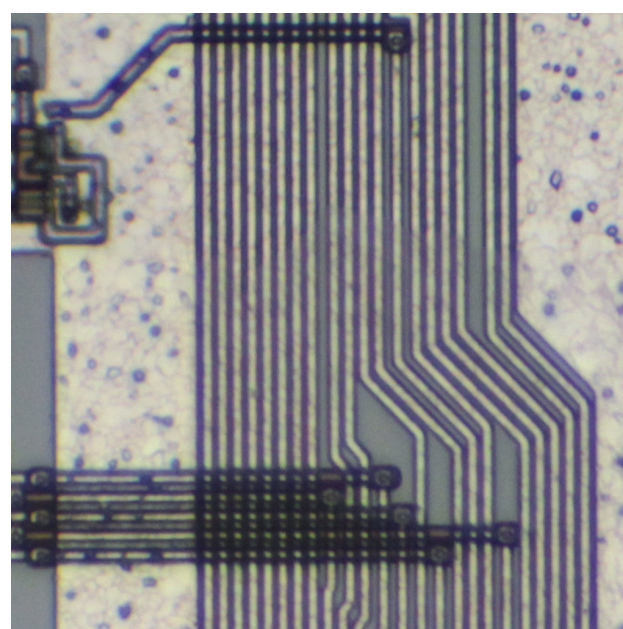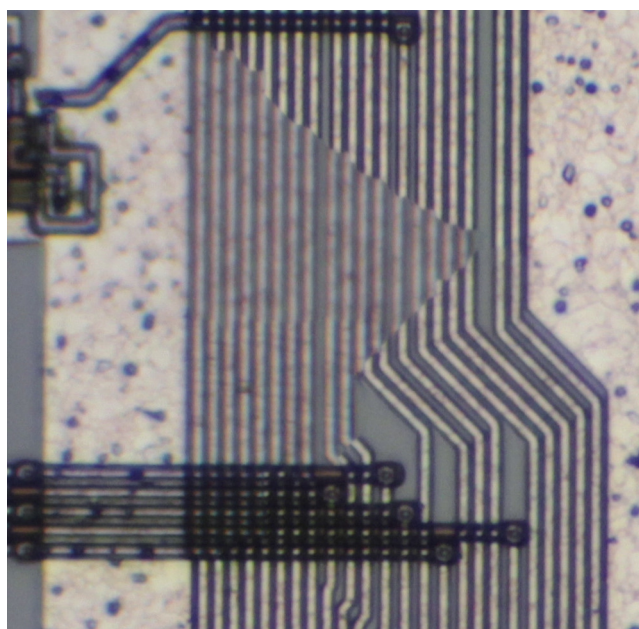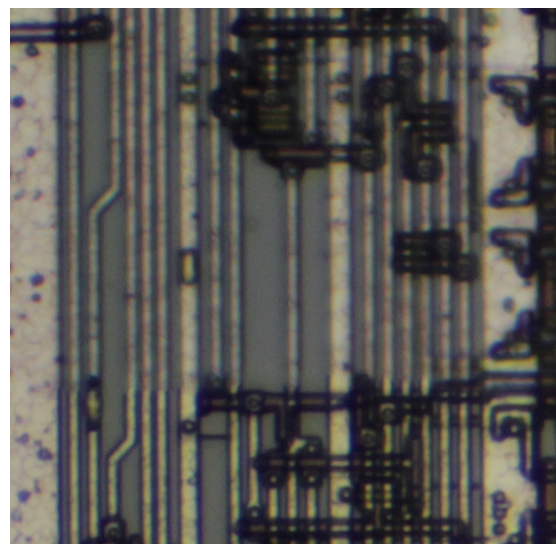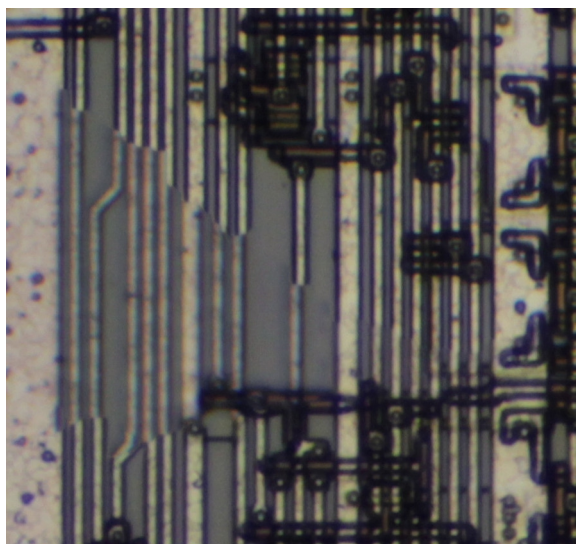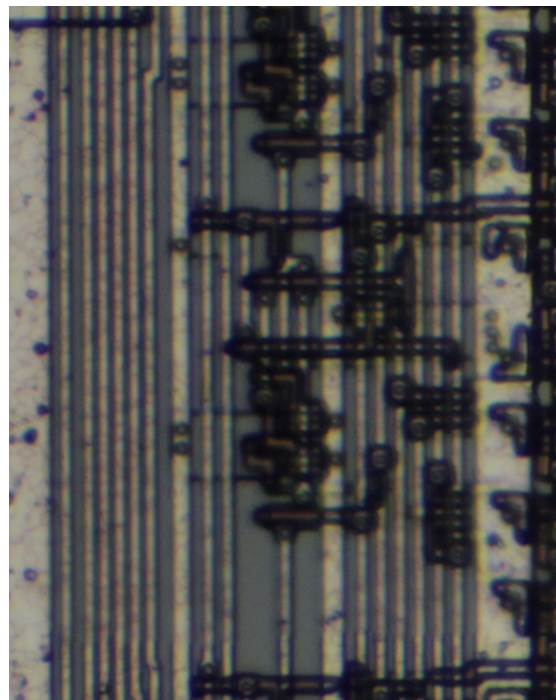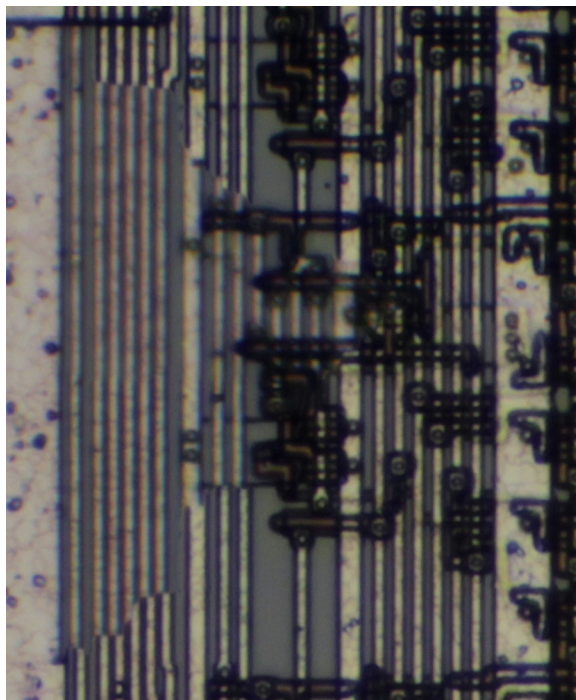
6 x 9 Images Approach

6 x 10 Images Approach

When 54 (6 (X) x 9 (Y)) images were taken, stitch errors happened on plural places.

All the following debugging approaches failed.
(1) Increasing the number of normal control points
(2) Specifying normal control points on lines between good and bad zone (probably Hugin might not care)
(3) Defining vertical line and horizontal line control points

I assumed that getting more overlap between the images might resolve the problem based upon Hugin architecture. The approach urged me to take 60 (6 (X) x 10 (Y)) images instead of 54 images and synthesize by Hugin. The result was successful.