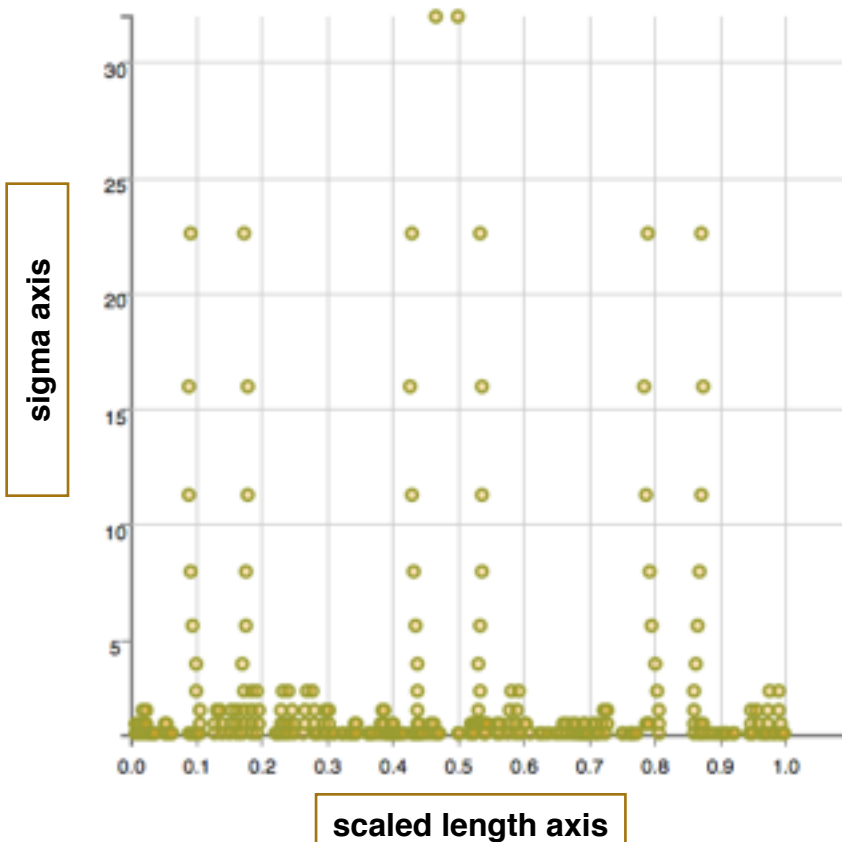


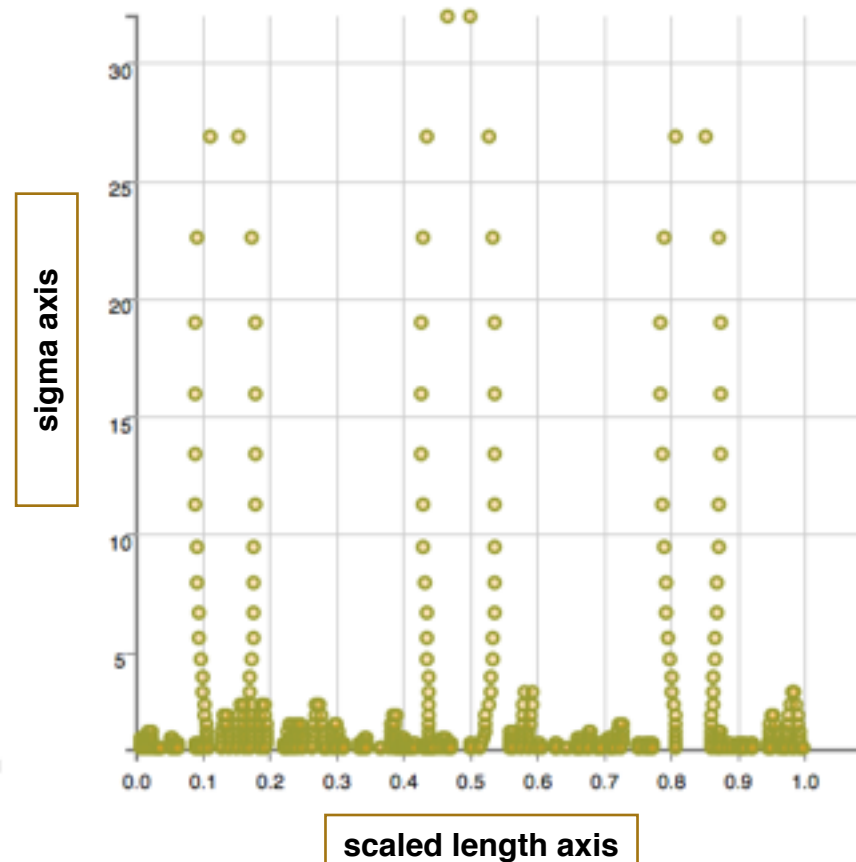
contour finder



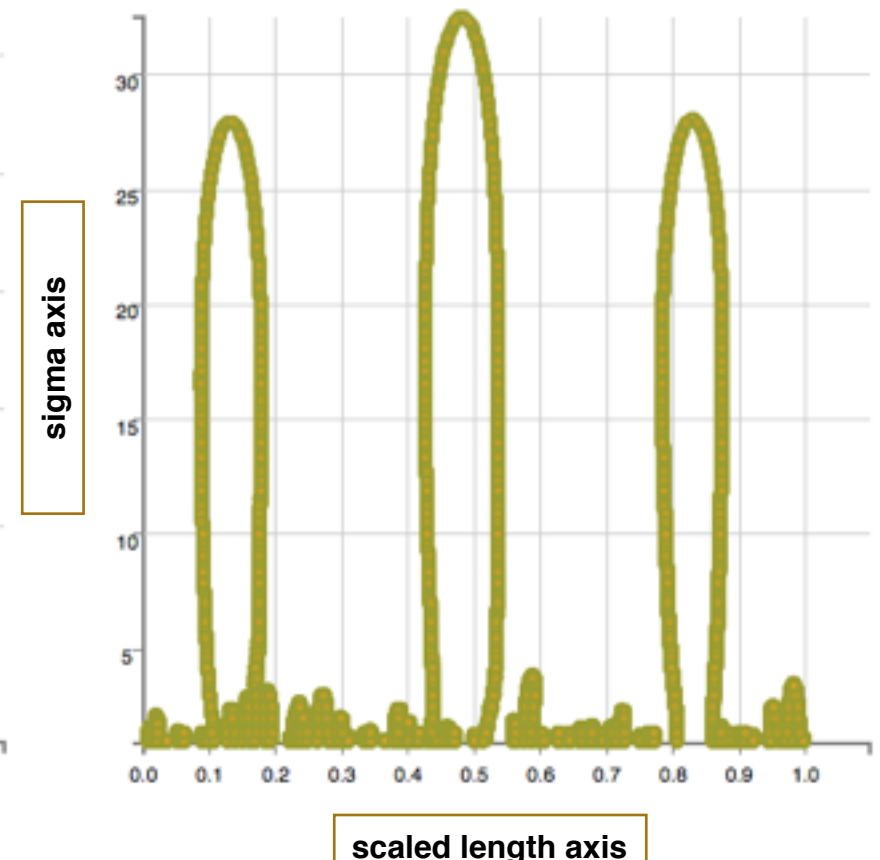
scale space image produced
for sigma factors of $\sqrt{2}$



scale space image produced
for sigma factors of $2^{1/8}$



scale space image produced
for sigma factors of $2^{1/128}$



There is an error in estimating the peak of a contour for fastest creation of scale space images ($\leq \sqrt{2}$). That error can be reduced overall, by having more contours in the final solution. For an error $< 10\%$ in determining a contour's peak height, one should choose a sigma factor of $2^{1/8}$ or smaller. It takes 2^3 more convolutions if the smaller sigma factor of $2^{1/8}$ is used instead of $2^{1/2}$.

Inflection points for $\sigma > 0$

Scale-Based Description and Recognition of Planar Curves and Two-Dimensional Shapes

FARZIN MOKHTARIAN AND ALAN MACKWORTH

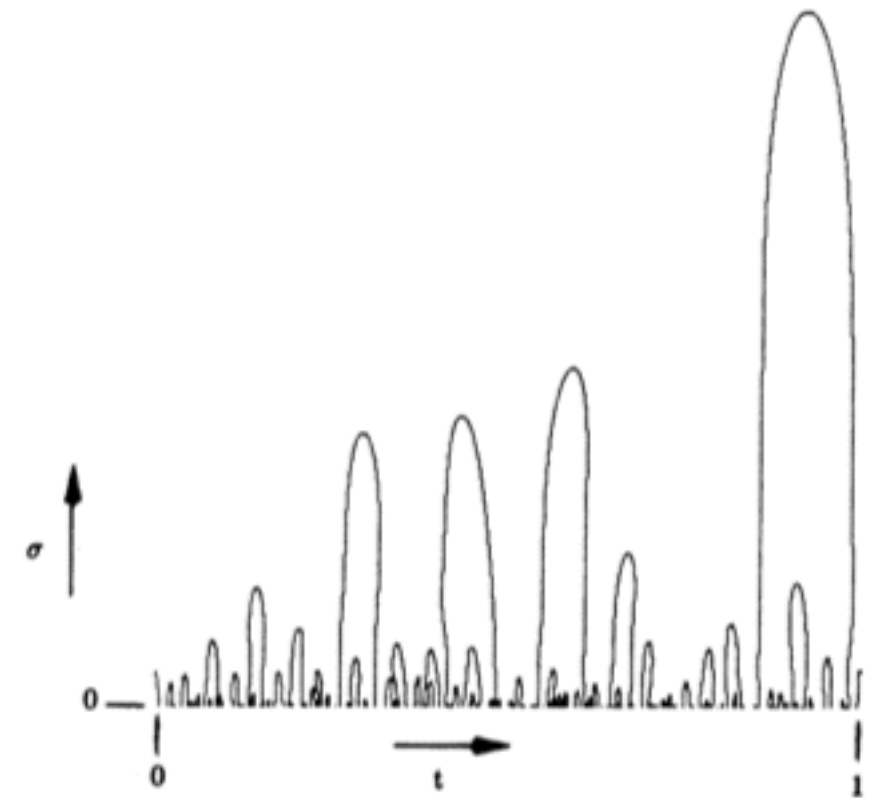
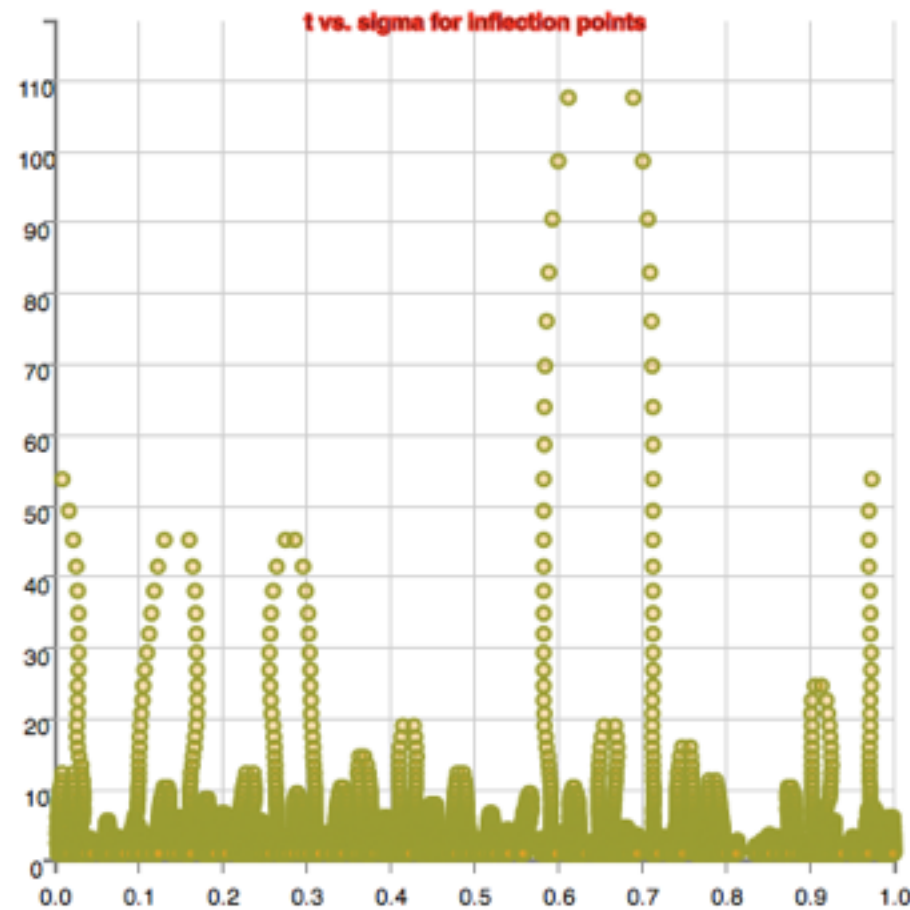
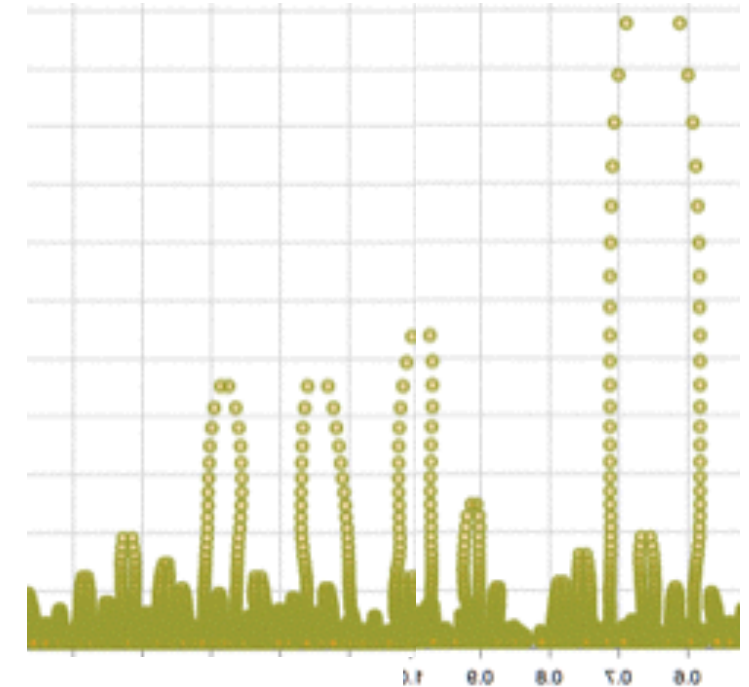


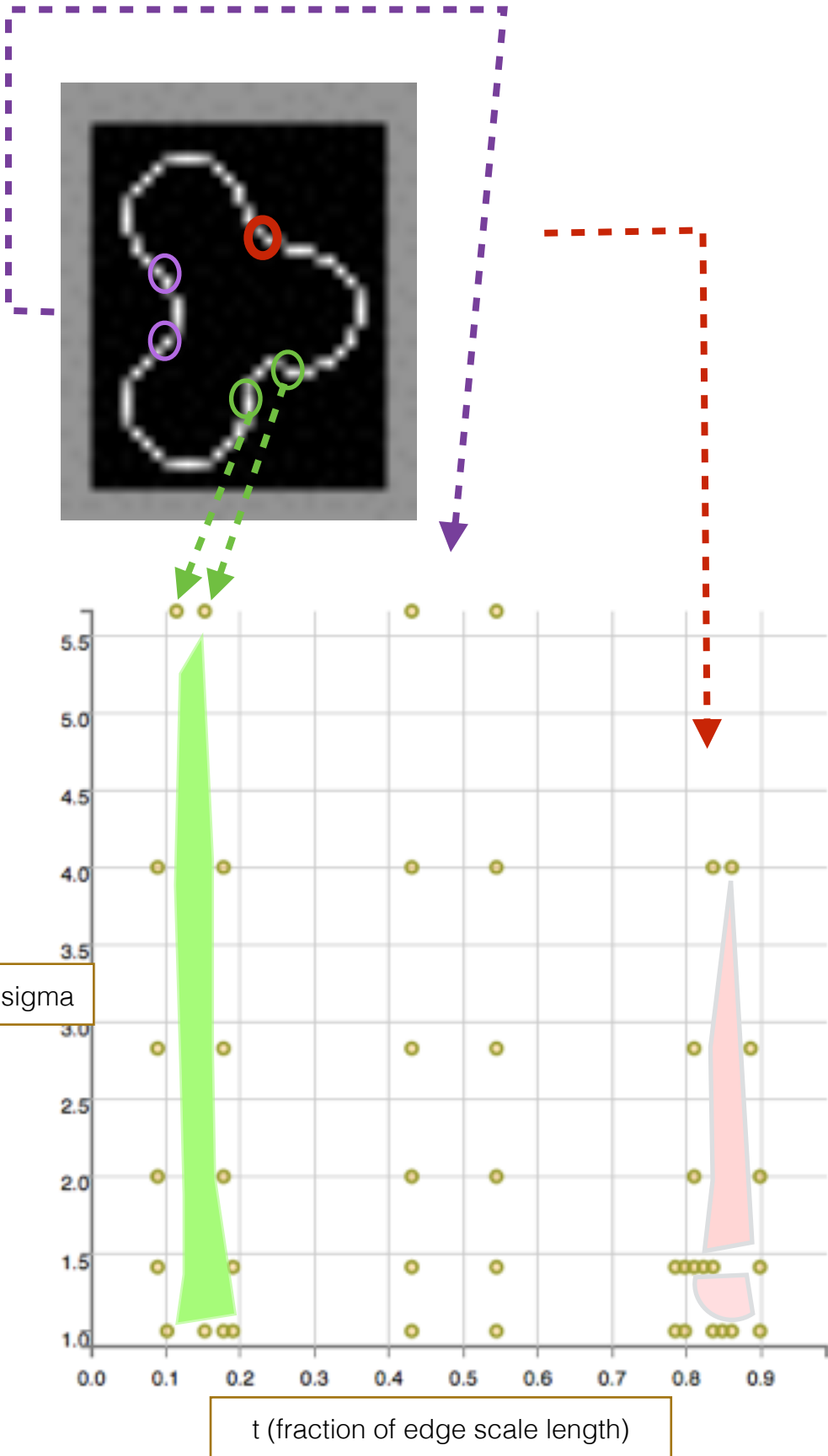
Fig. 3. Generalized scale space image of Africa.



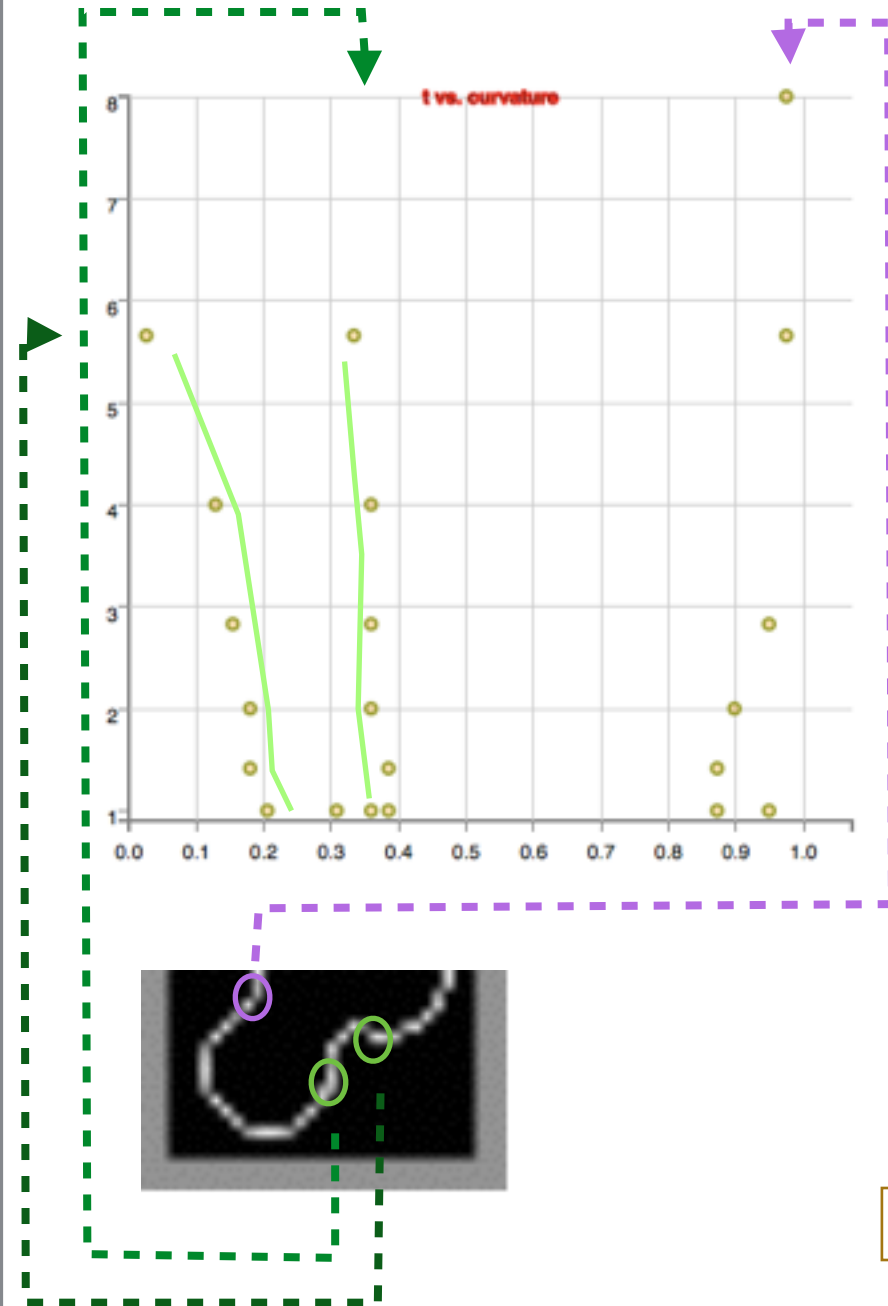
my scale space image
agrees with theirs

contour finder

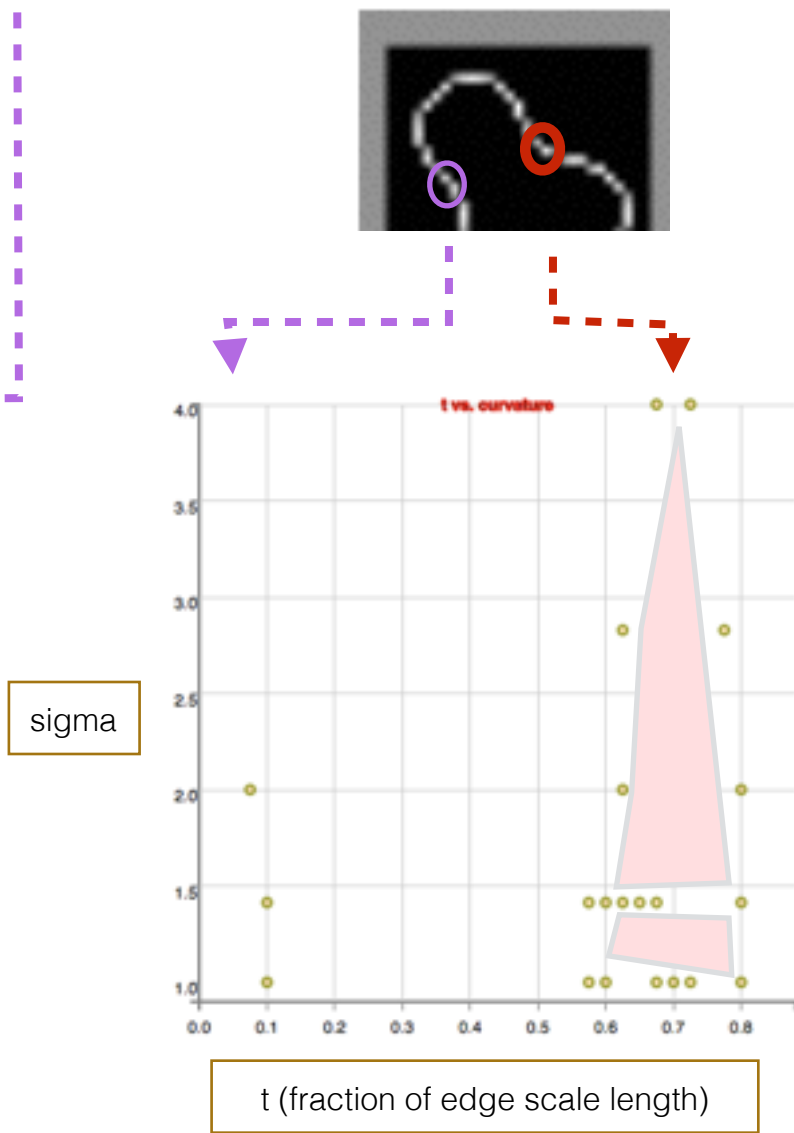
single closed curve's scale space image:



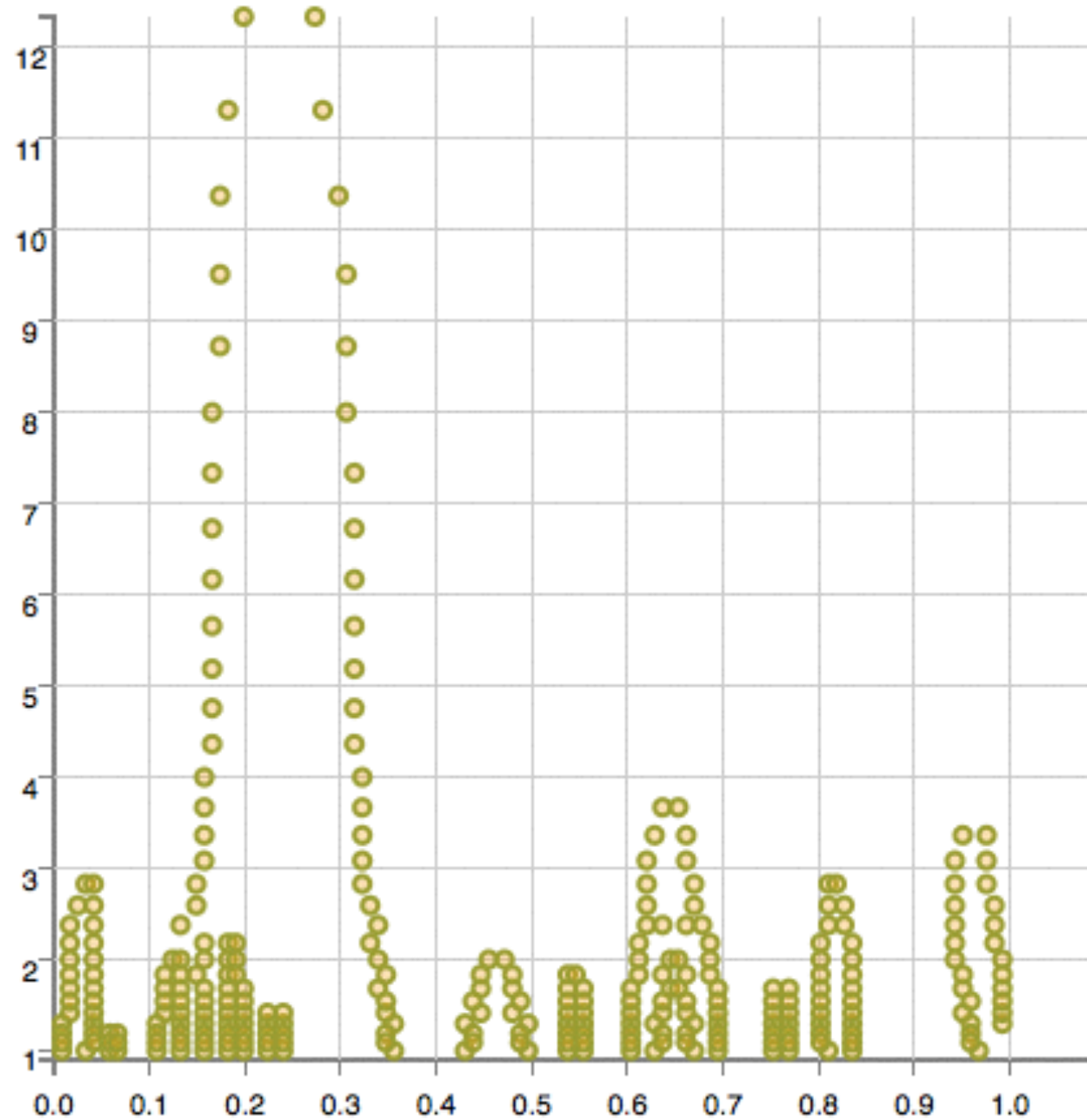
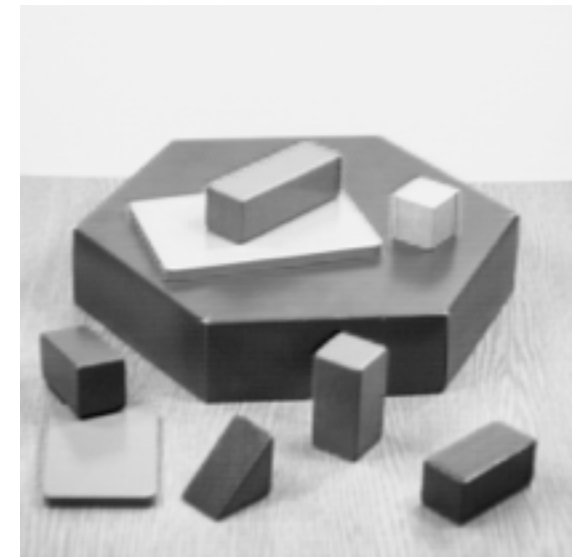
divided into 2 curves manually, then made into scale images (that is, 2 open curves possibly create open contours):



∴ open contours are hard to match in another image's scale images



contour finder



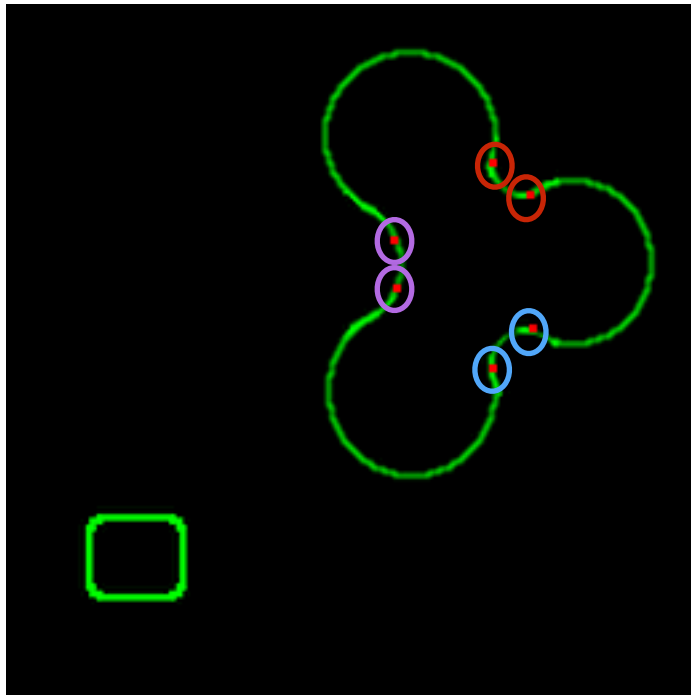
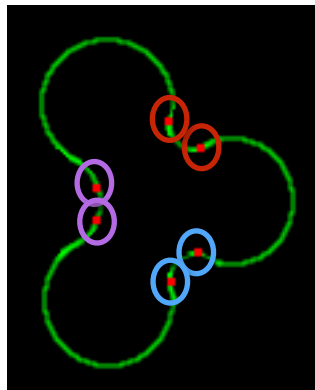
The contour finder looks for the peaks at the highest sigma and then follows the left and right branches down, subtracting that contour from the scale space image. each contour is found that way and subtracted to a lower threshold.

Then contours from one image are matched with the contours of another image (an image having the same content, that is).

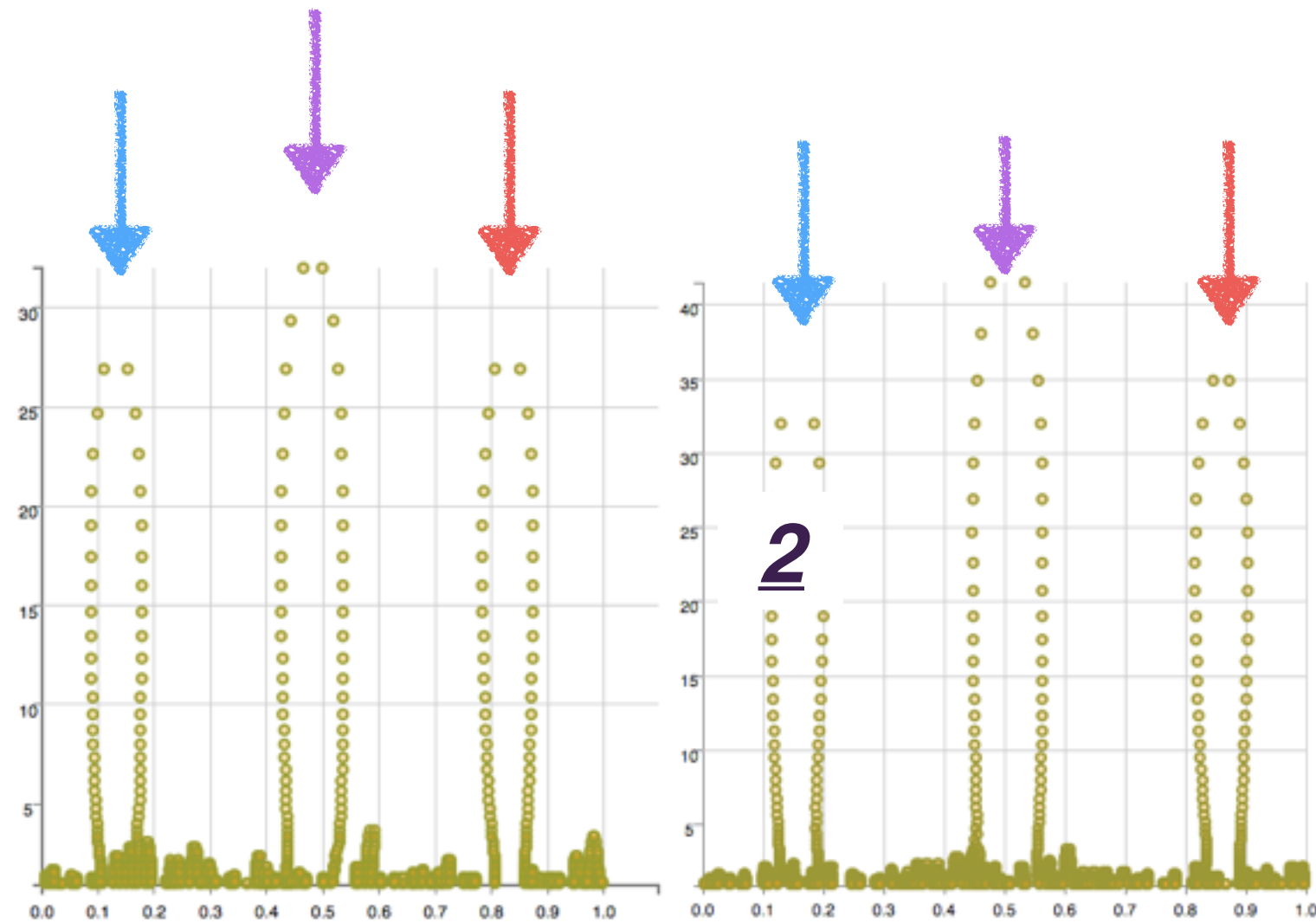
Then euclidean transformation parameters rotation, scale, and translation are calculated from the matched contour peak coordinates.

Then, the parameters are refined with small changes and applied to the edges in image 1. The transformed closed curve edges from image 1 are compared to the closest matches in image 2 to find the best fitting transformation parameters.

coordinate transformation, after matching contours



scale should be 1.3
rotation should be 360 - 20



Contour matcher solution scale=1.354256510734558

Contour matcher solution shift=-0.1688411384820938

CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72)

CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99)

CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54)

offsetImgX1=10 offsetImgY1=10

offsetImgX2=1 offsetImgY2=26

rotationInRadians=6.0030236

rotationInDegrees=343.94791799660214

scale=1.3542565

translationX=108.1361

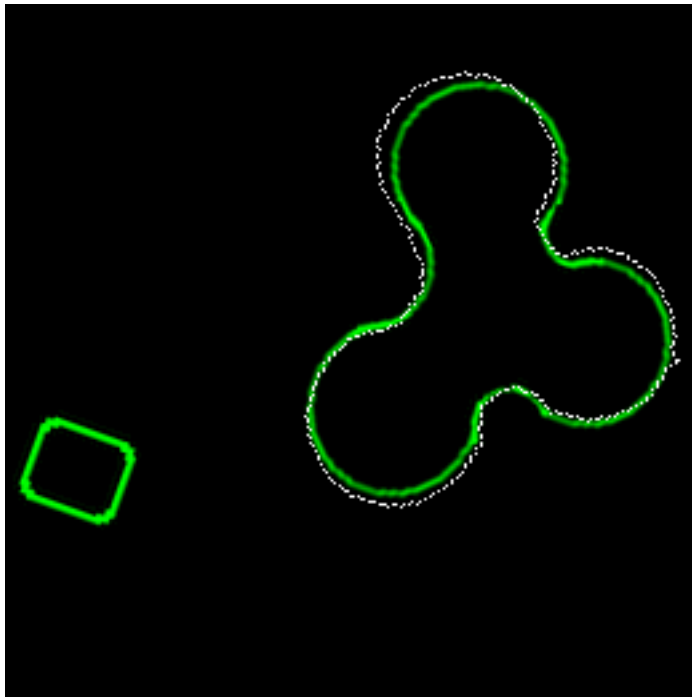
translationY=15.72716

CONTOUR PEAK2: (43.336529, 0.504396) (157, 108) (159, 101)

CONTOUR PEAK2: (34.148750, 0.157143) (190, 143) (177, 150)

CONTOUR PEAK2: (34.896511, 0.859341) (200, 85) (209, 97)

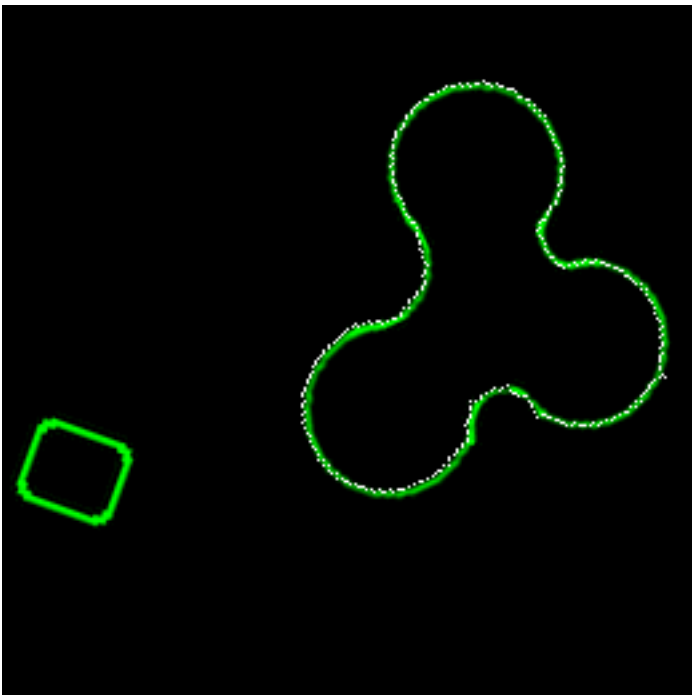
apply coordinate transformation



rotationInRadians=6.0030236
rotationInDegrees=343.94791799660214
scale=1.3542565
translationX=108.1361
translationY=15.72716

scale should be 1.3
rotation should be 360-20

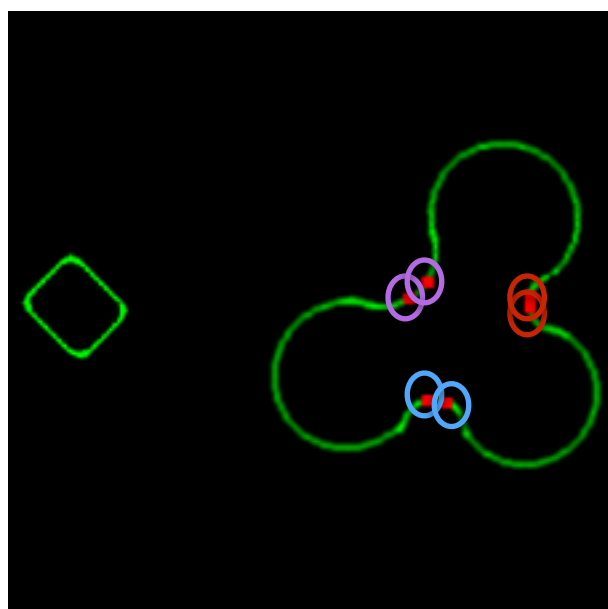
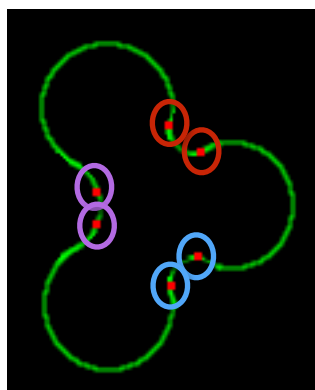
This shows that it's difficult to estimate scale unless some of the inflection points are further from the center of the shape



After Refinement

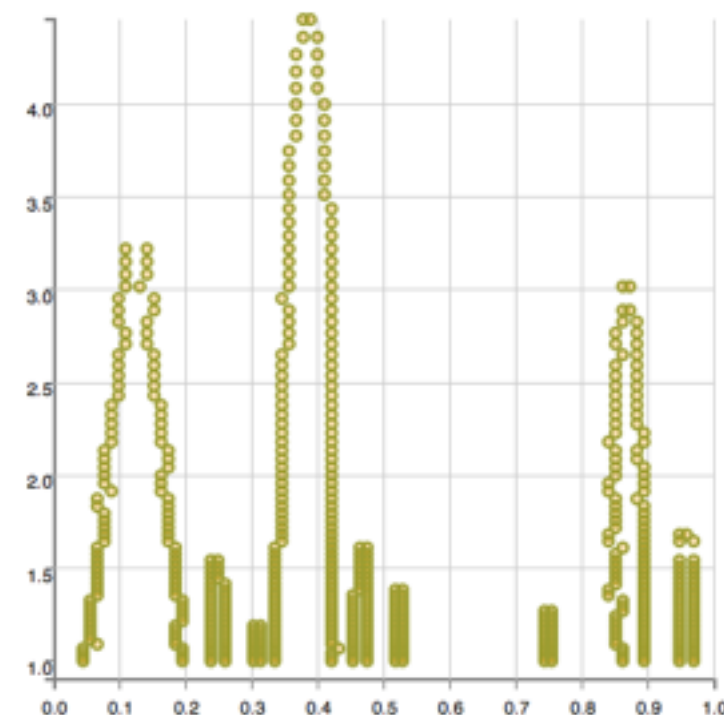
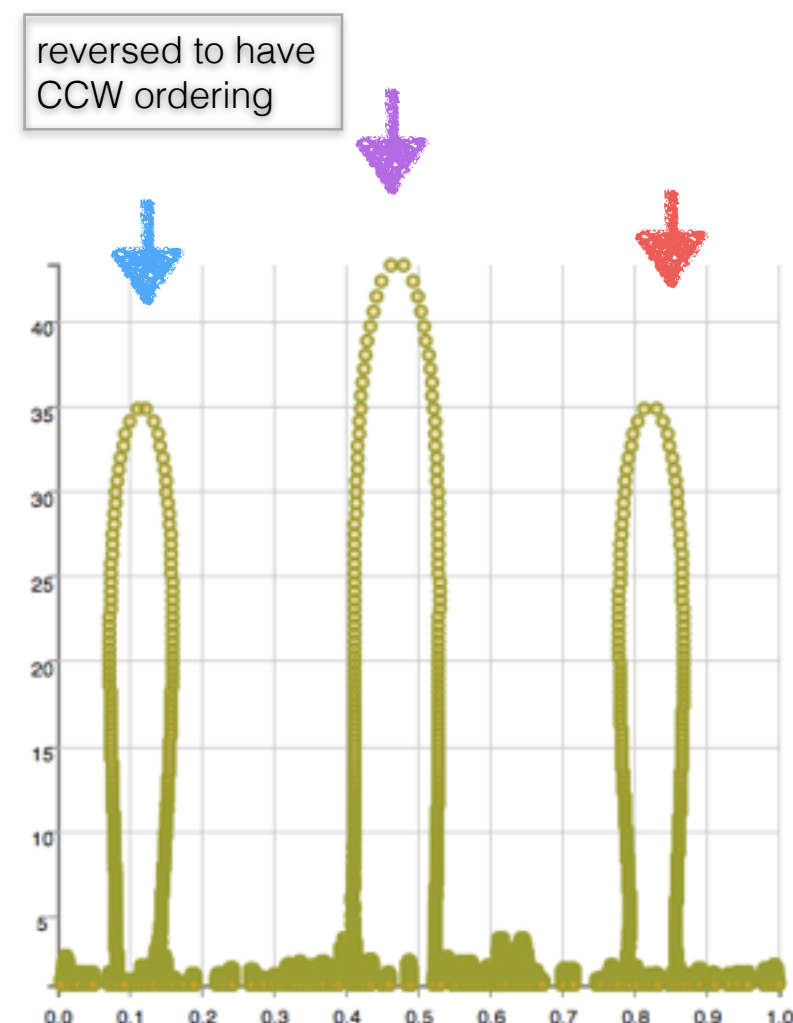
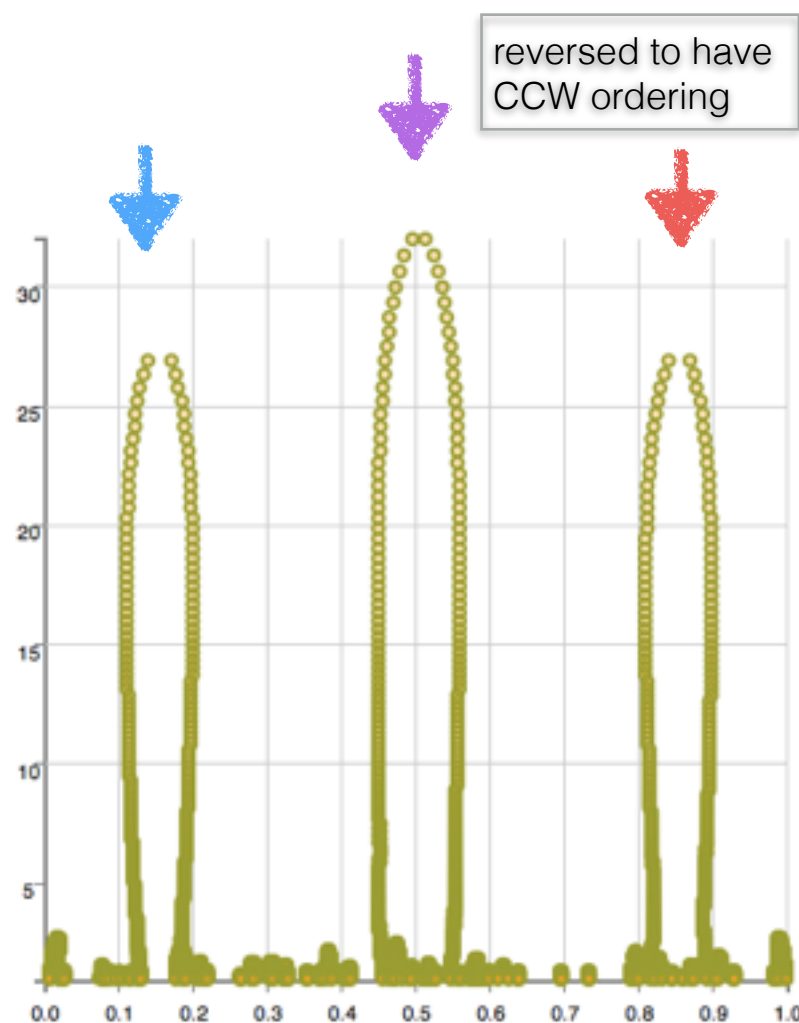
rotationInRadians=5.915757
rotationInDegrees=338.94791899582935
scale=1.3042566
translationX=111.0
translationY=20.0

coordinate transformation, after matching contours

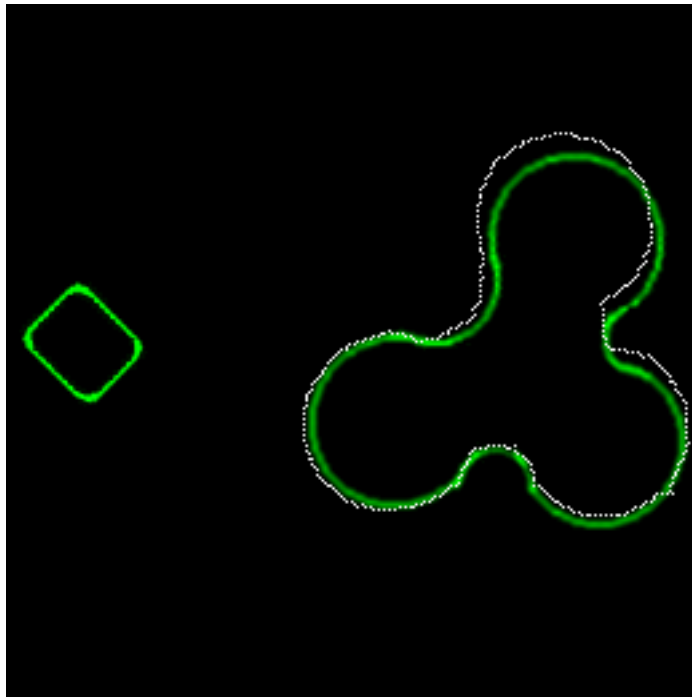


scale should be 1.3
rotation should be 360 - 45

Contour matcher solution scale=1.354256510734558
Contour matcher solution shift=-0.1425349861383438
CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72)
CONTOUR PEAK2: (43.336529, 0.530702) (172, 123) (180, 116)
CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99)
CONTOUR PEAK2: (34.896511, 0.179825) (188, 168) (180, 167)
CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54)
CONTOUR PEAK2: (34.896511, 0.884868) (224, 122) (224, 127)
offsetImgX1=10 offsetImgY1=10
offsetImgX2=3 offsetImgY2=52
rotationInRadians=5.5627766
rotationInDegrees=318.7236195803948
scale=1.3542565
translationX=119.984764
translationY=39.13688

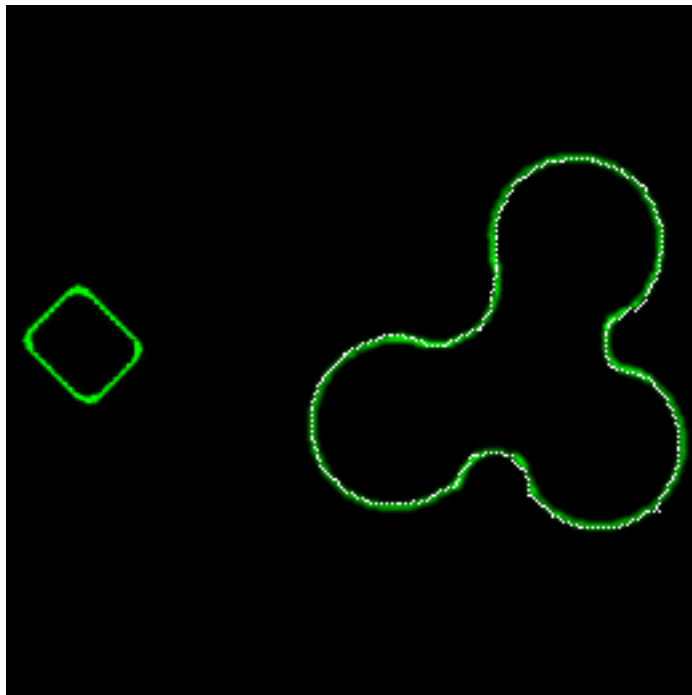


apply coordinate transformation



offsetImgX1=10 offsetImgY1=10
offsetImgX2=3 offsetImgY2=52
rotationInRadians=5.5627766
rotationInDegrees=318.7236195803948
scale=1.3542565
translationX=119.984764
translationY=39.13688

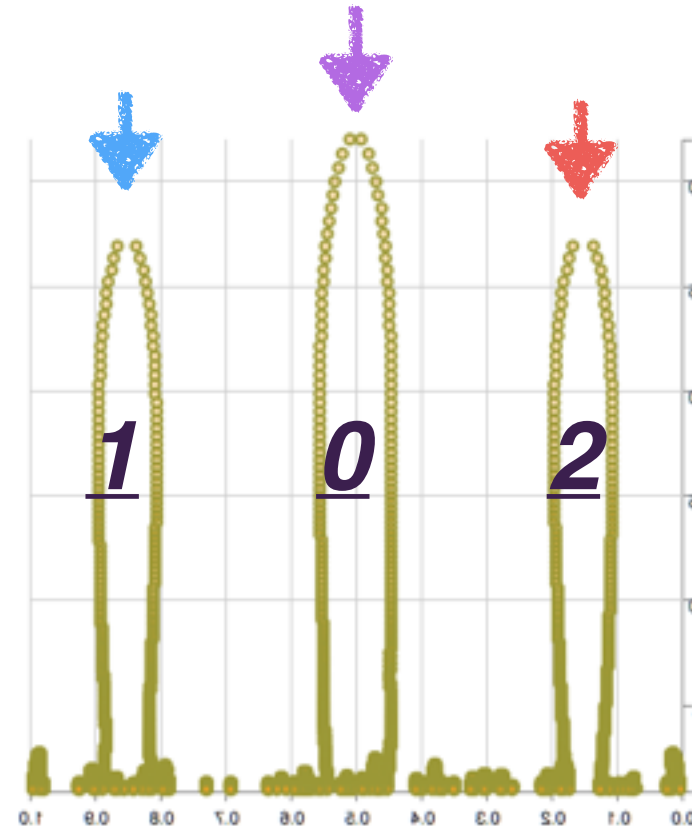
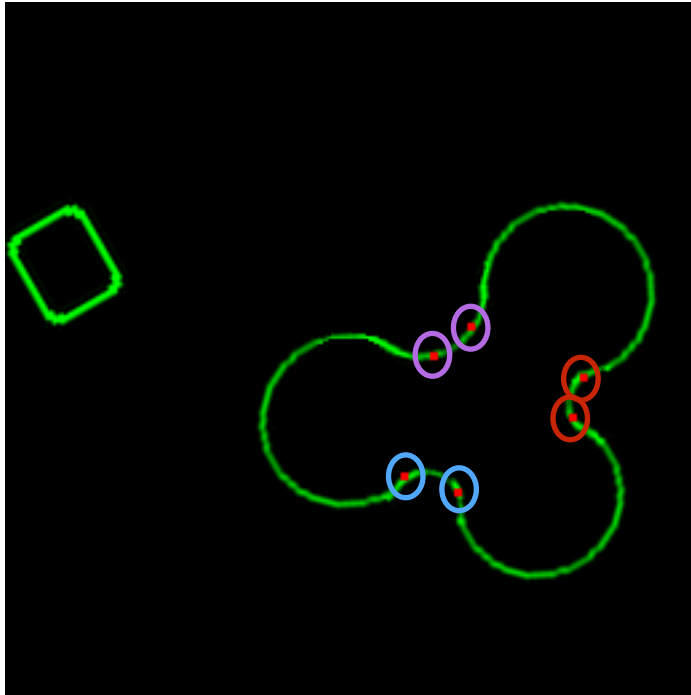
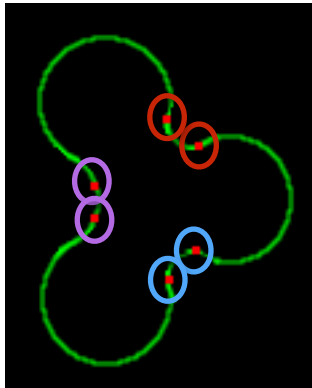
scale should be 1.3
rotation should be 360-45



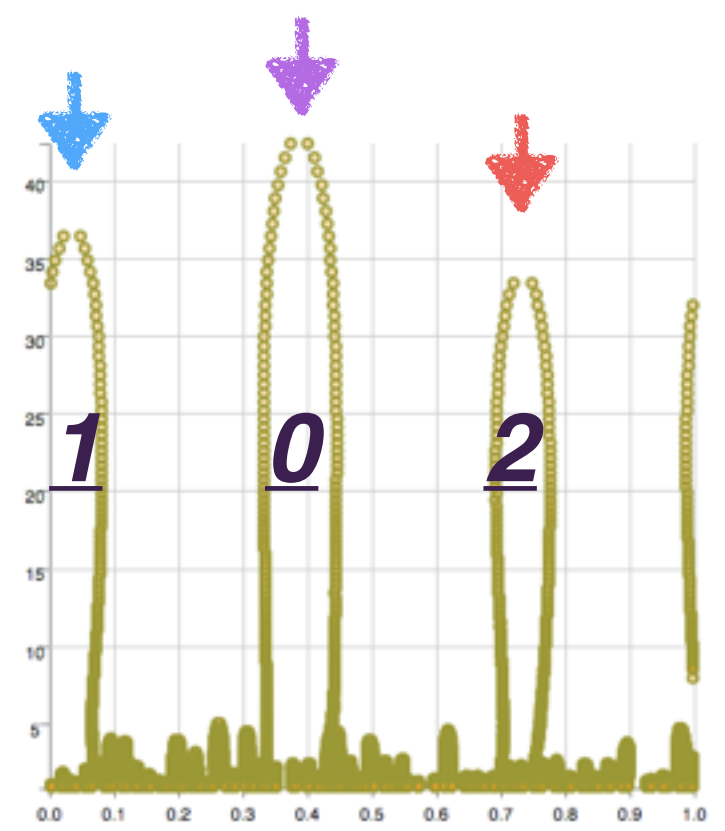
After Refinement

rotationInRadians=5.47551
rotationInDegrees=313.72362057962204
scale=1.3042566
translationX=124.0
translationY=47.0

coordinate transformation, after matching contours

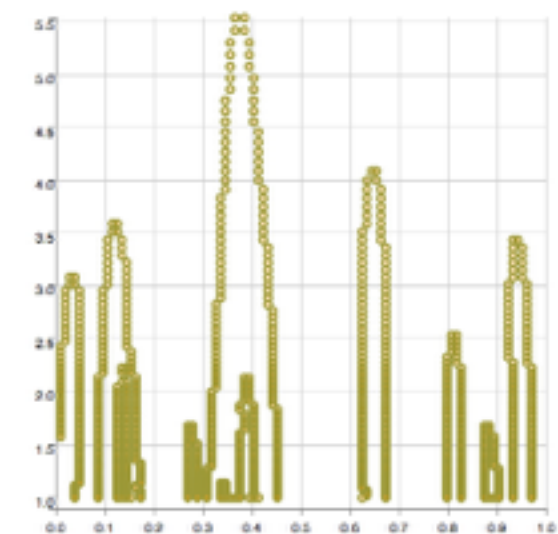


reversed to have
CCW ordering

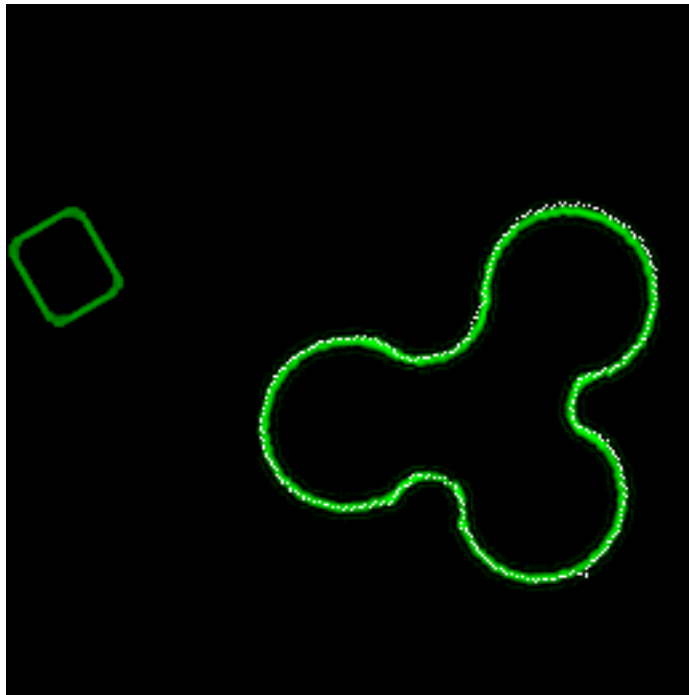


Contour matcher solution scale=1.325237512588501
 Contour matcher solution shift=-0.2715021073818207
 CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72)
 CONTOUR PEAK2: (42.407913, 0.387309) (161, 133) (172, 126)
 CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99)
 CONTOUR PEAK2: (36.441517, 0.035011) (168, 182) (157, 176)
 CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54)
 CONTOUR PEAK2: (33.417011, 0.734136) (215, 143) (213, 156)
 offsetImgX1=10 offsetImgY1=10
 offsetImgX2=0 offsetImgY2=71
 rotationInRadians=5.2398615
 rotationInDegrees=300.2219485151509
 scale=1.3252375
 translationX=107.96625
 translationY=59.87517

scale should be 1.3
 rotation should be 360 - 60

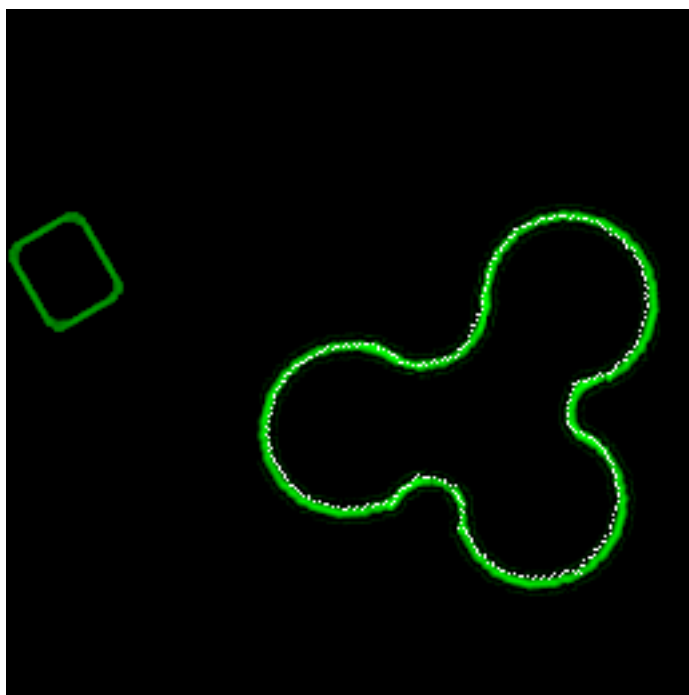


apply coordinate transformation



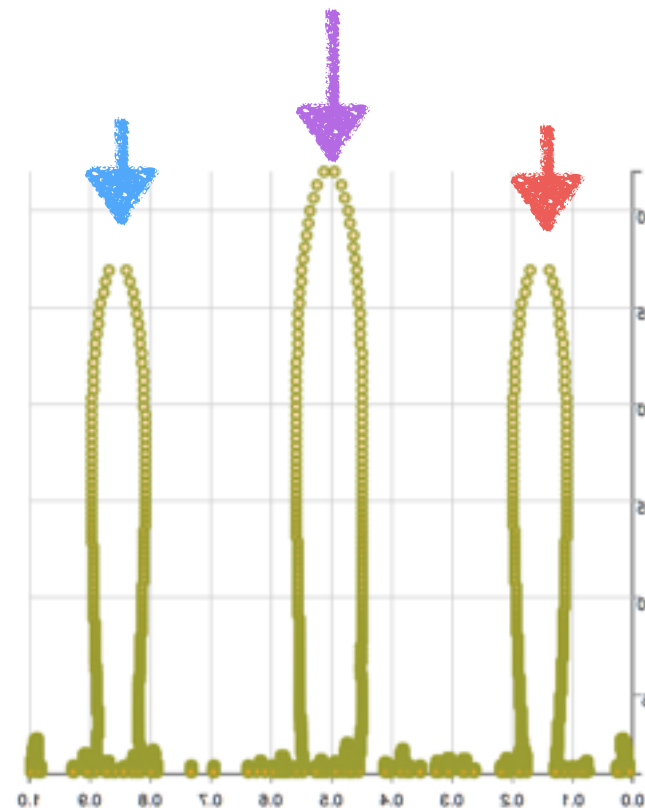
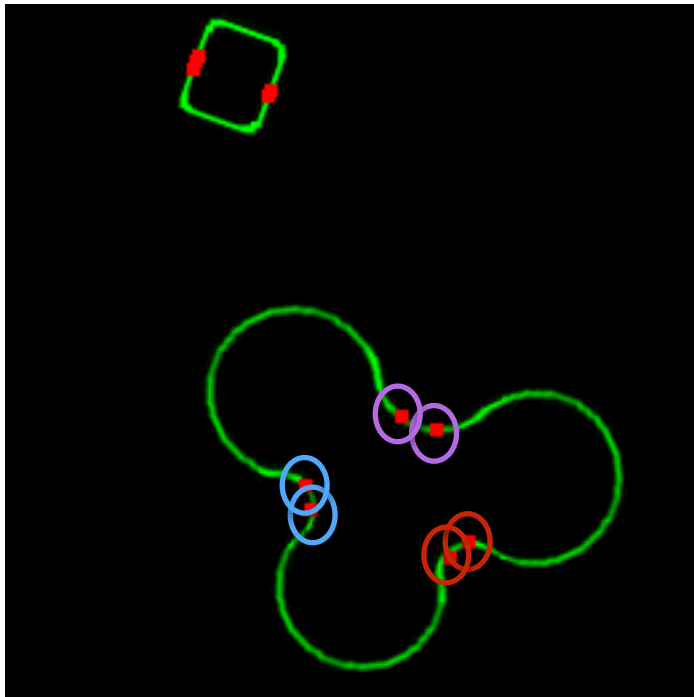
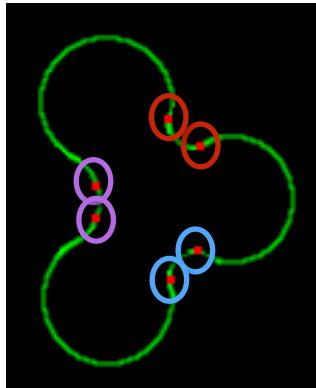
```
Contour matcher solution scale=1.325237512588501
Contour matcher solution shift=-0.2715021073818207
CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72)
  CONTOUR PEAK2: (42.407913, 0.387309) (161, 133) (172, 126)
CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99)
  CONTOUR PEAK2: (36.441517, 0.035011) (168, 182) (157, 176)
CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54)
  CONTOUR PEAK2: (33.417011, 0.734136) (215, 143) (213, 156)
offsetImgX1=10 offsetImgY1=10
offsetImgX2=0 offsetImgY2=71
rotationInRadians=5.2398615
rotationInDegrees=300.2219485151509
scale=1.3252375
translationX=107.96625
translationY=59.87517
```

scale should be 1.3
rotation should be 360 - 60

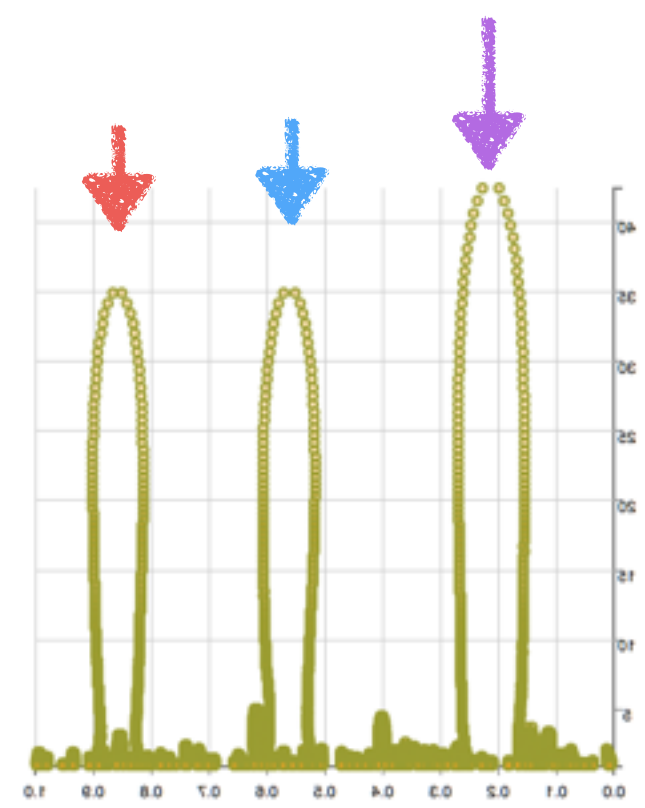


After Refinement

```
rotationInRadians=5.2398615
rotationInDegrees=300.2219485151509
scale=1.2752376
translationX=110.0
translationY=63.0
```



reversed to have
CCW ordering

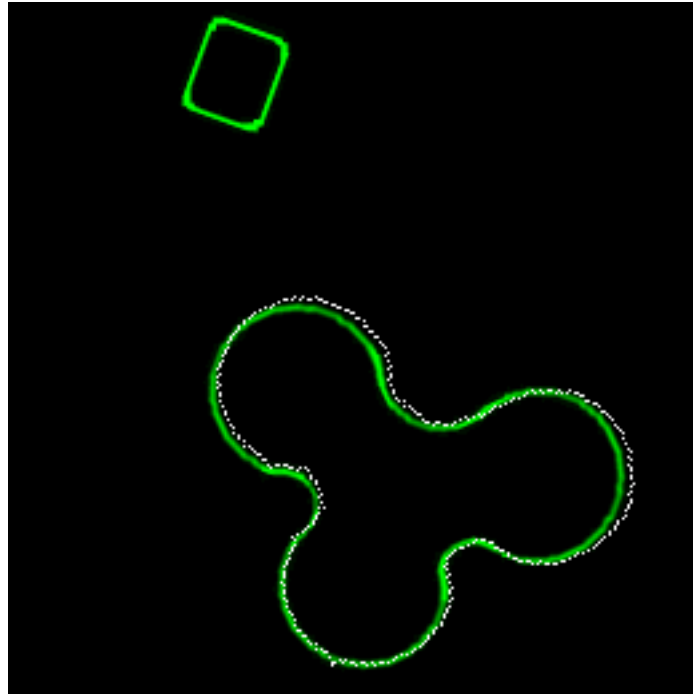


reversed to have
CCW ordering

CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72)
 CONTOUR PEAK2: (42.407913, 0.787445) (148, 154) (161, 159)
 CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99)
 CONTOUR PEAK2: (34.896511, 0.439427) (114, 189) (112, 180)
 CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54)
 CONTOUR PEAK2: (34.896511, 0.142070) (173, 201) (166, 207)
 offsetImgX1=10 offsetImgY1=10
 offsetImgX2=62 offsetImgY2=1
 rotationInRadians=4.336784
 rotationInDegrees=248.47941332561248
 scale=1.3252375
 translationX=70.99721
 translationY=91.054344

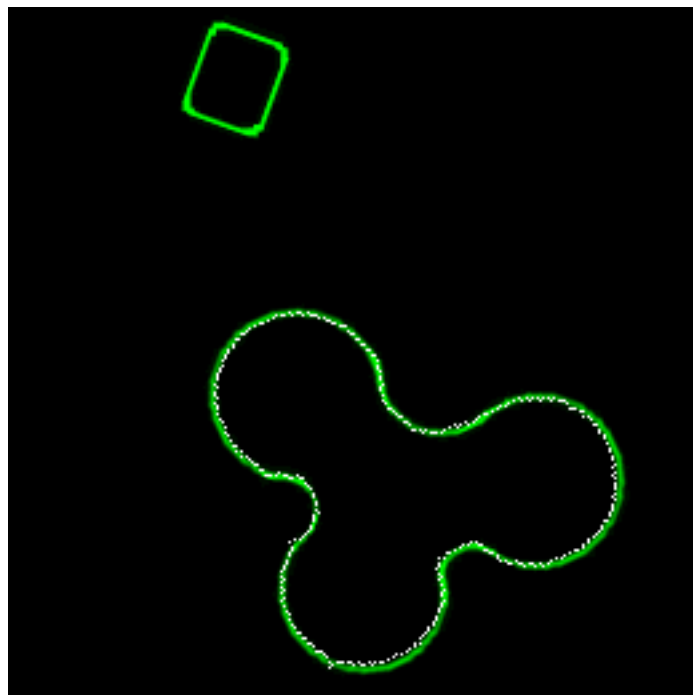
scale should be 1
 rotation should be 360 - 110 (250)

apply coordinate transformation



```
CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72)
CONTOUR PEAK2: (42.407913, 0.787445) (148, 154) (161, 159)
CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99)
CONTOUR PEAK2: (34.896511, 0.439427) (114, 189) (112, 180)
CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54)
CONTOUR PEAK2: (34.896511, 0.142070) (173, 201) (166, 207)
offsetImgX1=10 offsetImgY1=10
offsetImgX2=62 offsetImgY2=1
rotationInRadians=4.336784
rotationInDegrees=248.47941332561248
scale=1.3252375
translationX=70.99721
translationY=91.054344
```

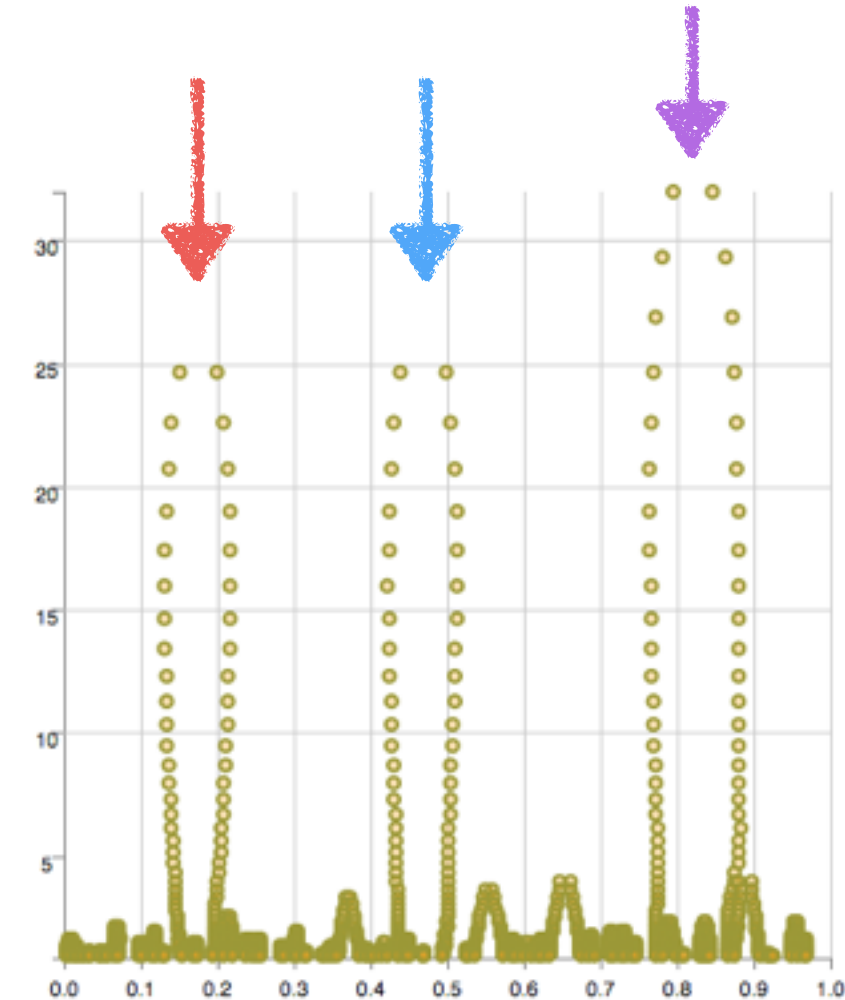
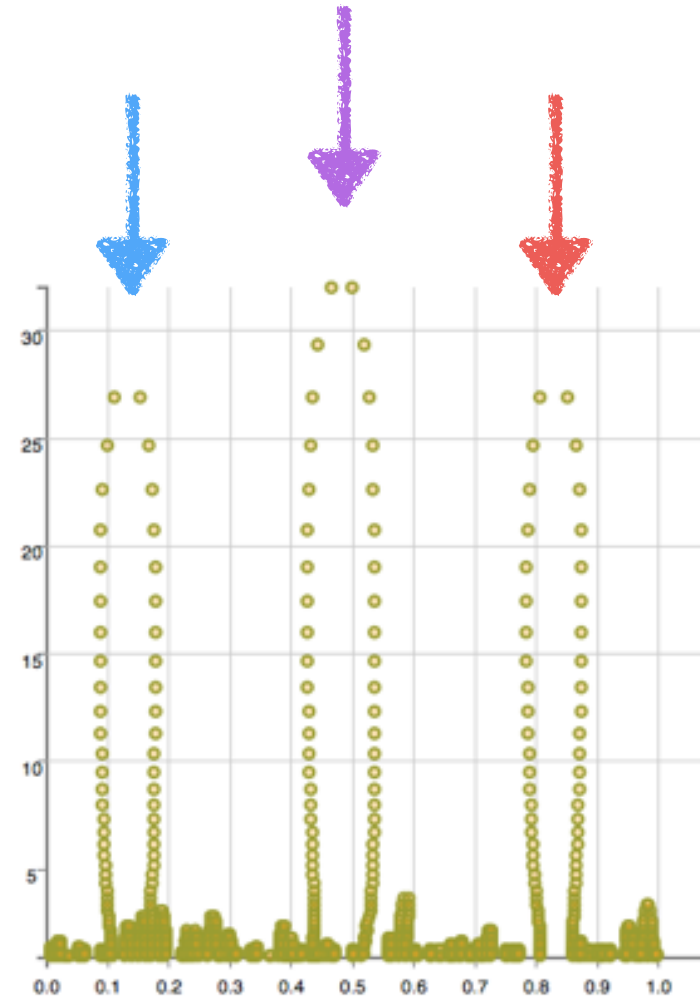
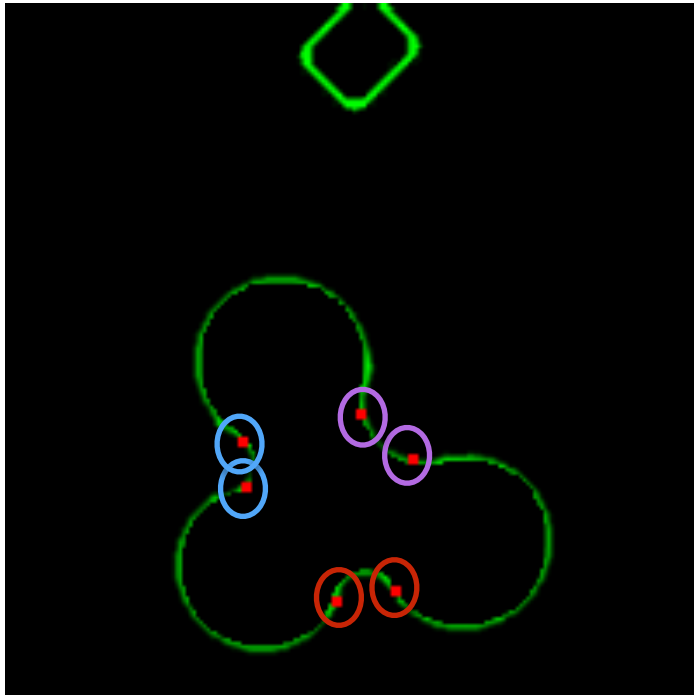
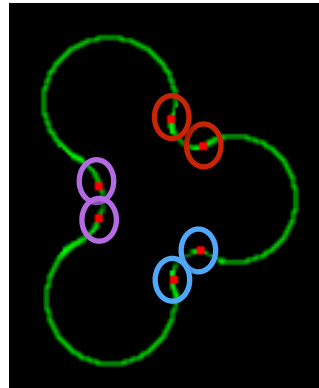
scale should be 1
rotation should be 360 - 110 (250)



After Refinement

```
rotationInRadians=4.354237
rotationInDegrees=249.4794076616157
scale=1.2752376
translationX=71.0
translationY=95.0
```

coordinate transformation, after matching contours



Contour matcher solution scale=1.0218971967697144

Contour matcher solution shift=0.3104316294193268

CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72) CONTOUR PEAK2: (32.700951, 0.818444) (103, 120) (115, 132)

CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99) CONTOUR PEAK2: (25.768024, 0.468300) (69, 136) (69, 127)

CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54) CONTOUR PEAK2: (25.768024, 0.175793) (105, 164) (97, 166)

offsetImgX1=10 offsetImgY1=10

offsetImgX2=46 offsetImgY2=0

rotationInRadians=3.9818497

rotationInDegrees=228.14318077005984

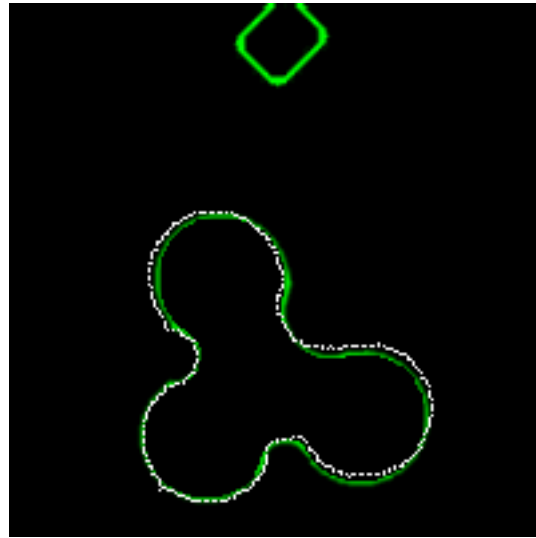
scale=1.0218972

translationX=32.712353

translationY=70.68979

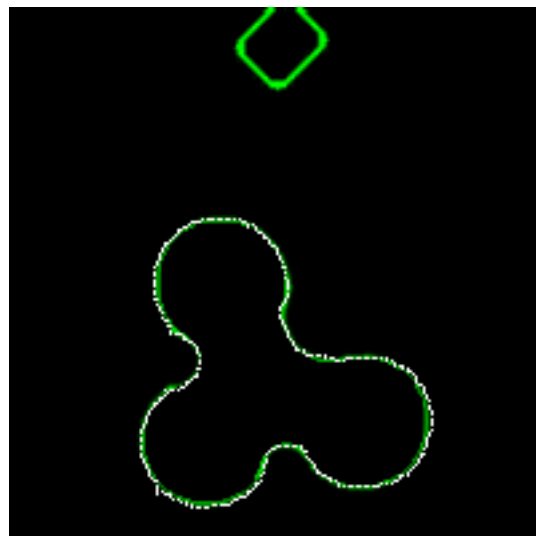
scale should be 1
rotation should be 360 - 135

apply coordinate transformation



```
offsetImgX1=10 offsetImgY1=10  
offsetImgX2=46 offsetImgY2=0  
rotationInRadians=3.9818497  
rotationInDegrees=228.14318077005984  
scale=1.0218972  
translationX=32.712353  
translationY=70.68979
```

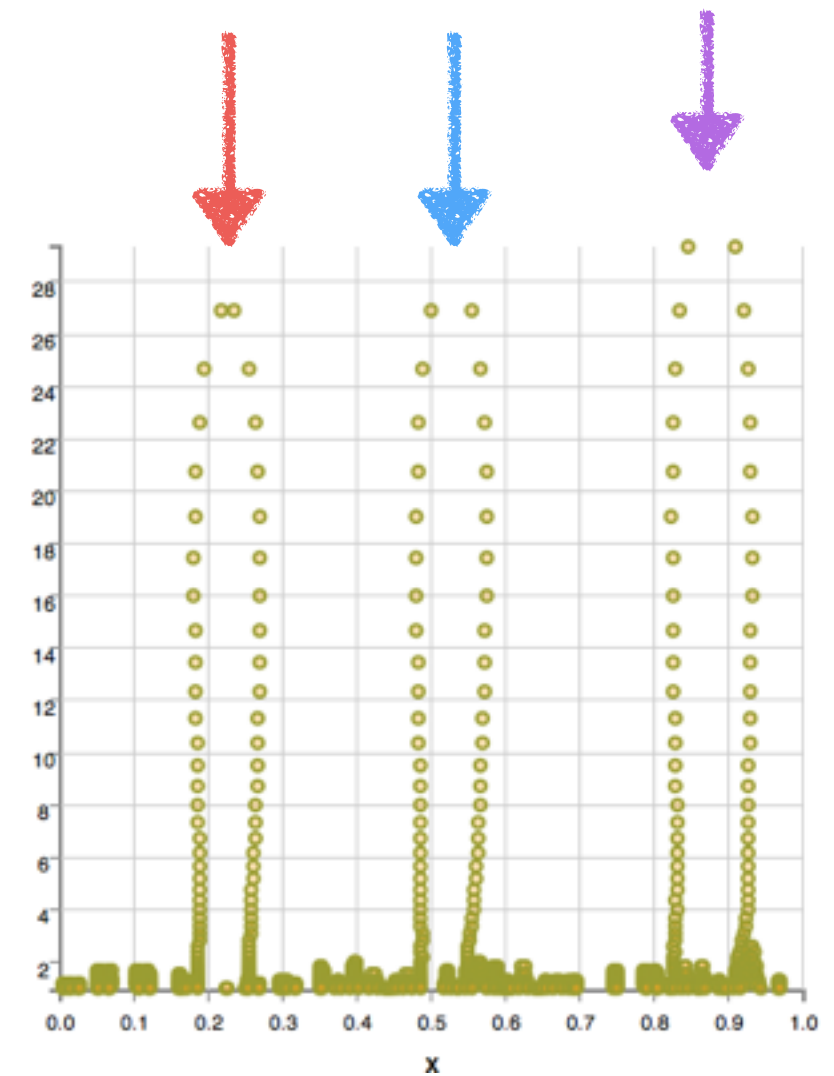
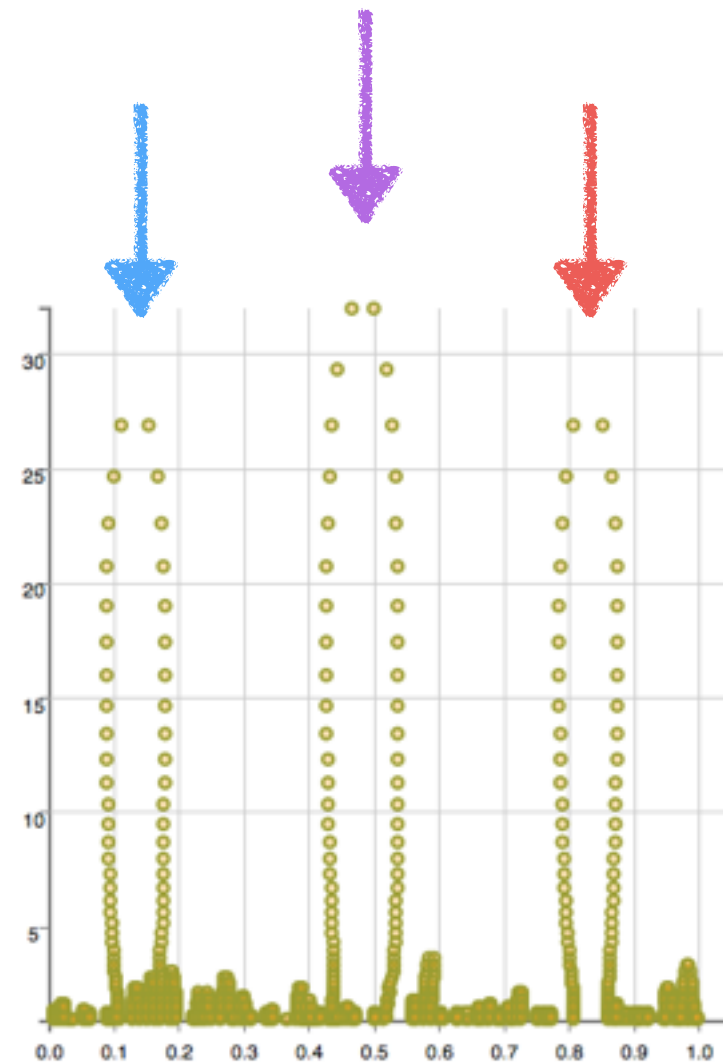
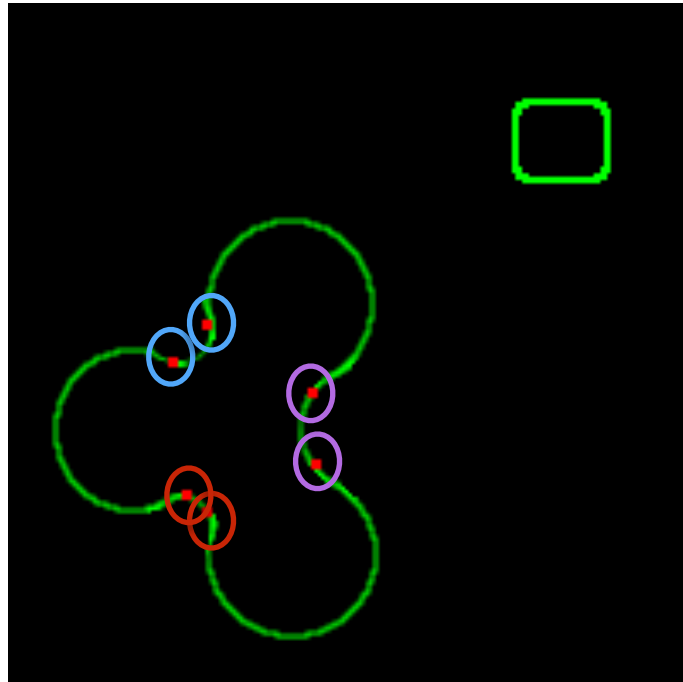
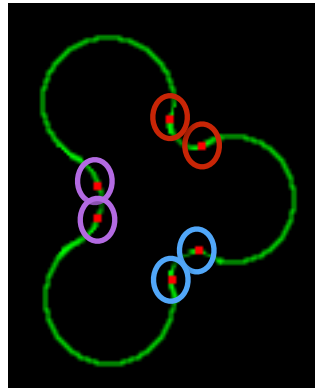
scale should be 1
rotation should be 360 - 135



After Refinement

```
rotationInRadians=3.9406004  
rotationInDegrees=225.77977139269535  
scale=1.0218972  
translationX=33.0  
translationY=72.0
```

coordinate transformation, after matching contours



Contour matcher solution scale=1.2968404293060303
Contour matcher solution shift=0.22837476432323456

CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72) CONTOUR PEAK2: (41.499199, 0.873068) (111, 158) (112, 167)

CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99) CONTOUR PEAK2: (35.660648, 0.522075) (67, 137) (77, 127)

CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54) CONTOUR PEAK2: (34.896511, 0.222958) (75, 194) (69, 188)

offsetImgX1=10 offsetImgY1=10

offsetImgX2=14 offsetImgY2=33

rotationInRadians=3.1657186

rotationInDegrees=181.38231235356184

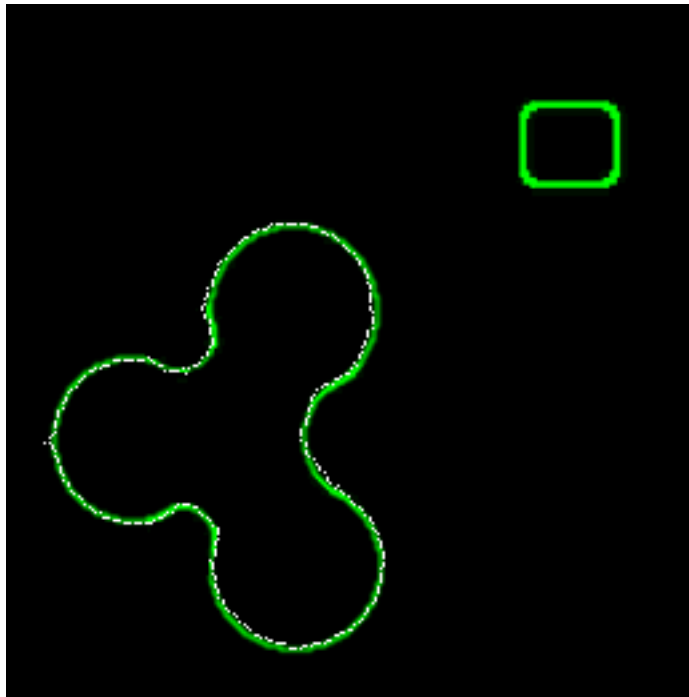
scale=1.2968404

translationX=5.891382

translationY=70.504585

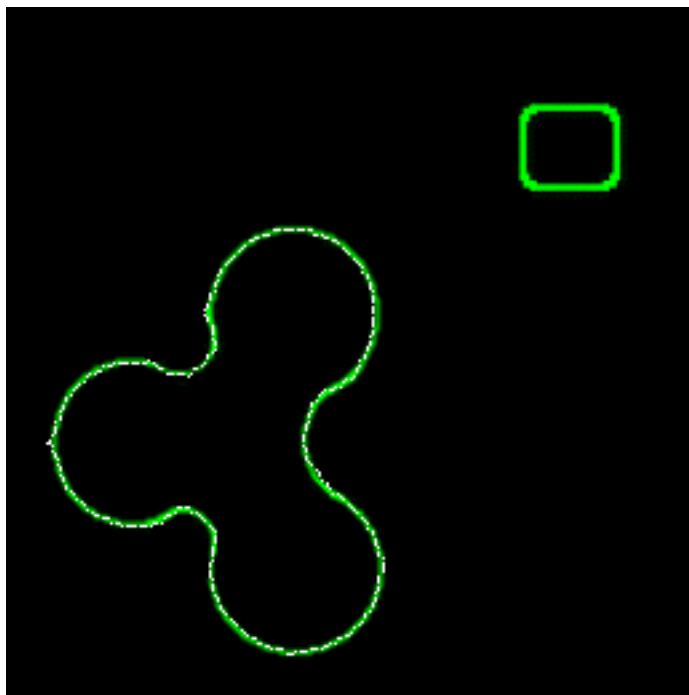
scale should be 1.3
rotation should be 180

apply coordinate transformation



offsetImgX1=10 offsetImgY1=10
offsetImgX2=14 offsetImgY2=33
rotationInRadians=3.1657186
rotationInDegrees=181.38231235356184
scale=1.2968404
translationX=5.891382
translationY=70.504585

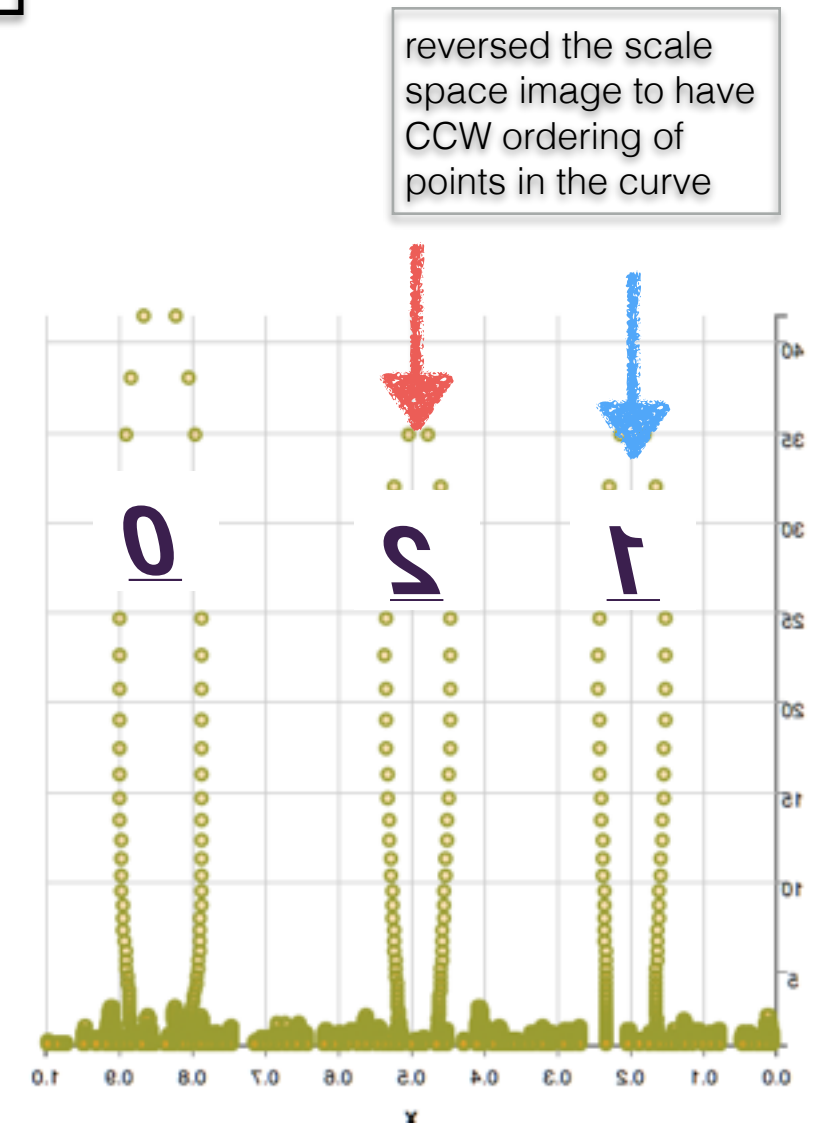
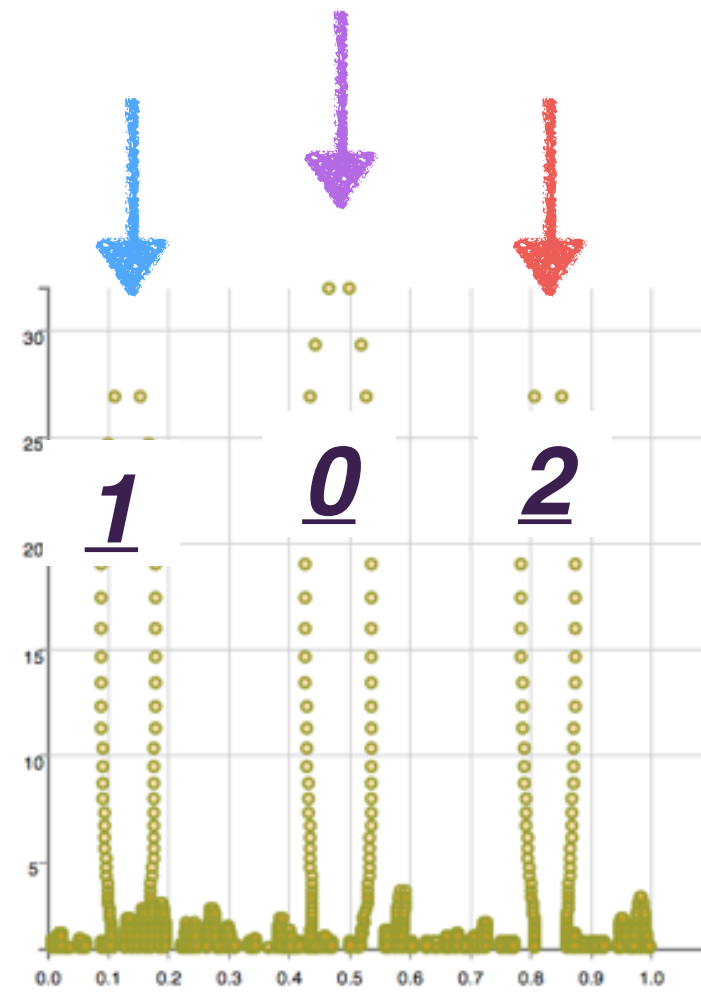
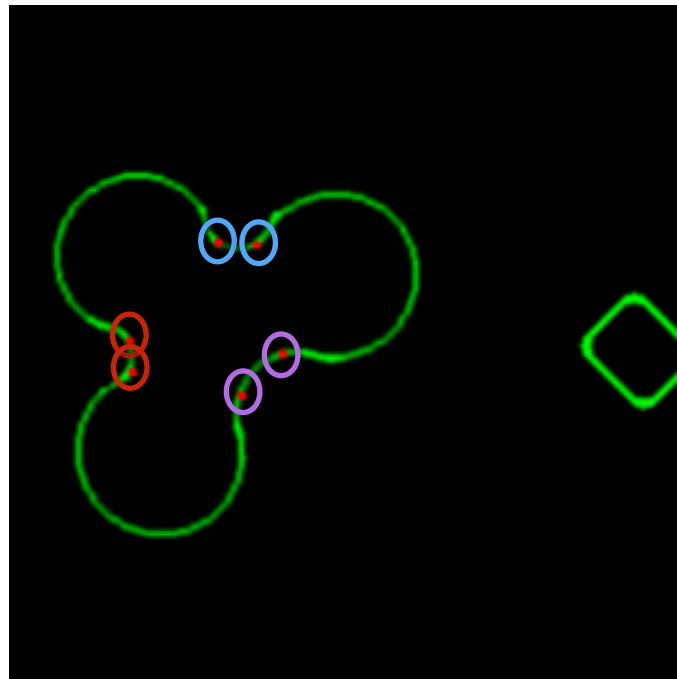
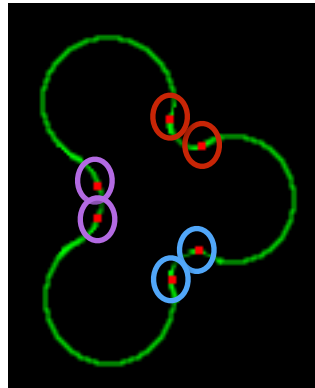
scale should be 1.3
rotation should be 180



After Refinement

rotationInRadians=3.1482654
rotationInDegrees=180.38231801755862
scale=1.2968404
translationX=6.0
translationY=71.0

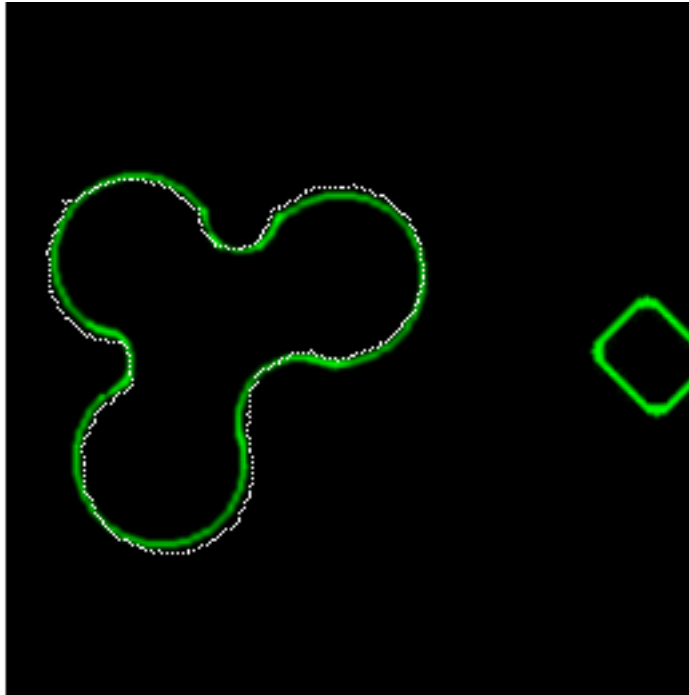
coordinate transformation, after matching contours



Contour matcher solution scale=1.325237512588501
 Contour matcher solution shift=-0.5053889751434326
 CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72) CONTOUR PEAK2: (42.407913, 0.153422) (98, 136) (91, 143)
 CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99) CONTOUR PEAK2: (34.896511, 0.802428) (81, 91) (92, 92)
 CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54) CONTOUR PEAK2: (34.896511, 0.508830) (46, 140) (45, 129)
 offsetImgX1=10 offsetImgY1=10
 offsetImgX2=14 offsetImgY2=61
 rotationInRadians=2.4194849
 rotationInDegrees=138.6262707153875
 scale=1.3252375
 translationX=-5.8268623
 translationY=25.13414

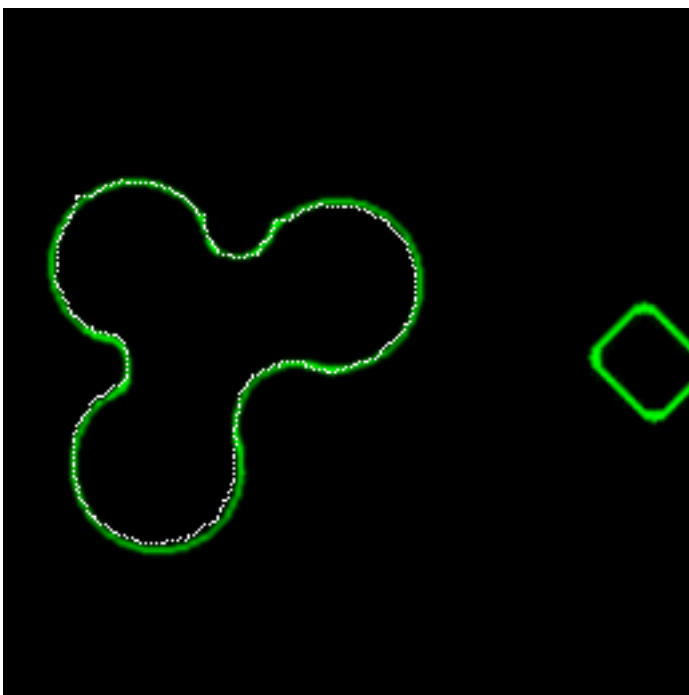
scale should be 1.3
 rotation should be 360 - 225

apply coordinate transformation



offsetImgX1=10 offsetImgY1=10
offsetImgX2=14 offsetImgY2=61
rotationInRadians=2.4194849
rotationInDegrees=138.6262707153875
scale=1.3252375
translationX=-5.8268623
translationY=25.13414

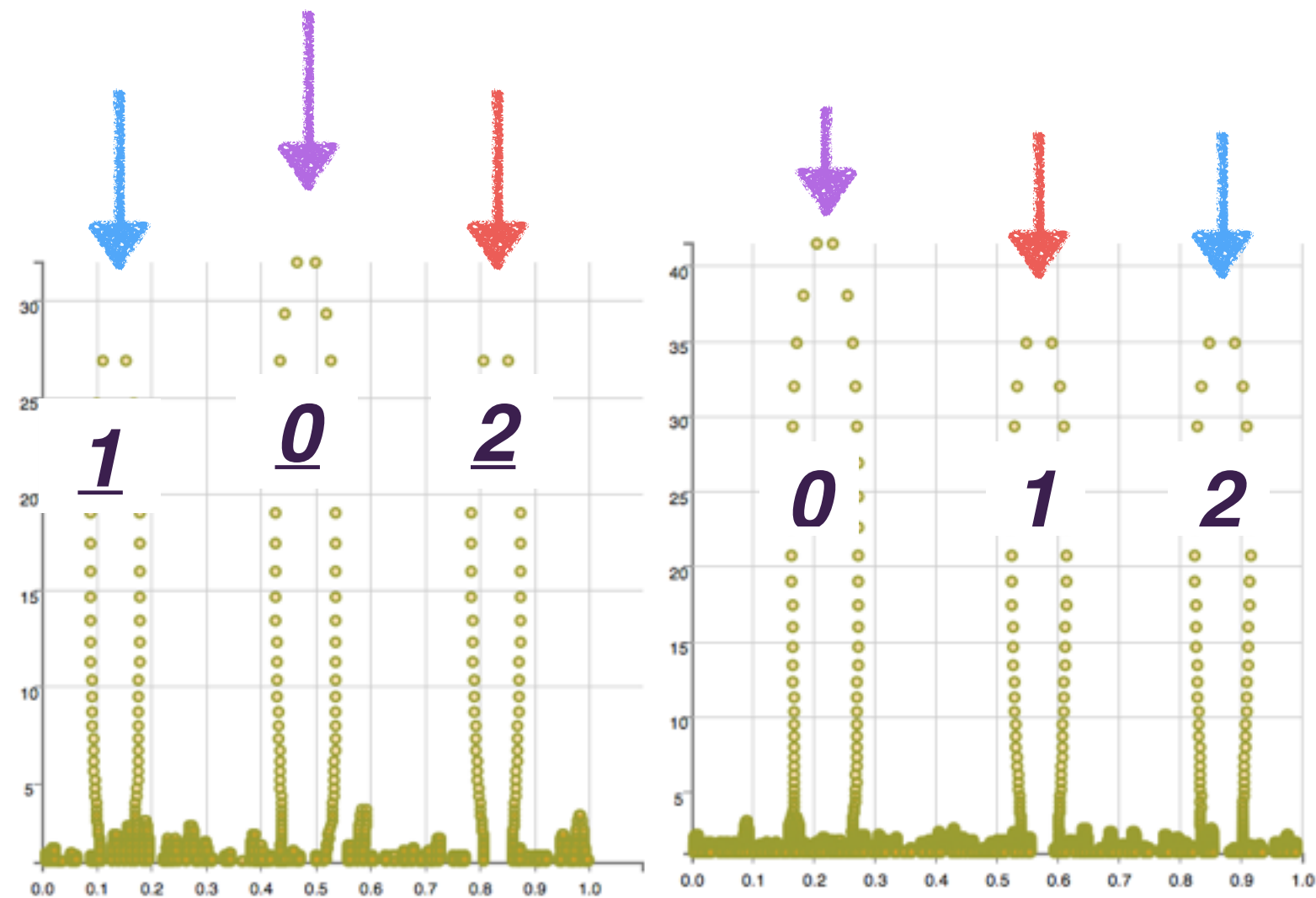
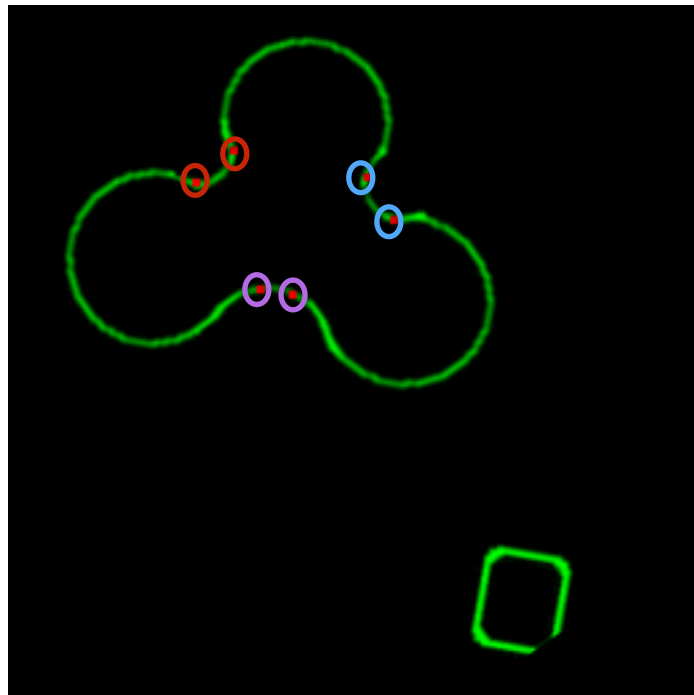
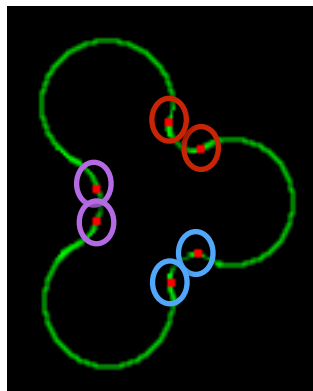
scale should be 1.3
rotation should be 360 - 225



After Refinement

rotationInRadians=2.3322184
rotationInDegrees=133.6262717146147
scale=1.2752376
translationX=-3.0
translationY=27.0

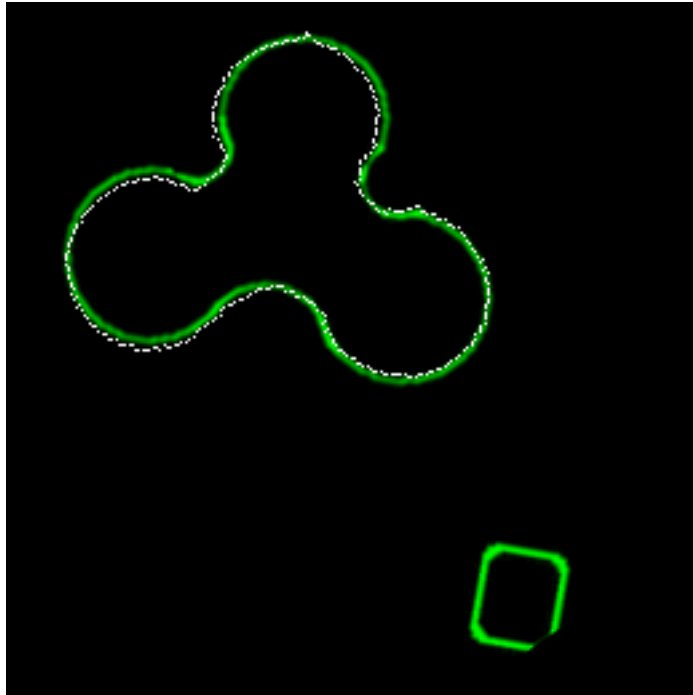
coordinate transformation, after matching contours



Contour matcher solution scale=1.2968404293060303
 Contour matcher solution shift=-0.4310373365879059
 CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72) CONTOUR PEAK2: (41.499199, 0.213656) (106, 108) (96, 106)
 CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99) CONTOUR PEAK2: (35.660648, 0.865639) (134, 70) (137, 76)
 CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54) CONTOUR PEAK2: (35.660648, 0.566079) (74, 67) (82, 60)
 offsetImgX1=10 offsetImgY1=10
 offsetImgX2=19 offsetImgY2=9
 rotationInRadians=1.4486057
 rotationInDegrees=82.9989903033234
 scale=1.2968404
 translationX=28.18638
 translationY=-16.518988

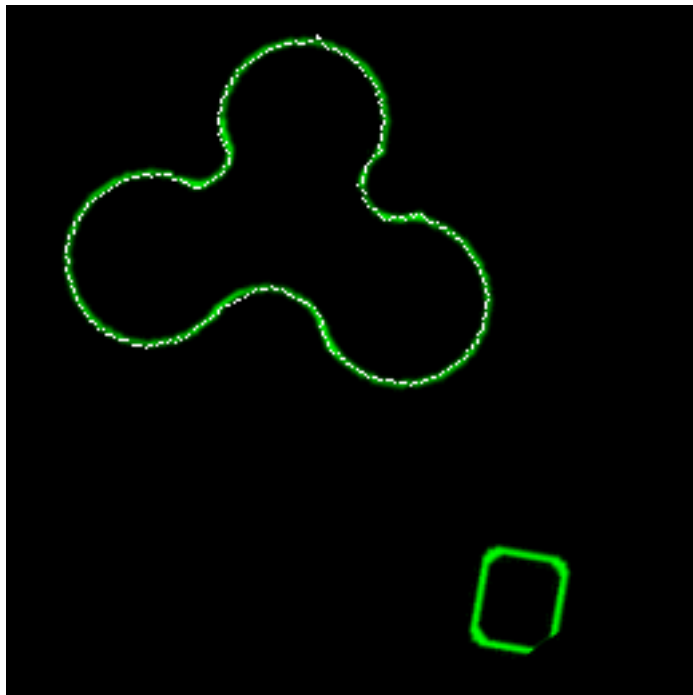
scale should be 1.3
 rotation should be 360 - 280

apply coordinate transformation



offsetImgX1=10 offsetImgY1=10
offsetImgX2=19 offsetImgY2=9
rotationInRadians=1.4486057
rotationInDegrees=82.9989903033234
scale=1.2968404
translationX=28.18638
translationY=-16.518988

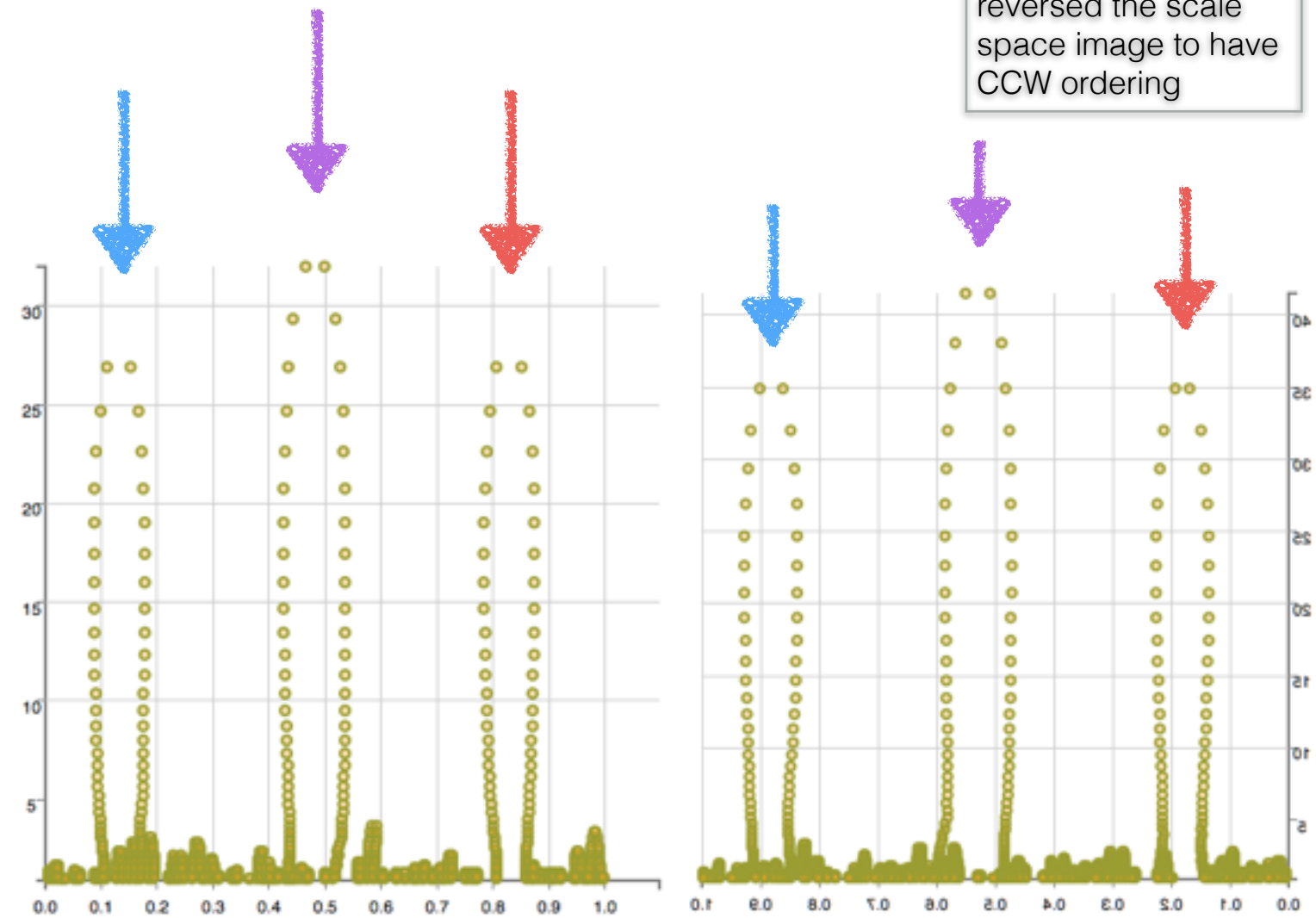
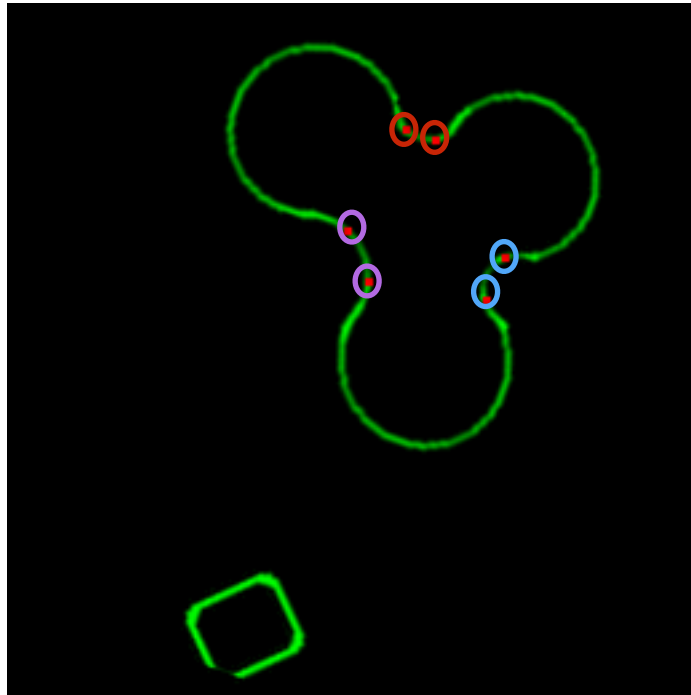
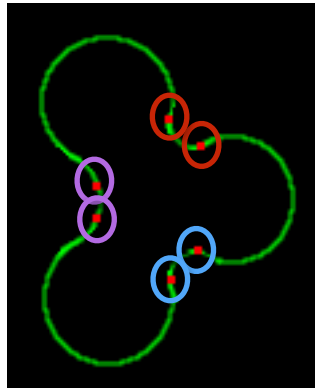
scale should be 1.3
rotation should be 360 - 280



After Refinement

rotationInRadians=1.4049724
rotationInDegrees=80.49899080293699
scale=1.2968404
translationX=29.0
translationY=-17.0

coordinate transformation, after matching contours



Contour matcher solution scale=1.325237512588501

Contour matcher solution shift=-0.19089026749134064

CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72) CONTOUR PEAK2: (42.407913, 0.467920) (134, 99) (131, 90)

CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99) CONTOUR PEAK2: (34.896511, 0.115044) (182, 98) (178, 106)

CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54) CONTOUR PEAK2: (34.896511, 0.818584) (150, 48) (158, 51)

offsetImgX1=10 offsetImgY1=10

offsetImgX2=63 offsetImgY2=12

rotationInRadians=0.43239865

rotationInDegrees=24.77461754427387

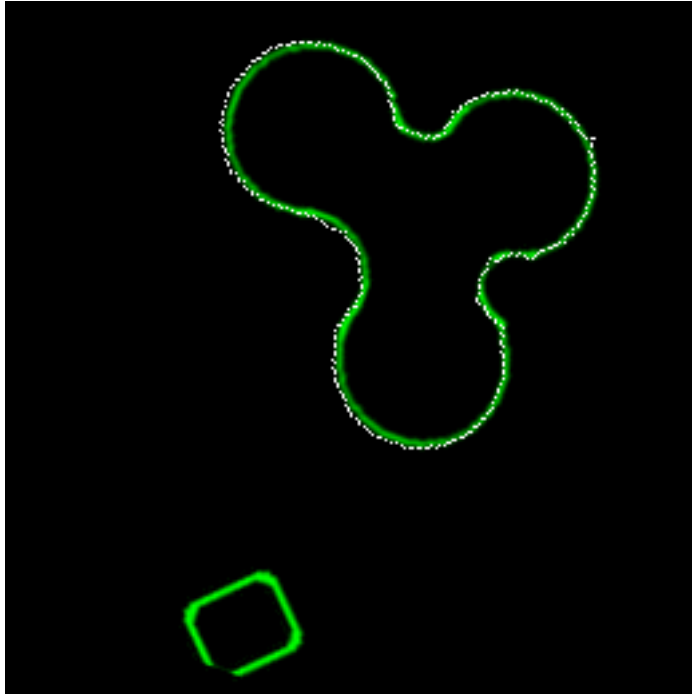
scale=1.3252375

translationX=81.613556

translationY=-16.98058

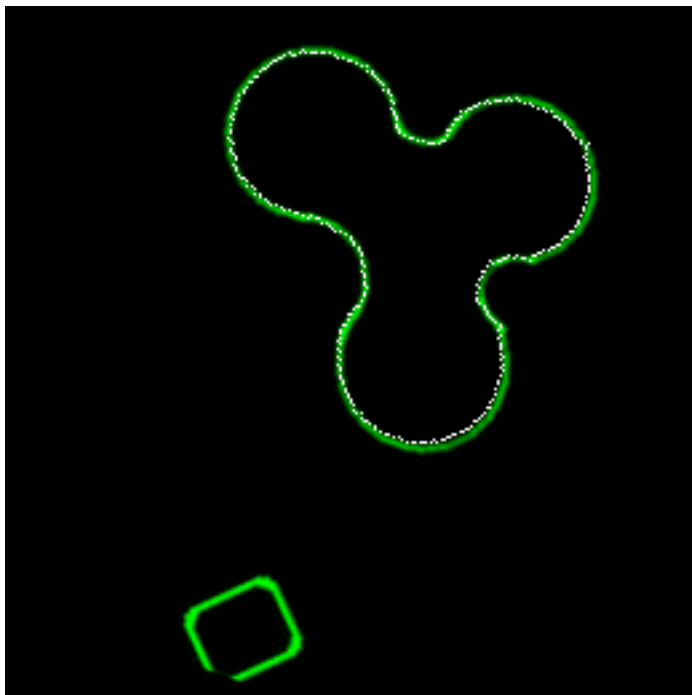
scale should be 1.3
rotation should be 360 - 335

apply coordinate transformation



```
offsetImgX1=10 offsetImgY1=10  
offsetImgX2=63 offsetImgY2=12  
rotationInRadians=0.43239865  
rotationInDegrees=24.77461754427387  
scale=1.3252375  
translationX=81.613556  
translationY=-16.98058
```

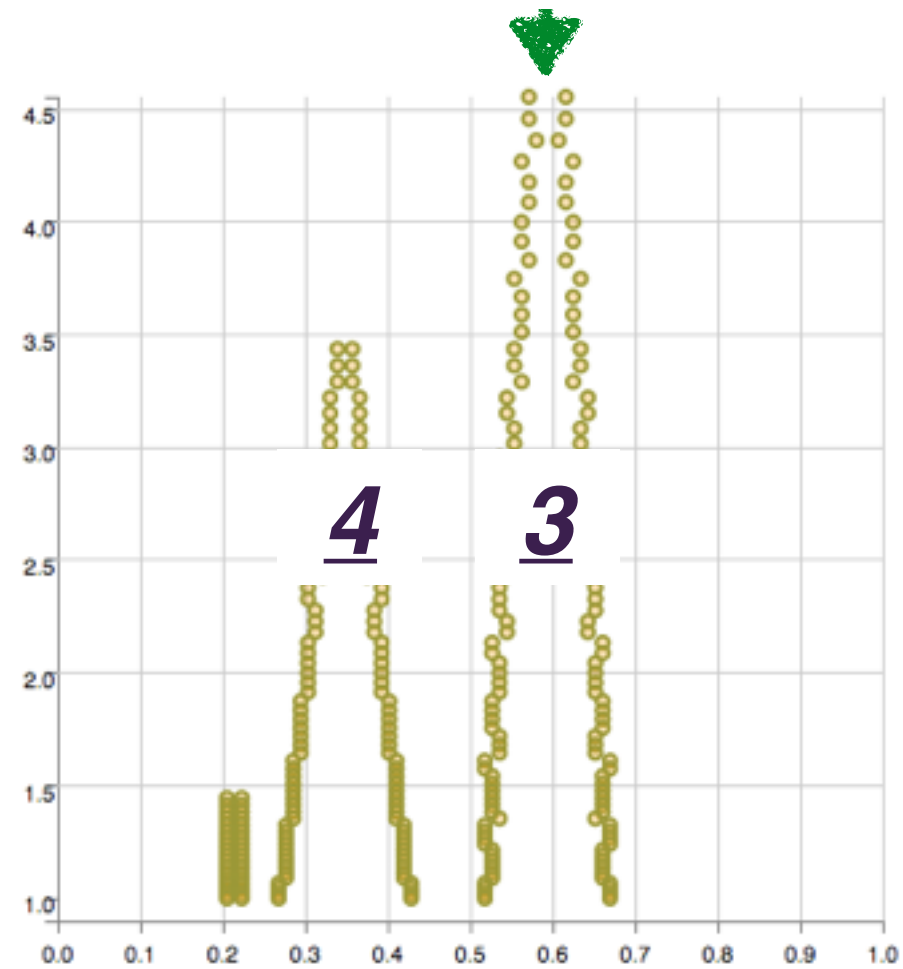
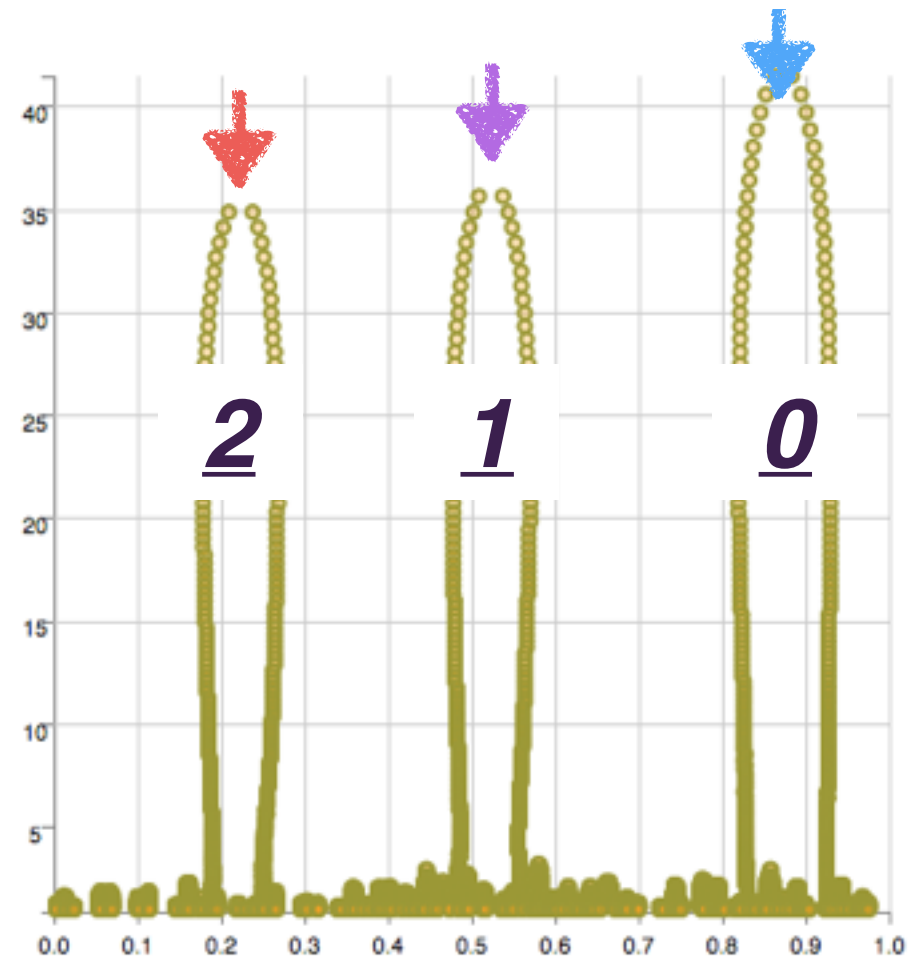
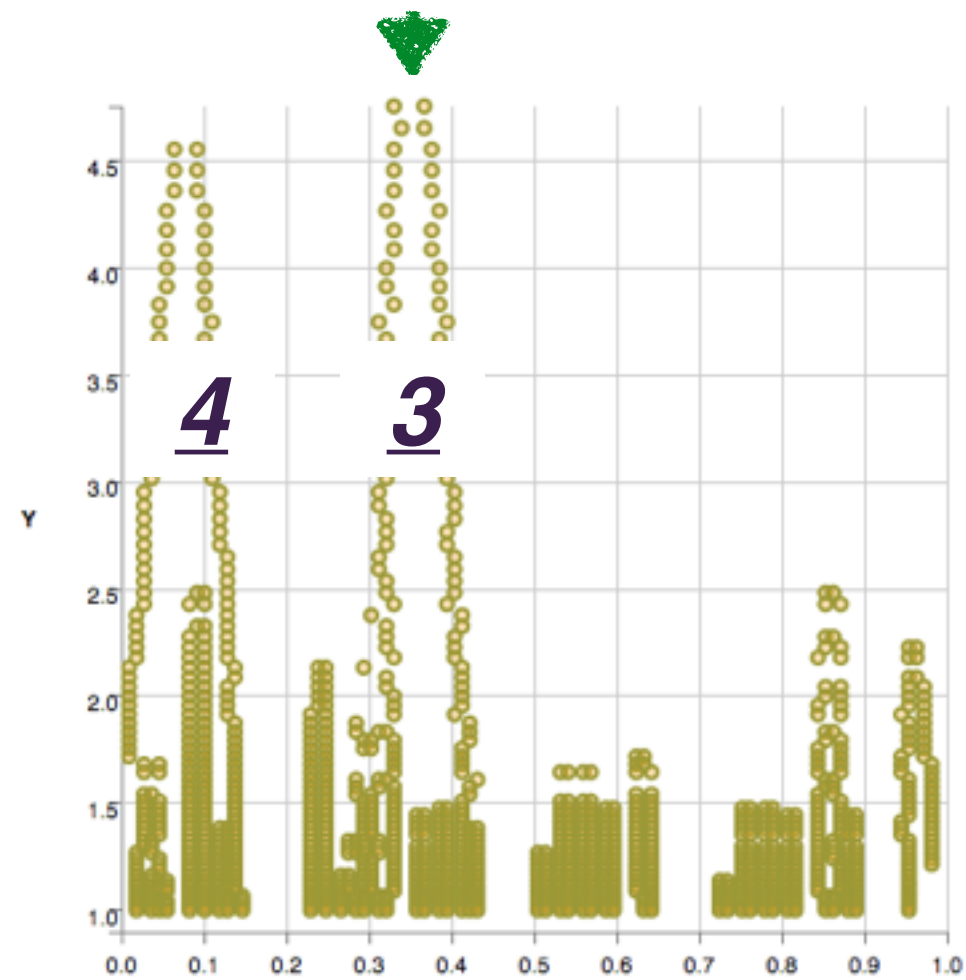
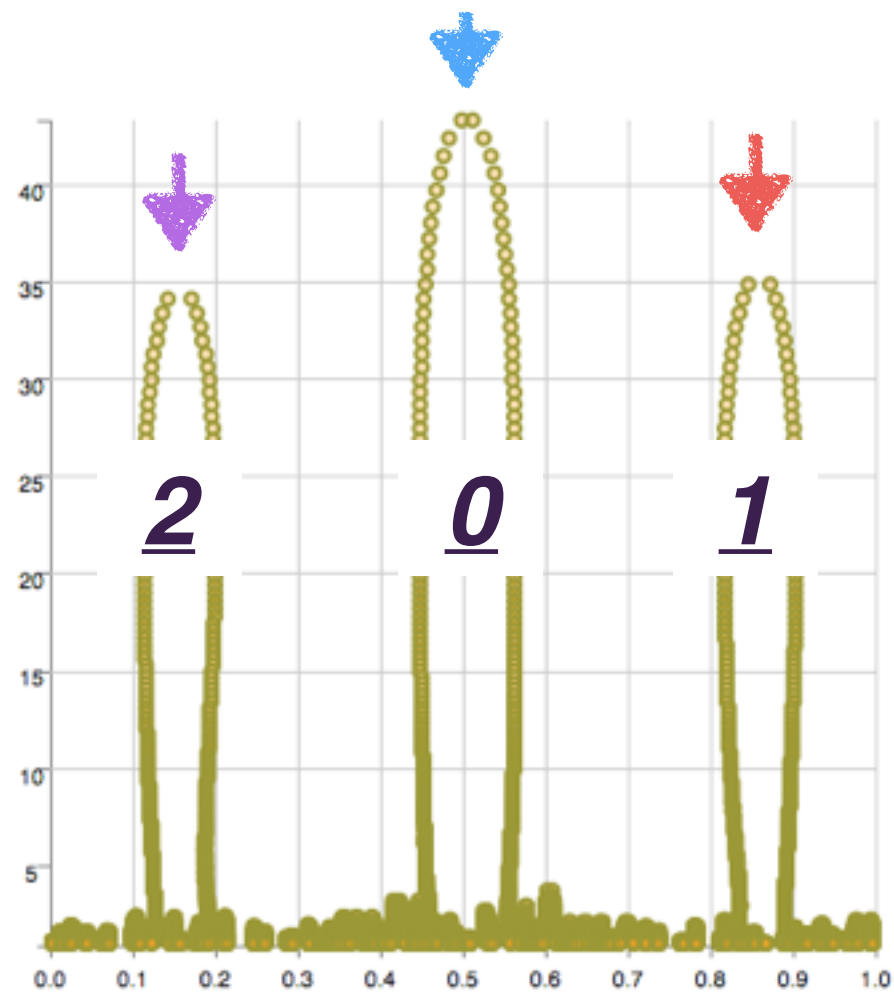
scale should be 1.3
rotation should be 360 - 335



After Refinement

```
rotationInRadians=0.43239865  
rotationInDegrees=24.77461754427387  
scale=1.2752376  
translationX=85.0  
translationY=-14.0
```

coordinate transformation, after matching contours



scale should be 1.0
rotation should be 20 - 180

apply coordinate transformation

scale should be 1.0
rotation should be 20-20

This shows that it's difficult to estimate scale unless some of the inflection points are further from the center of the shape

After Refinement