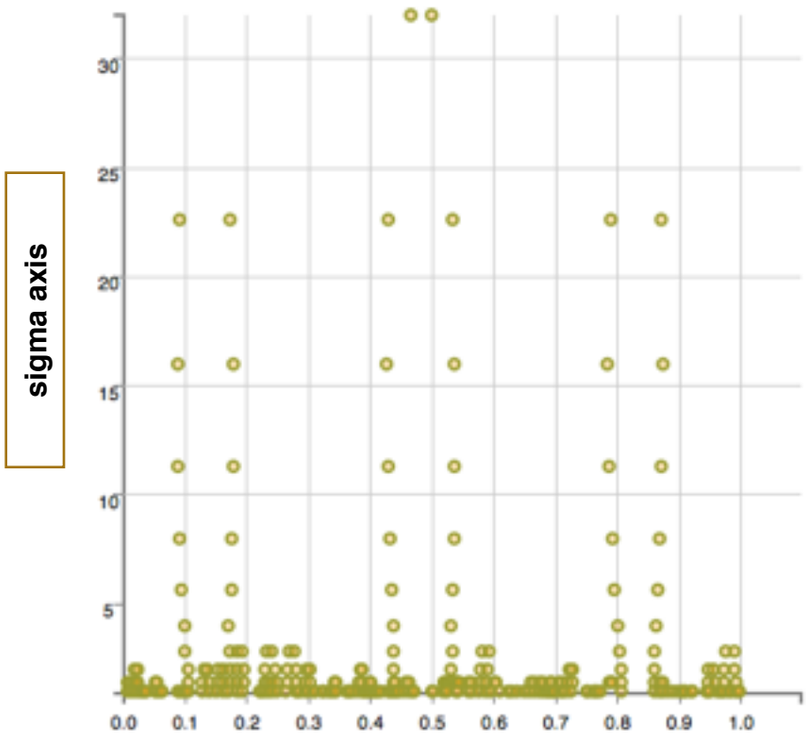
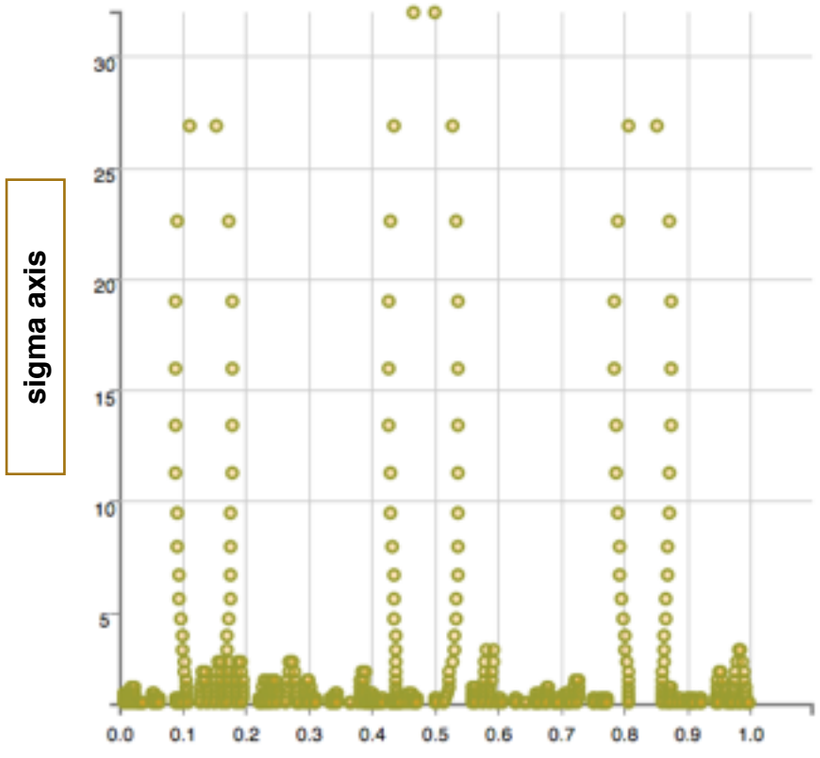
contour finder

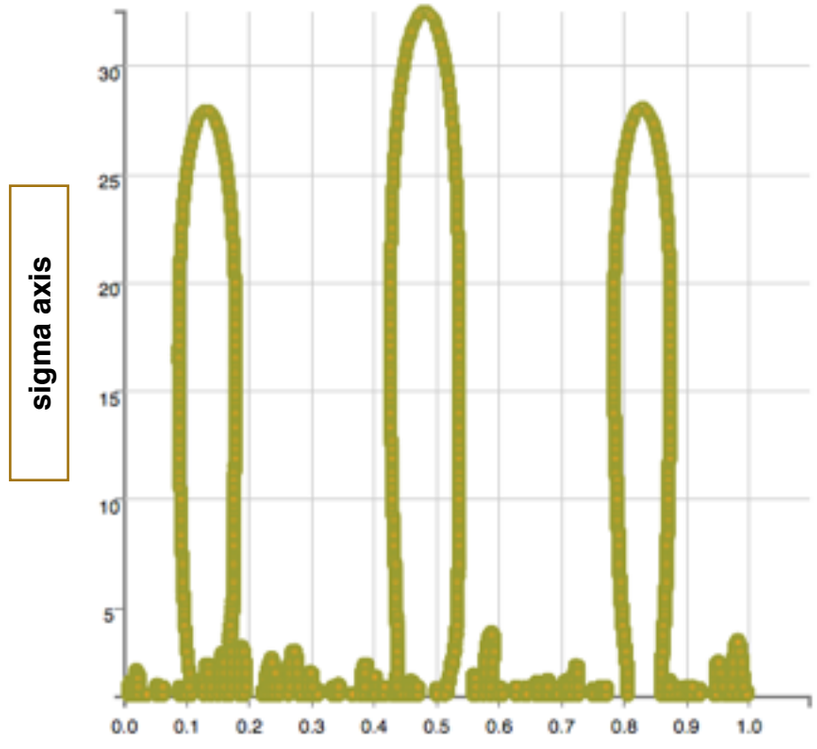
scale space image produced for sigma factors of sqrt(2)



scale space image produced for sigma factors of 2^(1/8)

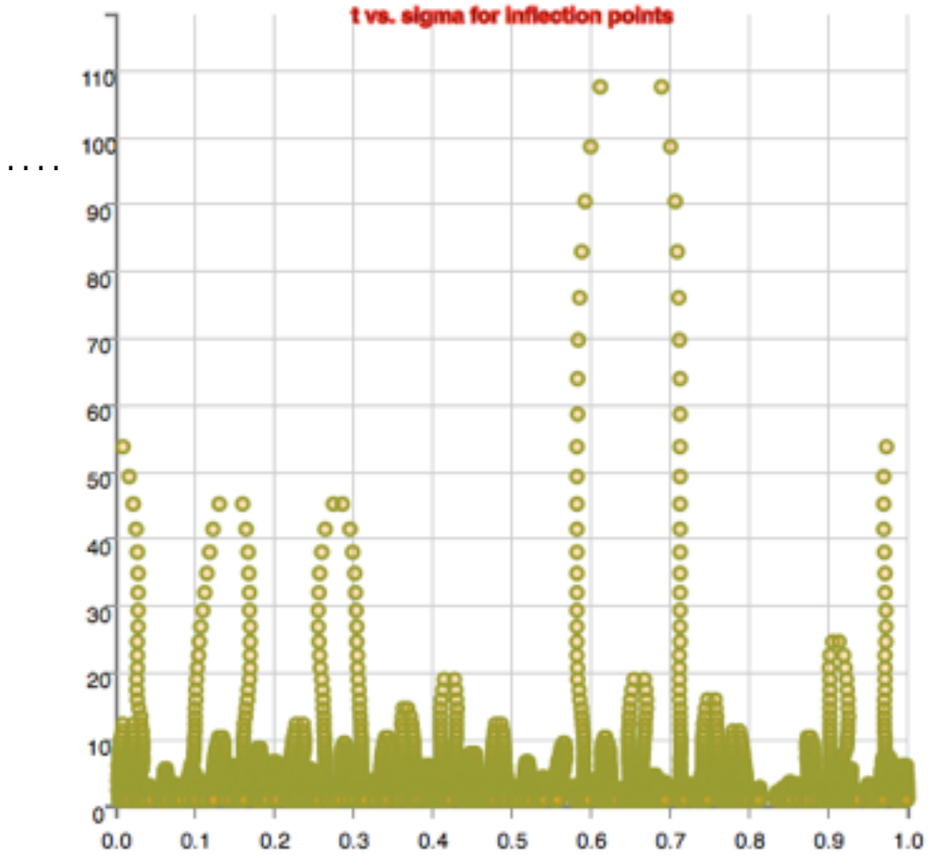


scale space image produced for sigma factors of 2^(1/128)



There is an error in estimating the peak of a contour for fastest creation of scale space images (<= 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



my scale space image agrees with theirs

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

FARZIN MOKHTARIAN AND ALAN MACKWORTH

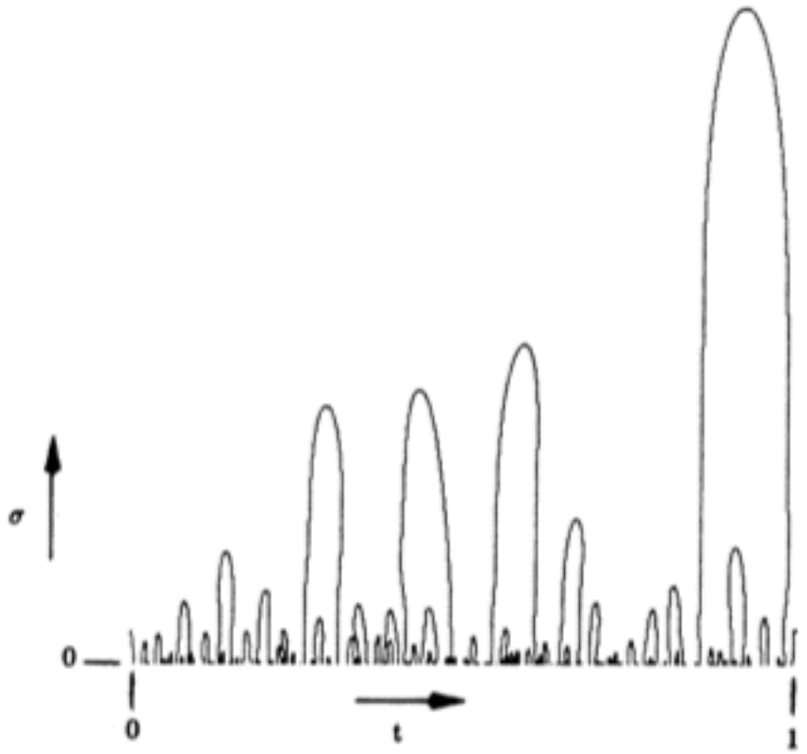
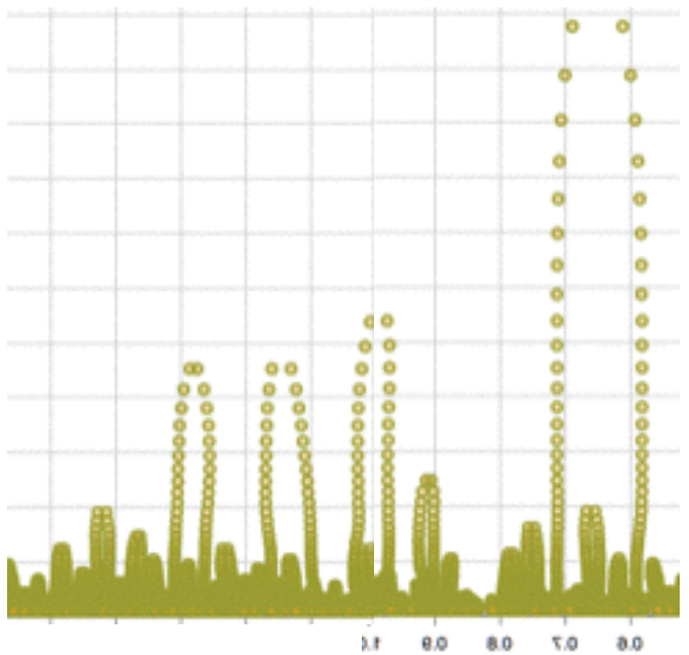
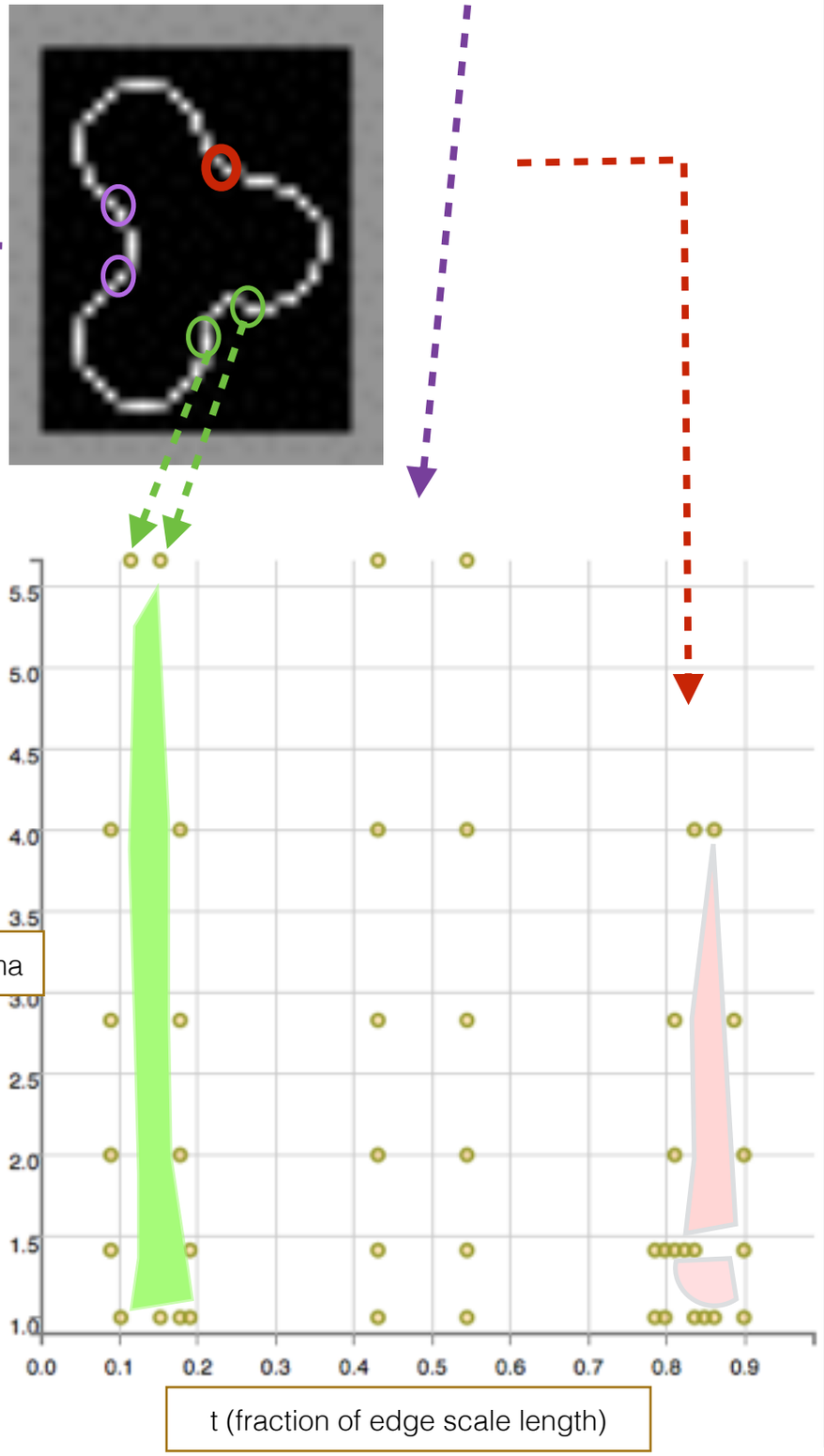


Fig. 3. Generalized scale space image of Africa.

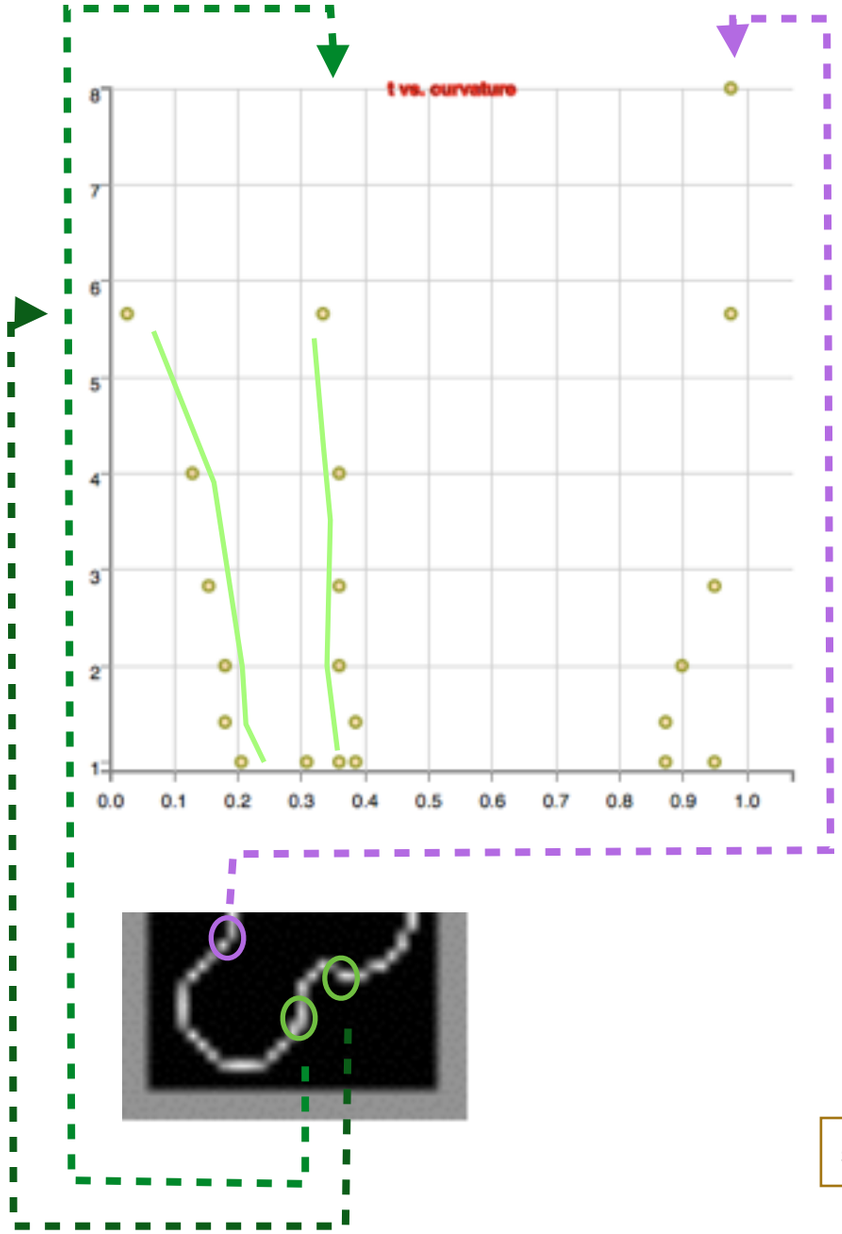


contour finder

single closed curve's scale space image:

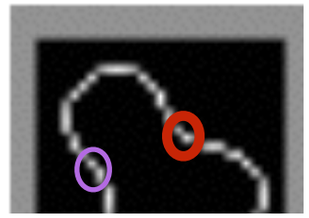


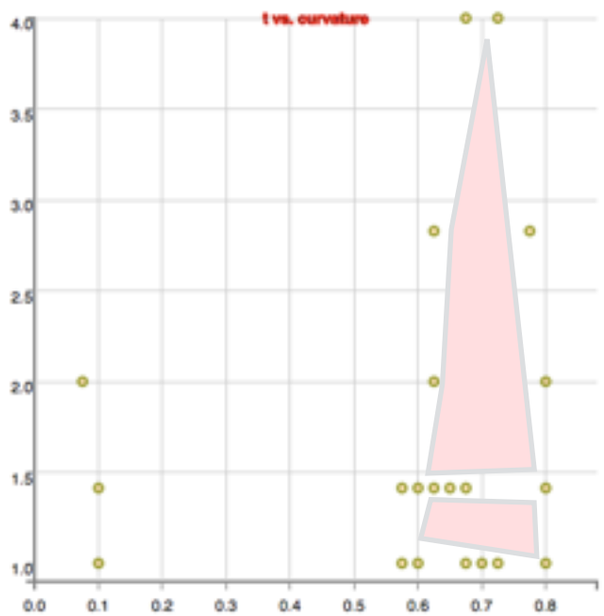
divided into 2 curves manually, then made into scale images (that is, 2 open curves possibly create open contours):



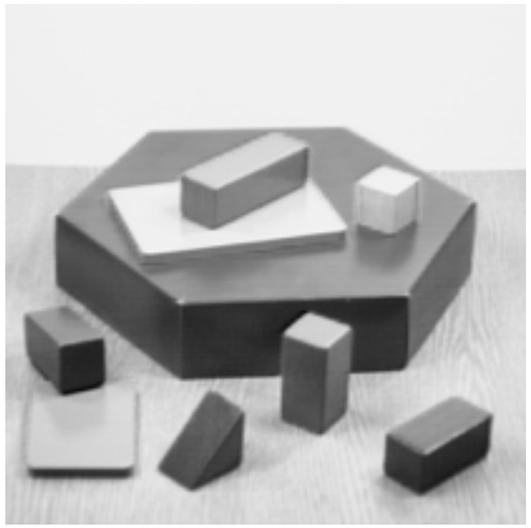
∴

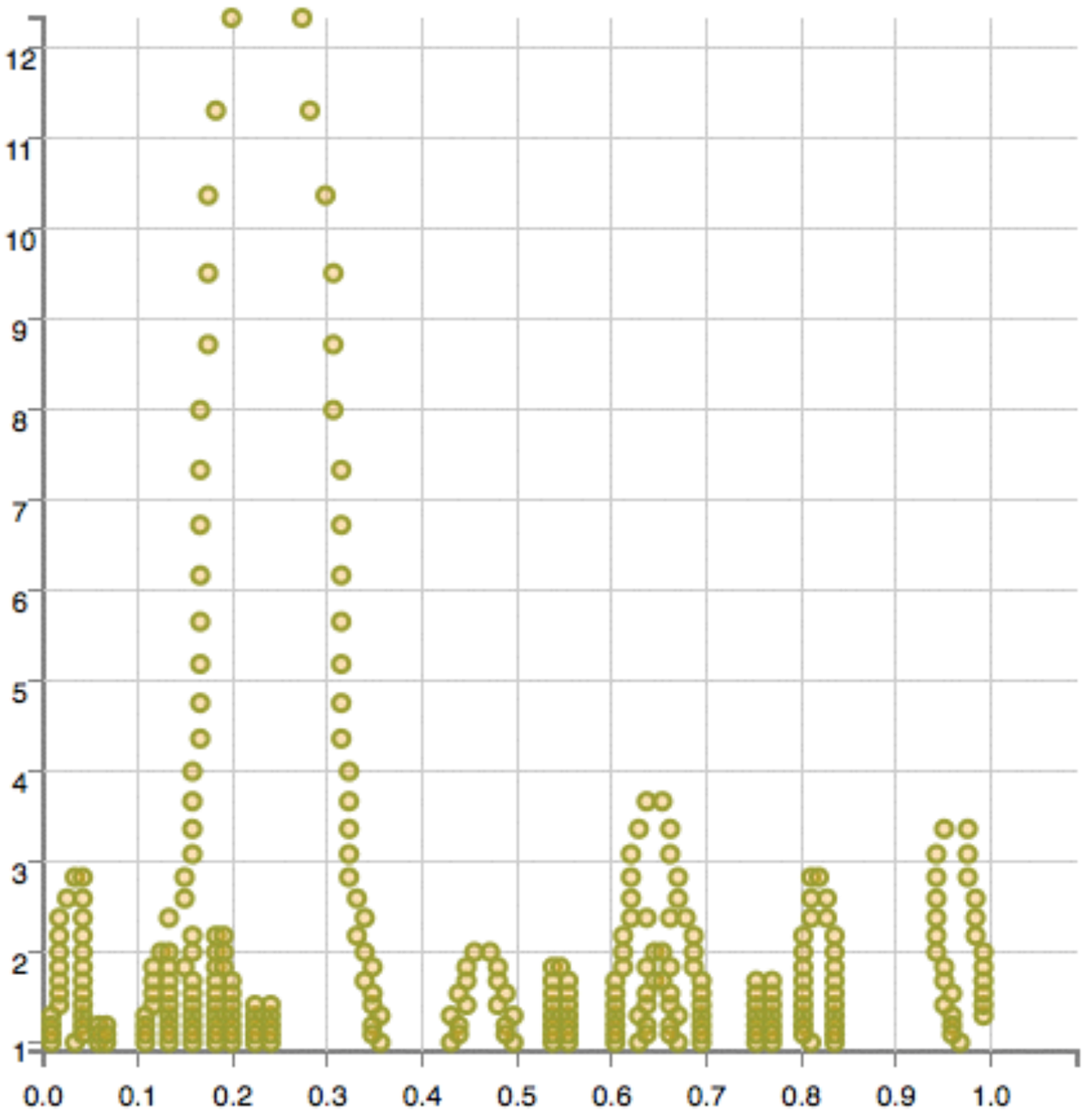
open contours are hard to match in another image's scale images





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.

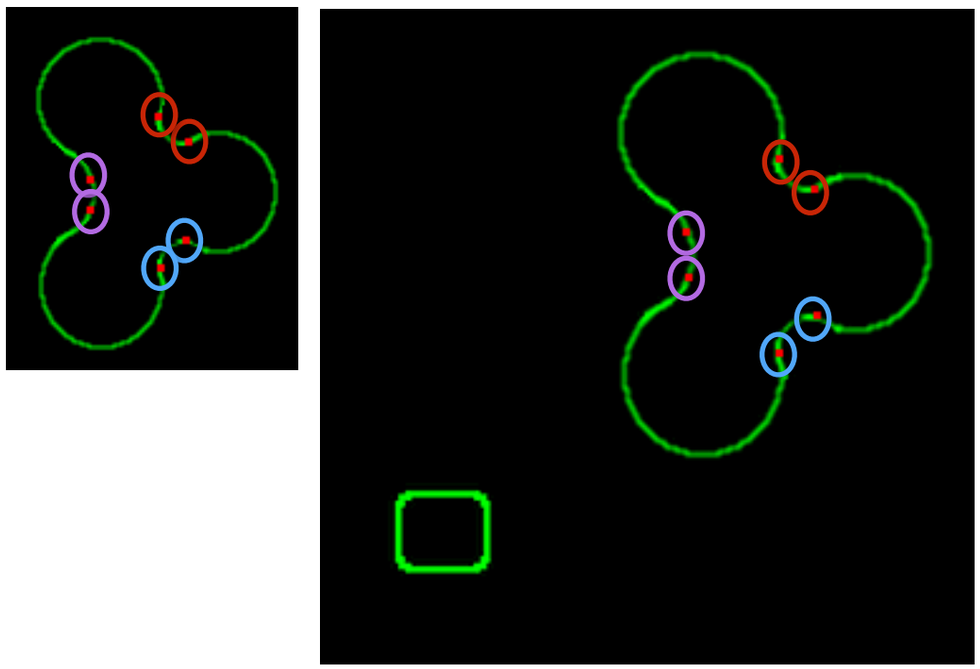
Then, the parameters are refined with small changes and applied to the edges in image 1. The transformed closed curve edges from image 1 are compared to the closest matches in image 2 to find the best fitting transformation parameters.

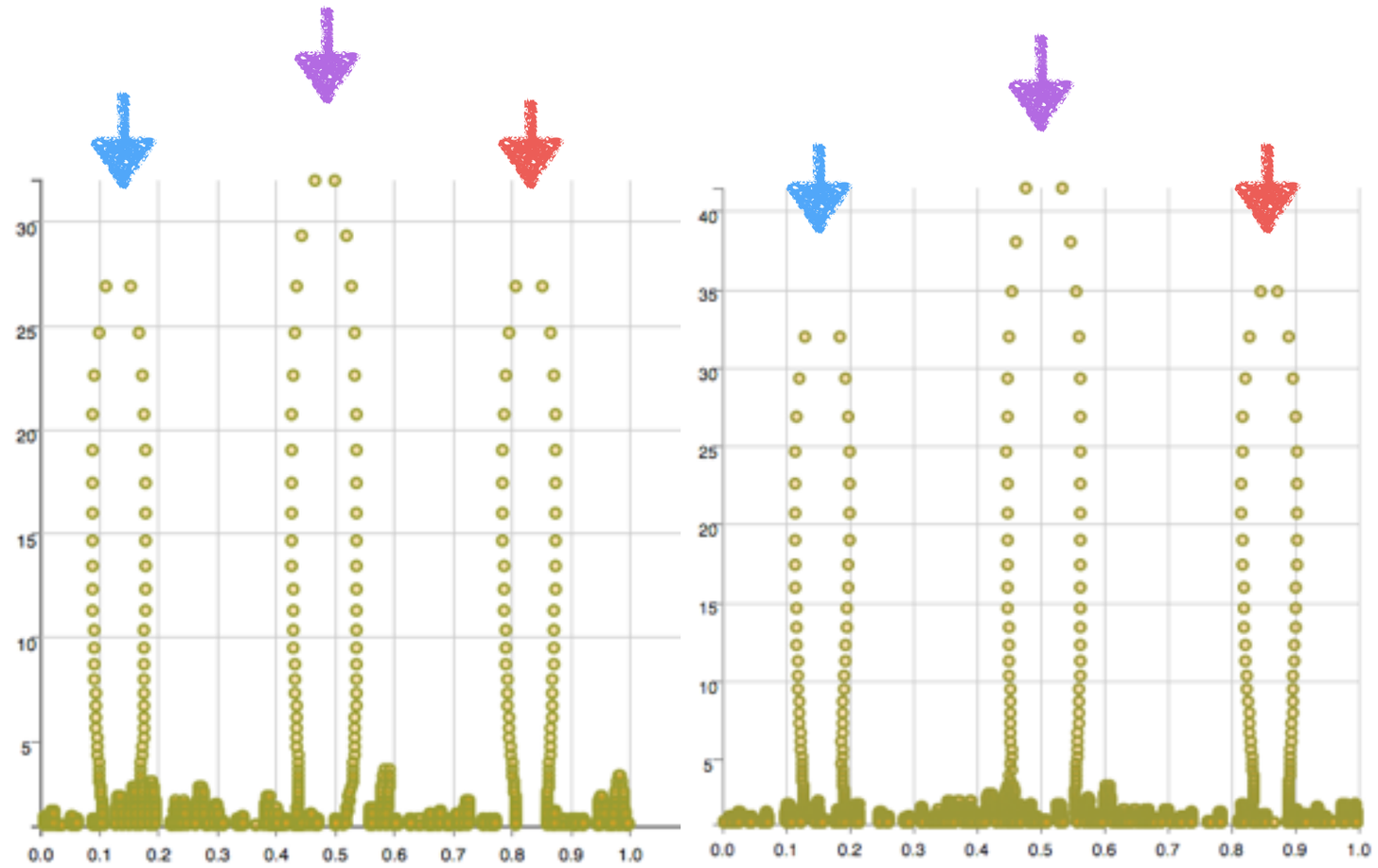
coordinate transformation, after matching contours

reversed to have CCW ordering

scale should be 1.3
rotation should be 360 -

coordinate transformation, after matching contours

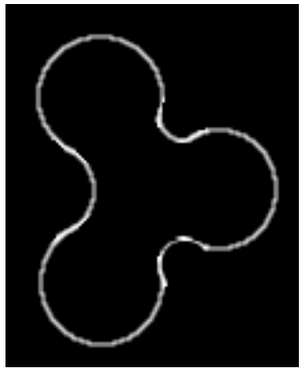


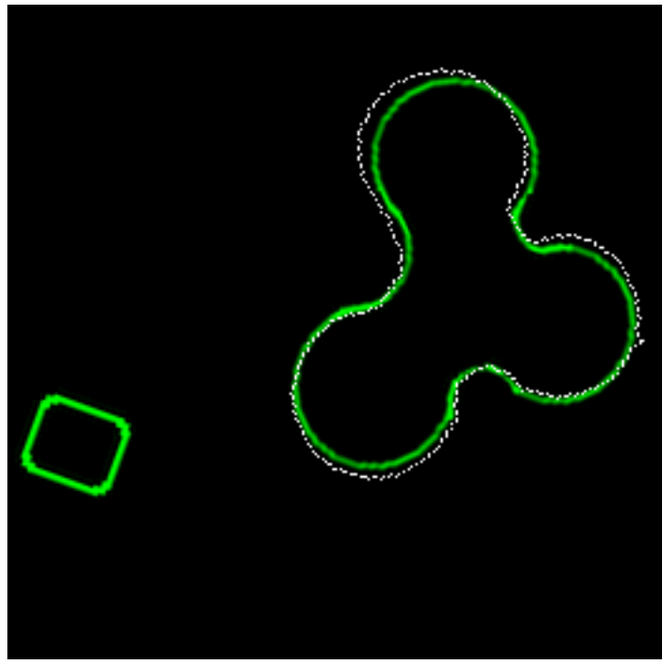


scale should be 1.3
rotation should be 360 - 20

```
Contour matcher solution scale=1.354256510734558
Contour matcher solution shift=-0.1688411384820938
CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72)  CONTOUR PEAK2: (43.336529, 0.504396) (157, 108) (159, 101)
CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99)  CONTOUR PEAK2: (34.148750, 0.157143) (190, 143) (177, 150)
CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54)  CONTOUR PEAK2: (34.896511, 0.859341) (200, 85) (209, 97)
offsetImgX1=10 offsetImgY1=10
offsetImgX2=1 offsetImgY2=26
rotationInRadians=6.0030236
rotationInDegrees=343.94791799660214
scale=1.3542565
translationX=108.1361
translationY=15.72716
```

apply coordinate transformation

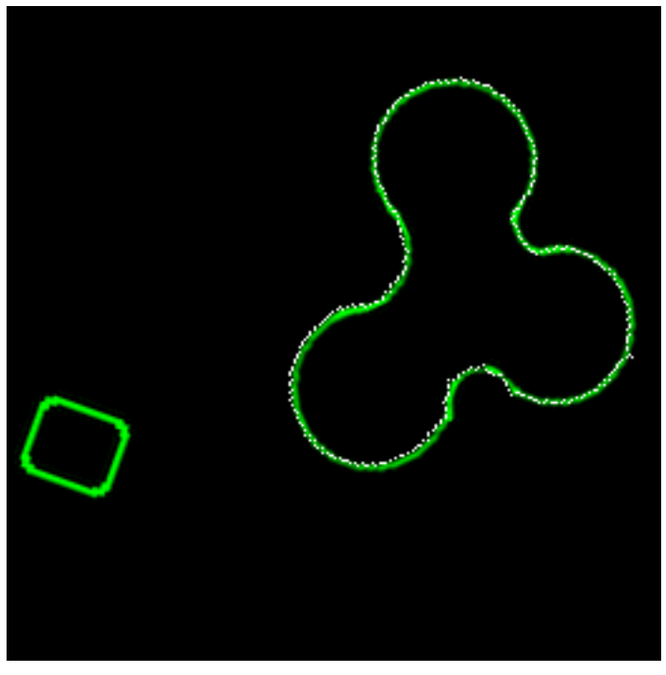




```
rotationInRadians=6.0030236
rotationInDegrees=343.94791799660214
scale=1.3542565
translationX=108.1361
translationY=15.72716
```

scale should be 1.3
rotation should be 360-20

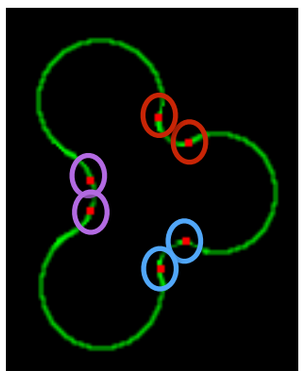
This shows that it's difficult to estimate scale unless some of the inflection points are further from the center of the shape

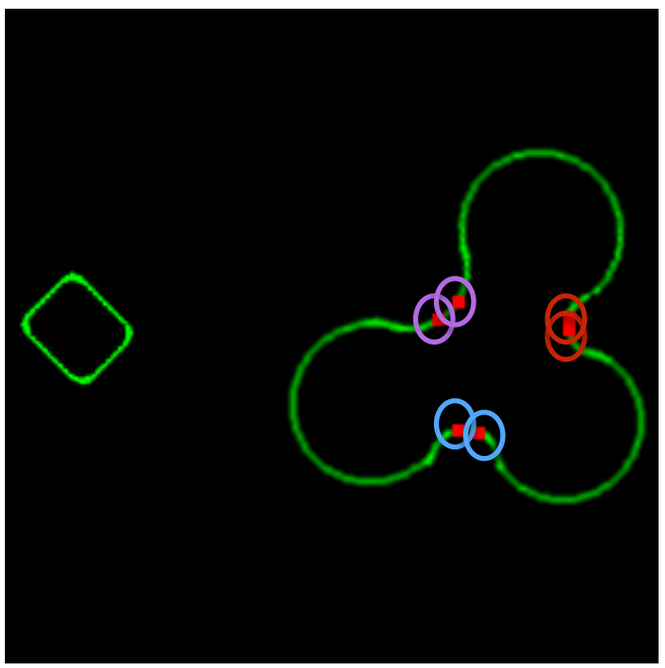


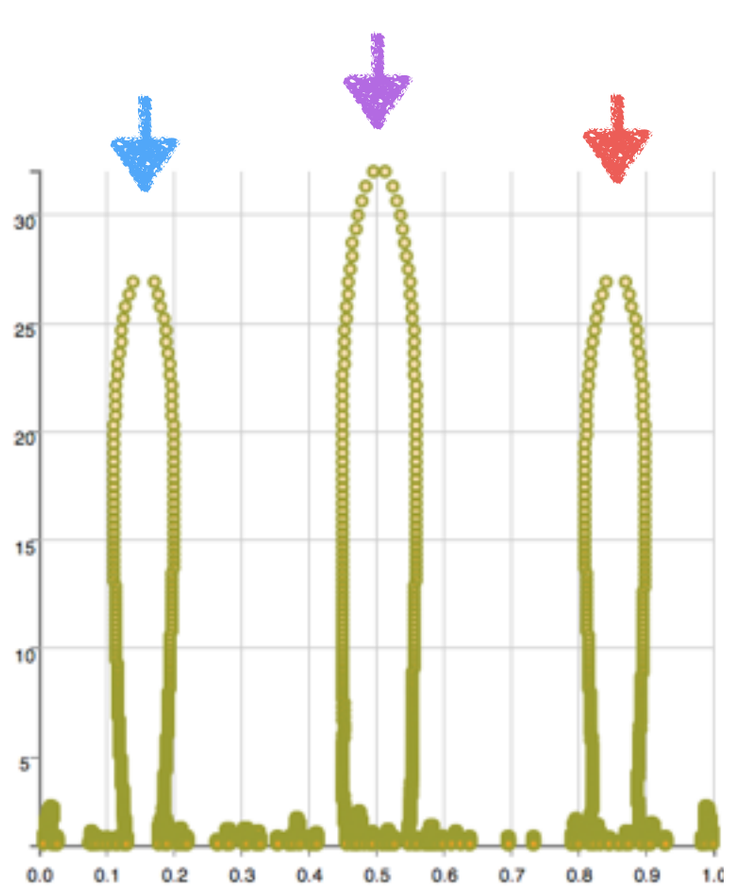
After Refinement

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

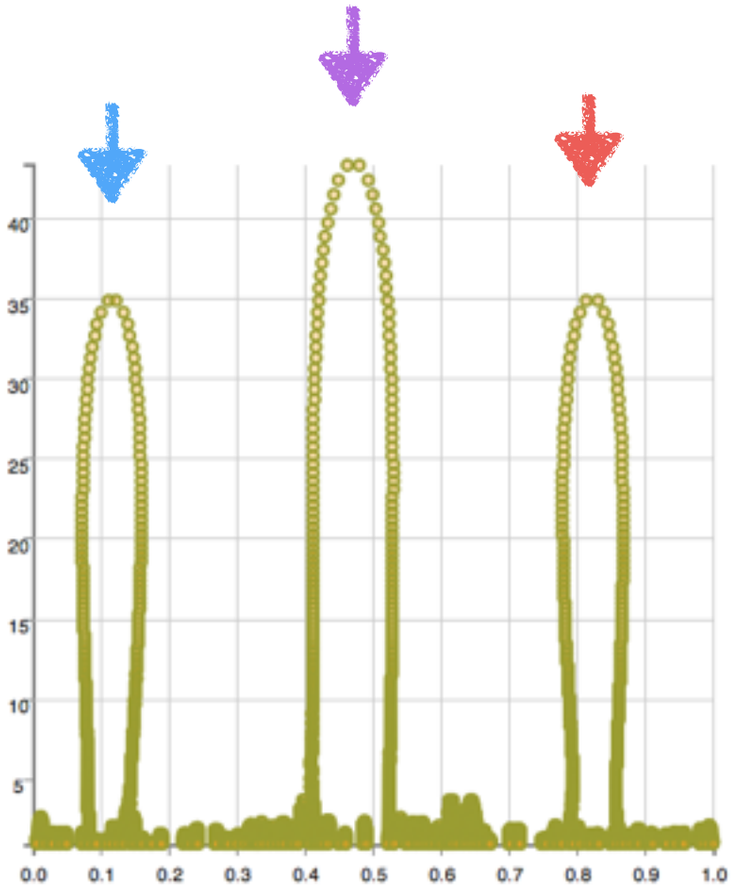
coordinate transformation, after matching contours





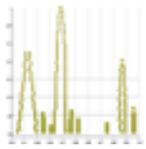


reversed to have CCW ordering



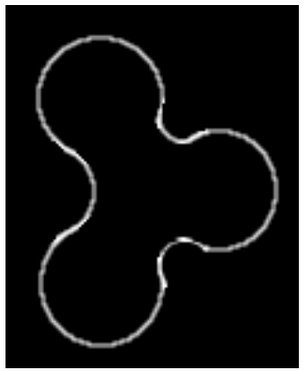
reversed to have CCW ordering

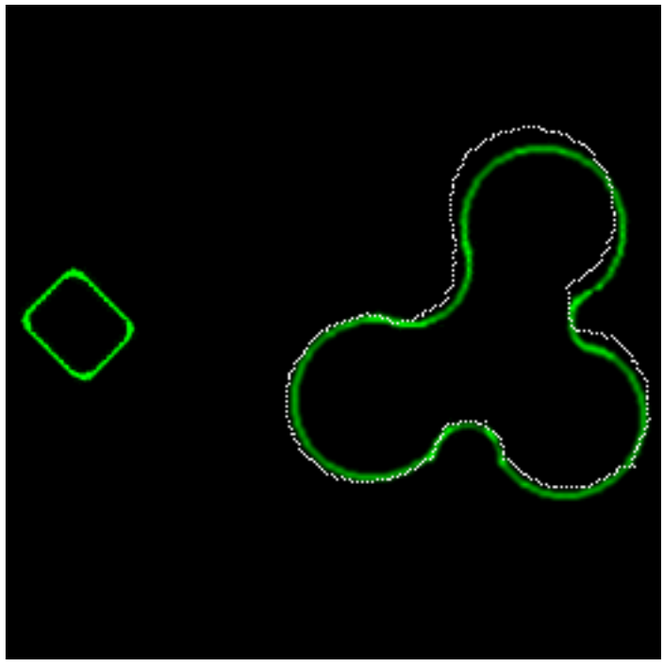
scale should be 1.3
rotation should be 360 - 45



```
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
```

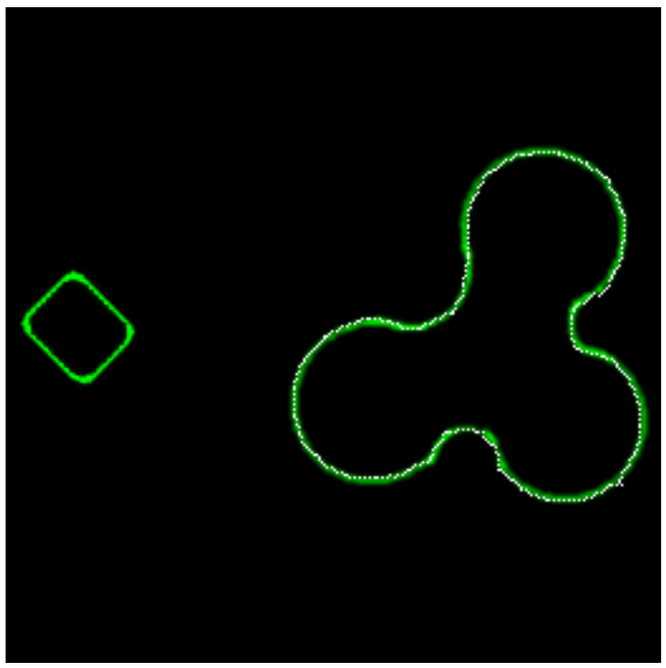
apply coordinate transformation





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

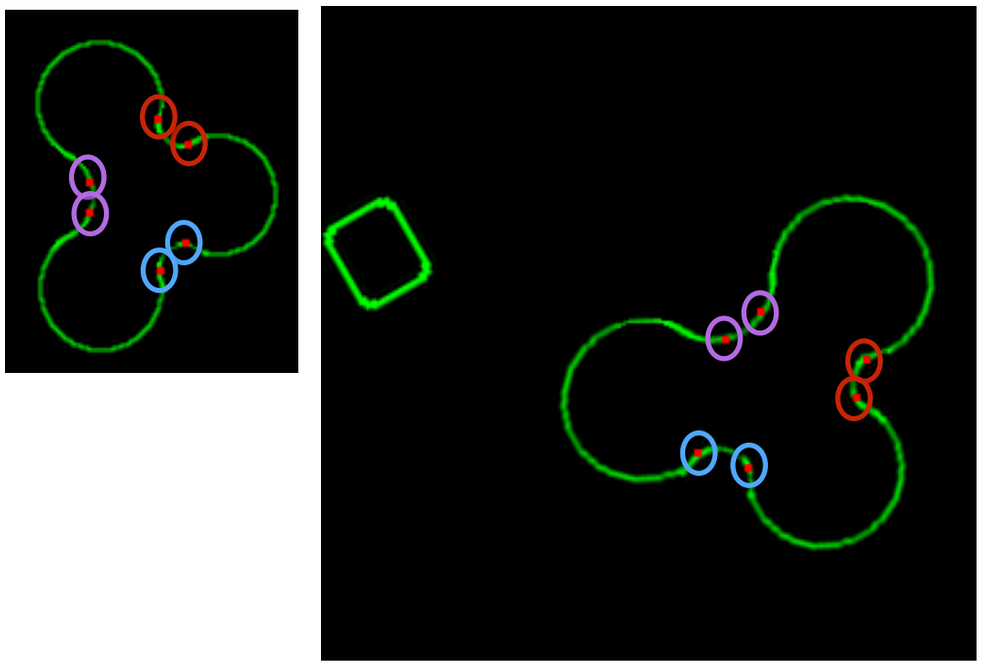
scale should be 1.3
rotation should be 360-45

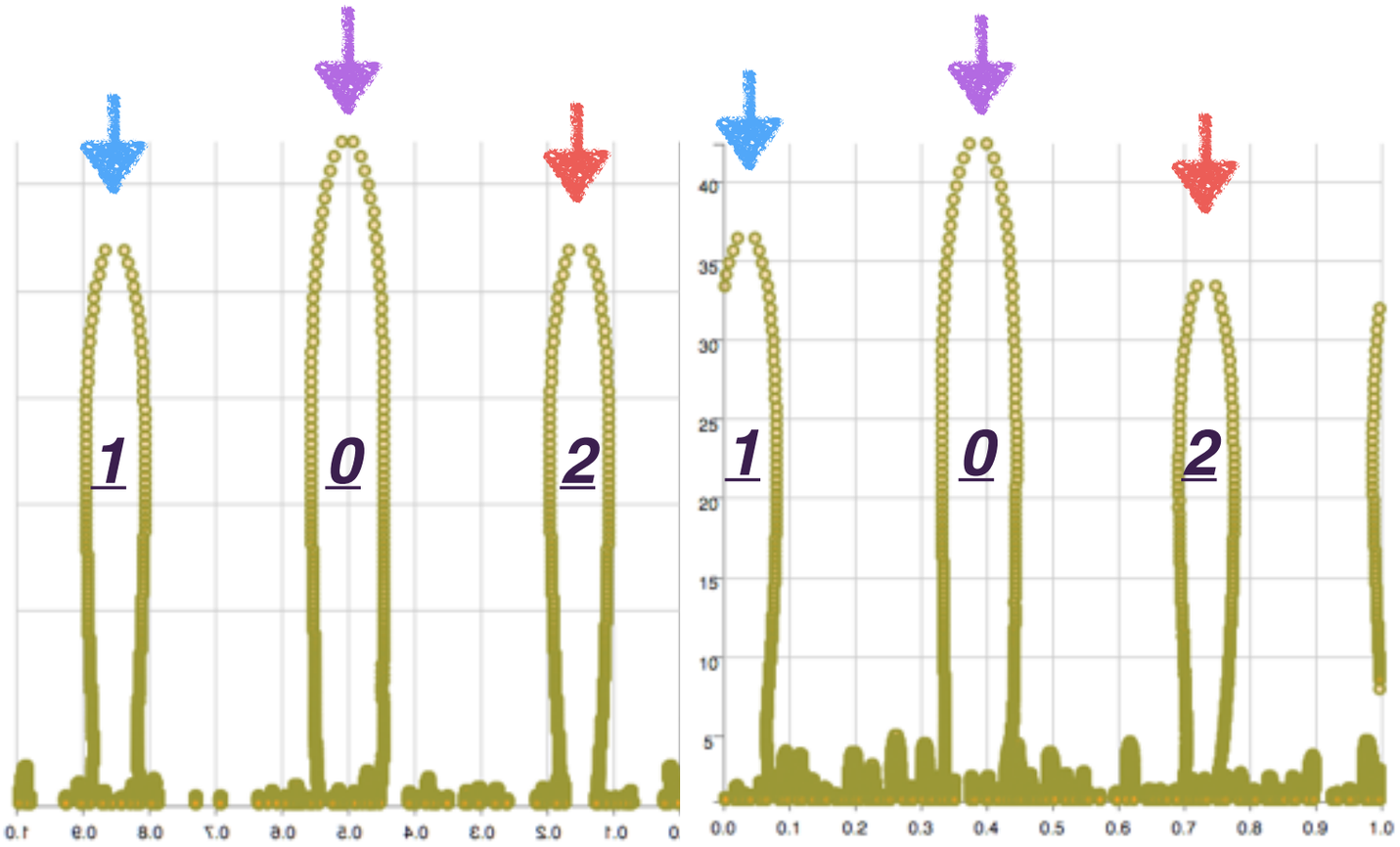


After Refinement

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

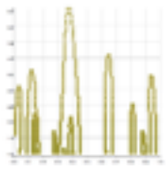
coordinate transformation, after matching contours





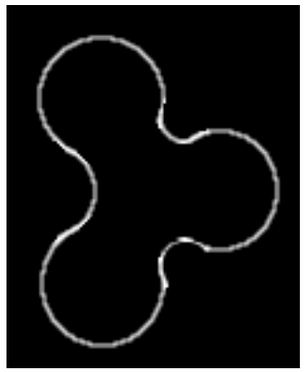
reversed to have CCW ordering

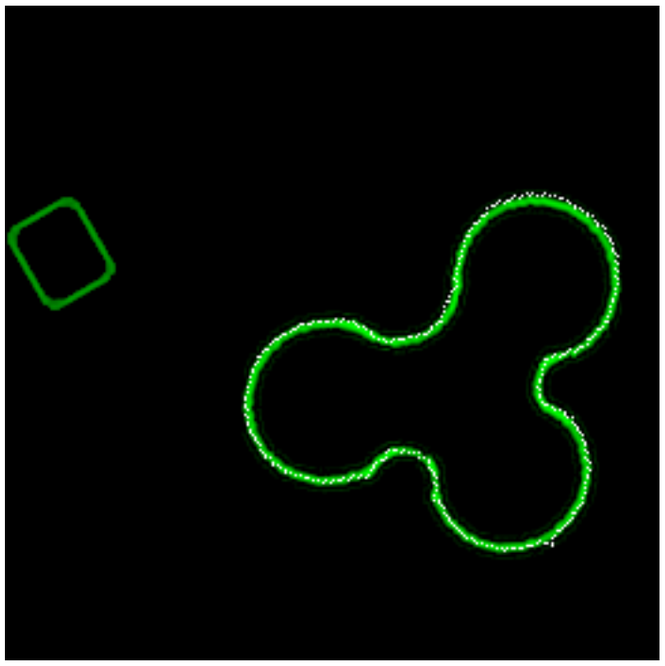
scale should be 1.3
rotation should be 360 - 60



```
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
```

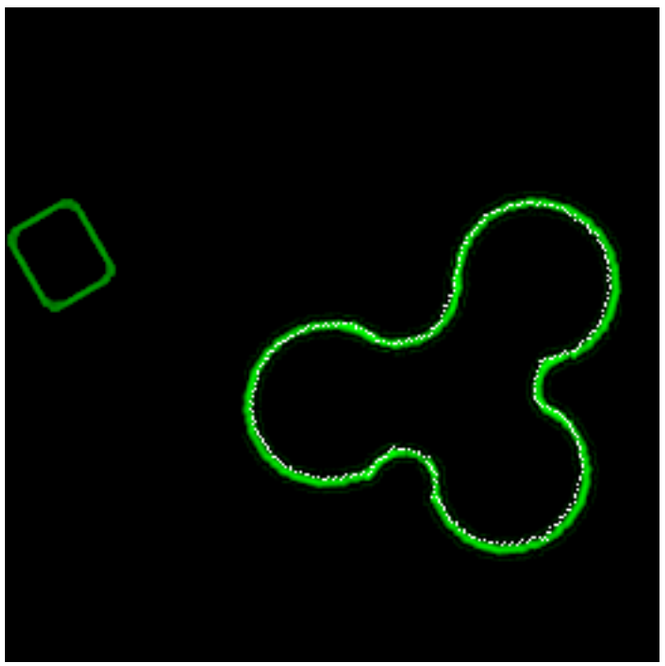
apply coordinate transformation





```
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
```

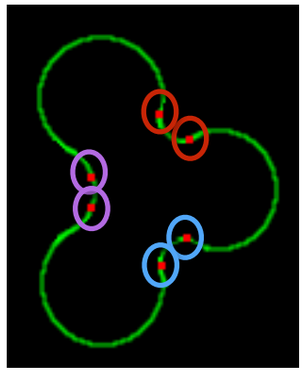
scale should be 1.3
rotation should be 360 - 60

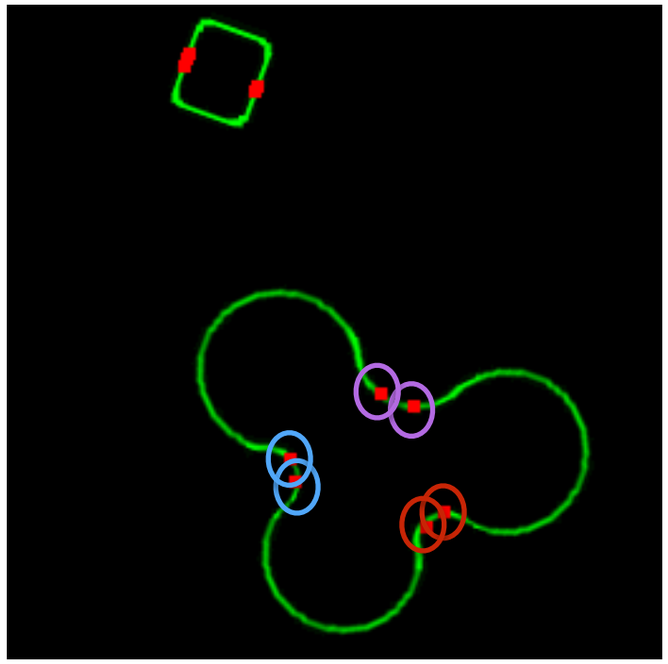


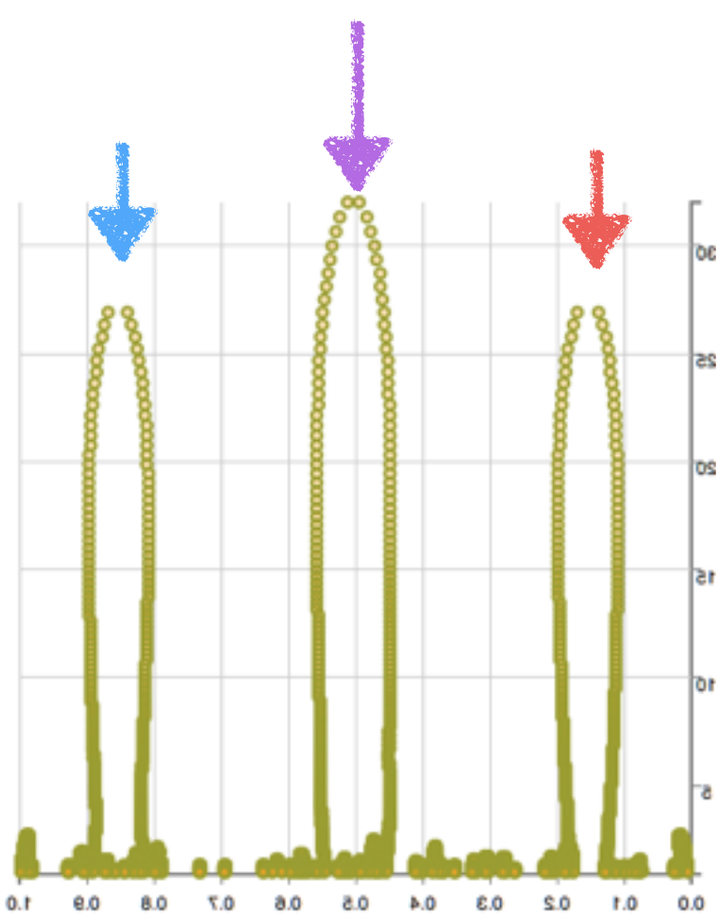
After Refinement

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

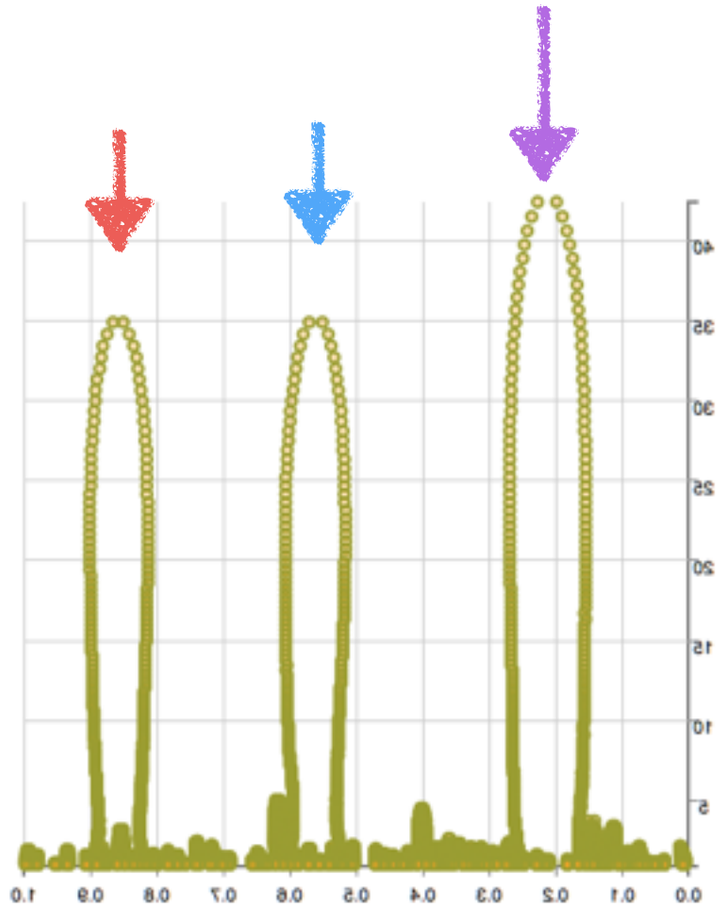
coordinate transformation, after matching contours





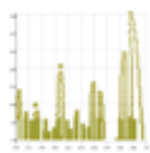


reversed to have CCW ordering



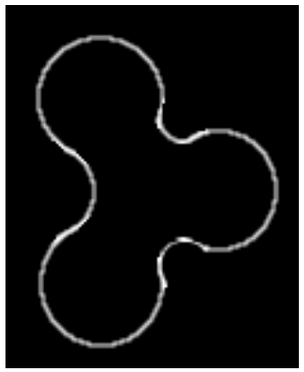
reversed to have CCW ordering

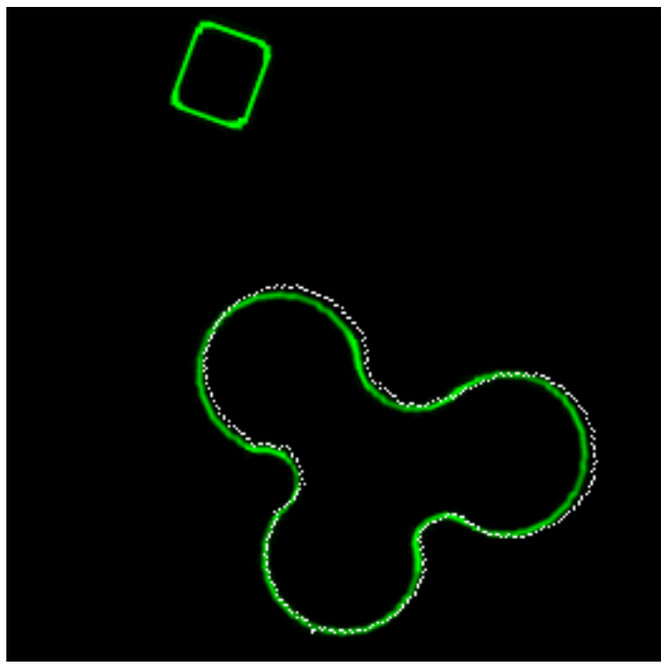
scale should be 1.3
rotation should be 360 -110



```
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
```

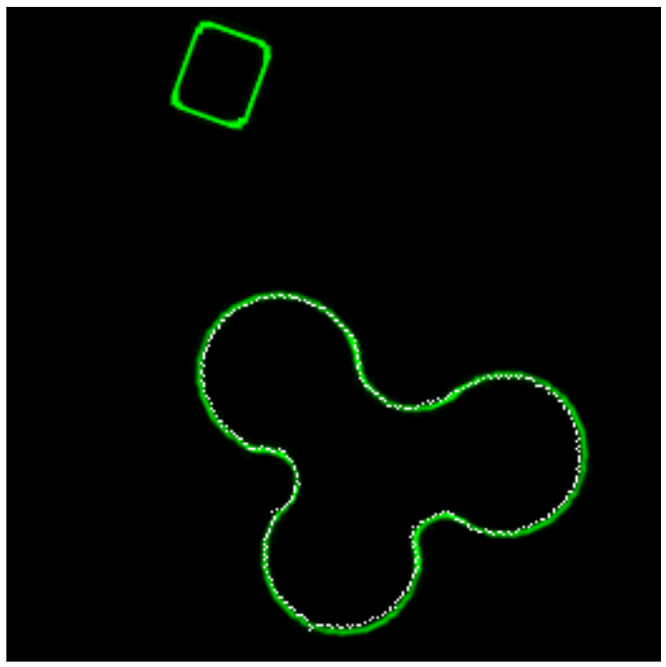
apply coordinate transformation





```
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
```

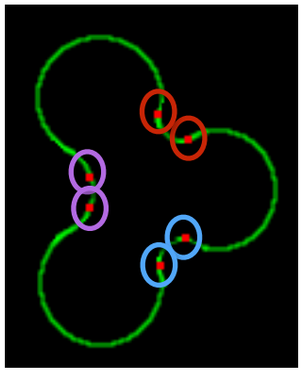
scale should be 1
rotation should be 360 - 110 (250)

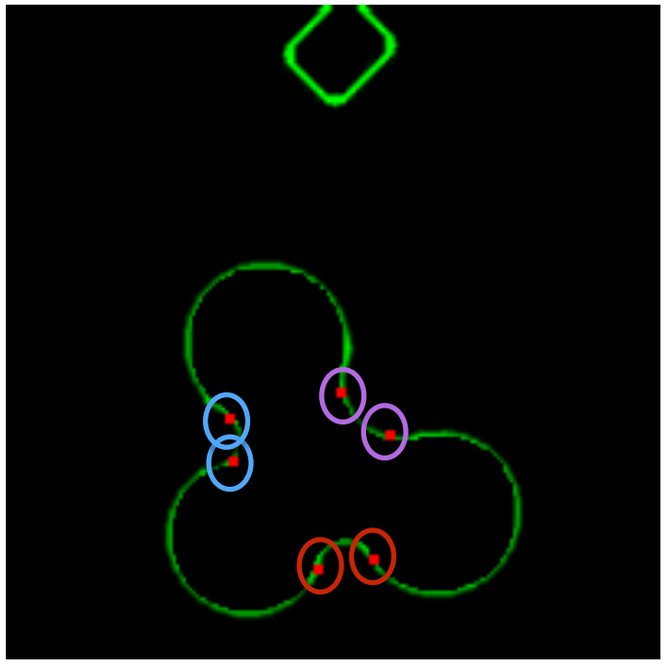


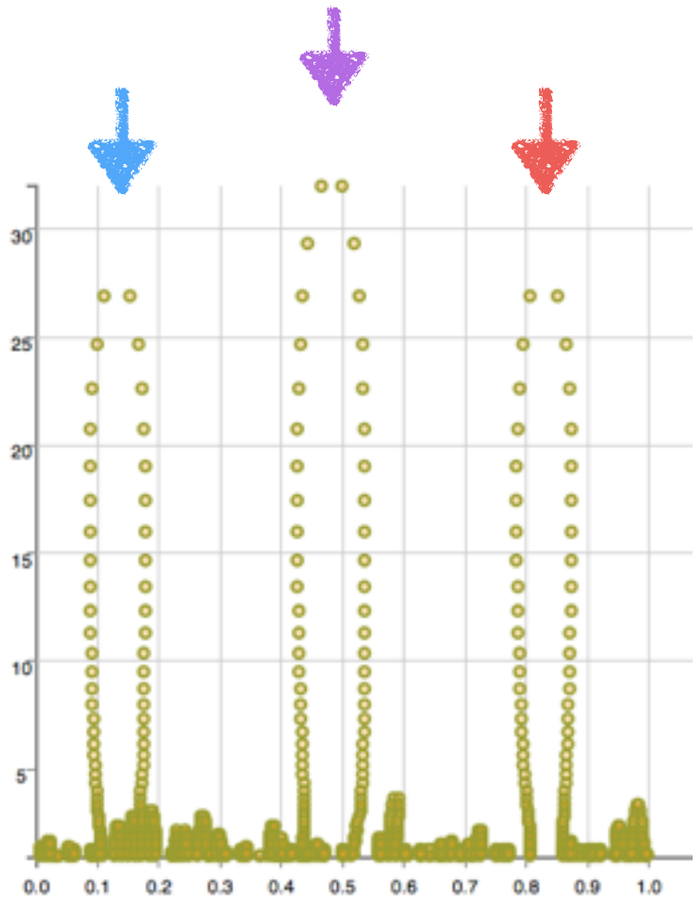
After Refinement

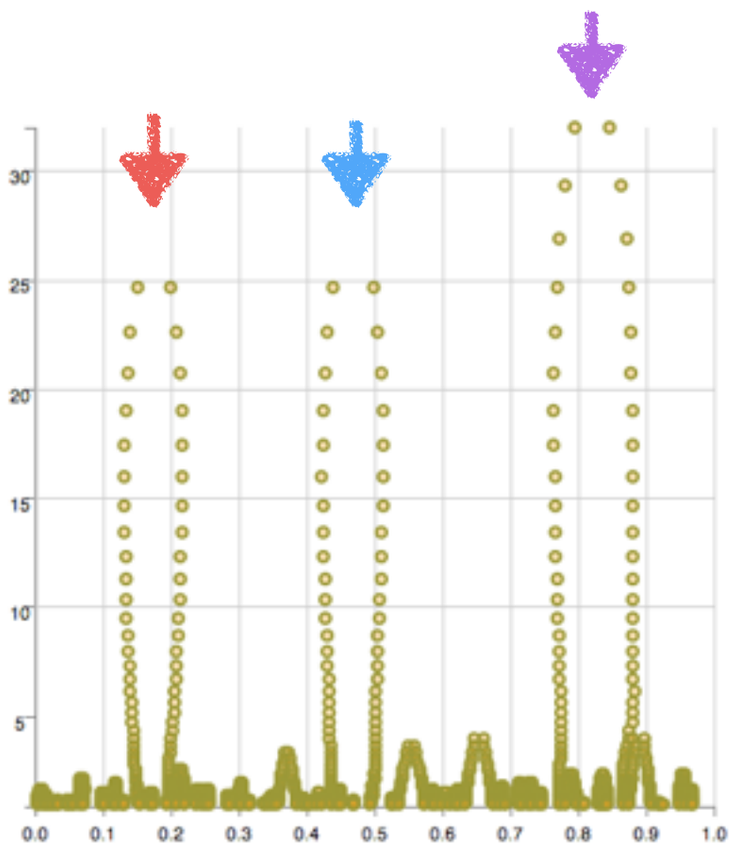
```
rotationInRadians=4.354237
rotationInDegrees=249.4794076616157
scale=1.2752376
translationX=71.0
translationY=95.0
```

coordinate transformation, after matching contours





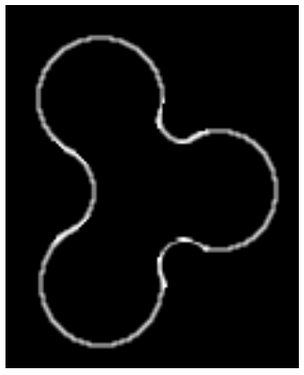


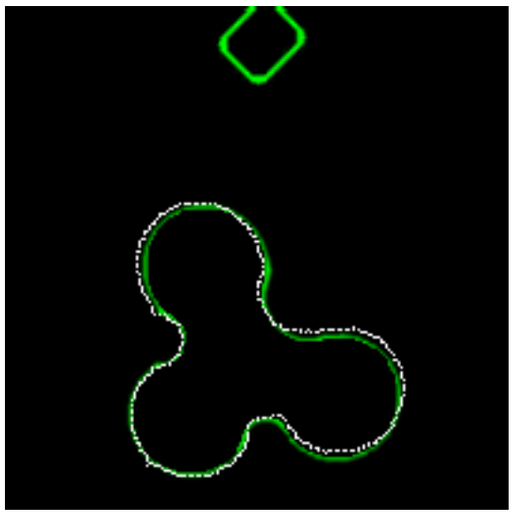


scale should be 1.3
rotation should be 360 - 135

```
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
```

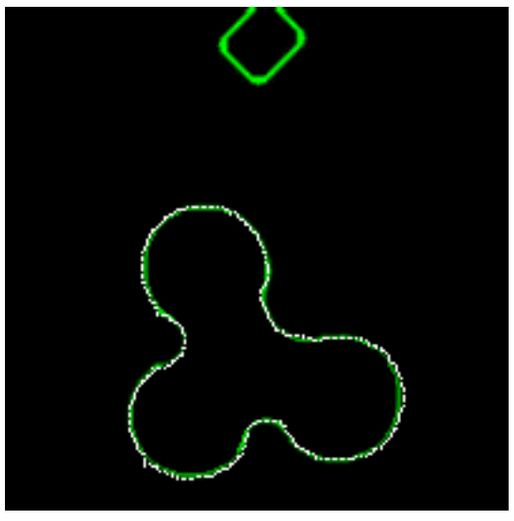
apply coordinate transformation





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

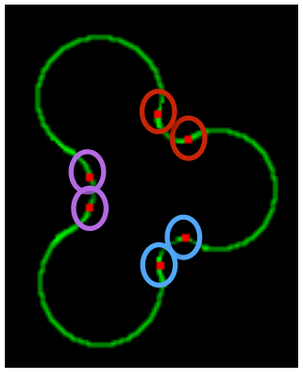
scale should be 1
rotation should be 360 - 135

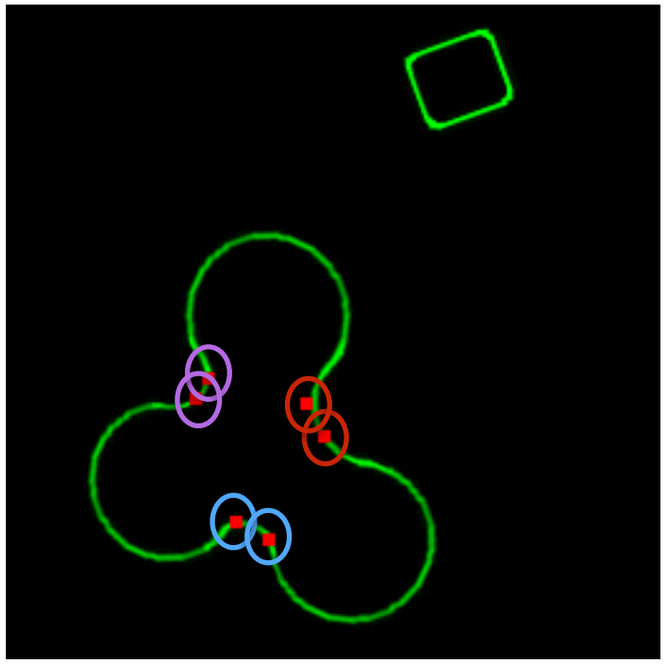


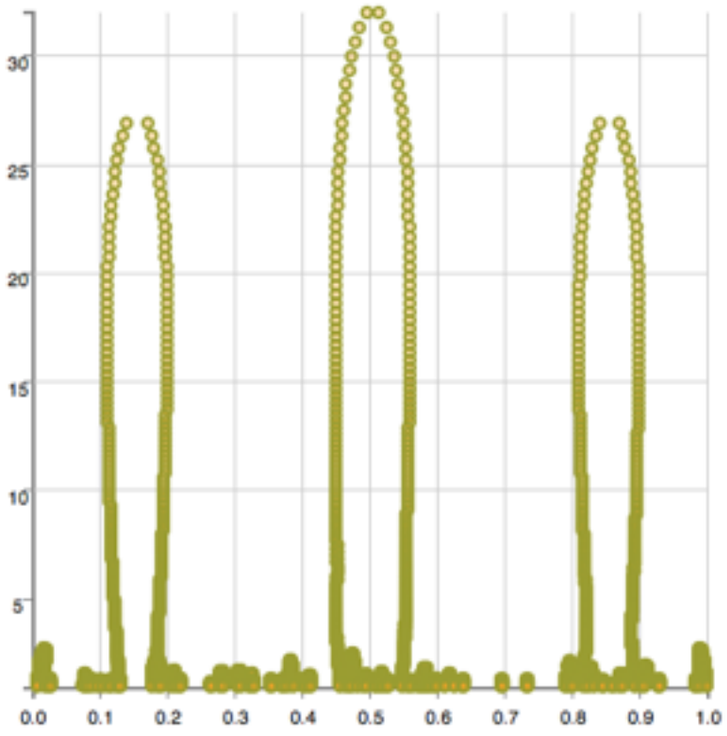
After Refinement

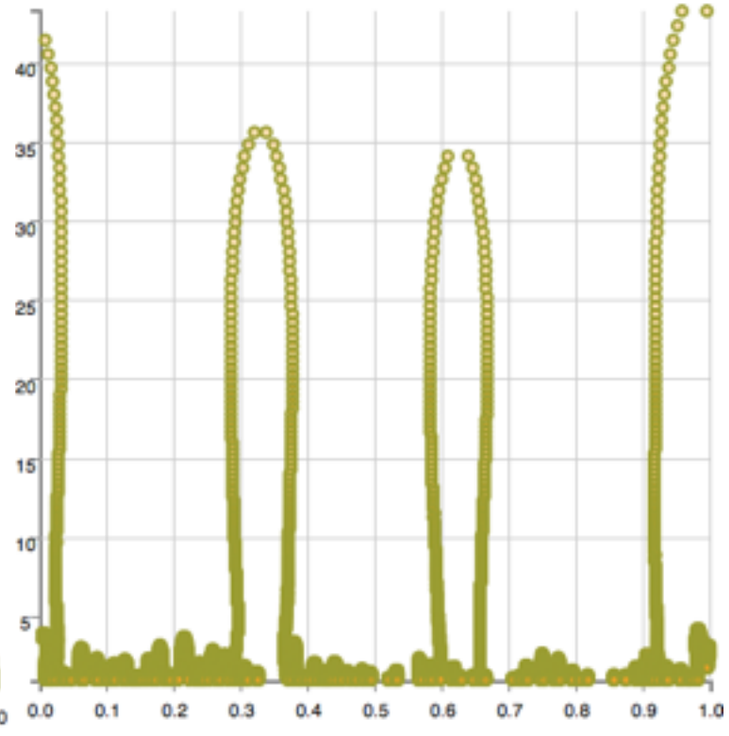
```
rotationInRadians=3.9406004
rotationInDegrees=225.77977139269535
scale=1.0218972
translationX=33.0
translationY=72.0
```

coordinate transformation, after matching contours







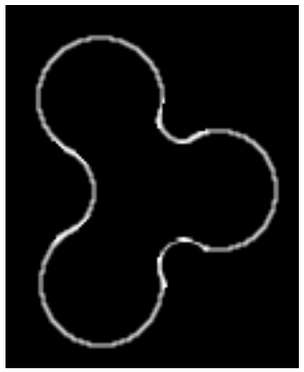


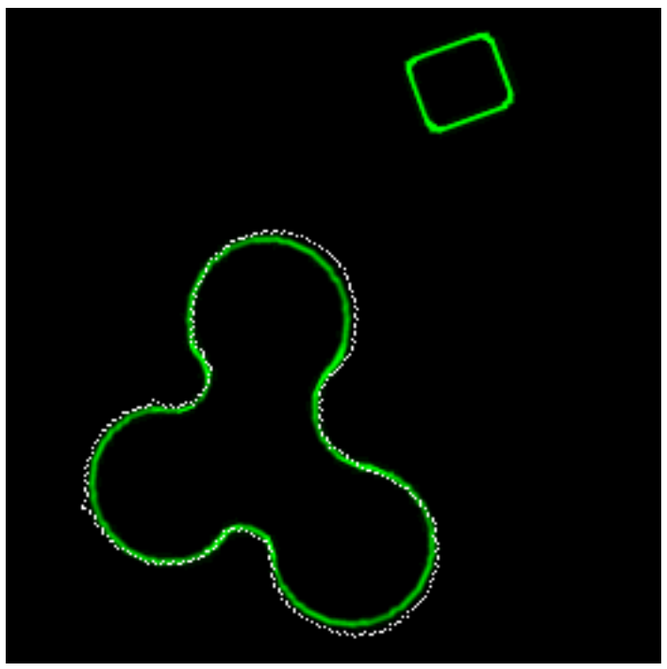
reversed to have CCW ordering

scale should be 1.3
rotation should be 360 - 160

```
Contour matcher solution shift=-0.648127555847168
Contour matcher solution cost=3.0
CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72) CONTOUR PEAK2: (43.336529, 0.025109) (119, 158) (126, 171)
CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99) CONTOUR PEAK2: (35.660648, 0.672489) (75, 156) (80, 148)
CONTOUR PEAK1: (26.908875, 0.846264) (60, 45) (69, 54) CONTOUR PEAK2: (34.148750, 0.377729) (104, 212) (91, 205)
offsetImgX1=10 offsetImgY1=10
offsetImgX2=29 offsetImgY2=6
rotationInRadians=3.4556763
rotationInDegrees=197.995668339729
scale=1.3542565
translationX=17.566353
translationY=81.42969
```

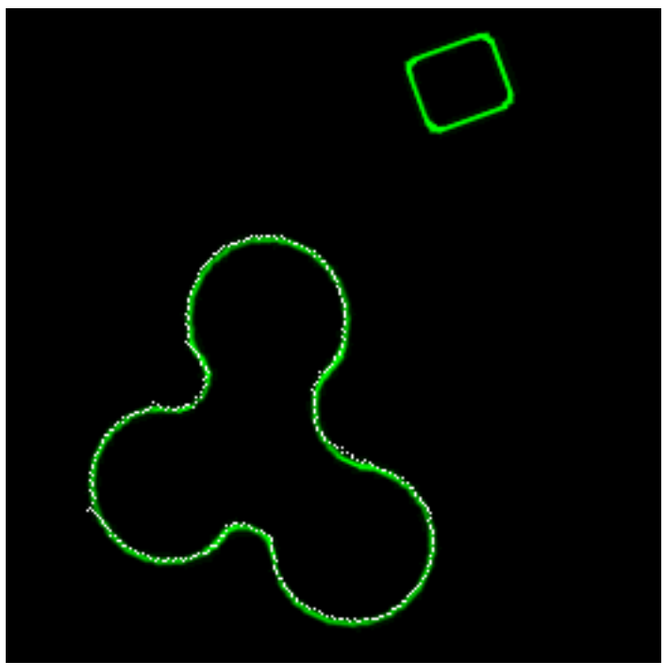
apply coordinate transformation





```
rotationInRadians=3.4556763
rotationInDegrees=197.995668339729
scale=1.3542565
translationX=17.566353
translationY=81.42969
```

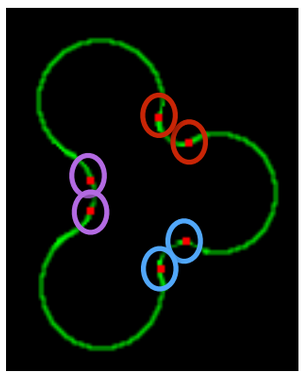
scale should be 1
rotation should be 360 - 160

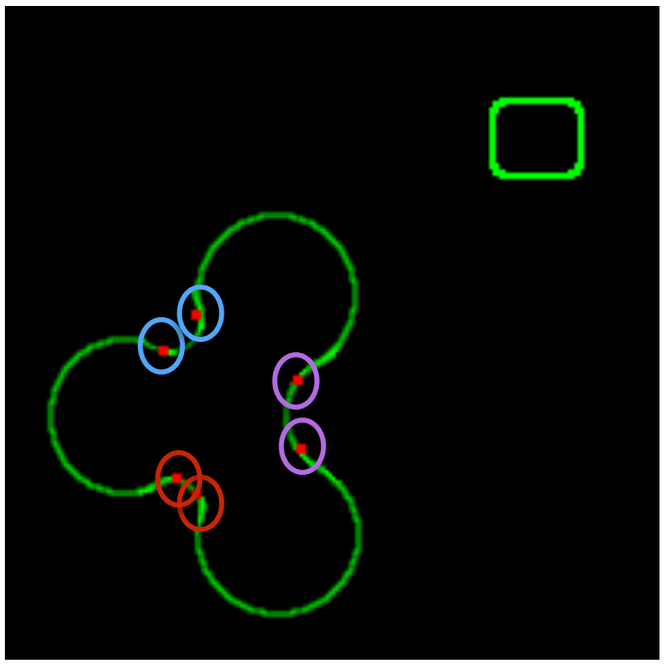


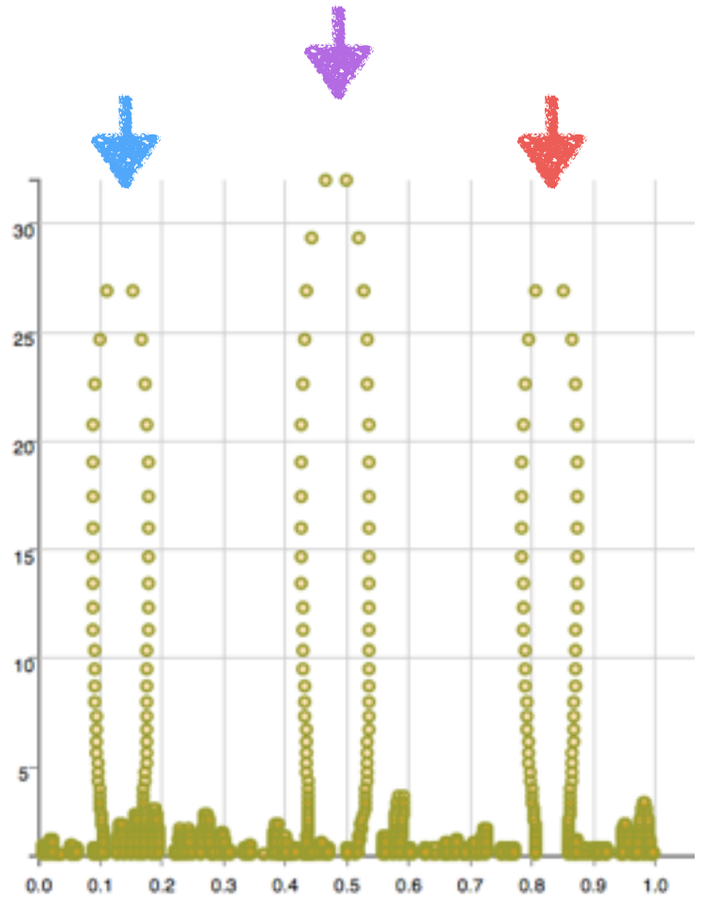
After Refinement

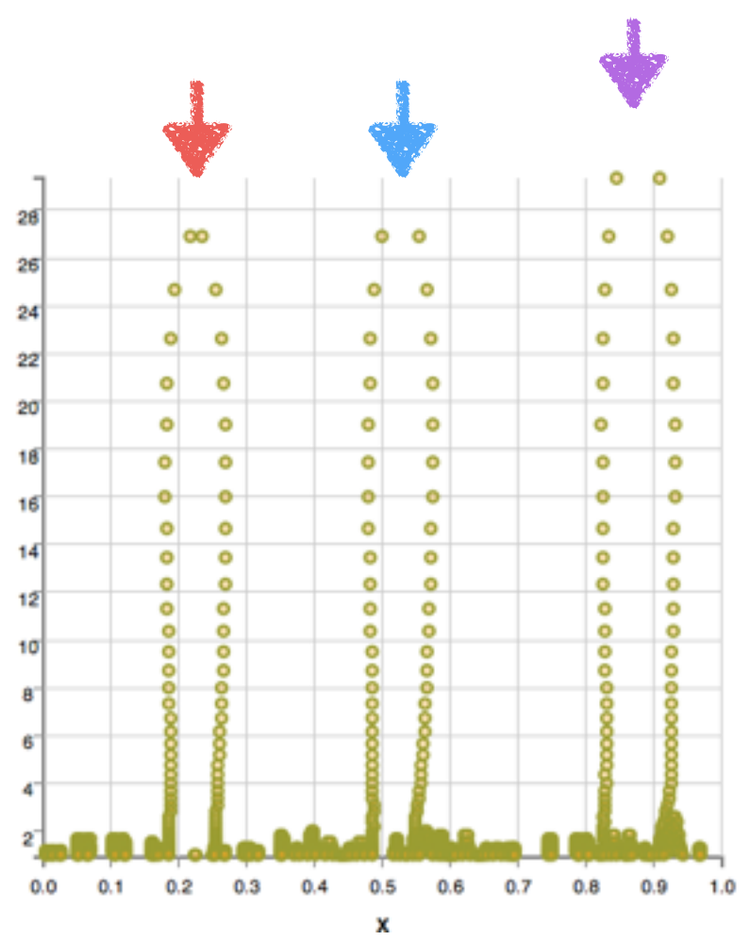
```
rotationInRadians=3.4993095
rotationInDegrees=200.49566784011543
scale=1.3042566
translationX=20.0
translationY=84.0
```

coordinate transformation, after matching contours







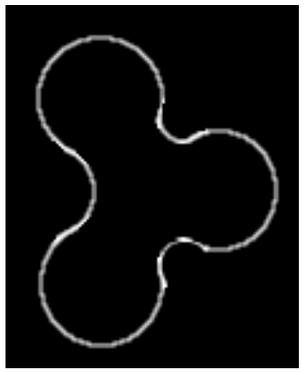


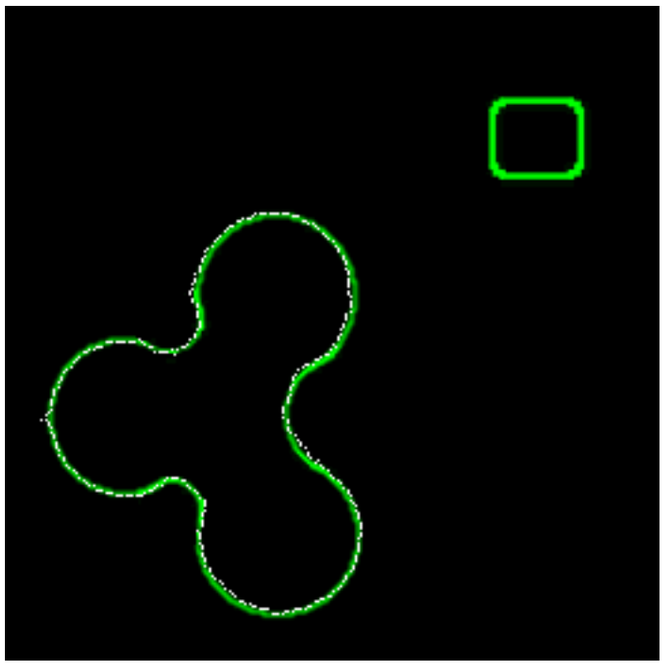
reversed to have CCW ordering

scale should be 1.3
rotation should be 180

```
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
```

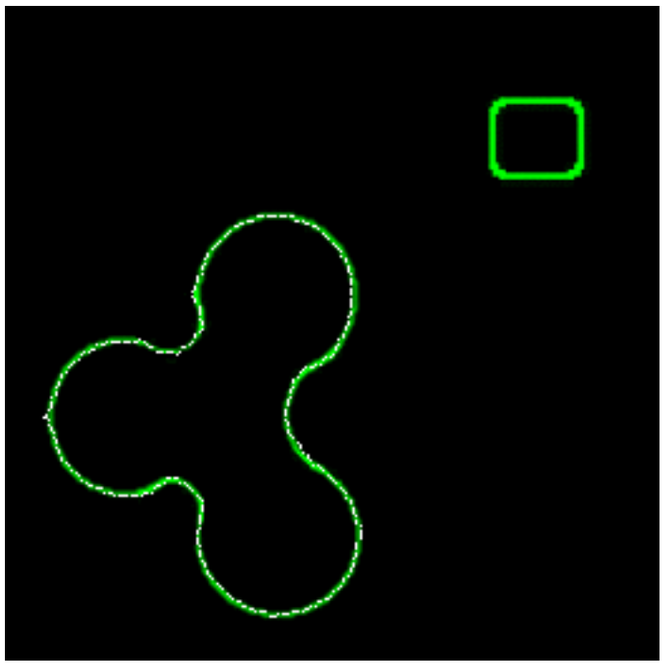
apply coordinate transformation





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

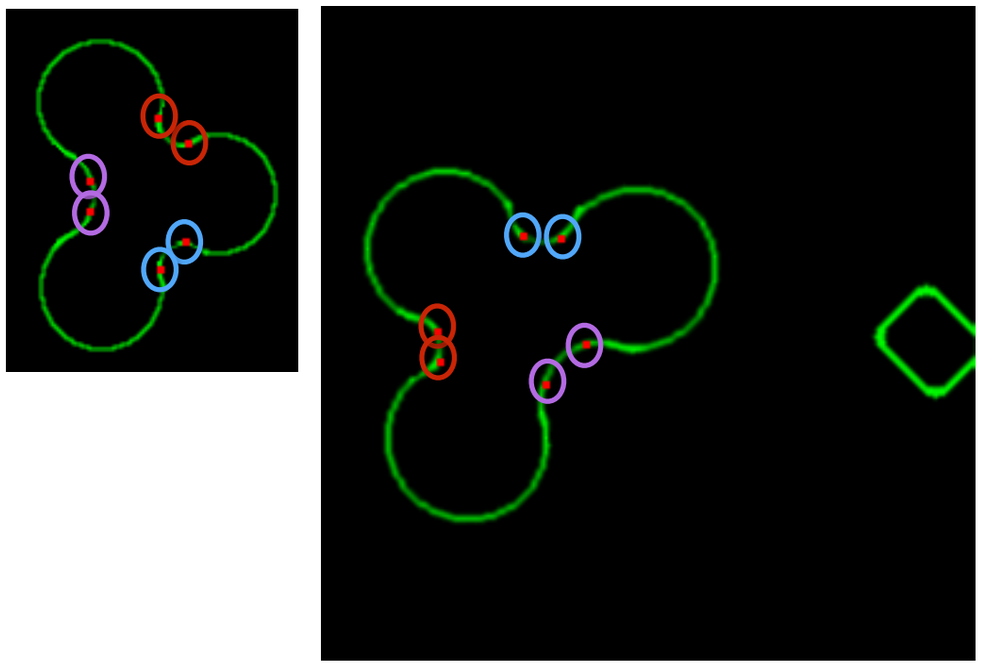
scale should be 1.3
rotation should be 180

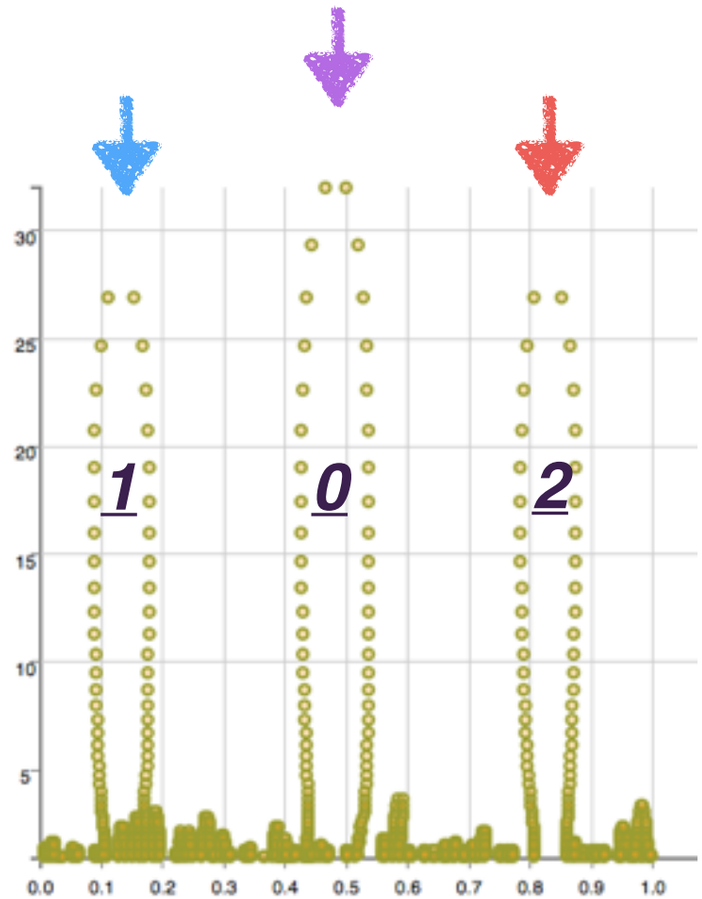


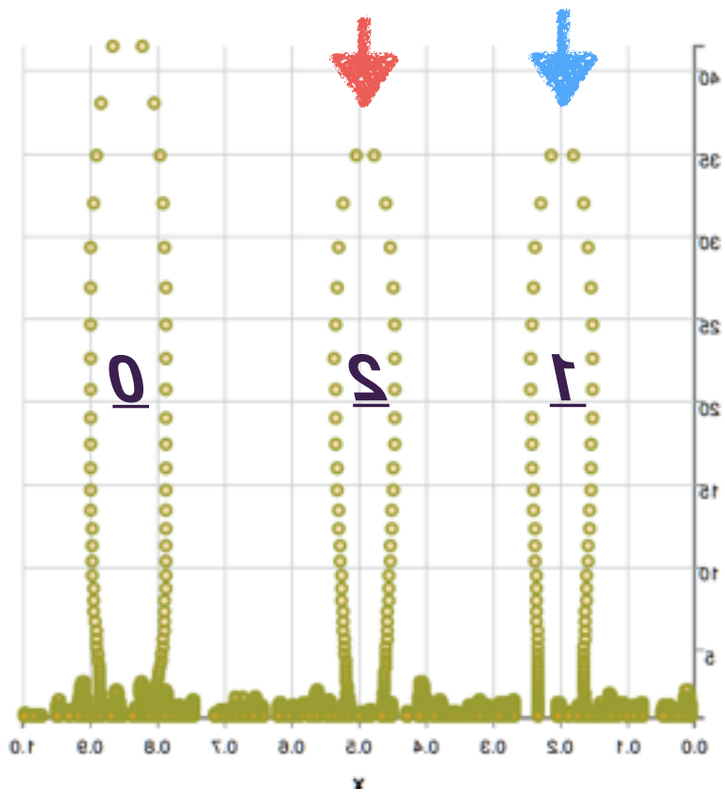
After Refinement

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

coordinate transformation, after matching contours





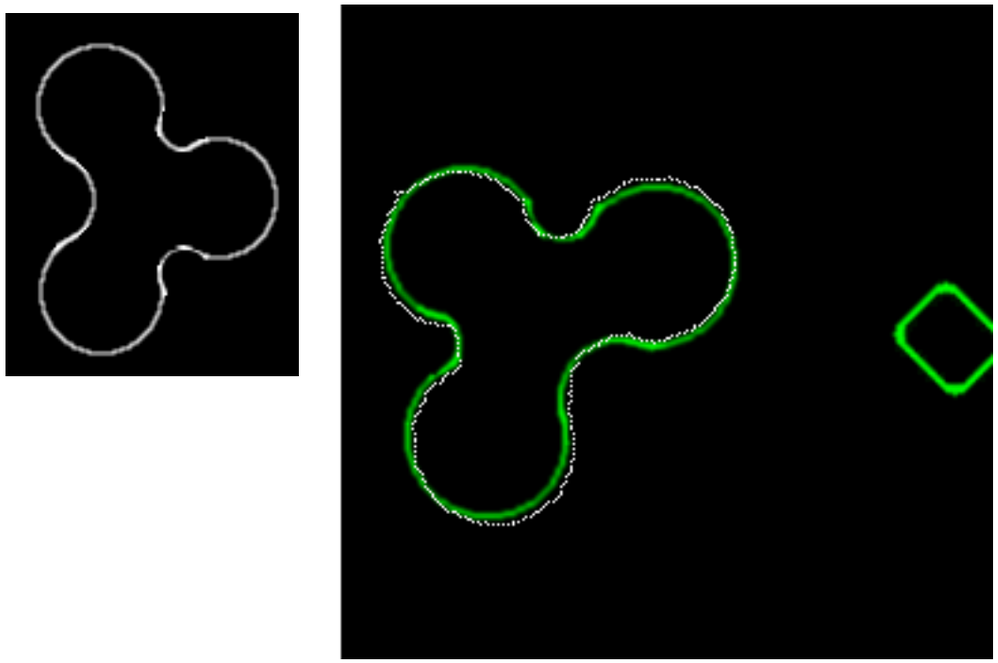


reversed to have CCW ordering

scale should be 1.3
rotation should be 360 - 225

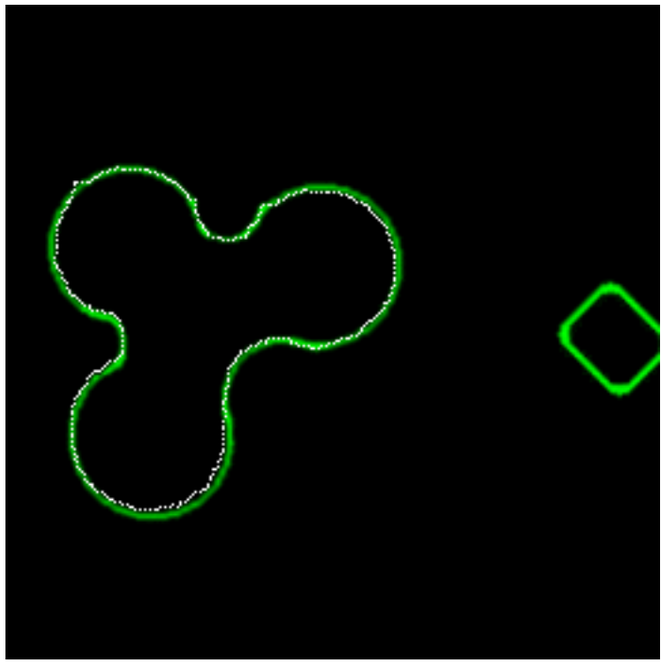
```
Contour matcher solution scale=1.325237512588501
Contour matcher solution shift=-0.5053889751434326
CONTOUR PEAK1: (32.000237, 0.497126) (34, 78) (35, 72) CONTOUR PEAK2: (42.407913, 0.153422) (98, 136) (91, 143)
CONTOUR PEAK1: (26.908875, 0.146552) (70, 93) (61, 99) CONTOUR PEAK2: (34.896511, 0.802428) (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
```

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
```

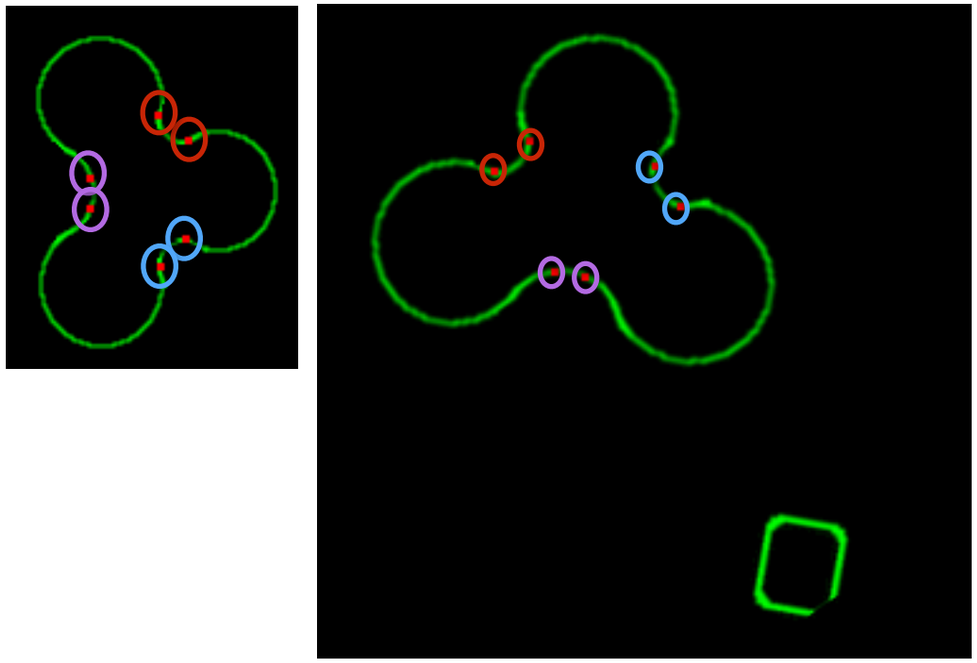
scale should be 1.3
rotation should be 360 - 225

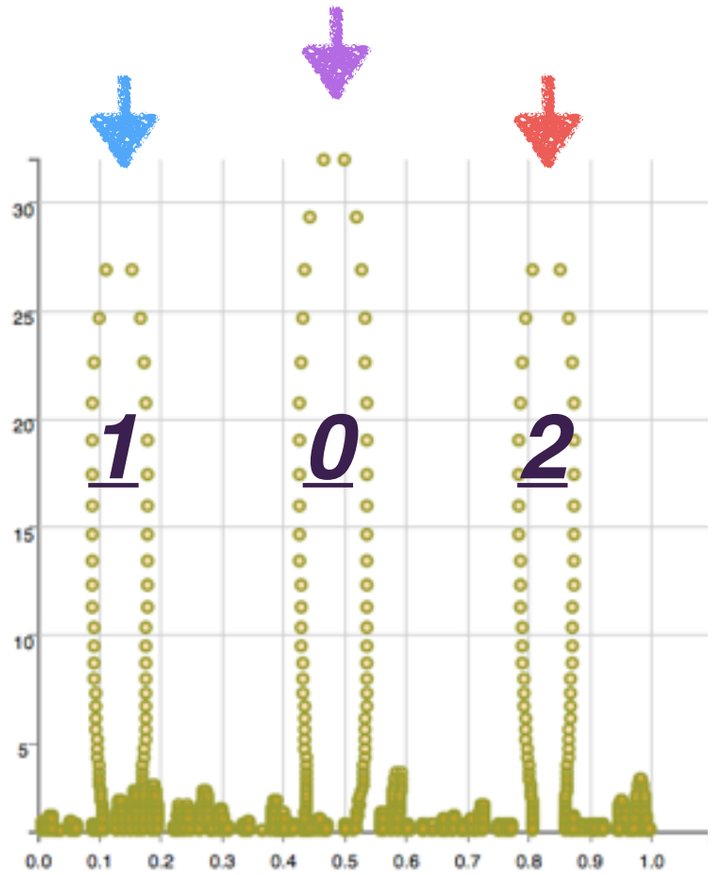


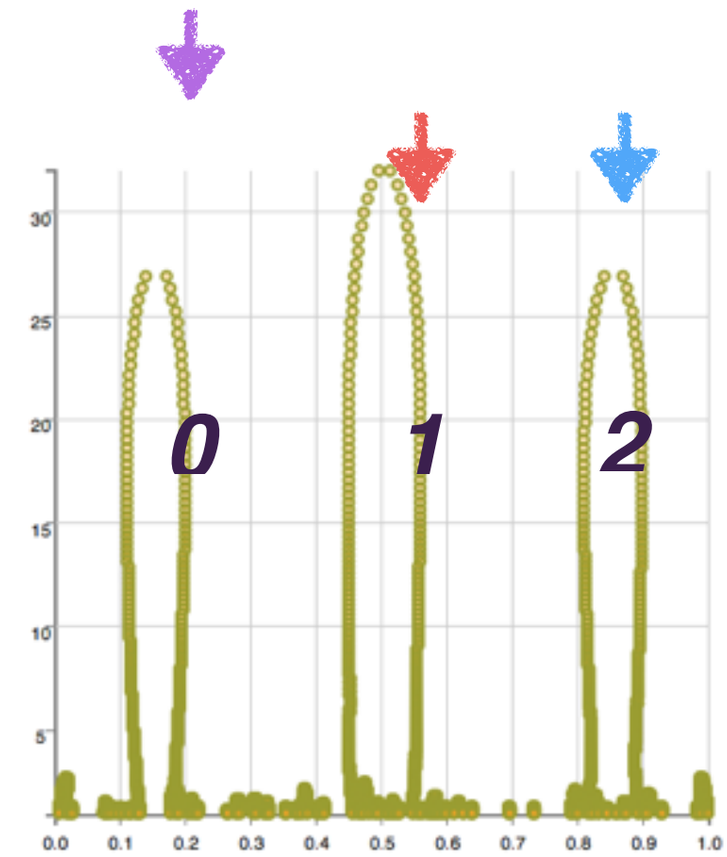
After Refinement

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

coordinate transformation, after matching contours



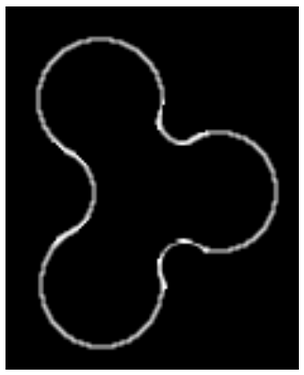


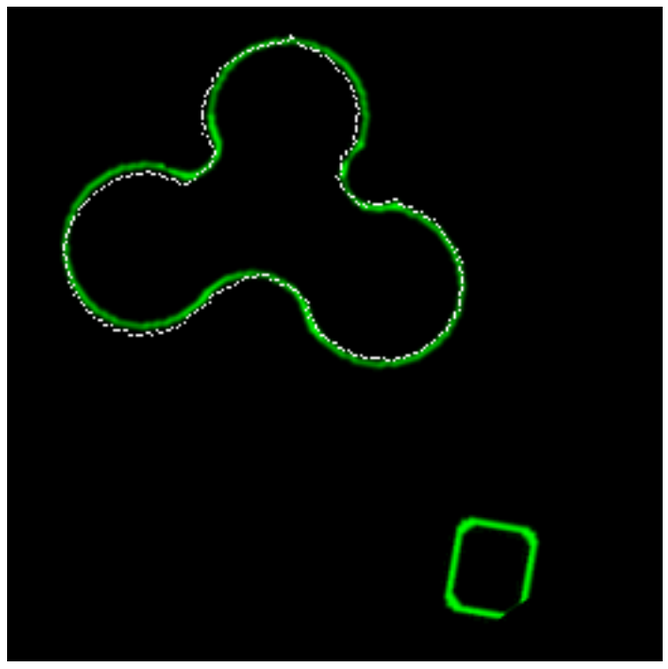


scale should be 1.3
rotation should be 360 - 280

```
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
```

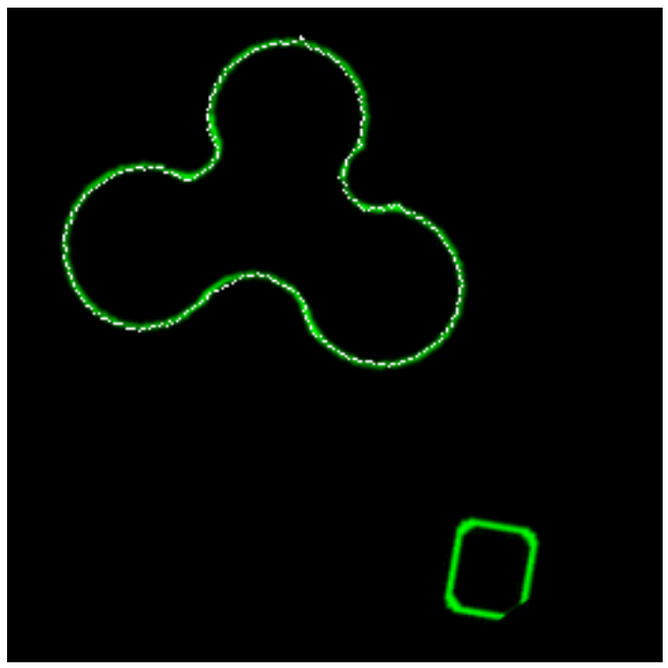
apply coordinate transformation





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

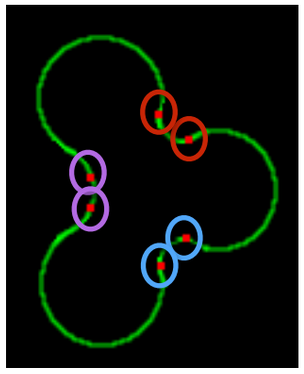
scale should be 1.3
rotation should be 360 - 280

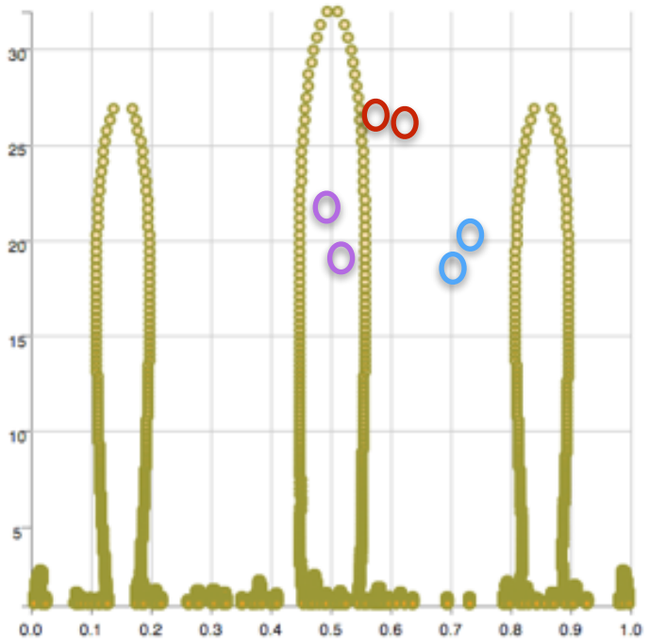


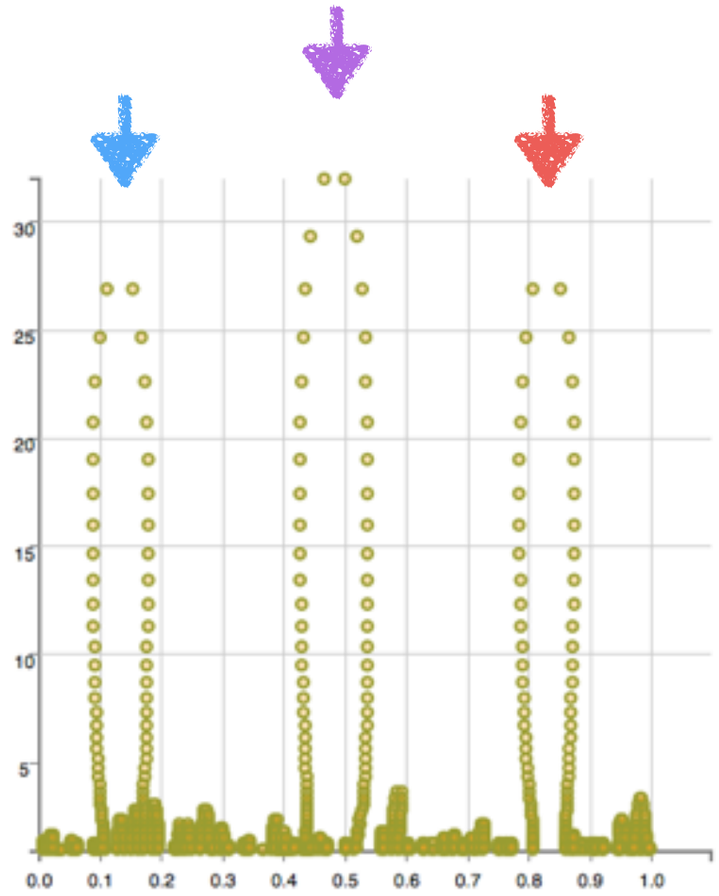
After Refinement

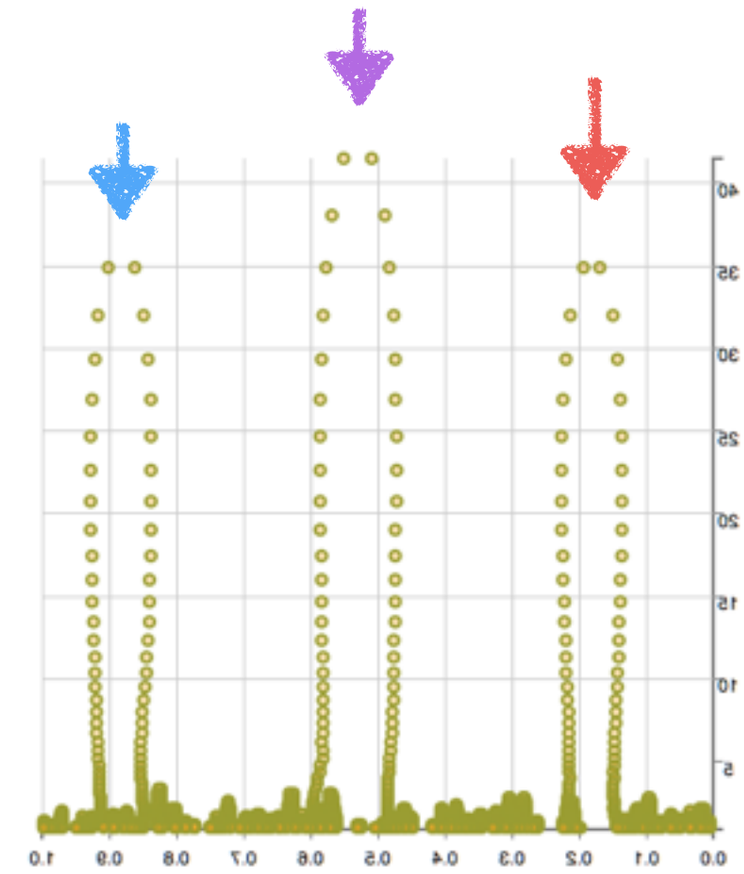
```
rotationInRadians=1.4049724
rotationInDegrees=80.49899080293699
scale=1.2968404
translationX=29.0
translationY=-17.0
```

coordinate transformation, after matching contours





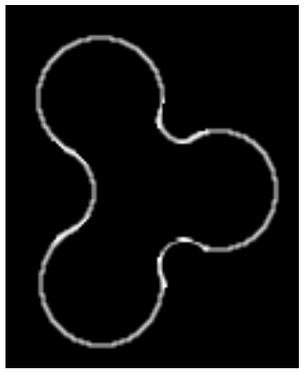


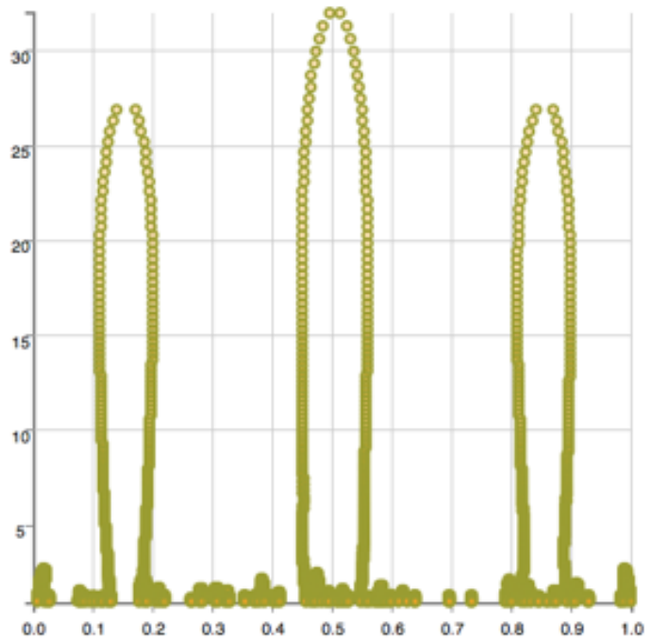


scale should be 1.3
rotation should be 360 - 335

```
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
```

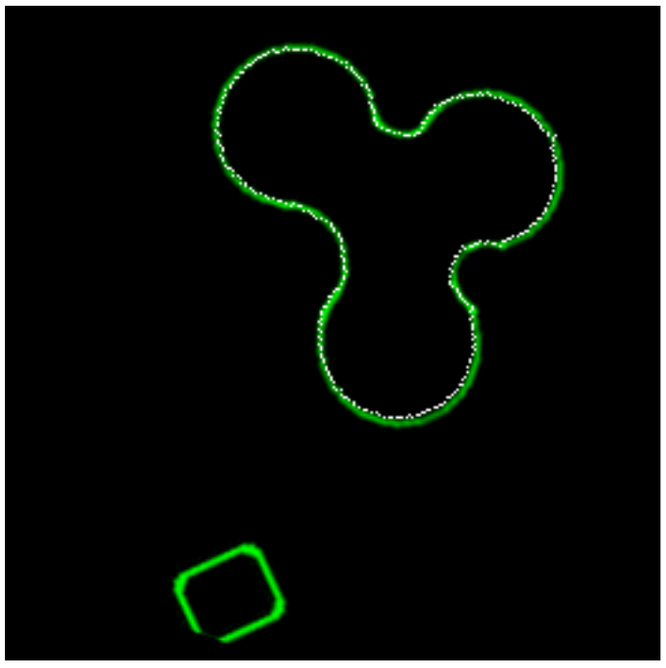
apply coordinate transformation






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

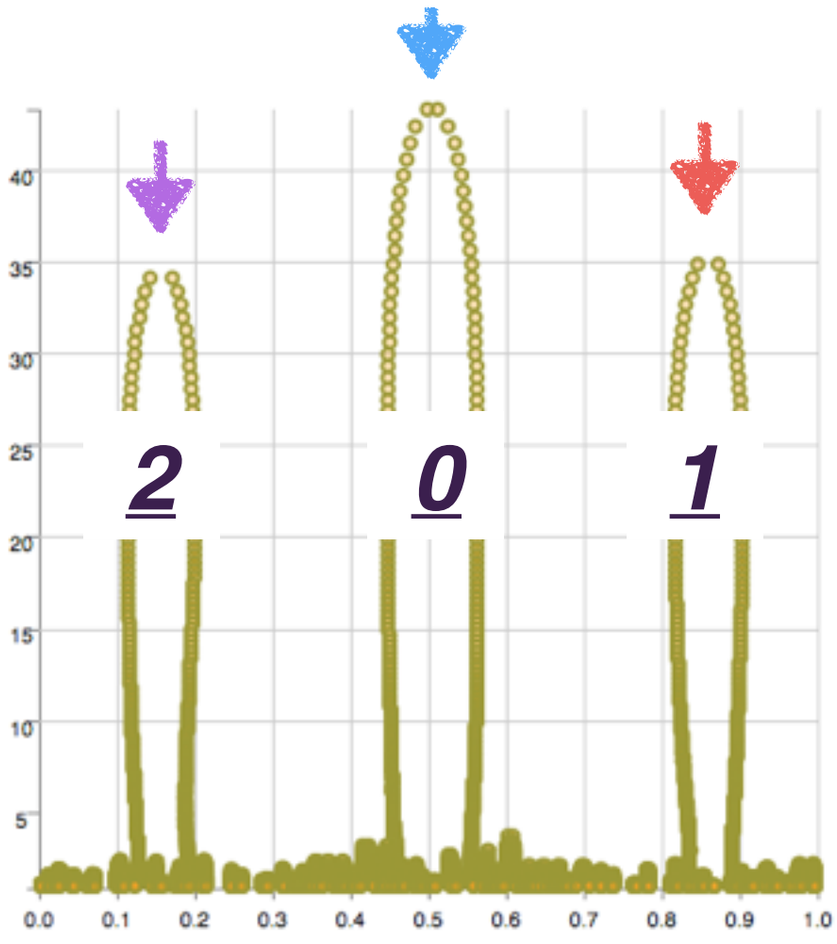
scale should be 1.3
rotation should be 360 - 335

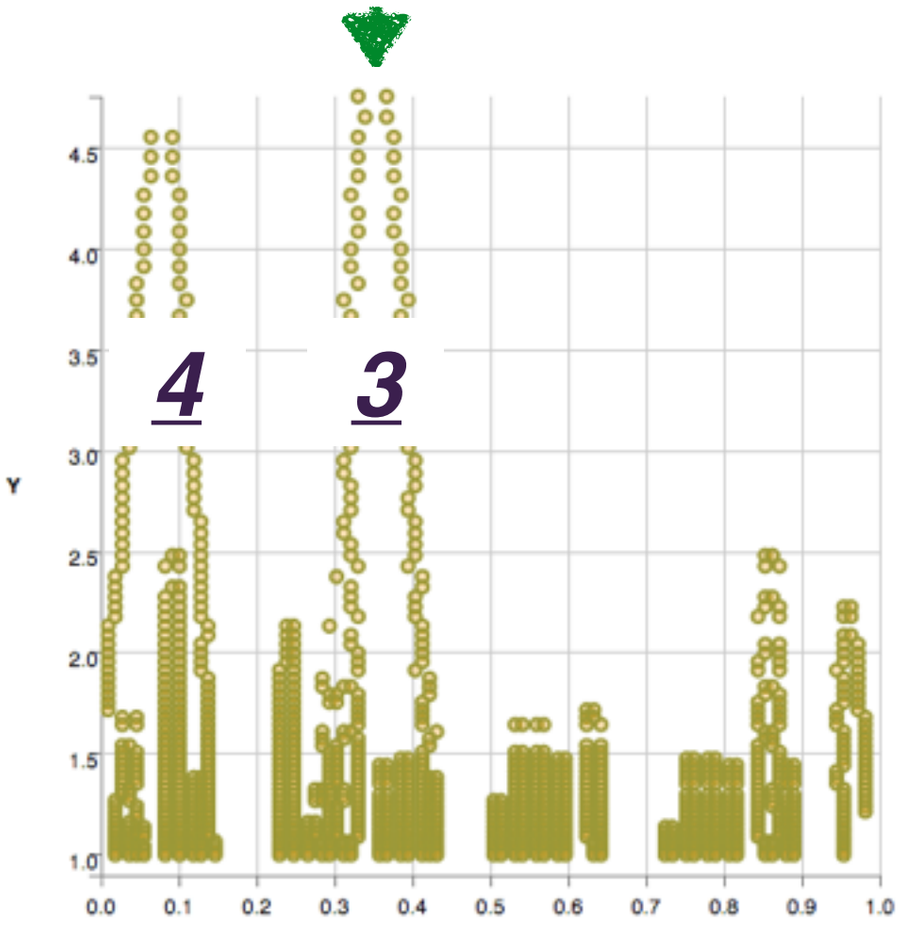


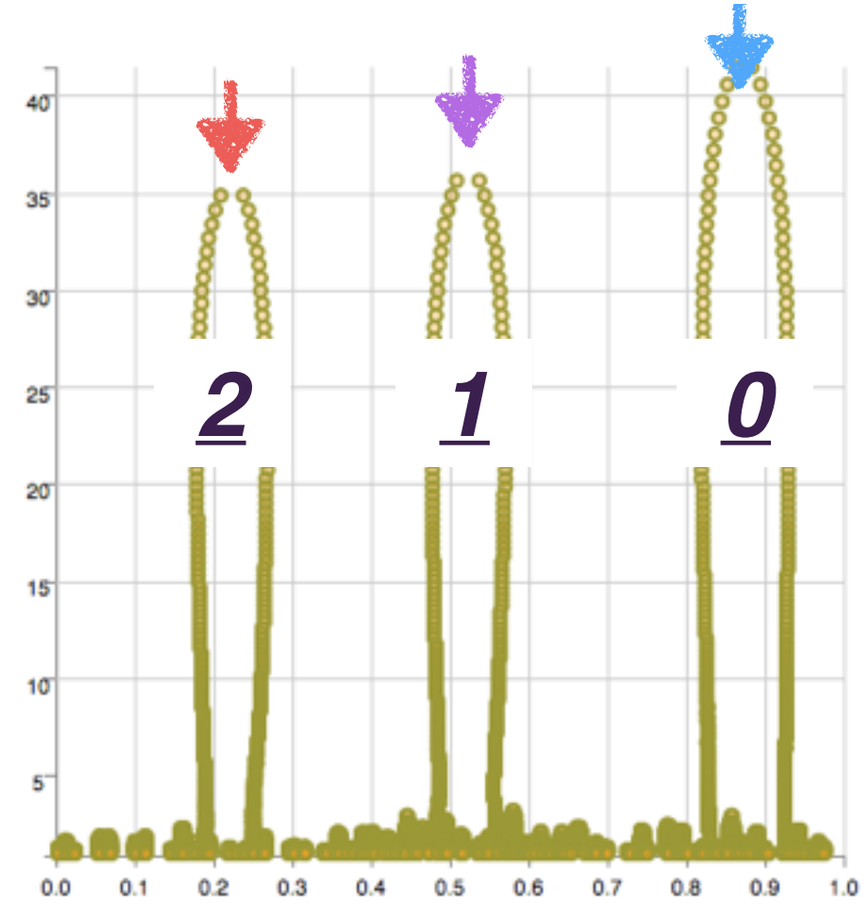
After Refinement

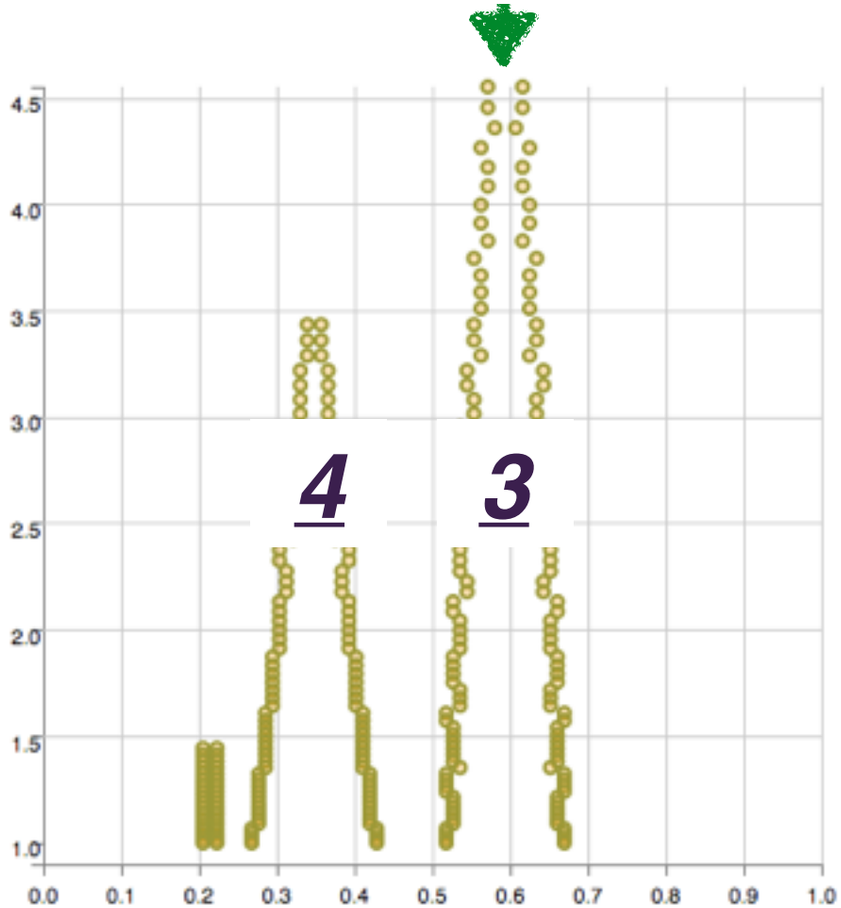
```
rotationInRadians=0.43239865
rotationInDegrees=24.77461754427387
scale=1.2752376
translationX=85.0
translationY=-14.0
```

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