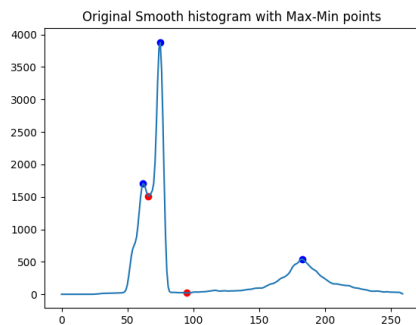


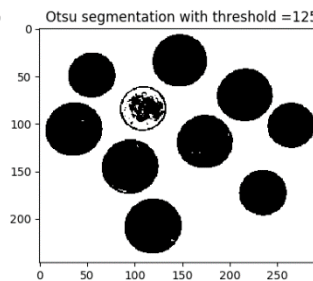
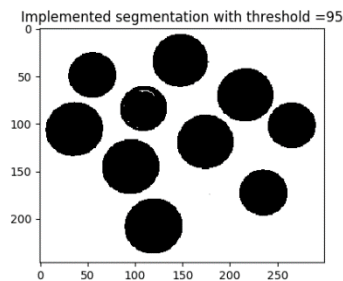
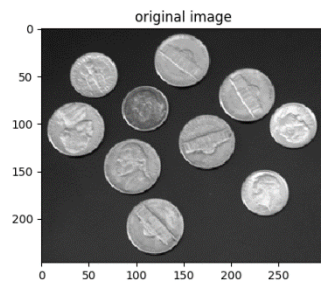
In this project we implemented a simple segmentation algorithm and identify connected components in an image. Then calculated shape features on connected component.

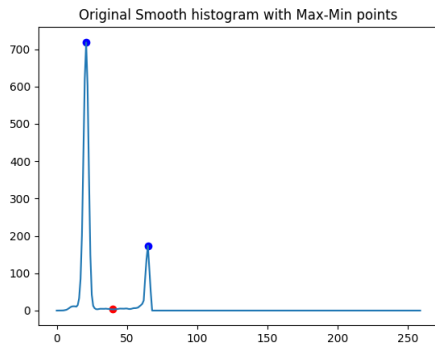
**1) Do the segmentation of the image based on an analysis of the intensities in the image (i.e. create a histogram, decide on a threshold and do the segmentation). Used a simple thresholding strategy to find the valley between two peaks.**

The threshold does 'non-maxima & non-minima' suppression on the histogram. It iterates through the histogram and based on a predetermined value delta (amount of data to compare), it keeps the maximum and minimum values. For our case, we assumed the lowest minima is the threshold value. Histogram was smoothen by using 1D averaging mask :  $(1/9, 2/9, 3/9, 2/9, 1/9)$ . We compared our result with otsu's method.

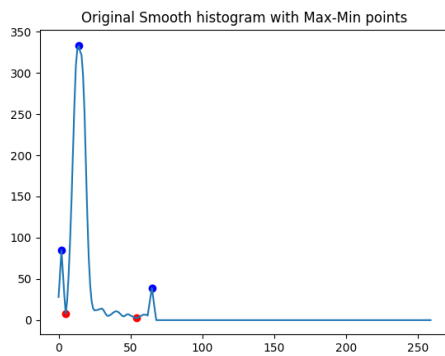
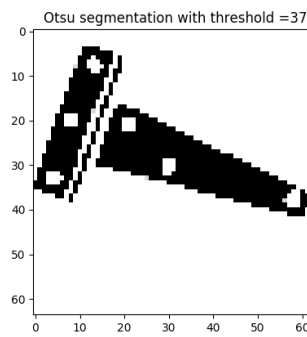
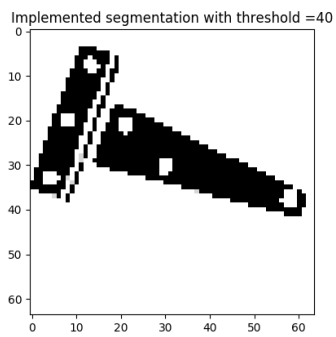
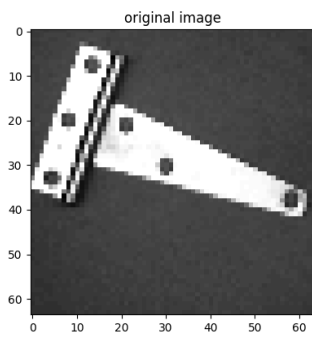


Coins

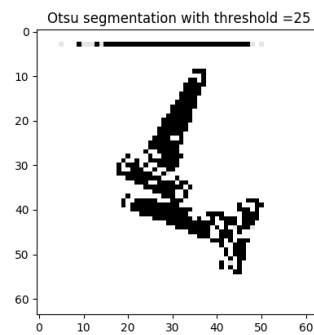
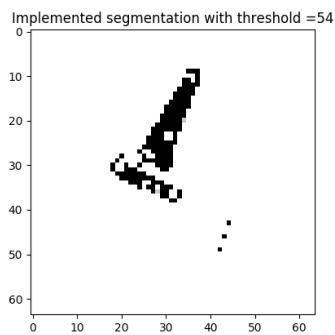
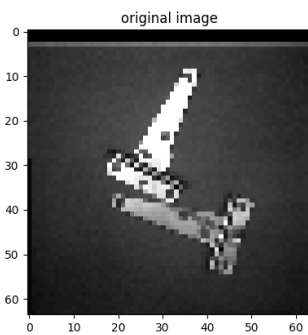


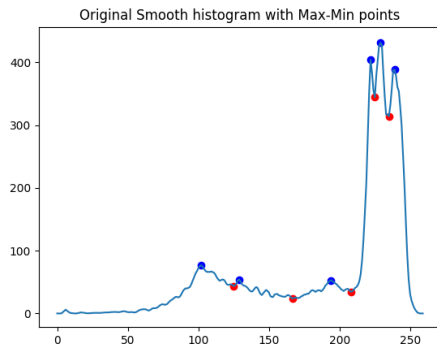


Hinge

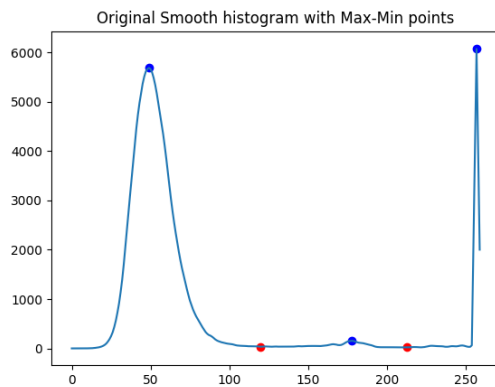
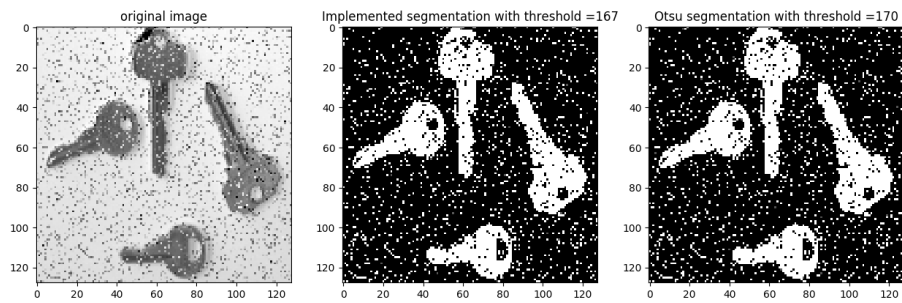


Hinges

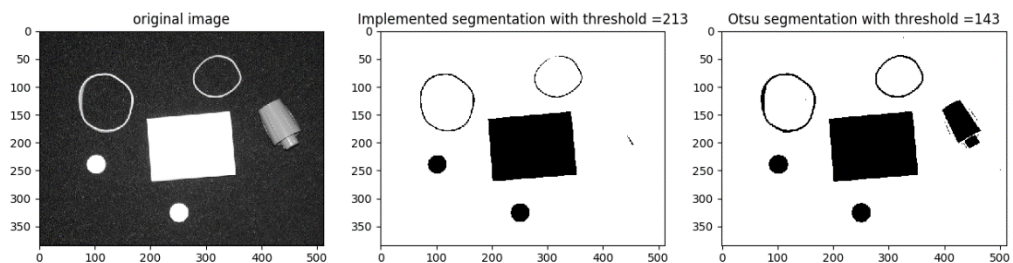


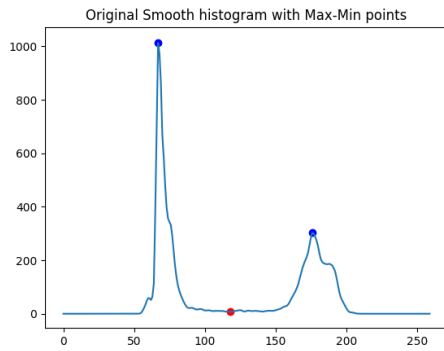


Keys

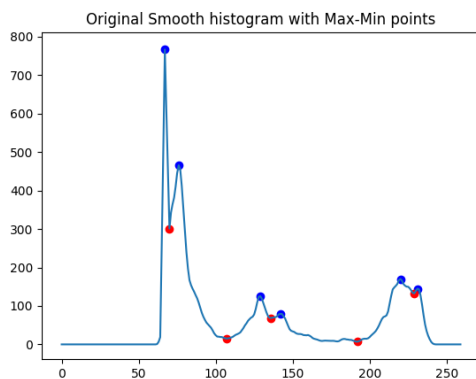
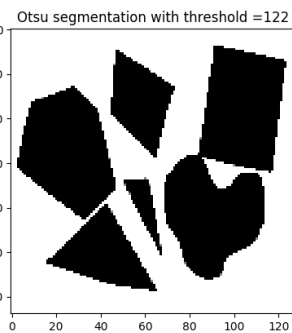
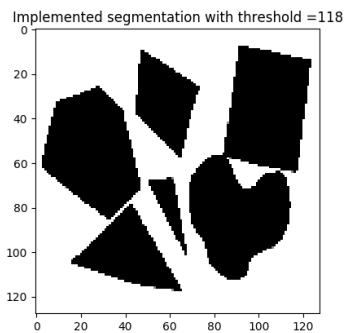
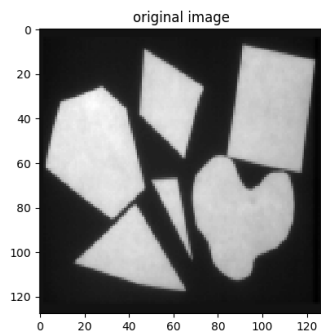


Pill-set

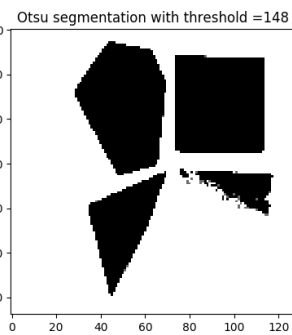
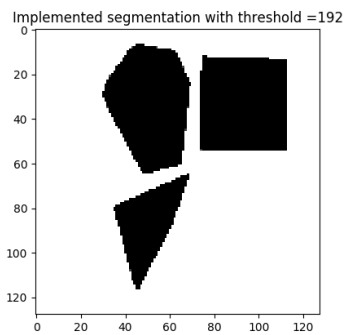
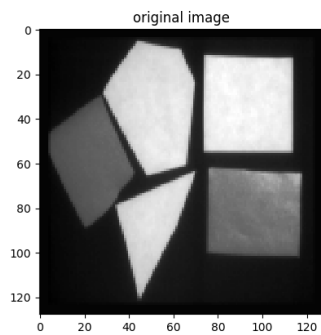


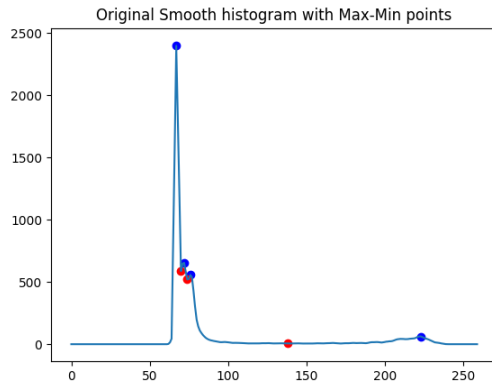


Shapes 1

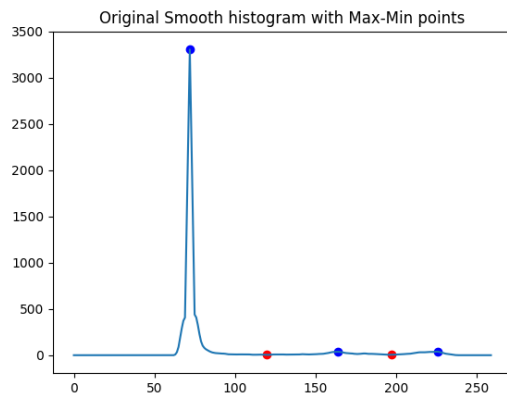
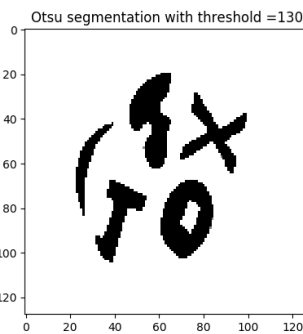
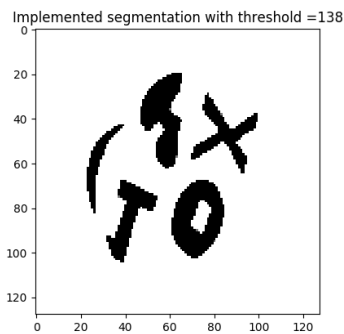
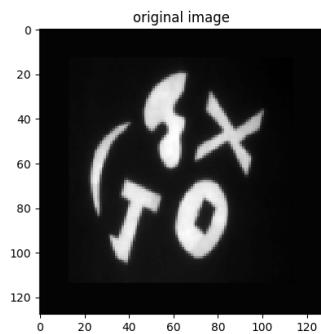


Shapes 2

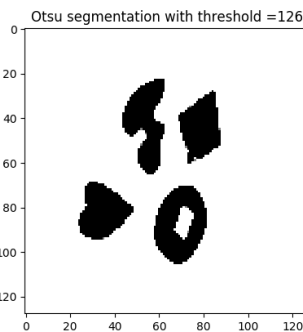
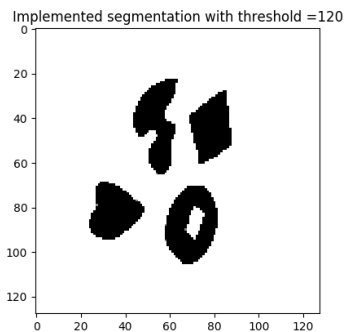
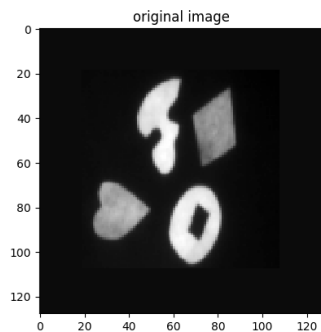




Shapes 3



Shapes 4



### Comments on histogram threshold segmentation:

- 1) Implemented threshold method works well when histogram is bi-modal. For more than two modes Otsu's method performs better. Using a weighted average to determine threshold (threshold value closer to higher peak) may improve the result.
- 2) Even with noisy input segmentation works reasonably well.

### 2) Perform a connected component analysis on the resulting binary image of step 1. Use 4-connected neighbor definition and the algorithm described in class for this.

#### Non-recursive algorithm

- Assume 4-connected neighbors

- **Pass 1:** to color pixel  $x_C$  (whose value =1), examine  $x_U$  (upper neighbor) and  $x_L$  (left neighbor):



- in raster scan pass,  $x_U$  and  $x_L$  are already labeled.

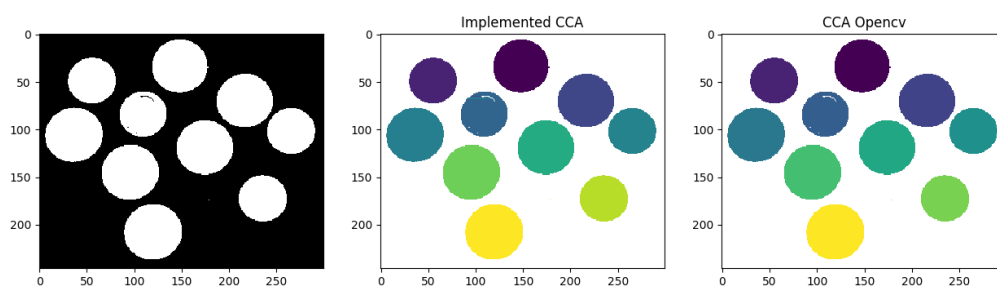
- The label of  $x_C$  is going to be determined by the labels of  $x_U$  and  $x_L$ .

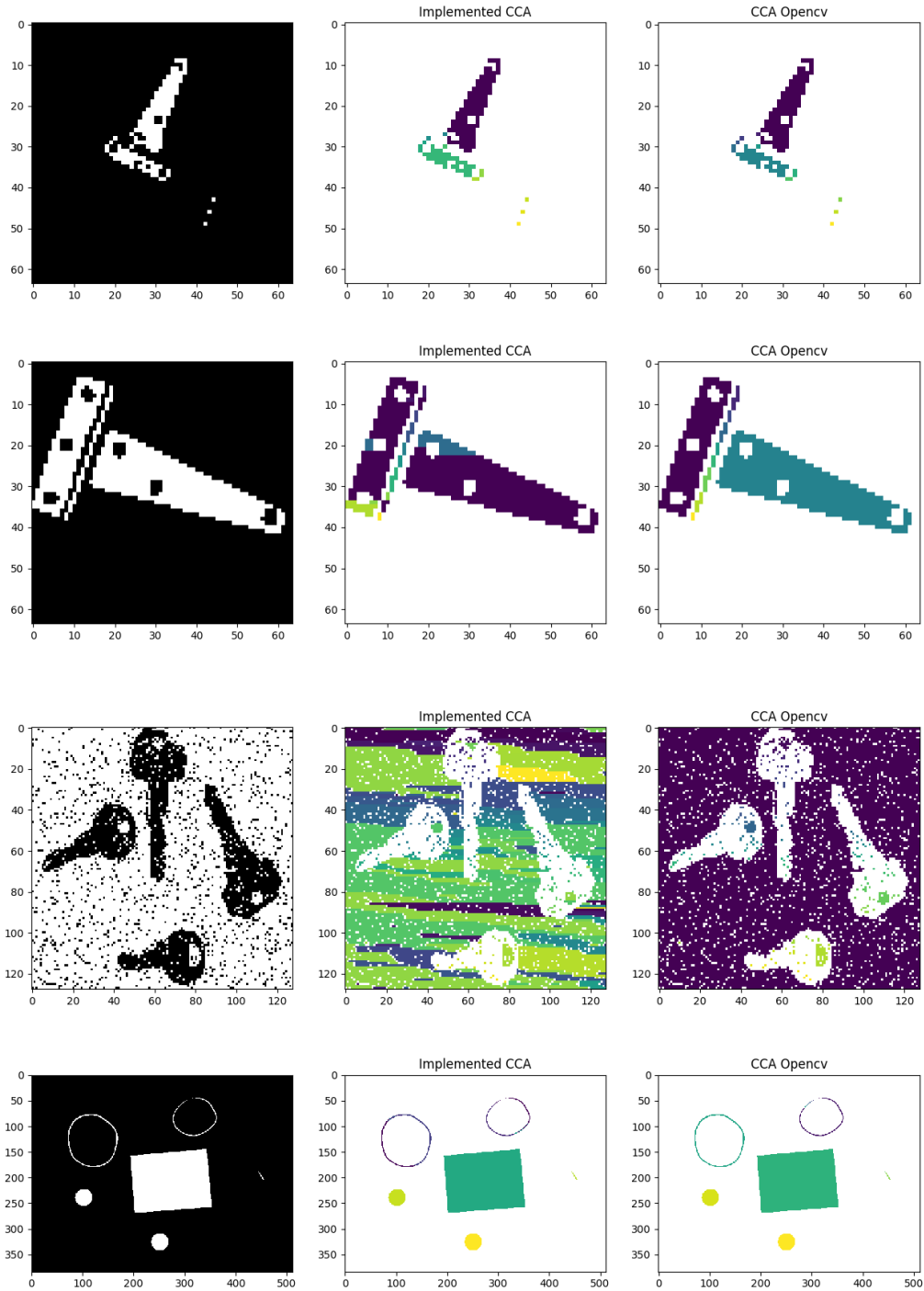
1. If  $x_U = 0$  and  $x_L = 0$  then  $x_C$  gets a new label
2. If  $x_U = 1$  and  $x_L = 0$  then  $\text{color}(x_C) = \text{color}(x_U)$
3. if  $x_U = 0$  and  $x_L = 1$  then  $\text{color}(x_C) = \text{color}(x_L)$
4. If  $x_U = 1$  and  $x_L = 1$  then
  - $\text{color}(x_C) = \text{color}(x_L)$
  - if  $\text{color}(x_L) \neq \text{color}(x_U)$  then mark  $\text{color}(x_L)$  to be equivalent to  $\text{color}(x_U)$ .

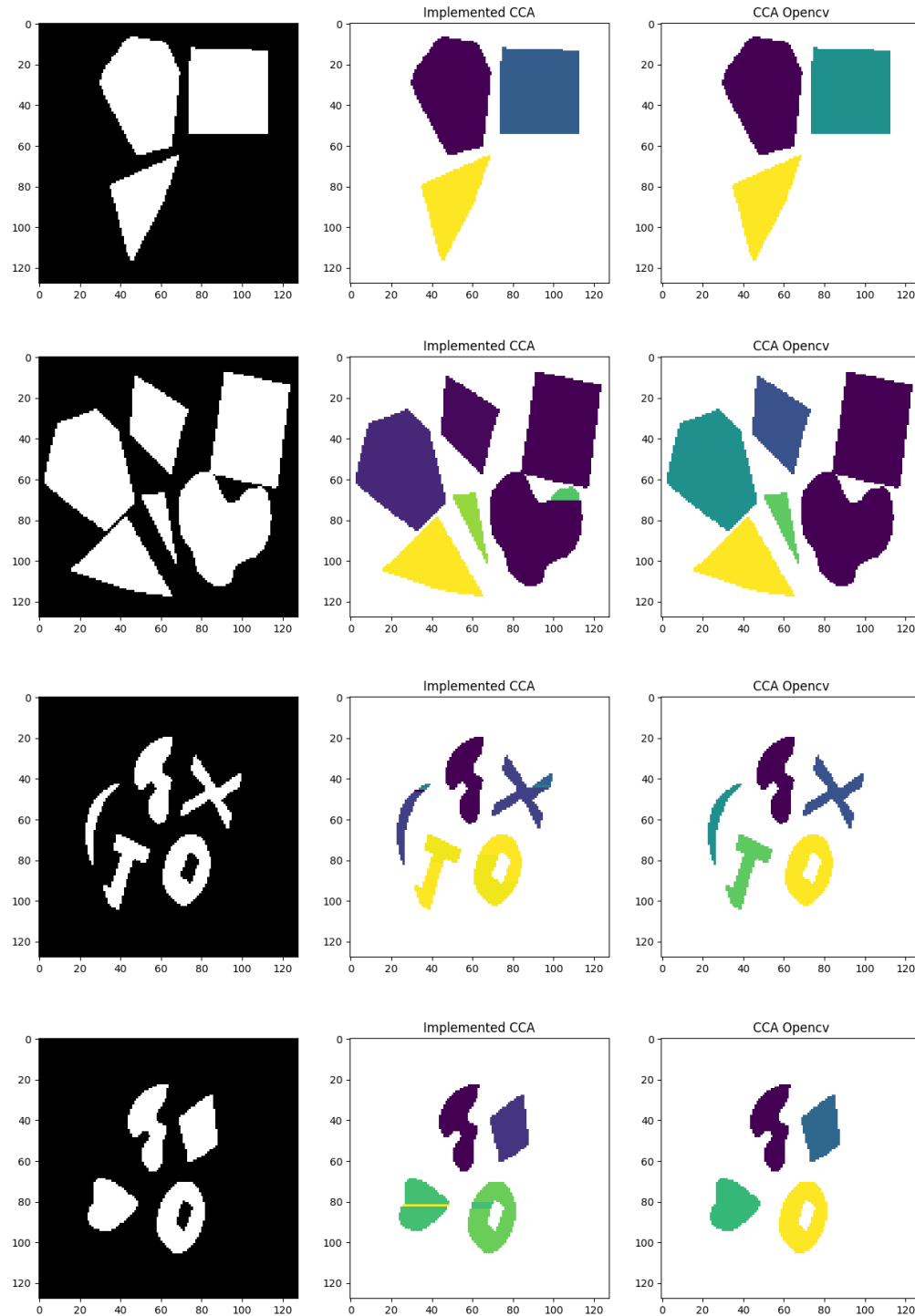
- The marking of equivalence of colors creates equivalence classes. For each class, pick one of the colors to represent the label for that class.

- **Pass 2:**

- do a raster scan and replace each pixel's label by the equivalence class label.







**Comments on CCA:**

- 1) Performs reasonably well. Had a few hiccups when connected-components are really small. Hugely dependent on how good the segmentation is.
- 2) Fails completely for noisy image.
- 3) Can be improved using 8 connected component.



- 3) For each component identified compute some features that will be useful in describing its shape. The features you are to compute are the following:**
- (a) Area, A.**
  - (b) The centroid**
  - (c) Second order moments around the centroid (i.e., central moments).**
  - (d) Perimeter, P**
  - (e) Compactness measure as defined by  $P^2=4\pi A$ .**
  - (f) An elongation measure computed from second order central moments given further below.**

Note that (a)–(c) are zeroth, first, and second order moments of area. As we saw in class, the  $(p+q)$ th moment of a region  $S$  is given by the expression:

$$m_{pq} = \sum_{(x,y) \in S} x^p y^q$$

According to this,  $m_{00} = A$ ,  $\bar{x} = m_{10}/m_{00}$ , and  $\bar{y} = m_{01}/m_{00}$ . Once you have the centroid  $(\bar{x}, \bar{y})$ , then the second order central moments are computed as

$$\mu_{pq} = \sum_{(x,y) \in S} (x - \bar{x})^p (y - \bar{y})^q, \quad \text{for } p + q = 2$$

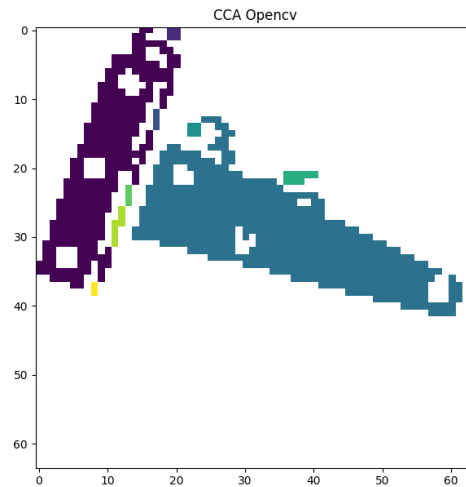
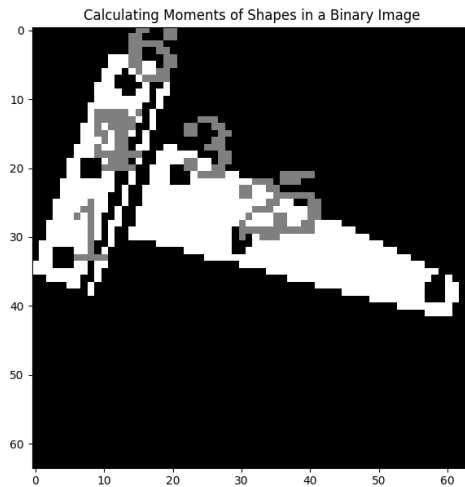
The scale invariant second order central moments are obtained from this by:

$$\mu'_{pq} = \mu_{pq} / m_{00}^{\gamma}$$

where  $\gamma = \frac{p+q}{2} + 1$ , which in the case of second order moments (i.e.,  $p + q = 2$ ) would be  $\gamma = 2$ .

The elongation measure from  $\mu_{pq}$  are computed as follows:

$$elong = \sqrt{\frac{\sqrt{(\mu'_{20} - \mu'_{02})^2 + 4(\mu'_{11})^2}}{\mu'_{20} + \mu'_{02} + \sqrt{(\mu'_{20} - \mu'_{02})^2 + 4(\mu'_{11})^2}}}$$



## Hinge

Shapes found : 7

### Moments for shape 1

Center (4, 33)

Area 15.0

mu20 0.0924609053497943

mu02 0.07037037037036498

mu11 0.0

Perimeter 14.485281229019165

Compactness 1.1131475625057927

Elongation 0.3456281033549841

### Moments for shape 2

Center (29, 30)

Area 16.5

mu20 0.06689793558481294

mu02 0.09906533965303758

mu11 -0.011614461109408626

Perimeter 15.071067690849304

Compactness 1.0954542198506352

Elongation 0.43925699520732503

### Moments for shape 3

Center (21, 21)

Area 14.0

mu20 0.07993197278911254

mu02 0.07993197278911254

mu11 0.0

Perimeter 13.656854152679443

Compactness 1.0601405419456786

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Elogation 0.0

**Moments for shape 4**

Center (8, 20)

Area 14.0

mu20 0.07993197278911544

mu02 0.07993197278911254

mu11 0.0

Perimeter 13.656854152679443

Compactness 1.0601405419456786

Elongation 1.34702058990622e-07

**Moments for shape 5**

Center (34, 29)

Area 429.0

mu20 0.3165492388192763

mu02 0.06153080007547224

mu11 0.10772035328248326

Perimeter 130.56854152679443

Compactness 3.1623501094884925

Elongation 0.6847839213842148

**Moments for shape 6**

Center (13, 7)

Area 14.5

mu20 0.08348481328103453

mu02 0.08348481328103291

mu11 0.015009043238983118

Perimeter 14.727921724319458

Compactness 1.190433304090277

Elongation 0.39036595373421723

**Moments for shape 7**

Center (8, 20)

Area 219.5

mu20 0.06455352711255433

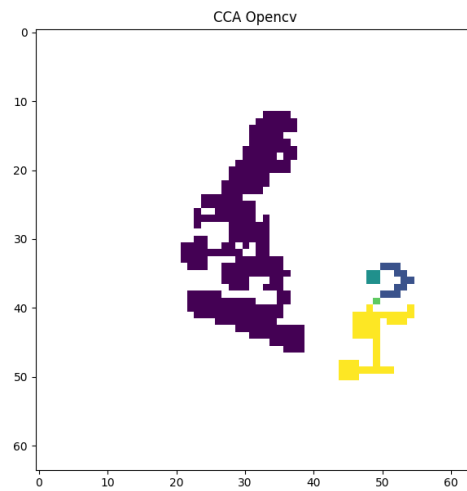
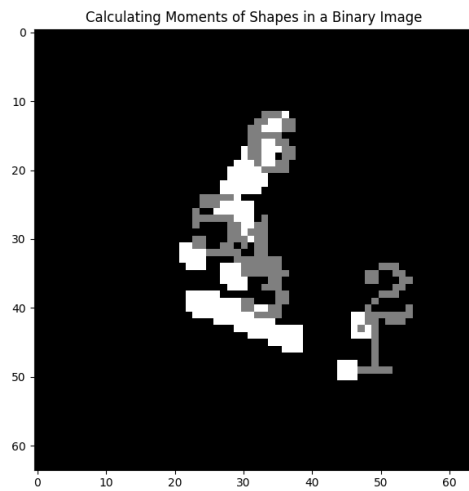
mu02 0.381429839594161

mu11 -0.1298157128515137

Perimeter 161.29646337032318

Compactness 9.432032780832376

Elongation 0.6919339352739294



## Hinges

Shapes found : 6

### Moments for shape 1

Center (45, 49)

Area 4.0

mu20 0.083333333333331439

mu02 0.083333333333325754

mu11 0.0

Perimeter 8.0

Compactness 1.2732395447351628

Elongation 5.840038639982836e-07

### Moments for shape 2

Center (47, 42)

Area 6.0

mu20 0.055555555555555555

mu02 0.125

mu11 0.0

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Perimeter 10.0

Compactness 1.3262911924324612

Elongation 0.5270462766947299

### **Moments for shape 3**

Center (29, 41)

Area 53.0

mu20 0.3549259157261092

mu02 0.07394676291316539

mu11 0.13570225383669052

Perimeter 42.14213538169861

Compactness 2.666535330355995

Elongation 0.6904214424357934

### **Moments for shape 4**

Center (28, 35)

Area 8.5

mu20 0.08306759843500258

mu02 0.08306759843502777

mu11 0.009781305832620373

Perimeter 11.41421353816986

Compactness 1.2197285698954283

Elongation 0.32457123474029603

### **Moments for shape 5**

Center (22, 32)

Area 8.0

mu20 0.0833333333333286

mu02 0.08333333333331439

mu11 0.020833333333328596

Perimeter 10.828427076339722

Compactness 1.1663553915641325

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Elongation 0.44721359549994266

### Moments for shape 6

Center (30, 20)

Area 74.5

mu20 0.07548876962734336

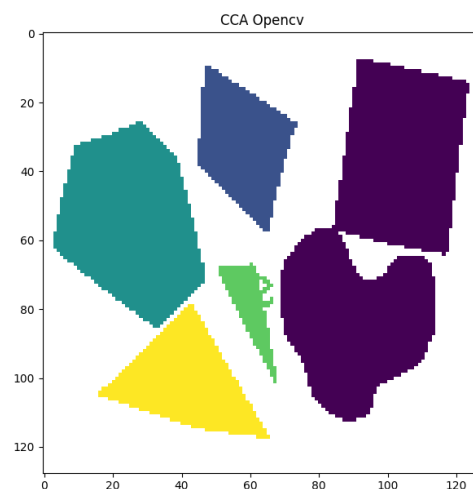
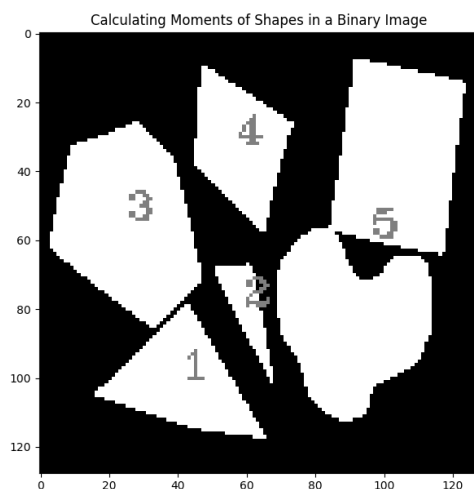
mu02 0.30706401794922183

mu11 -0.11628801814457725

Perimeter 51.21320307254791

Compactness 2.801545895242355

Elongation 0.6795350841613619



### Shapes 1

Shapes found : 5

### Moments for shape 1

Center (41, 100)

Area 856.5

mu20 0.11653354147302813

mu02 0.08105050376576435

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mu11 0.025920526449833337

Perimeter 139.43859779834747

Compactness 1.8064618003059207

Elongation 0.4911668348129967

### **Moments for shape 2**

Center (59, 79)

Area 186.0

mu20 0.06559001562048403

mu02 0.3230516045045239

mu11 0.11014396523489618

Perimeter 85.94112491607666

Compactness 3.1599430805213626

Elongation 0.6824748876852494

### **Moments for shape 3**

Center (25, 54)

Area 1682.5

mu20 0.06234203128393855

mu02 0.11185961903111974

mu11 0.018641056473586822

Perimeter 164.752308011055

Compactness 1.283802088139468

Elongation 0.5122849663628394

### **Moments for shape 4**

Center (57, 32)

Area 764.5

mu20 0.058384659146493496

mu02 0.13360388899162987

mu11 0.026361193858997652

Perimeter 123.63961005210876

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Compactness 1.5912114659528842

Elongation 0.568871256711881

### Moments for shape 5

Center (96, 59)

Area 3233.0

mu20 0.04878339487946385

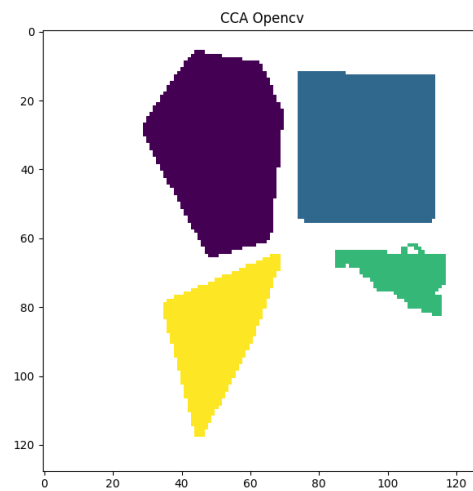
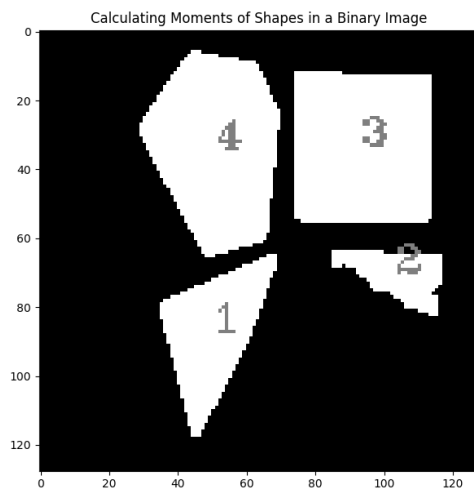
mu02 0.2317225117492772

mu11 -0.05093551814399461

Perimeter 348.4507908821106

Compactness 2.9885968923763135

Elongation 0.6537721658502534



### Shapes 2

Shapes found : 4

### Moments for shape 1

Center (50, 87)

Area 834.5

mu20 0.06707204526621012



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mu02 0.15924019666868128

mu11 -0.04635727152363894

Perimeter 143.63960921764374

Compactness 1.9674886007161685

Elongation 0.6051044317389114

### **Moments for shape 2**

Center (103, 70)

Area 318.0

mu20 0.19216250694395964

mu02 0.06068018653424445

mu11 0.05168527605065089

Perimeter 93.4558435678482

Compactness 2.18562646063281

Elongation 0.6309743262131283

### **Moments for shape 3**

Center (93, 33)

Area 1649.5

mu20 0.07692135635636713

mu02 0.09045329197659385

mu11 0.0014876262338956764

Perimeter 162.24264061450958

Compactness 1.2698950444077444

Elongation 0.27649732315653414

### **Moments for shape 4**

Center (51, 34)

Area 1660.5

mu20 0.05273832134644186

mu02 0.1277034634668004

mu11 0.010041271971969409

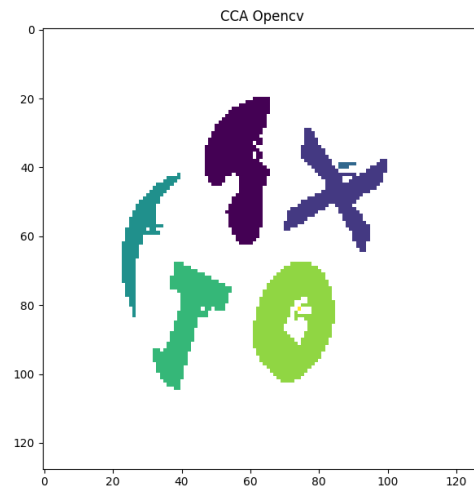
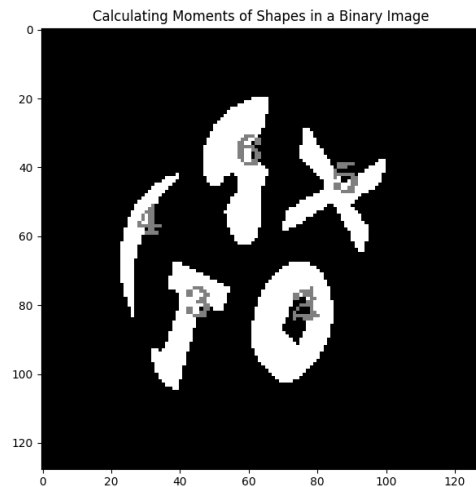
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Perimeter 166.95331728458405

Compactness 1.3357997610872205

Elongation 0.5484063773544917



### Shapes 3

Shapes found : 6

#### Moments for shape 1

Center (74, 83)

Area 89.5

mu20 0.04974029337139461

mu02 0.15186921722403277

mu11 -0.026523618646497275

Perimeter 40.870057225227356

Compactness 1.4851748705293828

Elongation 0.6028203280519302

#### Moments for shape 2

Center (72, 84)

Area 581.5

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mu20 0.05465431303756504

mu02 0.12072635385186561

mu11 -0.01550350664704495

Perimeter 93.49747347831726

Compactness 1.196300178837077

Elongation 0.5420920394575374

### **Moments for shape 3**

Center (41, 83)

Area 281.0

mu20 0.07927968819880238

mu02 0.3404572898326445

mu11 -0.10322314068996494

Perimeter 107.25483322143555

Compactness 3.257748547835472

Elongation 0.6650745787419455

### **Moments for shape 4**

Center (27, 59)

Area 132.5

mu20 0.09835216991207504

mu02 0.680352505759786

mu11 -0.213478822562699

Perimeter 97.0121921300888

Compactness 5.652321992970494

Elongation 0.6935729383142425

### **Moments for shape 5**

Center (84, 47)

Area 283.5

mu20 0.18006171736528814

mu02 0.19947674132340198

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mu11 0.028891142463085783

Perimeter 145.0954531431198

Compactness 5.909417569821299

Elongation 0.37199796594248563

### Moments for shape 6

Center (56, 39)

Area 438.0

mu20 0.0419733513502555

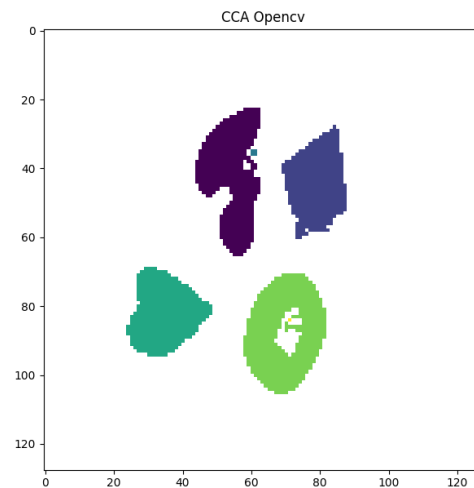
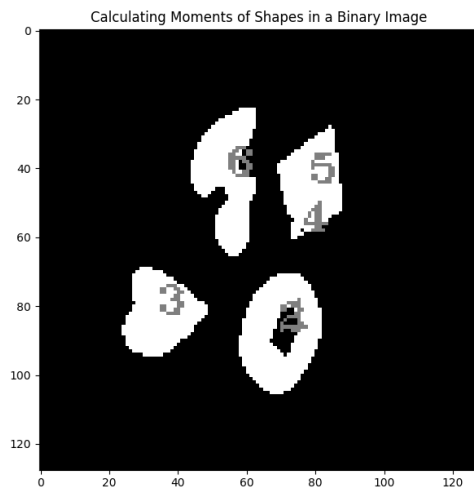
mu02 0.2716838206849555

mu11 0.009450749748249726

Perimeter 122.56854152679443

Compactness 2.729443207258434

Elongation 0.6508278361917369



### Shapes 4

Shapes found : 6

### Moments for shape 1

Center (71, 86)

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Area 91.5

mu20 0.04889147644073012

mu02 0.14993958178875486

mu11 -0.02357470575979148

Perimeter 40.870057225227356

Compactness 1.4527120318292872

Elongation 0.5994230095482433

### **Moments for shape 2**

Center (69, 87)

Area 586.0

mu20 0.05399598443794238

mu02 0.12179736695110192

mu11 -0.014708469488715313

Perimeter 94.08326029777527

Compactness 1.2020353435166935

Elongation 0.5440454180438618

### **Moments for shape 3**

Center (34, 82)

Area 391.5

mu20 0.07613985504858706

mu02 0.09571085049360943

mu11 -0.005589647039743871

Perimeter 80.6690468788147

Compactness 1.3227330985754109

Elongation 0.3405097479394655

### **Moments for shape 4**

Center (76, 58)

Area 2.0

mu20 0.08333333333303017

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mu02 0.08333333333325754

mu11 0.0

Perimeter 5.656854152679443

Compactness 1.2732395011540298

Elongation 1.1680077279969655e-06

#### **Moments for shape 5**

Center (78, 44)

Area 371.0

mu20 0.05129253946192563

mu02 0.13883208743405748

mu11 -0.012209518409848723

Perimeter 85.59797871112823

Compactness 1.5716044336209243

Elongation 0.5686957466131558

#### **Moments for shape 6**

Center (54, 42)

Area 439.0

mu20 0.041876077433748264

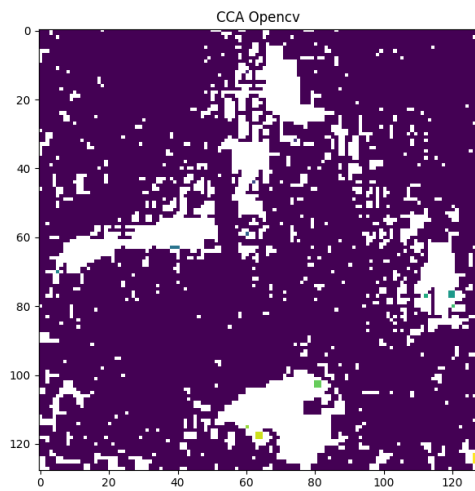
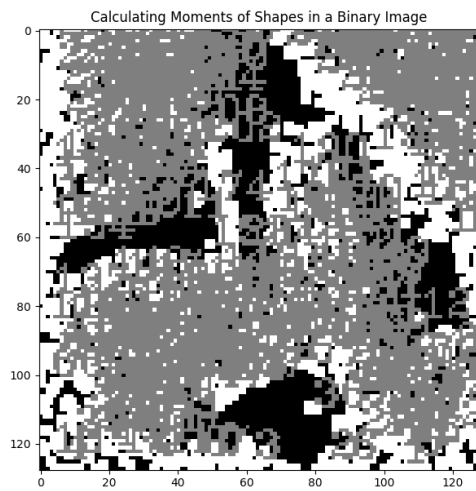
mu02 0.2685821867531959

mu11 0.01013871342052501

Perimeter 120.56854128837585

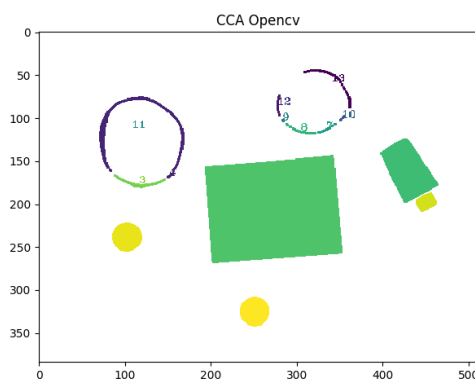
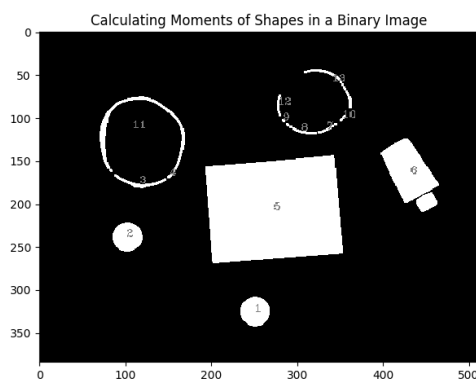
Compactness 2.6350789330005417

Elongation 0.6503956256888345



## Keys

Shapes found : 284



## Pillset

Shapes found : 13

## Moments for shape 1

Center (250, 325)

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Area 883.0

mu20 0.07880401896902389

mu02 0.08044541799648638

mu11 -0.00010377633795292489

Perimeter 110.56854128837585

Compactness 1.101774185127508

Elongation 0.1014018949884407

### **Moments for shape 2**

Center (101, 238)

Area 876.5

mu20 0.0822077949805792

mu02 0.07711873561468441

mu11 -0.0003952902596230656

Perimeter 111.15432798862457

Compactness 1.1217368067699638

Elongation 0.17695212454534823

### **Moments for shape 3**

Center (116, 176)

Area 180.0

mu20 1.4554869684499234

mu02 0.07213944139614425

mu11 0.1307041609510607

Perimeter 141.39696836471558

Compactness 8.838891990326646

Elongation 0.6925278963588497

### **Moments for shape 4**

Center (151, 167)

Area 16.0

mu20 0.10677083333325754



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mu02 0.10677083333325754

mu11 -0.0703125

Perimeter 16.485280990600586

Compactness 1.3516456823486132

Elongation 0.6301260378127392

#### **Moments for shape 5**

Center (272, 207)

Area 16935.0

mu20 0.11129332545190648

mu02 0.06264400827132761

mu11 -0.004019906060930999

Perimeter 542.2253956794739

Compactness 1.3815437538482163

Elongation 0.4699715049596495

#### **Moments for shape 6**

Center (431, 165)

Area 3032.5

mu20 0.07353051422228996

mu02 0.13412960683422218

mu11 0.053906740034797423

Perimeter 301.2619730234146

Compactness 2.3816501057599724

Elongation 0.6109552581390368

#### **Moments for shape 7**

Center (334, 113)

Area 43.0

mu20 0.7986445637906383

mu02 0.1921979616049968

mu11 -0.37683159973333336

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Perimeter 55.79898953437805

Compactness 5.762014530143648

Elongation 0.7028542559908323

### **Moments for shape 8**

Center (304, 115)

Area 75.0

mu20 1.3303857777775991

mu02 0.13726281481480435

mu11 0.38352059259257393

Perimeter 84.62741661071777

Compactness 7.598905429936884

Elongation 0.7010492522283689

### **Moments for shape 9**

Center (283, 103)

Area 8.0

mu20 0.08333333333212067

mu02 0.0833333333325754

mu11 0.02083333333303017

Perimeter 10.828427076339722

Compactness 1.1663553915641325

Elongation 0.44721359549873774

### **Moments for shape 10**

Center (352, 100)

Area 21.0

mu20 0.17681675844946176

mu02 0.17681675844939576

mu11 -0.15206241226636816

Perimeter 23.313708305358887

Compactness 2.0596506252295748

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Elongation 0.6799746990863849

### **Moments for shape 11**

Center (108, 112)

Area 711.0

mu20 1.971504017075397

mu02 0.8554490191009586

mu11 -0.0776725458744071

Perimeter 489.3036046028137

Compactness 26.79645636200784

Elongation 0.5338517173224004

### **Moments for shape 12**

Center (277, 85)

Area 49.0

mu20 0.01892706270375037

mu02 1.000468908929662

mu11 0.0006452810194968604

Perimeter 55.31370830535889

Compactness 4.968892558940523

Elongation 0.7003864077227889

### **Moments for shape 13**

Center (340, 58)

Area 162.0

mu20 1.6583154926887338

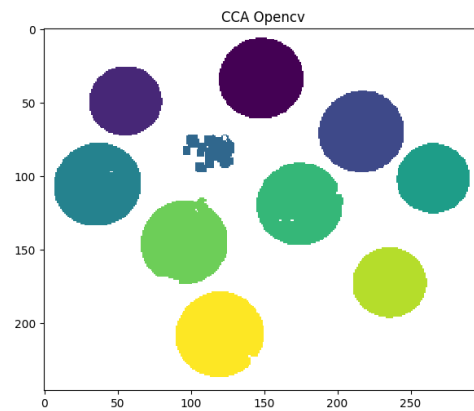
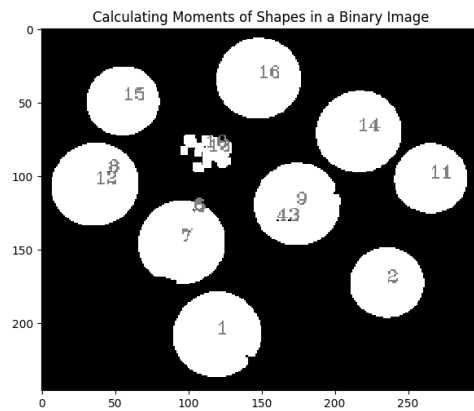
mu02 1.193104396819215

mu11 1.2244227839967186

Perimeter 177.39696836471558

Compactness 15.458505640164486

Elongation 0.6829583699121953



## Coins

Shapes found : 16

### Moments for shape 1

Center (119, 207)

Area 2651.5

mu20 0.08236710326422093

mu02 0.07729340619427144

mu11 -0.0027821620816834867

Perimeter 199.9238806962967

Compactness 1.1995762286372873

Elongation 0.2122254869228236

### Moments for shape 2

Center (235, 172)

Area 1822.0

mu20 0.0837512233053824

mu02 0.07569281589147123

mu11 1.3756219198460037e-05

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Perimeter 160.36753058433533

Compactness 1.1232453953224997

Elongation 0.219338686036211

### **Moments for shape 3**

Center (168, 130)

Area 4.0

mu20 0.104166666666606034

mu02 0.0625

mu11 0.0

Perimeter 7.656854152679443

Compactness 1.166355372497387

Elongation 0.4472135954980056

### **Moments for shape 4**

Center (160, 130)

Area 4.0

mu20 0.104166666666606034

mu02 0.0625

mu11 0.0

Perimeter 7.656854152679443

Compactness 1.166355372497387

Elongation 0.4472135954980056

### **Moments for shape 5**

Center (104, 124)

Area 2.0

mu20 0.08333333333303017

mu02 0.08333333333303017

mu11 0.0

Perimeter 5.656854152679443

Compactness 1.2732395011540298

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Elongation 0.0

#### **Moments for shape 6**

Center (103, 123)

Area 2.0

mu20 0.083333333333303017

mu02 0.083333333333303017

mu11 0.0

Perimeter 5.656854152679443

Compactness 1.2732395011540298

Elongation 0.0

#### **Moments for shape 7**

Center (95, 144)

Area 2560.5

mu20 0.08453090001014125

mu02 0.07519984064807912

mu11 -0.0005608995329581637

Perimeter 191.0954532623291

Compactness 1.1349221282967878

Elongation 0.23572978868294114

#### **Moments for shape 8**

Center (45, 97)

Area 4.0

mu20 0.10416666666662877

mu02 0.0625

mu11 0.0

Perimeter 7.656854152679443

Compactness 1.166355372497387

Elongation 0.4472135954998359

#### **Moments for shape 9**

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Center (173, 119)

Area 2503.0

mu20 0.08260830353399118

mu02 0.07687995978383595

mu11 -0.00023745427705679082

Perimeter 190.50966572761536

Compactness 1.1538870953102465

Elongation 0.18651147573724675

Moments for shape 10

Center (111, 80)

Area 2.0

mu20 0.08333333333303017

mu02 0.08333333333303017

mu11 0.0

Perimeter 5.656854152679443

Compactness 1.2732395011540298

Elongation 0.0

#### **Moments for shape 11**

Center (264, 101)

Area 1797.5

mu20 0.08382767474898468

mu02 0.07562067906931888

mu11 -0.000894468263272744

Perimeter 158.6101713180542

Compactness 1.1137386862566114

Elongation 0.2237040754671143

#### **Moments for shape 12**

Center (36, 105)

Area 2569.5

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mu20 0.08428058703268261

mu02 0.07527317144448617

mu11 -0.002745414101763805

Perimeter 189.09545230865479

Compactness 1.1073978667875675

Elongation 0.24902972221564662

Moments for shape 13

Center (113, 83)

Area 484.5

mu20 0.15648135329536458

mu02 0.07717960005324659

mu11 0.02098473184713046

Perimeter 163.8406196832657

Compactness 4.408994107397737

Elongation 0.5267354350992869

#### **Moments for shape 14**

Center (215, 69)

Area 2468.5

mu20 0.08352706916988918

mu02 0.07590914520339896

mu11 -0.0015842773830414768

Perimeter 185.9238805770874

Compactness 1.1143647223651068

Elongation 0.22181630550309184

#### **Moments for shape 15**

Center (55, 48)

Area 1787.0

mu20 0.08417165914041085

mu02 0.07531417864530848



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CS557 project 4

mu11 -0.0012028830639480874

Perimeter 158.36753129959106

Compactness 1.1168577883513742

Elongation 0.23327680227265538

### **Moments for shape 16**

Center (147, 33)

Area 2434.0

mu20 0.08377426799408655

mu02 0.07566591128623228

mu11 -0.001286248864708218

Perimeter 184.5096663236618

Compactness 1.113032405914737

Elongation 0.22505751460290227

### **Comments on Moments:**

- 1) Depends highly on segmentation. If segmentation is bad and has smaller connected component, will produce unnecessary results. Morphological operation is recommended in these situations before applying moments.
- 2) Completely fails for noisy image.
- 3) From Pillset image:

For circle: Compactness 1.101774185127508 Elongation 0.1014018949884407

For rectangle: Compactness 2.3816501057599724 Elongation 0.6109552581390368

Compactness value for circle is very close to 1. Also, circle has lower compactness and elongation value than rectangle. So, numbers make sense

- 4) Elongation is given as a value between 0 and 1. If the ratio is equal to 1, the object is roughly square or circularly shaped. As the ratio decreases from 1, the object becomes more elongated. Compactness has a minimum value of 1 (for circle). It increases as objects become less compact.