Fundamentals of Image Processing

BIP -DLF - Jean-Christophe Taveau

Why Image Processing?

Processing

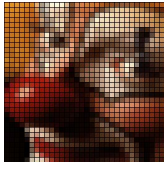
Measurements - Quantification

Results

File Edit Font Results

	Area	XM	YM	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR
1	1	338.500	18.500	1.000	1.414	338	18	135	1	1.000
2	113	329.969	36.969	0.112	41.485	324	60	74.624	8.995	6.254
3	2	325.500	22.000	1.000	2.236	325	21	116.565	1.000	2.000
4	51	357.520	33.578	0.123	30.529	346	21	121.608	7.203	5.210
5	67	321.739	35.828	0.095	21.954	314	43	59.931	12.000	2.342
6	2	334.500	25.000	1.000	2.236	334	24	116.565	1.000	2.000
7	1	345.500	27.500	1.000	1.414	345	27	135.000	1.000	1.000
8	2	348.000	28.000	0.785	2.828	347	29	45.000	1.414	2.646
9	7	335.357	32.357	0.621	4.472	335	30	116.565	3.000	1.697
10	2	348.000	30.500	1.000	2.236	347	30	153.435	1.000	2.000
11	4	315.000	32.000	1.000	2.828	314	31	135.000	2.000	1.000
12	1	318.500	31.500	1.000	1.414	318	31	135.000	1.000	1.000

- Statistics
- Machine Learning



Why Image Processing?

Measurements of ROI

Results

File Edit Font Results

	Area	XM	YM	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR
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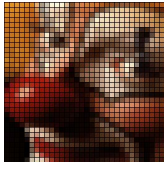
12	1	318.500	31.500	1.000	1.414	318	31	135.000	1.000	1.000

- Objects of Interest (Region of Interest)
- Background



Why Image Processing?

Measurements - Quantification

Columns: Features

Rows: Samples (ROI)

Results

File Edit Font Results

	Area	XM	YM	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR
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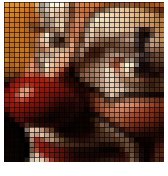


Digital Image

Properties

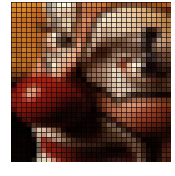
Image is characterized by:

① Pixels number → Resolution

- Pixels number per unit of length of the object to digitize
- Units : dpi (dots per inch) ou ppp (point par pouce)

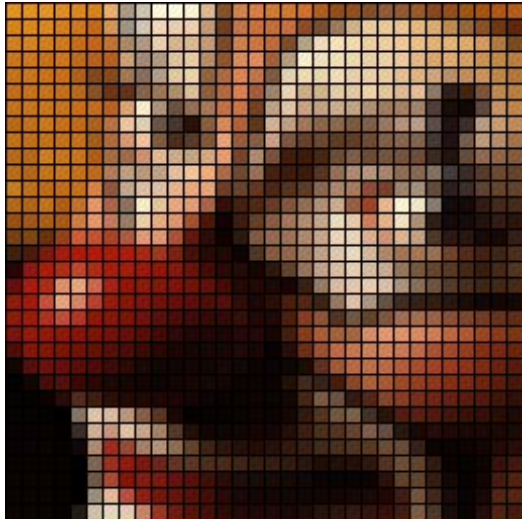
② Range of gray levels or colors

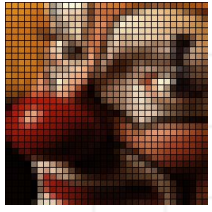
→ Dynamic range
1-bit, 8-bits (256), 16-bits (2 16 =65536), RGB, etc.

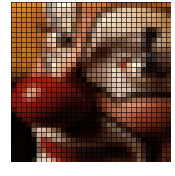


Digital Image

2D array of pixels

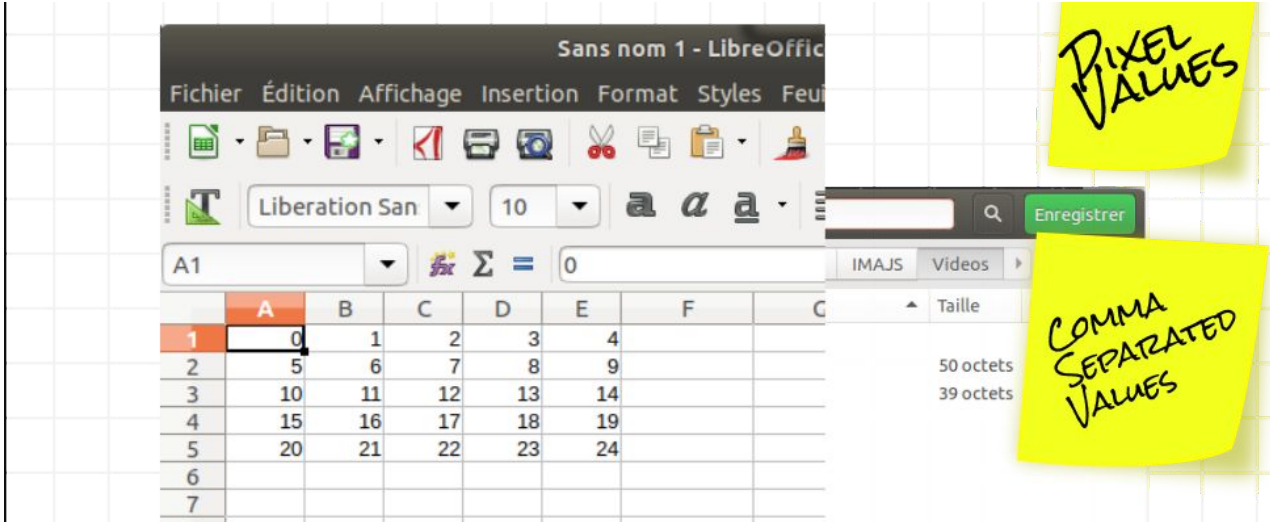


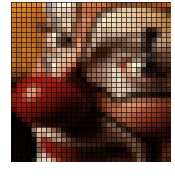




Digital Image

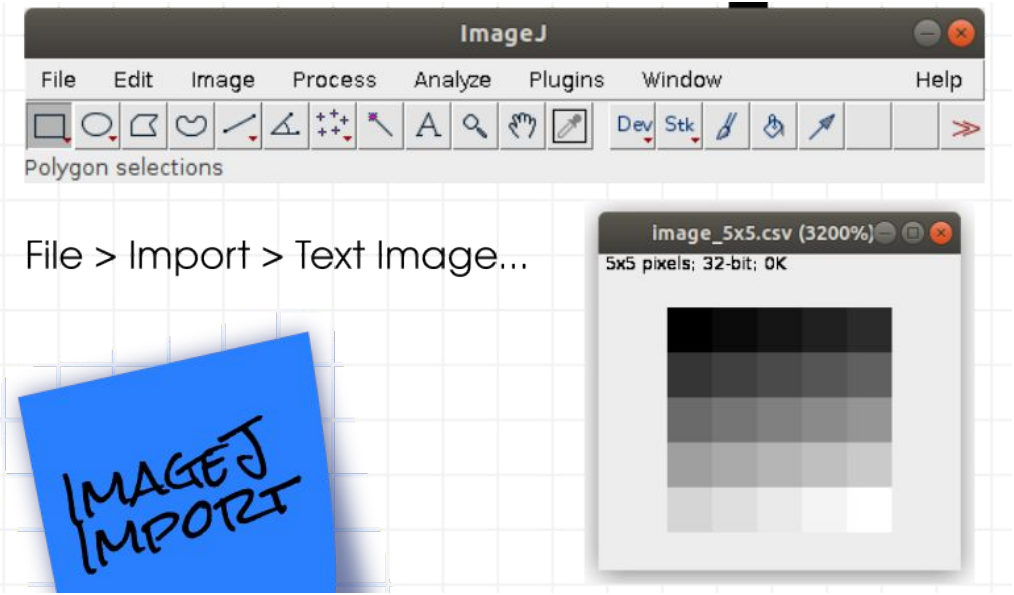
2D arrays of pixels in a spreadsheet

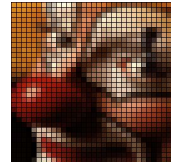




Digital Image

2D arrays of pixels in ImageJ



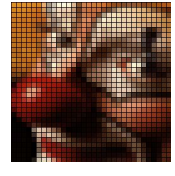


Digital Image

2D arrays of pixels in Python

```
import numpy as np
import matplotlib.pyplot as plt

img = np.arange(25).reshape(5,5)

print(img)
```

```
[3] print(img)

0s

[[ 0  1  2  3  4]
 [ 5  6  7  8  9]
 [10 11 12 13 14]
 [15 16 17 18 19]
 [20 21 22 23 24]]
```

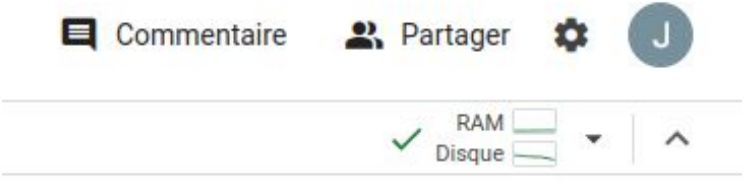


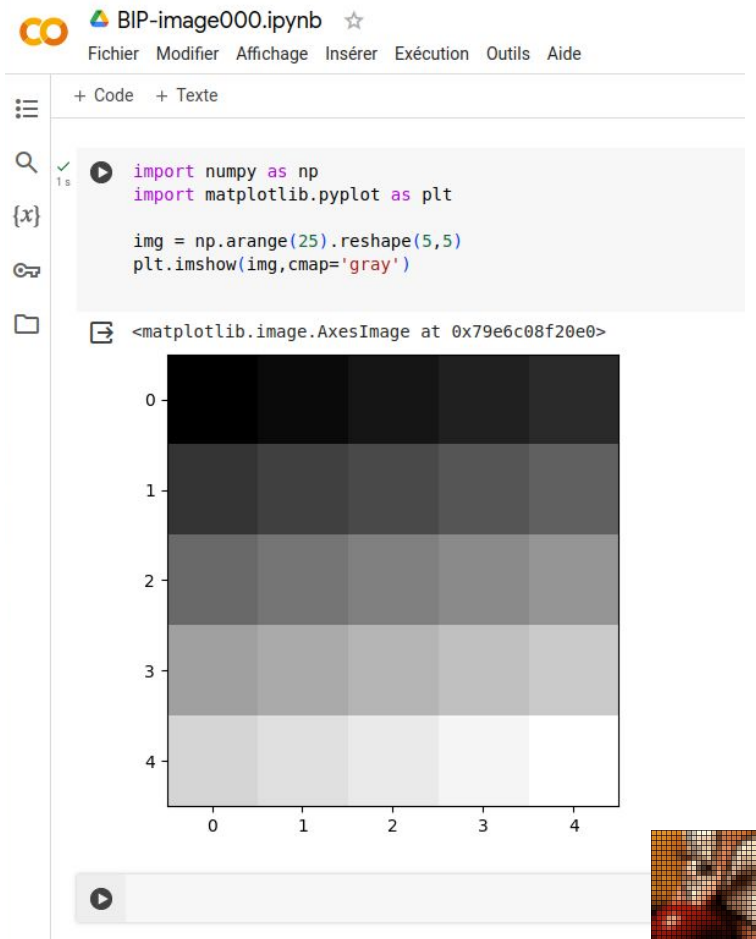
Digital Image

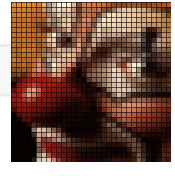
2D arrays of pixels in Python

```
import numpy as np
import matplotlib.pyplot as plt

img = np.arange(25).reshape(5,5)
plt.imshow(img,cmap='gray')
```

Web Python Environment: Google Colab

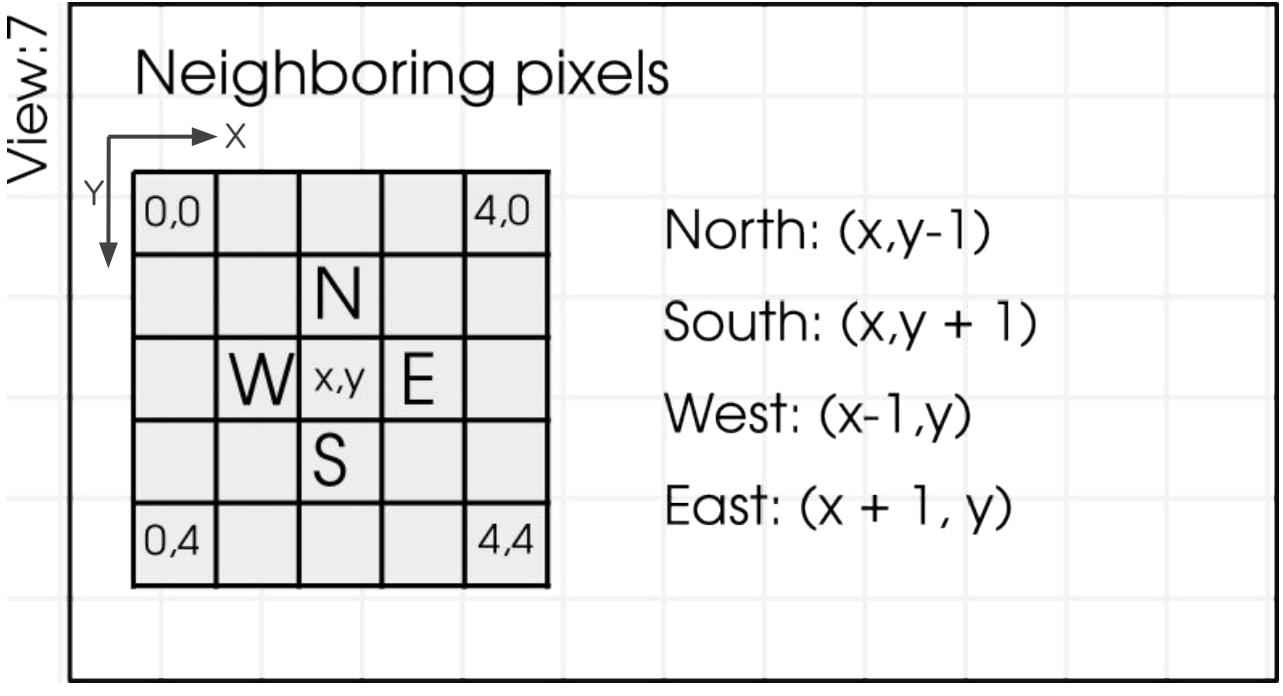


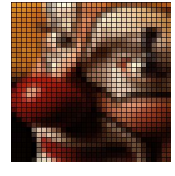




Digital Image

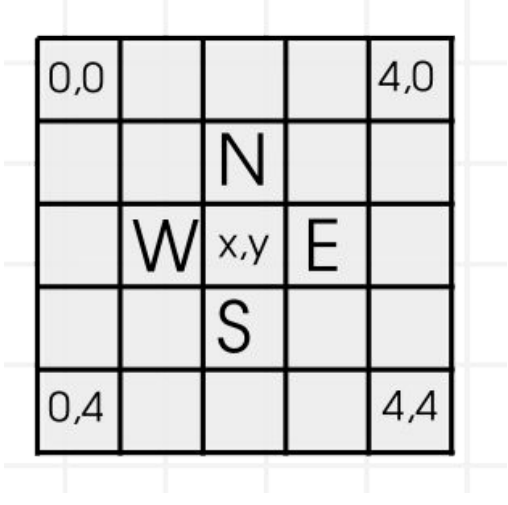
Coordinates



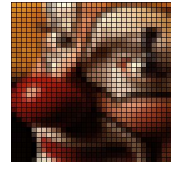


Digital Image

Coordinates in Python with numpy




```
import numpy as np

img = np.arange(25).reshape(5,5)

pix_XY00 = img[0,0] # Top left
pix_XY40 = img[0,4] # img[Y,X]
pix_XY04 = img[4,0] # Bottom left
pix_XY44 = img[4,4] # Bottom right
```



Digital Image

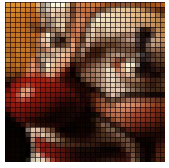
Dynamic Range

1 bit = 2 values: 0 (False) or 1 (True)

1 byte = 8 bits = 256 gray levels

00000000 = 0_{10}
11111111 = $2^7+2^6+2^5+2^4+2^3+2^2+2^1+2^0 = 2^8 - 1 = 255$

Other storages: 16bits, float32, float64



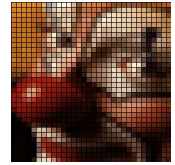
Digital Image

Dynamic Range of Color Image

color = Red + Green + Blue = 8 + 8 + 8 = 24 bits

color = Hue + Saturation + Value = 8 + 8 + 8 = 24 bits

color = 3-channel image (+ 4th for alpha or transparency)



Digital Image

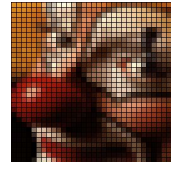
Dynamic Range of RGB color image

```
import numpy as np
import matplotlib.pyplot as plt
import skimage as ski

cup = ski.data.coffee()

cup.ndim # Return the dim. number
```

```
import skimage as ski

cup = ski.data.coffee()
plt.imshow(cup)
```

```
<matplotlib.image.AxesImage at 0x79e68539c850>
```


```
[12] cup.ndim

3
```



Digital Image

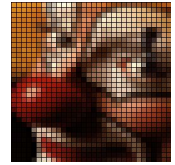
Dynamic Range of RGB color image

```
import skimage as ski

cup = ski.data.coffee()
plt.imshow(cup)
```

```
<matplotlib.image.AxesImage at 0x79e68539c850>
```

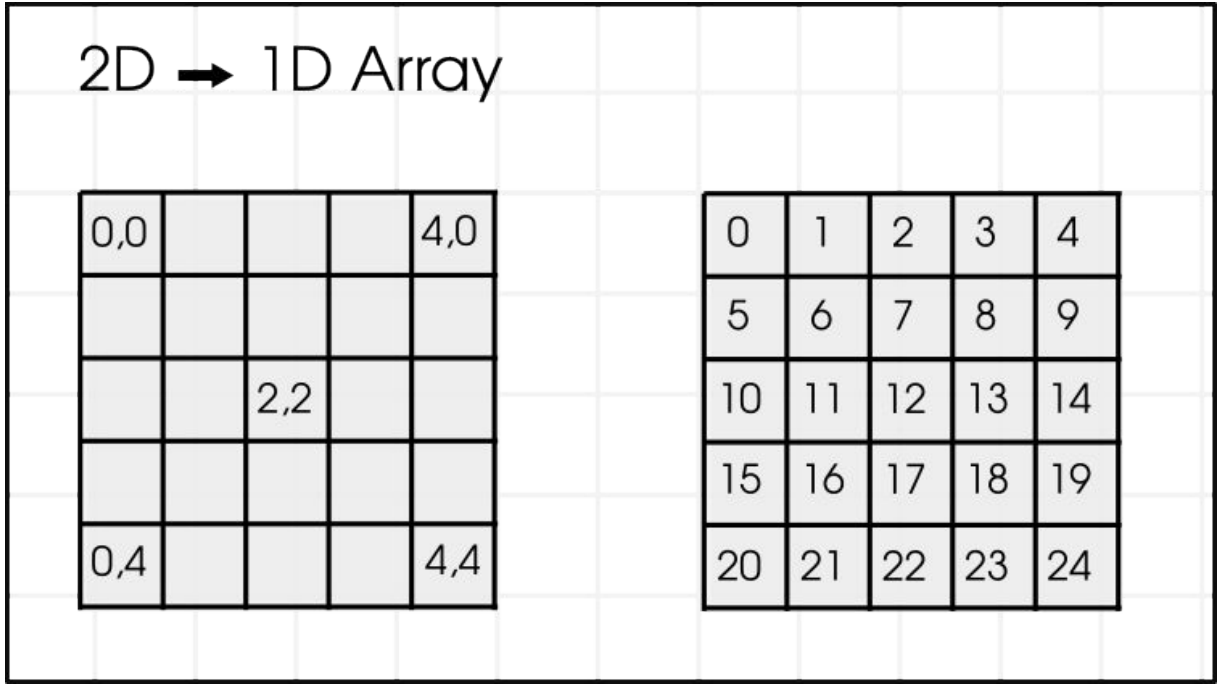

```
import numpy as np
import matplotlib.pyplot as plt
import skimage as ski

cup = ski.data.coffee()

cup.shape # Return the H x W x Ch
```

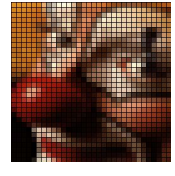
```
(400, 600, 3)
```



Digital Image

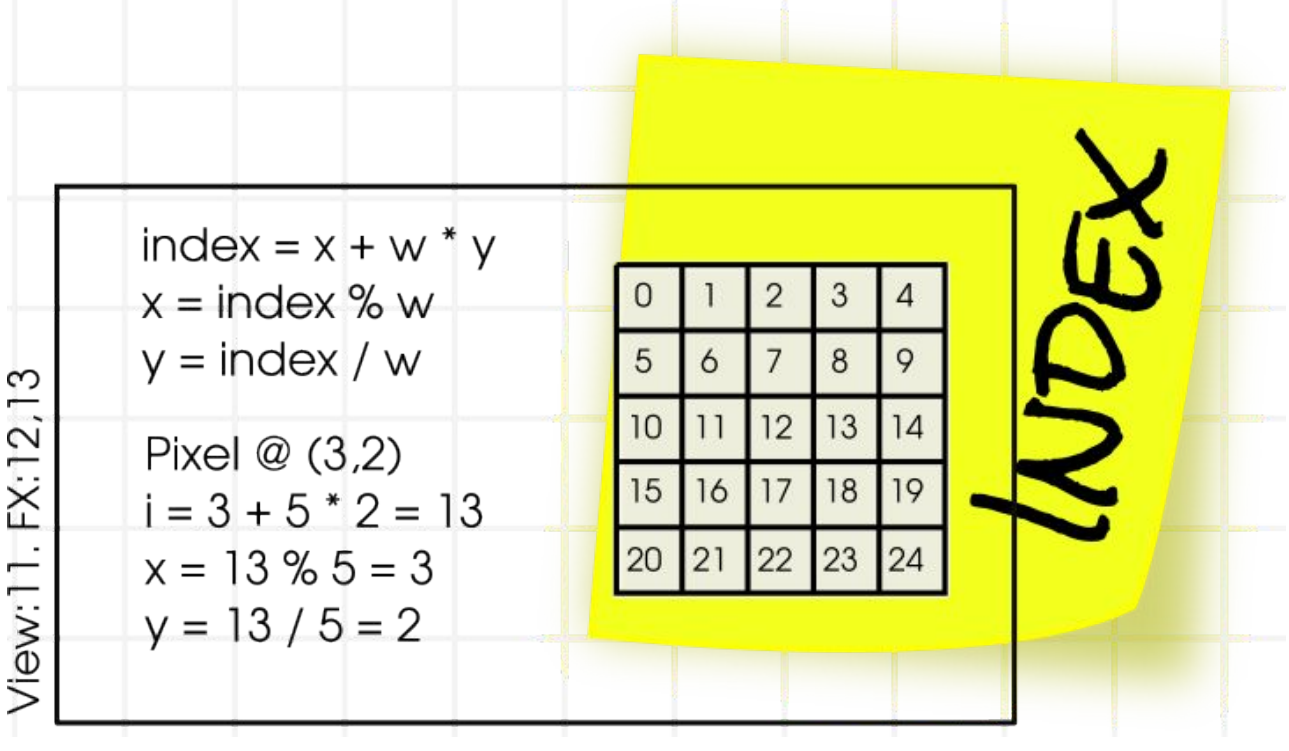
Storage 2D ➜ 1D

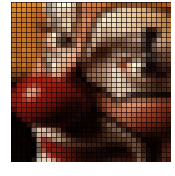




Digital Image

Storage 2D ➜ 1D

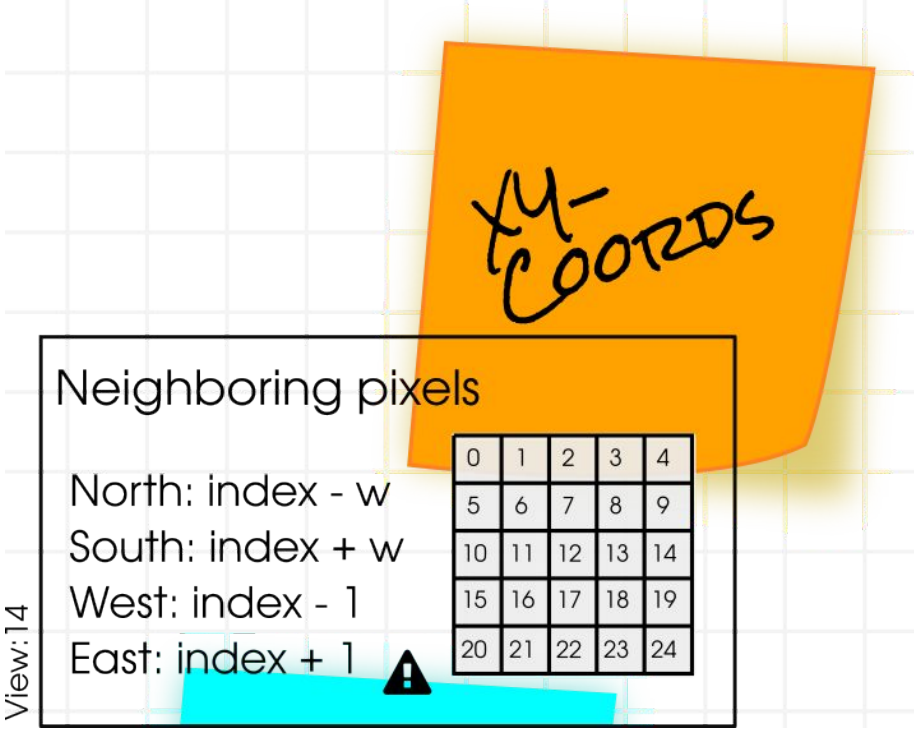


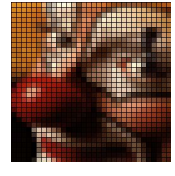


Digital Image

Storage 2D ➜ 1D

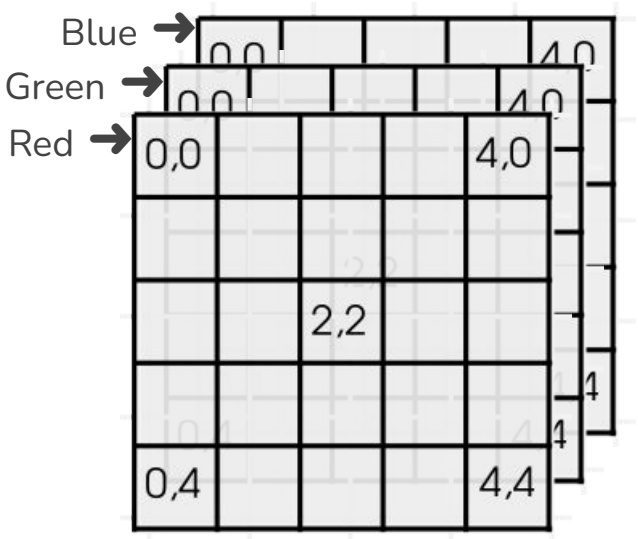
```
index = 9
# Wrong !!
right_neighbor = 9 + 1
```





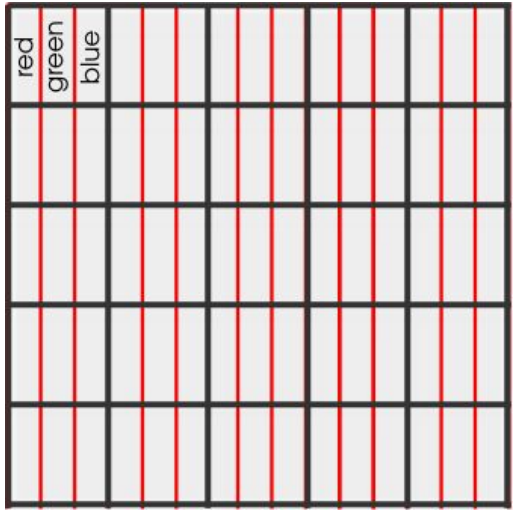
Digital Image

Other Storages: color image



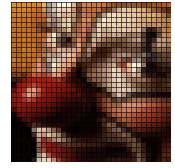
Planar RGB images

shape: (3,5,5)



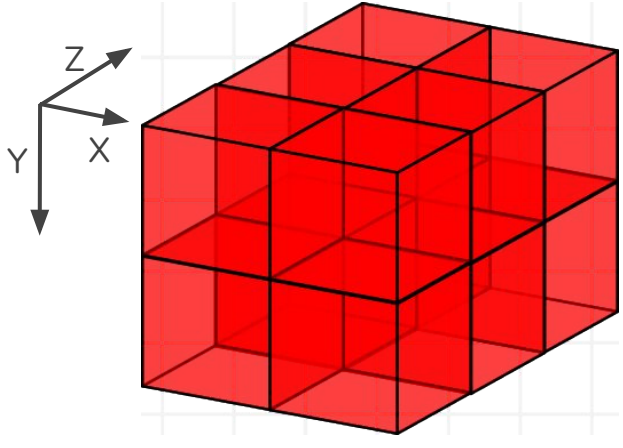
Packed RGB images ➔

shape: (5,5,3)



Digital Image

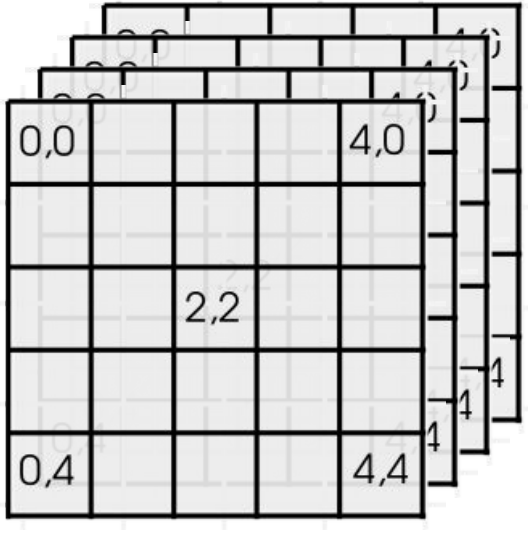
Other Storages

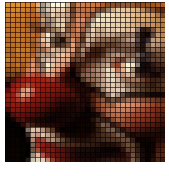


➔ Volume (3D) with voxels

➔ RGB Volume (4D)

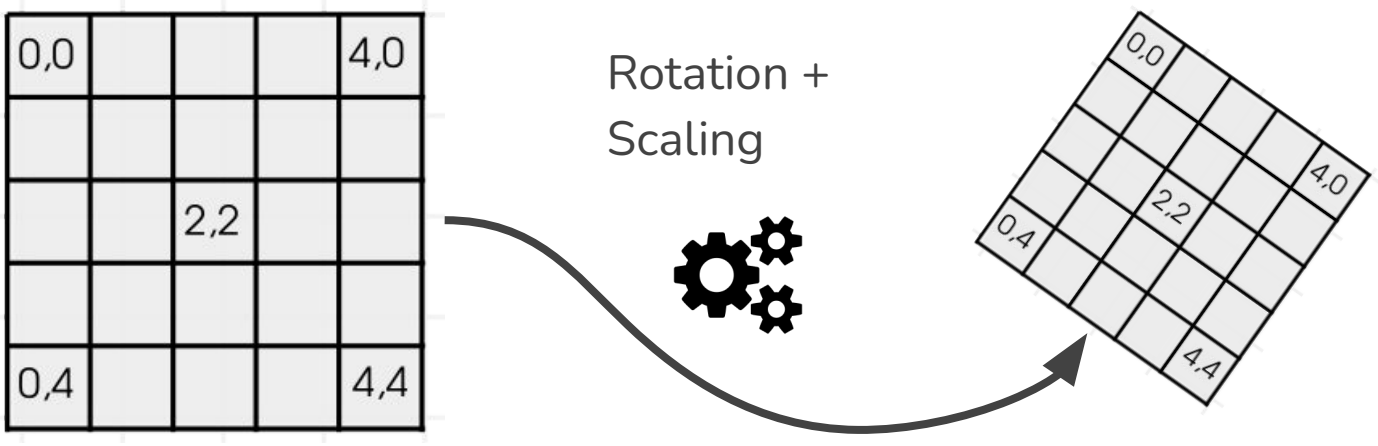
➔ Stack of *n* 2D images (*n*D)

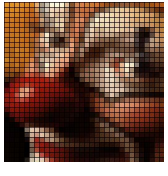




Geometrical Transforms

Translation, Rotation, Flip, Scaling





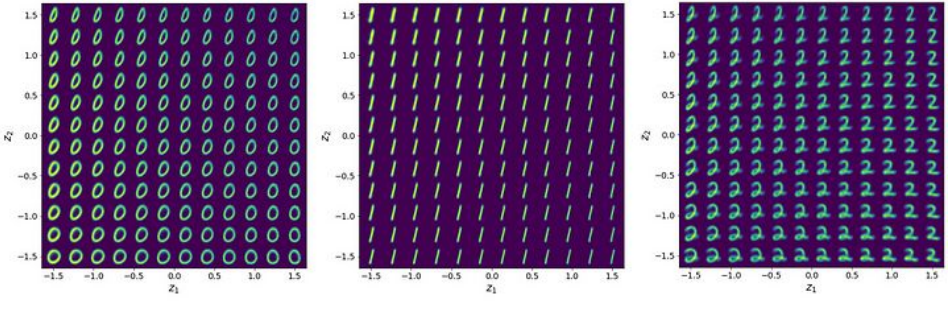
Geometrical Transforms

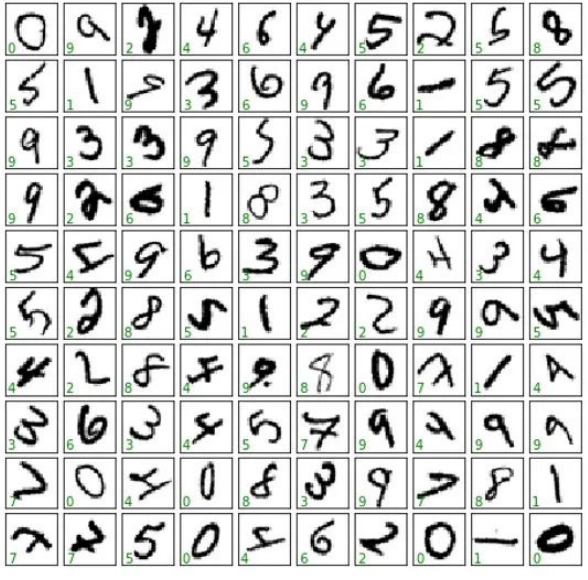
Translation, Rotation, Flip, Scaling

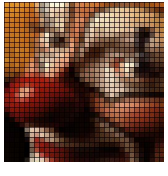
Popular Image manipulation

Clustering

Data Augmentation (Deep Learning)

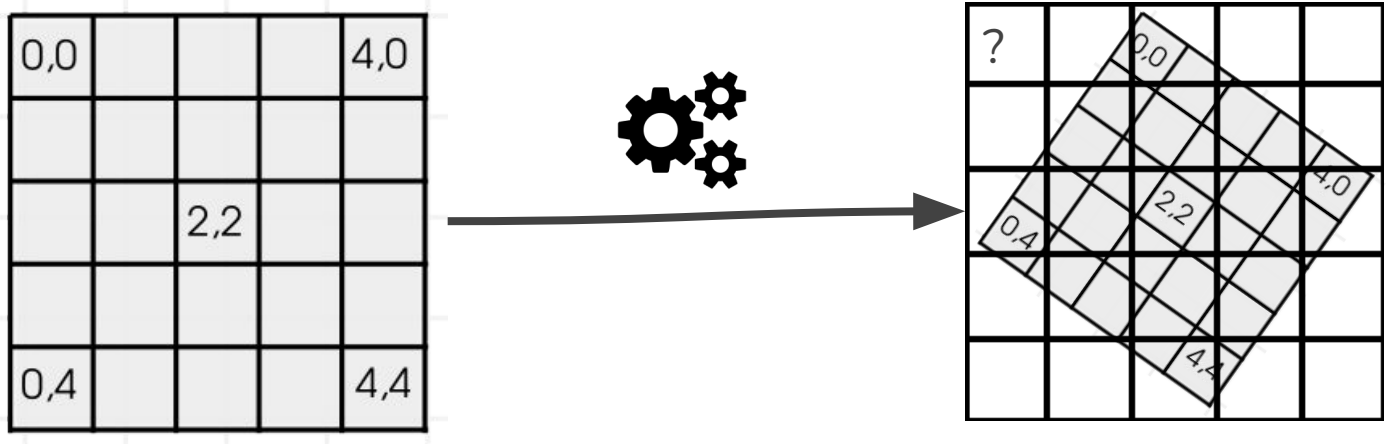


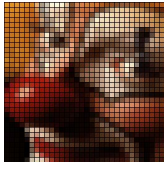




Geometrical Transforms

Translation, Rotation, Flip, Scaling





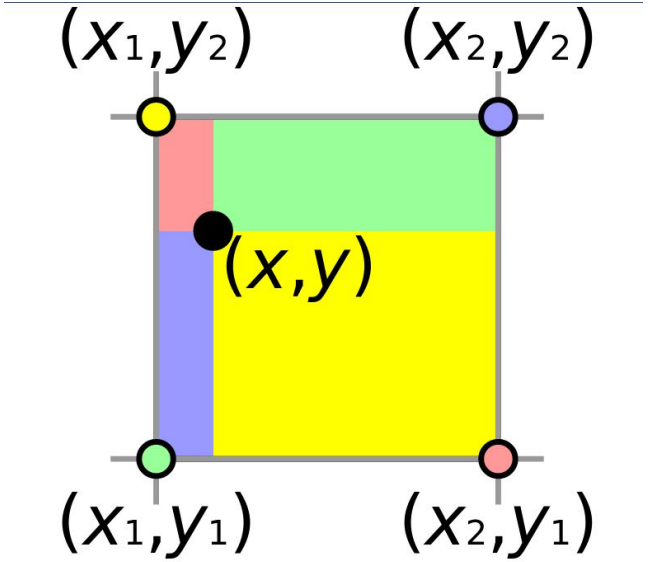
Geometrical Transforms

Translation, Rotation, Flip, Scaling

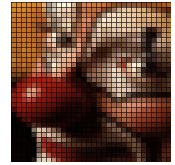
```
# Pseudo-code
for each pixel(x',y') of output:
   out[y',x'] = calc_intensity(img,T)
```

Interpolation Schemes

➔ Nearest Neighbor
➔ Bilinear Interpolation
➔ Bicubic Interpolation



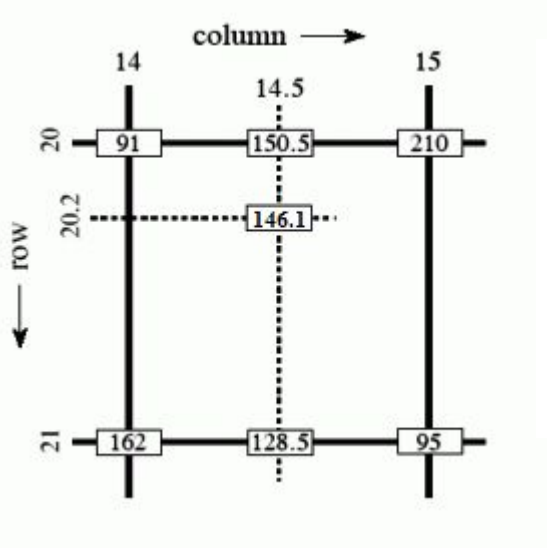
From Wikipedia



Geometrical Transforms

Translation, Rotation, Flip, Scaling

➔ Bilinear Interpolation

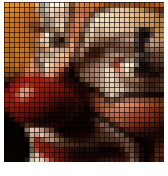


$$I_{20,14.5} = \frac{15-14.5}{15-14} \cdot 91 + \frac{14.5-14}{15-14} \cdot 210 = 150.5,$$

$$I_{21,14.5} = \frac{15-14.5}{15-14} \cdot 162 + \frac{14.5-14}{15-14} \cdot 95 = 128.5,$$

$$I_{20.2,14.5} = \frac{21-20.2}{21-20} \cdot 150.5 + \frac{20.2-20}{21-20} \cdot 128.5 = 146.1.$$

From Wikipedia



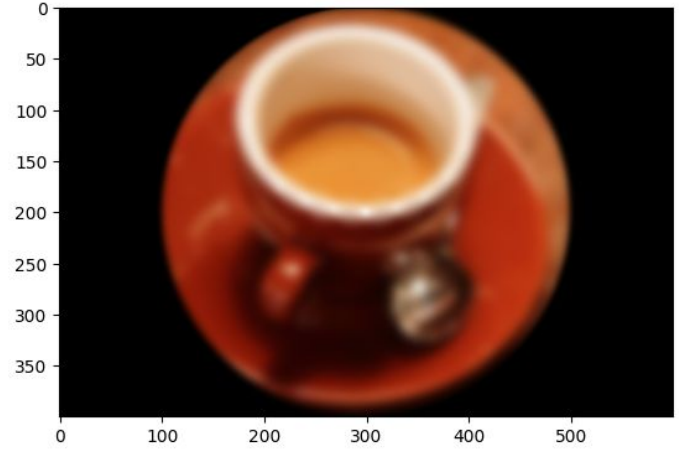
Geometrical Transforms

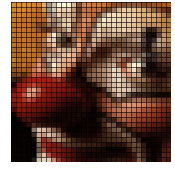
Accumulating Transforms

➔ Repeating many small rotations of 2° over 360°.

```
rotated = cup
angle = 360 / 180
for i in range(180):
  rotated = ski.transform.rotate(rotated, angle, resize=False)

plt.imshow(rotated)
```

```
<matplotlib.image.AxesImage at 0x7d3b29de13c0>
```

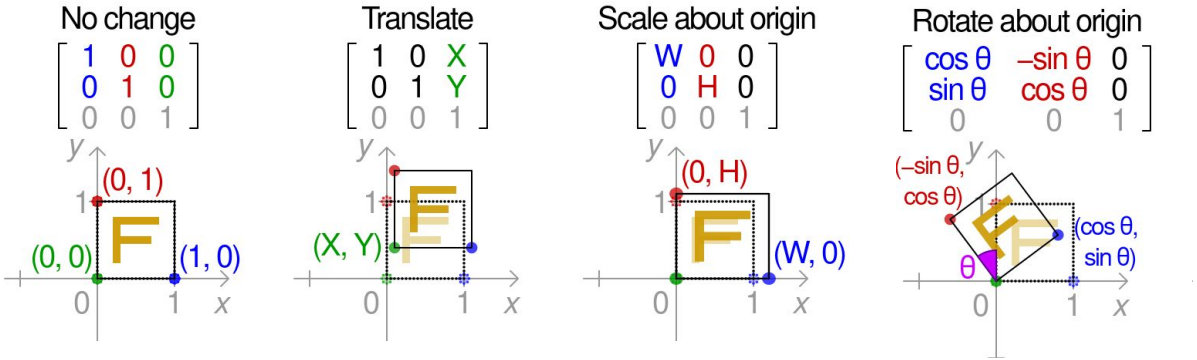


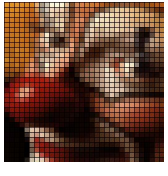


Geometrical Transforms

Accumulating Transforms

➔ Using 2D matrix of 3x3. Accumulating Transforms = Multiplying matrices



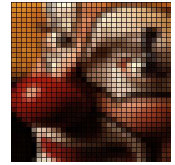


Geometrical Transforms

Accumulating Transforms

```
shift = ski.transform.EuclideanTransform(translation=-np.array([300,200]) ) # Image center
rot= ski.transform.EuclideanTransform(rotation= np.deg2rad(2.0) )
# Compose transforms by multiplying their matrices for the rotations
rots = np.identity(3)
for i in range(180):
    rots = np.matmul(rot,rots)
# Compose transforms by multiplying their matrices to rotate around the image center
matrix =  np.linalg.inv(shift.params) @ rots @ shift.params
```

```
[[ 1.00000000e+00  1.01708908e-15 -2.27373675e-12]
 [-6.30919087e-16  1.00000000e+00 -1.10844667e-12]
 [ 0.00000000e+00  0.00000000e+00  1.00000000e+00]]
```



Fundamentals of Image Processing

BIP -DLF - Jean-Christophe Taveau

Digital Image

Pipeline

Image Enhancement

- Brightness/contrast
- Non Uniform Illumination
- Noise Removal

Segmentation

- Threshold
- Math. Morphology

Results

File Edit Font Results

	Area	XM	YM	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR
1	1	338.500	18.500	1.000	1.414	338	18	135	1	1.000
2	113	329.969	36.969	0.112	41.485	324	60	74.624	8.995	6.254
3	2	325.500	22.000	1.000	2.236	325	21	116.565	1.000	2.000
4	51	357.520	33.578	0.123	30.529	346	21	121.608	7.203	5.210
5	67	321.739	35.828	0.095	21.954	314	43	59.931	12.000	2.342
6	2	334.500	25.000	1.000	2.236	334	24	116.565	1.000	2.000
7	1	345.500	27.500	1.000	1.414	345	27	135.000	1.000	1.000
8	2	348.000	28.000	0.785	2.828	347	29	45.000	1.414	2.646
9	7	335.357	32.357	0.621	4.472	335	30	116.565	3.000	1.697
10	2	348.000	30.500	1.000	2.236	347	30	153.435	1.000	2.000
11	4	315.000	32.000	1.000	2.828	314	31	135.000	2.000	1.000
12	1	318.500	31.500	1.000	1.414	318	31	135.000	1.000	1.000

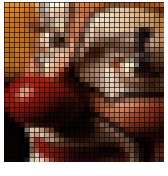
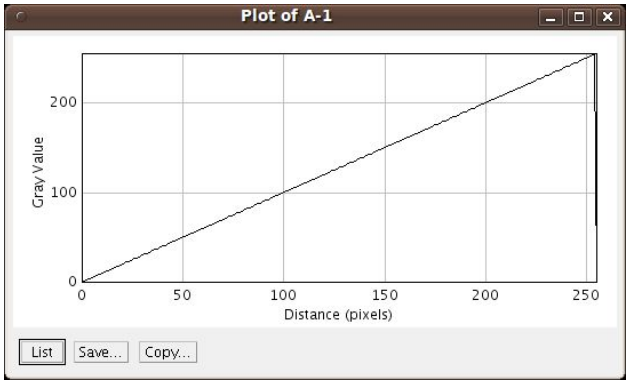
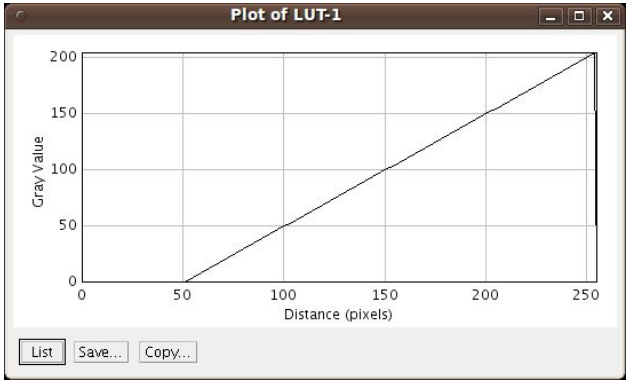


Image Enhancement

Principle - Brightness / Contrast





Transfer Function: Y = a . x + b

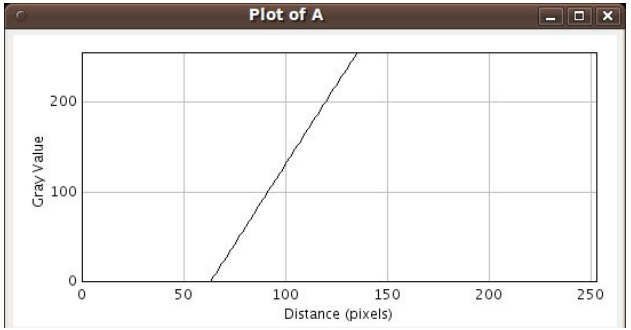
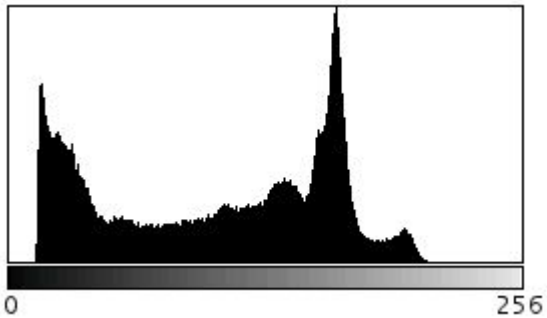
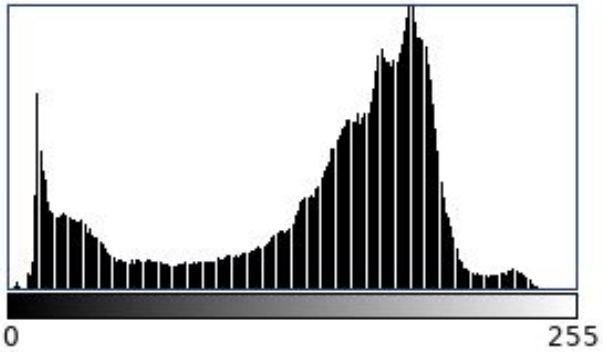


Image Enhancement

Principle - Normalization



$v' = (v - min) / (max - min)$



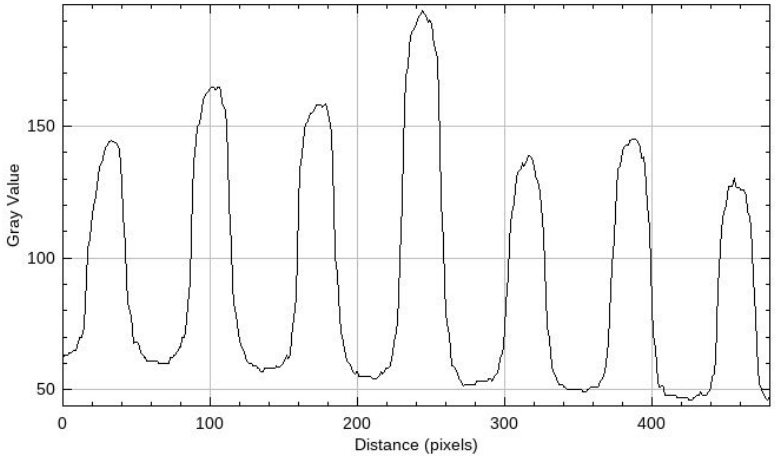
N: 414720	Min: 0
Mean: 137.016	Max: 255
StdDev: 57.807	Mode: 180 (7480)
Value: 112	Count: 1131

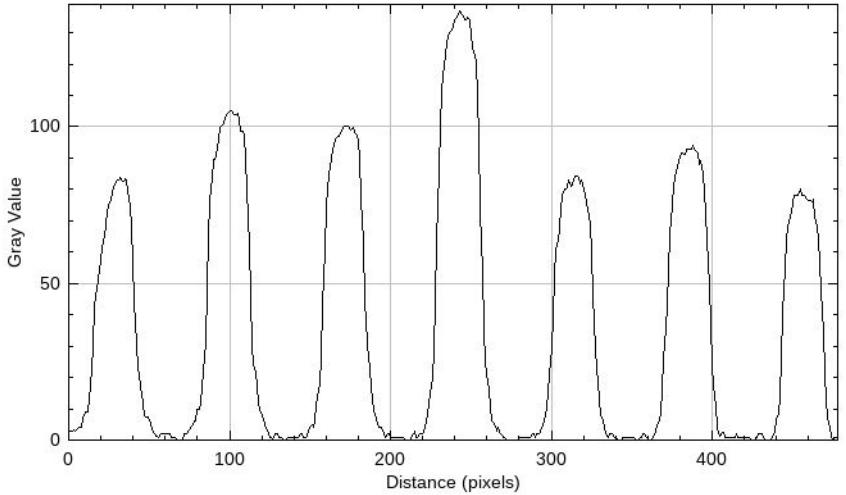
Image Enhancement

Non Uniform Illumination - Subtract Background

Removing the Baseline

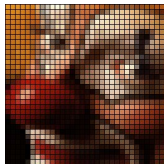
- Polynomial Functions
- Rolling Ball

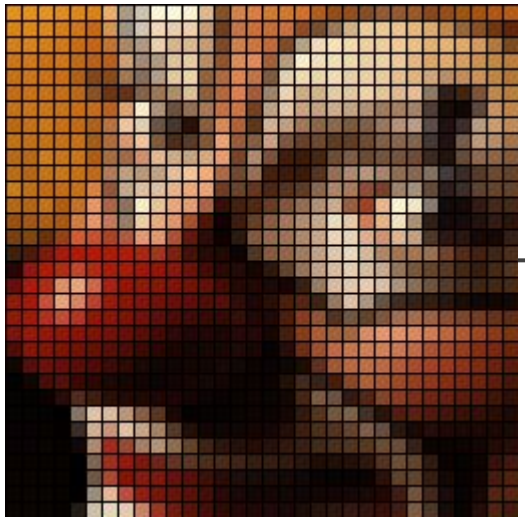


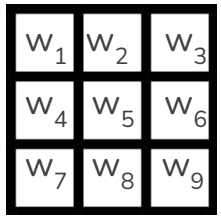


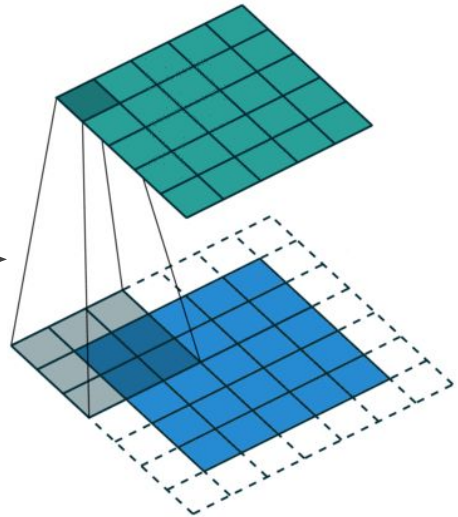
Denoising - Filters

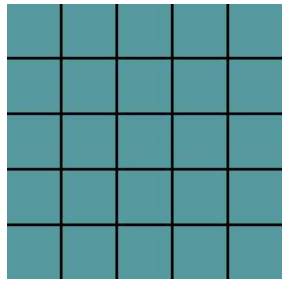
Principle - Convolution









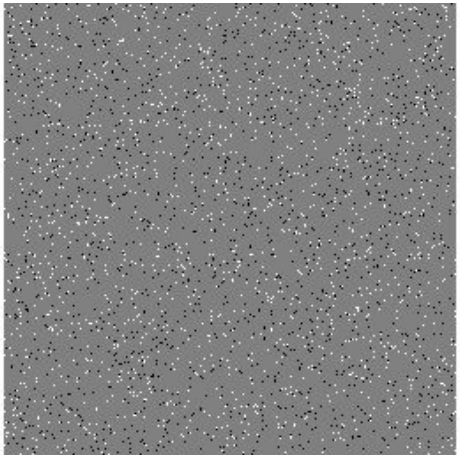


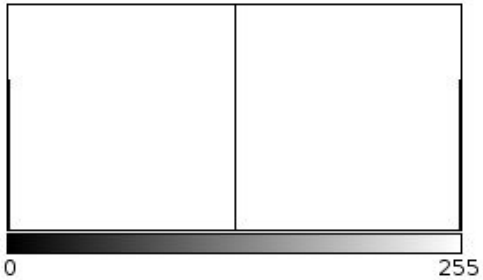
Mean 3x3
Gaussian 7x7
Median 3x3

Denoising - Filters

Principle - Noise

Impulse Noise (Salt and Pepper)

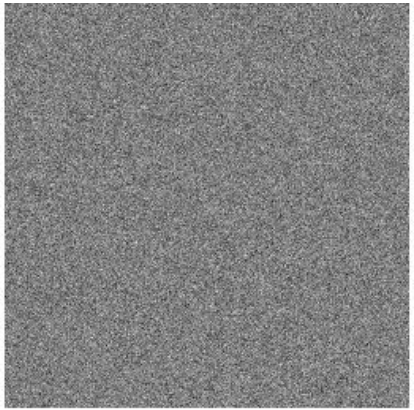


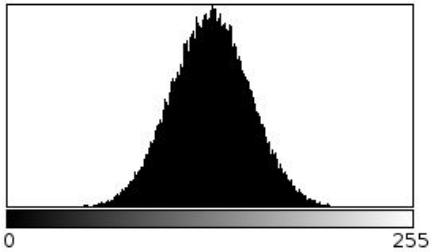


N: 65536
Mean: 127.974
StdDev: 28.161
Value: 167

Min: 0
Max: 255
Mode: 128 (62339)
Count: 0

Gaussian Noise





N: 65536
Mean: 127.915
StdDev: 24.918
Value: 176

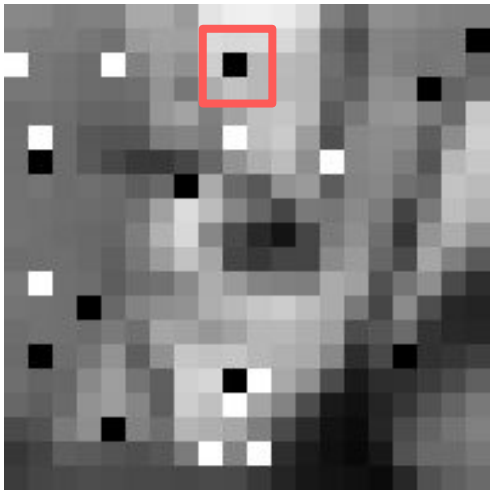
Min: 26
Max: 232
Mode: 129 (1092)
Count: 171

Denoising - Filters

Principle - Noise

Denoise Filters:

- Mean 3x3
- Median 3x3



219	216	218
207	0	184
174	195	184

Mean 3x3: All the weights are equal to 1:

219+216+218+207+0+184+174+195+184 => 177

Median 3x3: Sorting + Median value

0 < 174 < 184 <184 < 195 < 207 < 216 < 218 < 219 => 195

Denoising - Filters

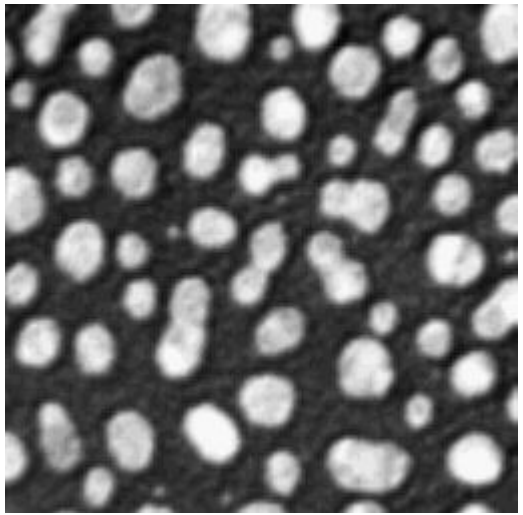
Principle - Noise

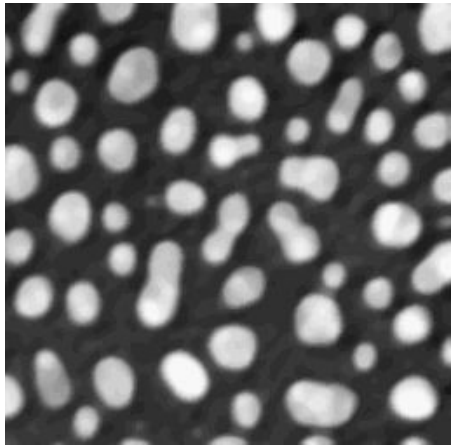
Linear Filters:

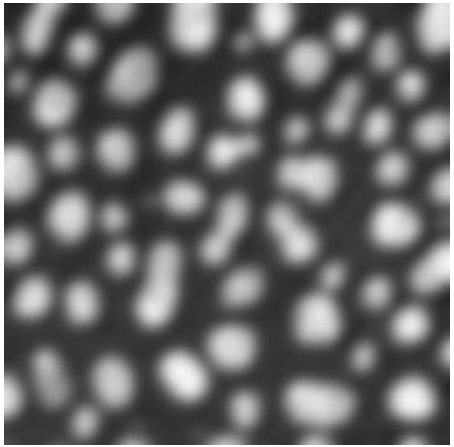
- Mean
- Weighted Mean

Non-linear Filters:

- Median ***





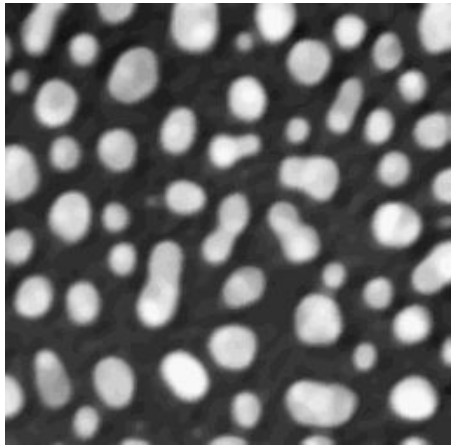


Segmentation

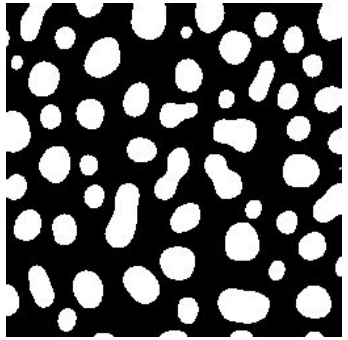
Separating ROI from background

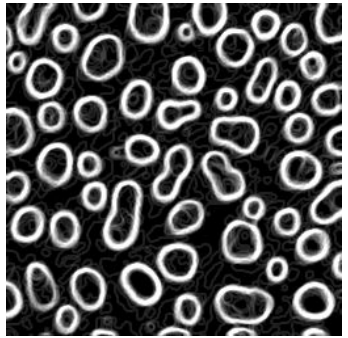
Methods

- Threshold
- Edges
- Clustering



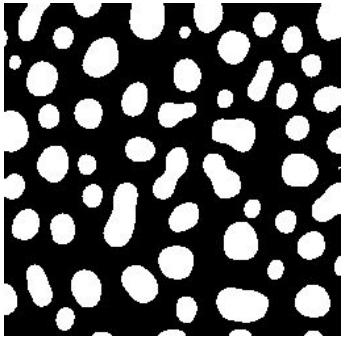
Binary (1bit) Image





Analyze

Measurements



Results

File Edit Font Results

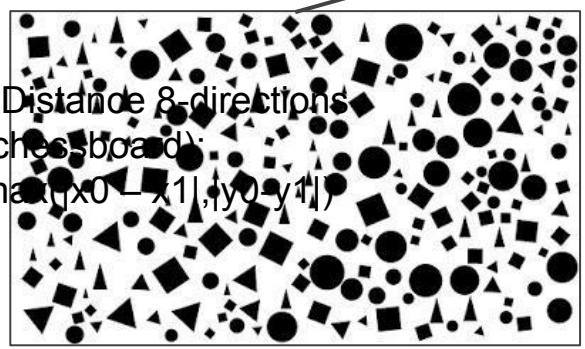
	Area	XM	YM	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR
1	1	338.500	18.500	1.000	1.414	338	18	135	1	1.000
2	113	329.969	36.969	0.112	41.485	324	60	74.624	8.995	6.254
3	2	325.500	22.000	1.000	2.236	325	21	116.565	1.000	2.000
4	51	357.520	33.578	0.123	30.529	346	21	121.608	7.203	5.210
5	67	321.739	35.828	0.095	21.954	314	43	59.931	12.000	2.342
6	2	334.500	25.000	1.000	2.236	334	24	116.565	1.000	2.000
7	1	345.500	27.500	1.000	1.414	345	27	135.000	1.000	1.000
8	2	348.000	28.000	0.785	2.828	347	29	45.000	1.414	2.646
9	7	335.357	32.357	0.621	4.472	335	30	116.565	3.000	1.697
10	2	348.000	30.500	1.000	2.236	347	30	153.435	1.000	2.000
11	4	315.000	32.000	1.000	2.828	314	31	135.000	2.000	1.000
12	1	318.500	31.500	1.000	1.414	318	31	135.000	1.000	1.000

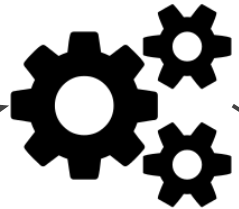
Analyze - Measurements

- Euclidian Distance :
√(x0 – x1) 2 + (y0 – y1) 2
Pixel connectivity
- Distance north-south-east-west
(city-block or Manhattan):
|x0 – x1| + |y0-y1|
0 1 2 3 4 5 6 7 8
9 0 1 2 3 4 5 6 7 8 9
8
7
6
5
4
3
2
1
0
- Distance 8-directions
(chessboard):
max(|x0 – x1|,|y0-y1|)

Principle

1. Learning Step with a labelled dataset (measurements/features + labels).
2. Prediction Step with an unknown dataset (measurements).





Results

File Edit Font Results

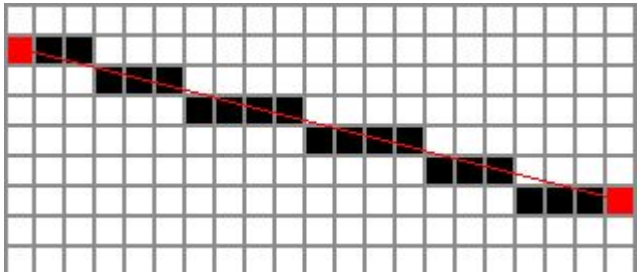
	Area	Circ.	AR	Round	Solidity
224	43	0.671	1.012	0.988	0.827
225	63	0.983	1.056	0.947	0.913
226	36	0.832	1.040	0.962	0.847
227	358	0.968	1.015	0.986	0.957
228	24	0.702	1.152	0.868	0.828
229	92	0.897	1.019	0.981	0.958
230	86	0.980	1.056	0.947	0.925
231	34	0.654	1.015	0.985	0.773
232	85	0.604	1.023	0.977	0.821
233	52	1.000	1.022	0.979	0.920
234	98	0.801	1.072	0.933	0.875
235	126	0.948	1.032	0.969	0.913
236	20	0.717	1.138	0.879	0.769
237	20	0.717	1.057	0.946	0.800
238	33	0.810	1.104	0.906	0.776
239	64	0.998	1.034	0.968	0.921

Analyze - Measurements

Distance

- Euclidean Distance :

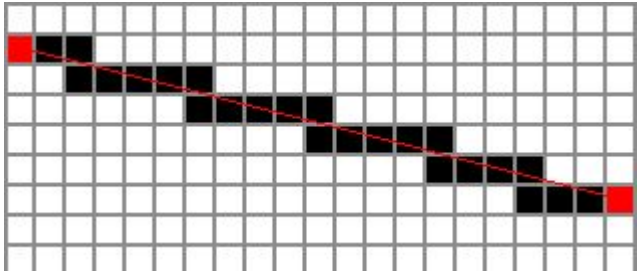
$\sqrt{(x0 - x1)^2 + (y0 - y1)^2}$



Pixel connectivity

- Distance north-south-east-west (city-block or Manhattan):

$|x0 - x1| + |y0-y1|$



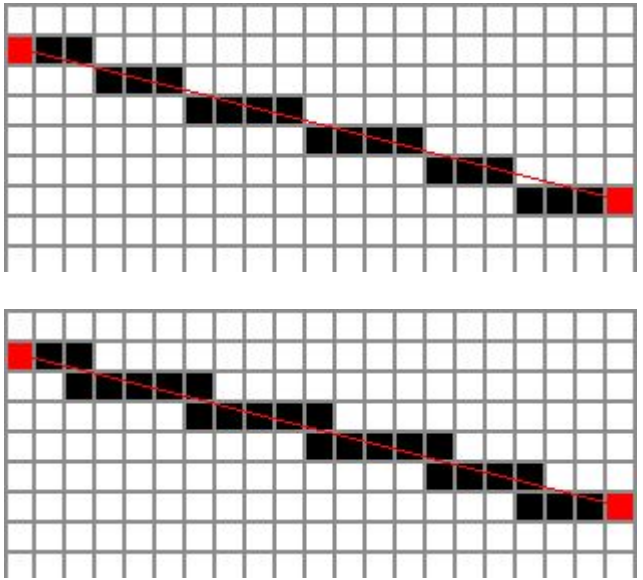
- Distance 8-directions (chessboard):

$max(|x0 - x1|,|y0-y1|)$

Analyze - Measurements

Distance

A(0,0) ⇔ B(20,5)

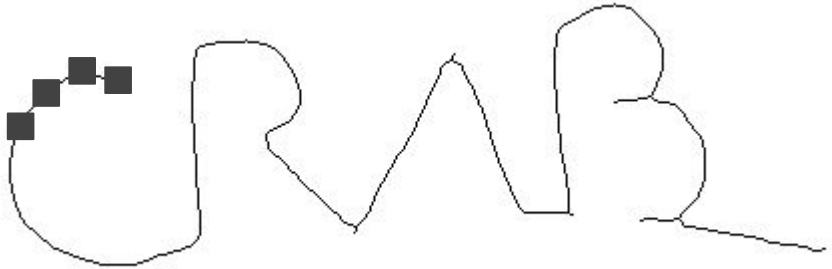


Pixel connectivity

- Distance 4-pixel connectivity: factor = 1.273
- Distance 8-pixel connectivity: factor = 0.9
- Factor = NSEW (1.0) + Diagonals (√2)

Analyze - Measurements

Object Length

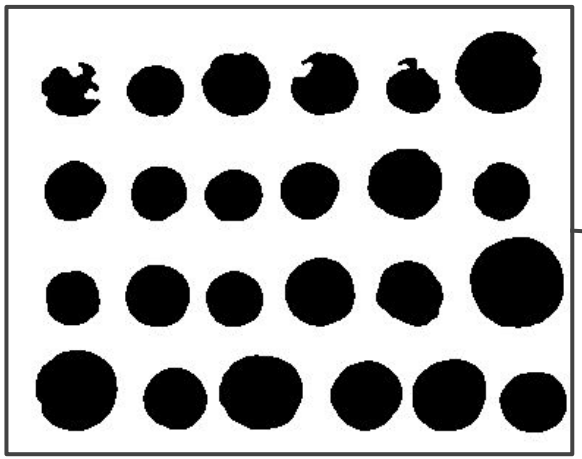


Length = Pixel_Number / connectivity_factor

Analyze - Measurements

Counting

Segmented Image



Convolution

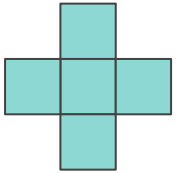


Table K	
X	Y
Xn	Yn
Xi	Yi
Xj	Yj
Xw	**Yw**

Table L	
Xi	Yi
Xj	Yj

Analyze - Measurements

Counting

Convolution

①

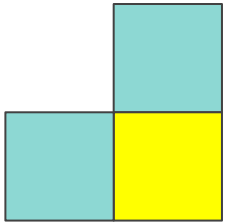


Table K	
Xm	**Ym**

②

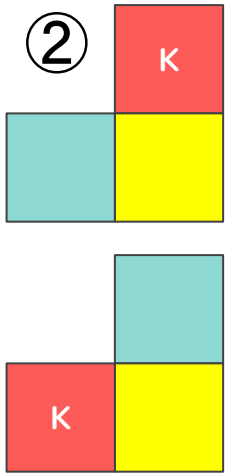


Table K	
X	Y
Xn	**Yn**

③

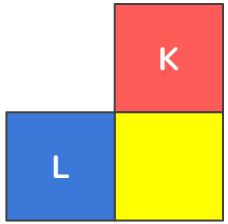


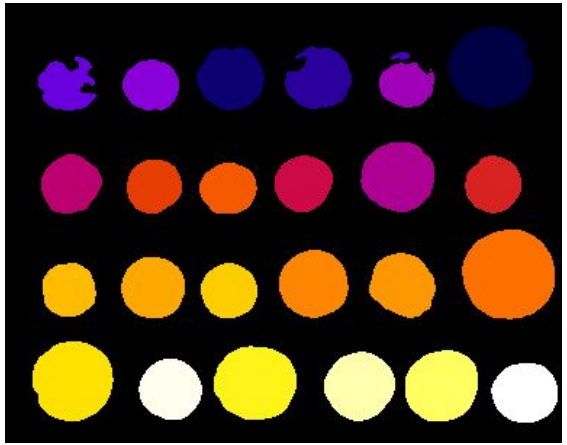
Table K	
X	Y
Xn	Yn

Table L	
Xi	Yi
Xj	Yj

Table K	
X	Y
Xn	Yn
Xi	Yi
Xj	Yj
Xw	**Yw**

Analyze - Measurements

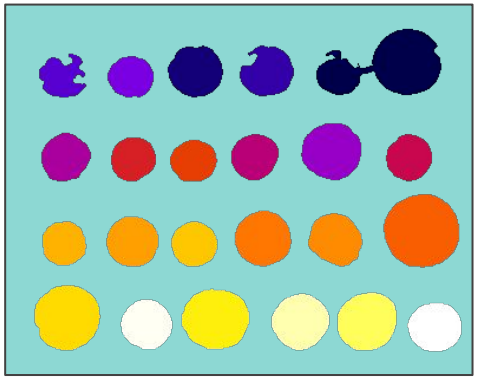
Counting



◂ 25 Objects

Table K	
X	Y
Xn	Yn
Xi	Yi
Xj	Yj
Xw	**Yw**

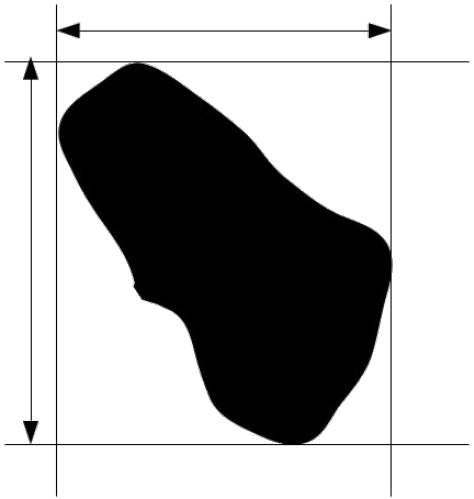
Table L	
Xi	Yi
Xj	Yj



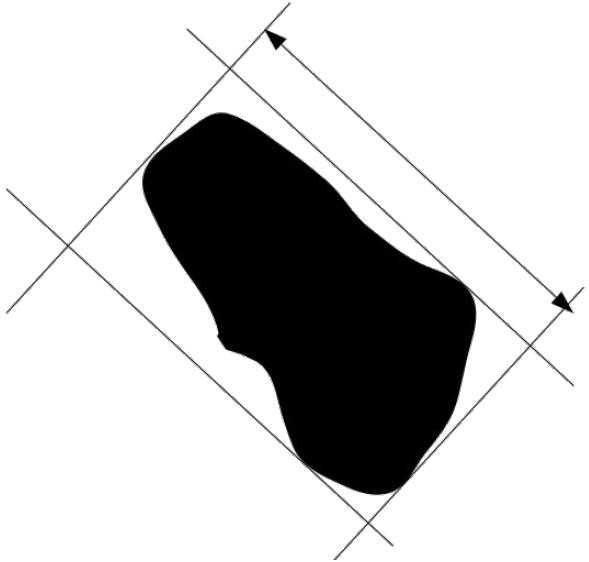
23 Objects ▸

Analyze - Measurements

Bounding Box - Size



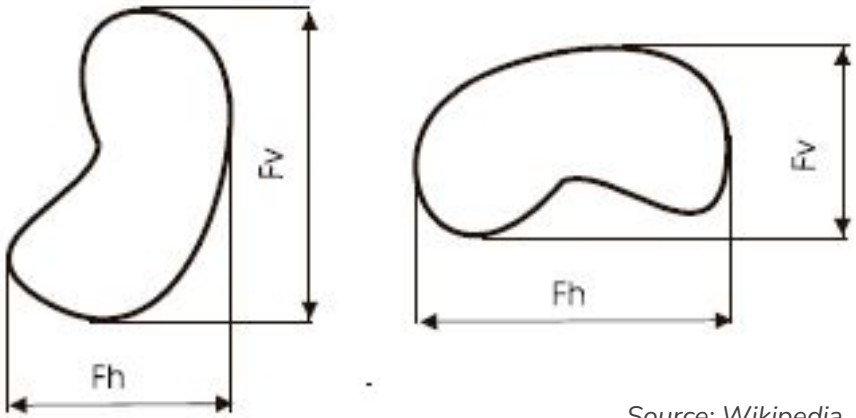
Axis-Aligned Bounding Box



Oriented Bounding Box

Analyze - Measurements

Size - Feret's Diameters



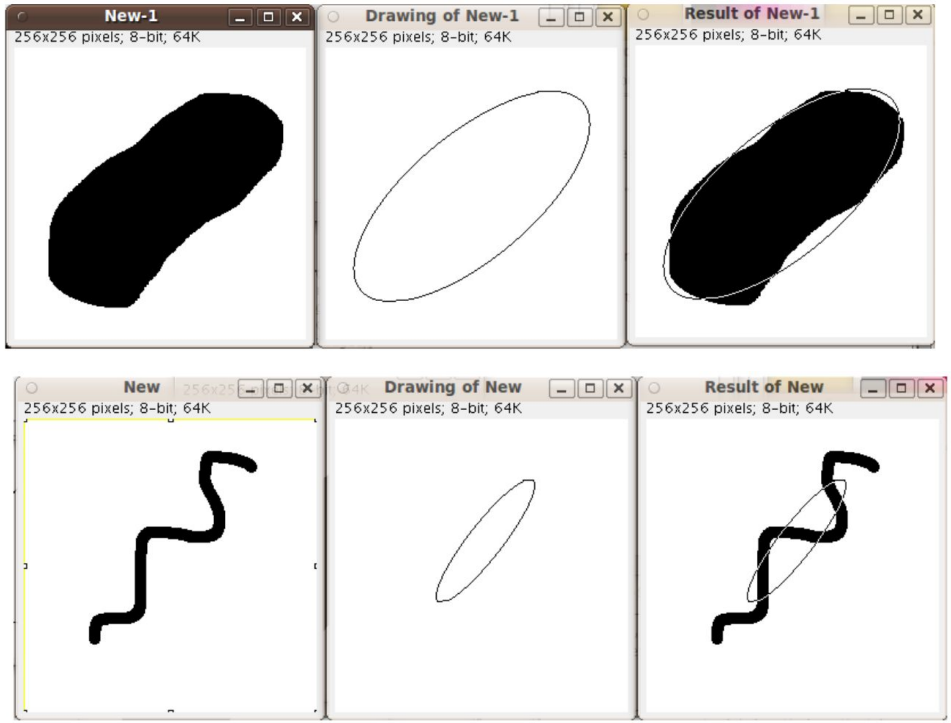
Source: Wikipedia

Size: Max. Feret Diameter x Min. Feret Diameter

Analyze - Measurements

Size - Ellipse

Ellipse
→ Major Axis
→ Minor Axis
→ Angle
→ Centroid



Analyze - Measurements

Shape Descriptors

Circularity = (4 . Area) / √ (Perimeter)

Roundness = 4. area / (Max_diameter . 2)

Shape Factor = Perim . 2 / (4 . area)

Aspect ratio = Max_diameter / Min_diameter

Compacity = √ (4 / Area) / Max_diameter

Analyze - Measurements

Shape Descriptors

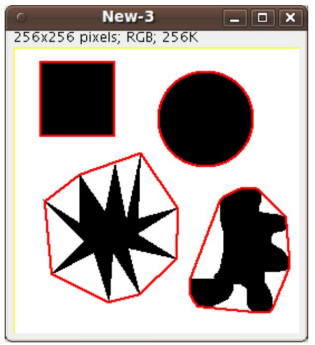
Circularity: 4π*area/sqrt(perimeter)

- A value of 1.0 indicates a perfect circle.
- As the value approaches 0.0, it indicates an increasingly elongated shape.
- Values may not be valid for very small particles.

Aspect ratio: major axis/minor axis.

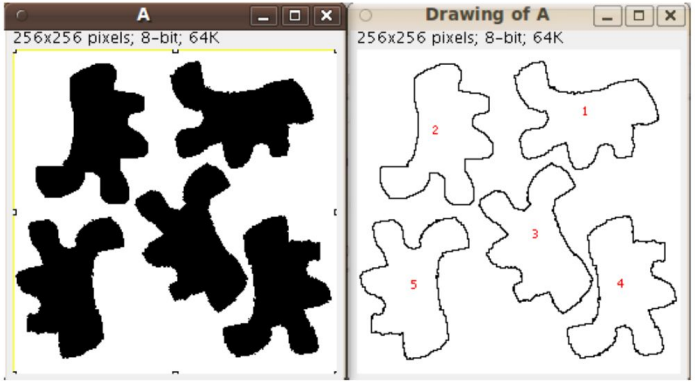
Roundness: 4 . area / (π*sqrt(major axis))

Solidity: area/convex area.



Analyze - Measurements

Shape Descriptors

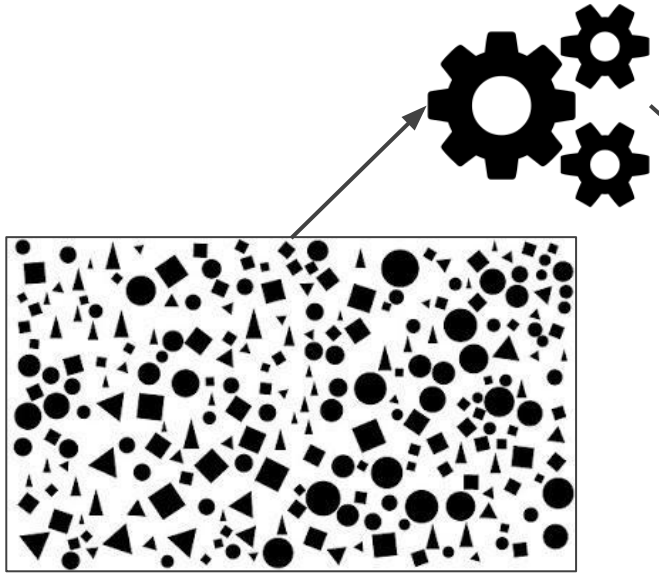


#	Label	Area	Circ.	AR	Round	Solidity
1	A	5312	0.335	1.604	0.624	0.701
2	A	5327	0.369	1.605	0.623	0.706
3	A	5304	0.328	1.603	0.624	0.699
4	A	5325	0.314	1.604	0.624	0.703
5	A	5322	0.325	1.601	0.625	0.702

Analyze - Machine Learning

Principle

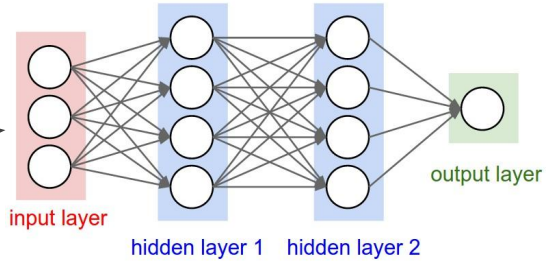
1. Learning Step with a labelled dataset (measurements/features + labels).
2. Prediction Step with an unknown dataset (measurements).



Results

File Edit Font Results

	Area	Circ.	AR	Round	Solidity
224	43	0.671	1.012	0.988	0.827
225	63	0.983	1.056	0.947	0.913
226	36	0.832	1.040	0.962	0.847
227	358	0.968	1.015	0.986	0.957
228	24	0.702	1.152	0.868	0.828
229	92	0.897	1.019	0.981	0.958
230	86	0.980	1.056	0.947	0.925
231	34	0.654	1.015	0.985	0.773
232	85	0.604	1.023	0.977	0.821
233	52	1.000	1.022	0.979	0.920
234	98	0.801	1.072	0.933	0.875
235	126	0.948	1.032	0.969	0.913
236	20	0.717	1.138	0.879	0.769
237	20	0.717	1.057	0.946	0.800
238	33	0.810	1.104	0.906	0.776
239	64	0.998	1.034	0.968	0.921



Digital Image

Pipeline

Image Enhancement

- Brightness/contrast
- Non Uniform Illumination
- Noise Removal

Segmentation

- Threshold
- Math. Morphology

Results

File Edit Font Results

	Area	XM	YM	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR
1	1	338.500	18.500	1.000	1.414	338	18	135	1	1.000
2	113	329.969	36.969	0.112	41.485	324	60	74.624	8.995	6.254
3	2	325.500	22.000	1.000	2.236	325	21	116.565	1.000	2.000
4	51	357.520	33.578	0.123	30.529	346	21	121.608	7.203	5.210
5	67	321.739	35.828	0.095	21.954	314	43	59.931	12.000	2.342
6	2	334.500	25.000	1.000	2.236	334	24	116.565	1.000	2.000
7	1	345.500	27.500	1.000	1.414	345	27	135.000	1.000	1.000
8	2	348.000	28.000	0.785	2.828	347	29	45.000	1.414	2.646
9	7	335.357	32.357	0.621	4.472	335	30	116.565	3.000	1.697
10	2	348.000	30.500	1.000	2.236	347	30	153.435	1.000	2.000
11	4	315.000	32.000	1.000	2.828	314	31	135.000	2.000	1.000
12	1	318.500	31.500	1.000	1.414	318	31	135.000	1.000	1.000

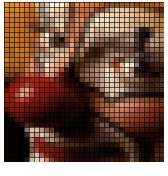
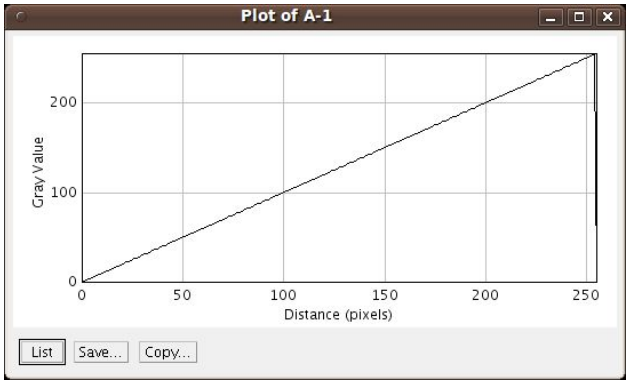
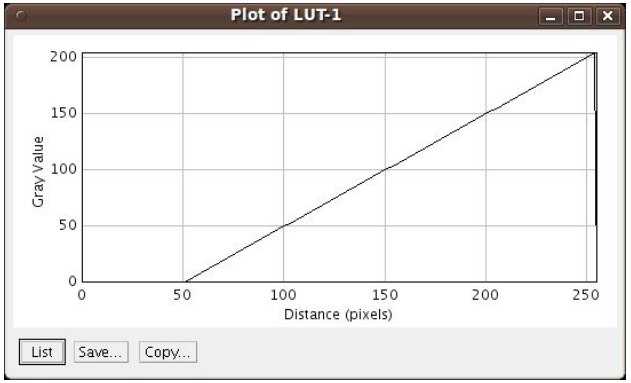


Image Enhancement

Principle - Brightness / Contrast





Transfer Function: Y = a . x + b

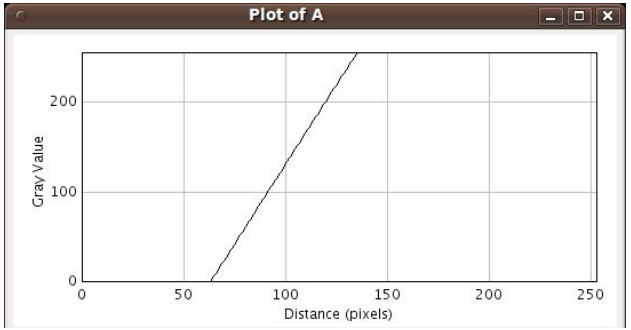
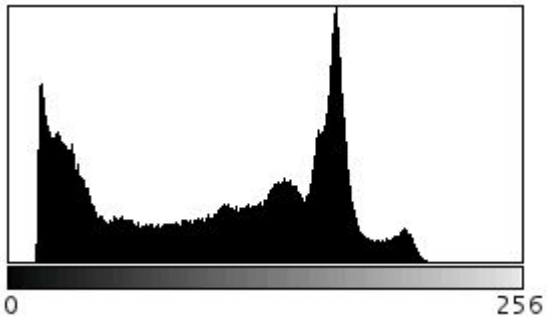
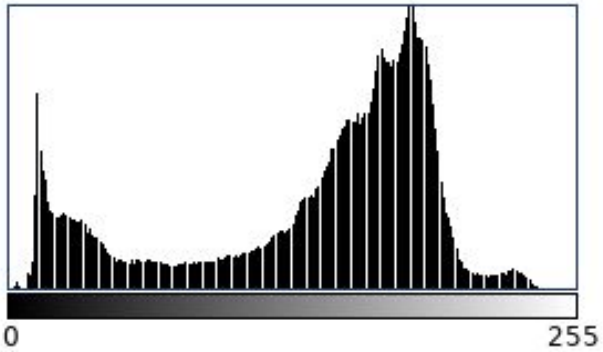


Image Enhancement

Principle - Normalization



$v' = (v - min) / (max - min)$



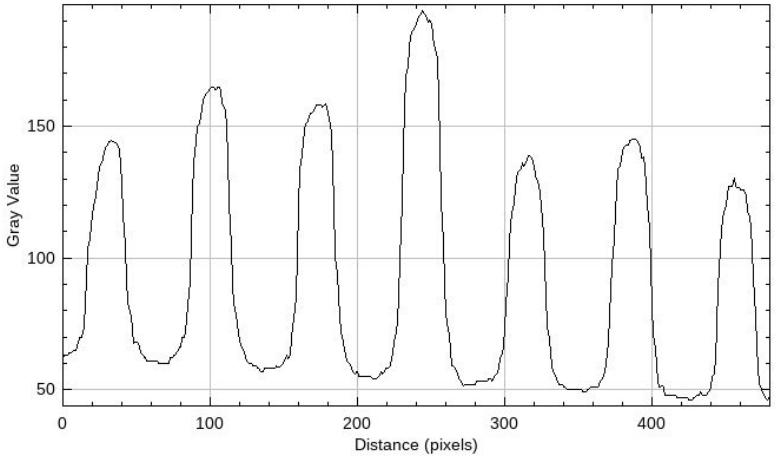
N: 414720	Min: 0
Mean: 137.016	Max: 255
StdDev: 57.807	Mode: 180 (7480)
Value: 112	Count: 1131

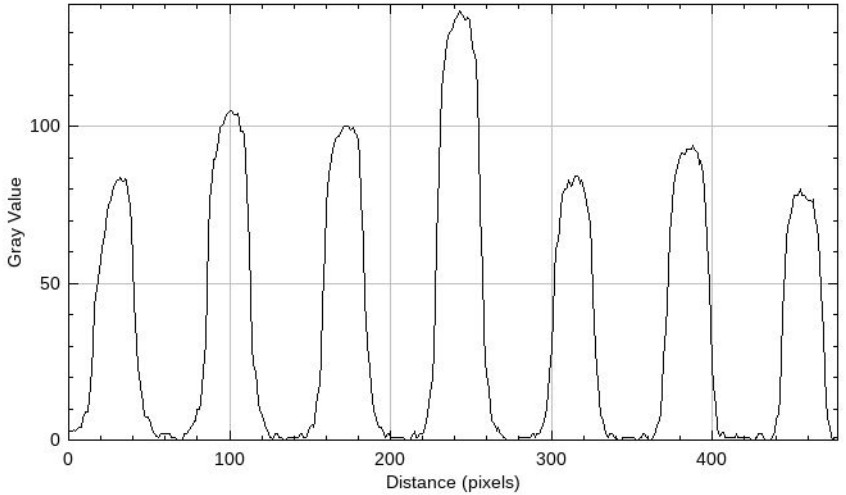
Image Enhancement

Non Uniform Illumination - Subtract Background

Removing the Baseline

- Polynomial Functions
- Rolling Ball

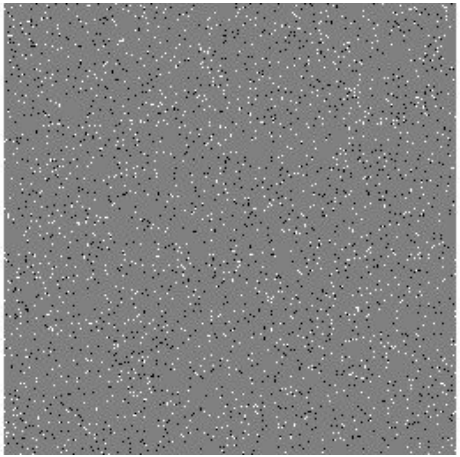


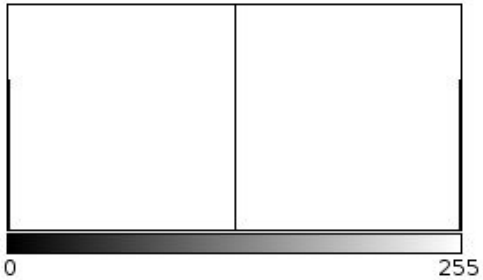


Denoising - Filters

Principle - Noise

Impulse Noise (Salt and Pepper)

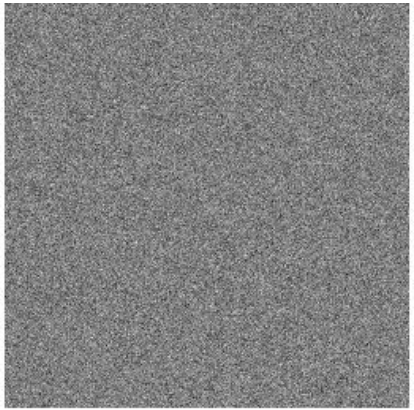


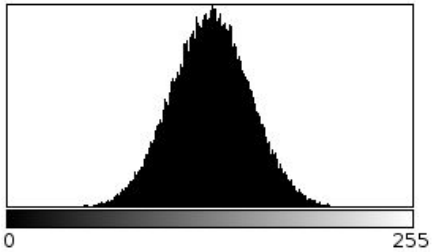


N: 65536
Mean: 127.974
StdDev: 28.161
Value: 167

Min: 0
Max: 255
Mode: 128 (62339)
Count: 0

Gaussian Noise





N: 65536
Mean: 127.915
StdDev: 24.918
Value: 176

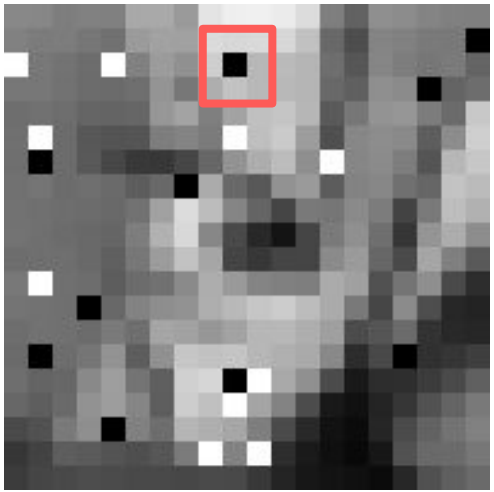
Min: 26
Max: 232
Mode: 129 (1092)
Count: 171

Denoising - Filters

Principle - Noise

Denoise Filters:

- Mean 3x3
- Median 3x3



219	216	218
207	0	184
174	195	184

Mean 3x3: All the weights are equal to 1:

219+216+218+207+0+184+174+195+184 => 177

Median 3x3: Sorting + Median value

0 < 174 < 184 <184 < 195 < 207 < 216 < 218 < 219 => 195

Denoising - Filters

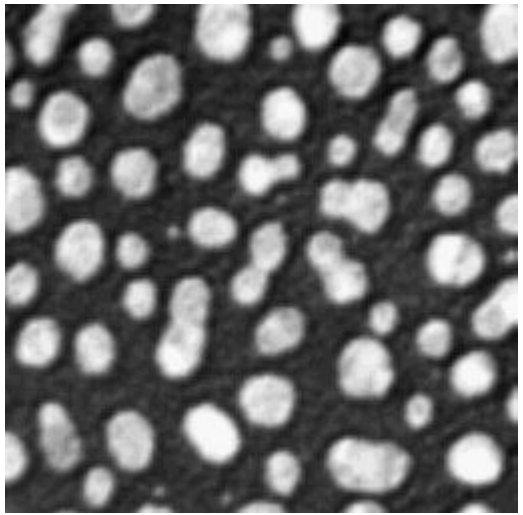
Principle - Noise

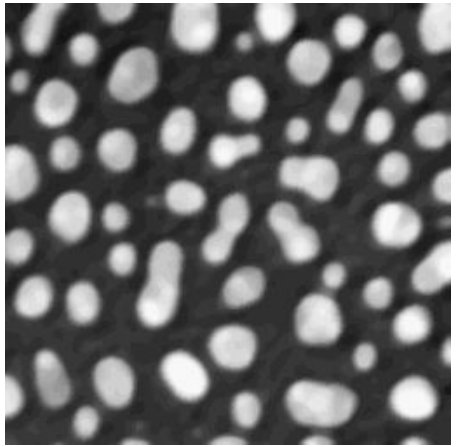
Linear Filters:

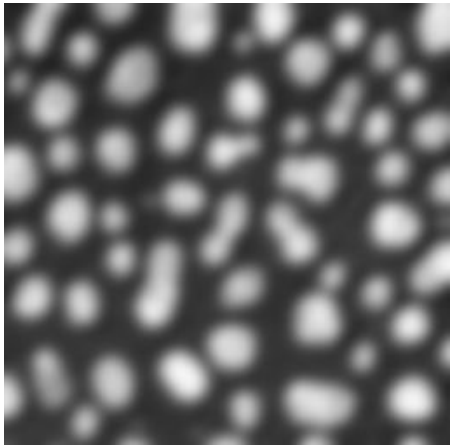
- Mean
- Weighted Mean

Non-linear Filters:

- Median ***





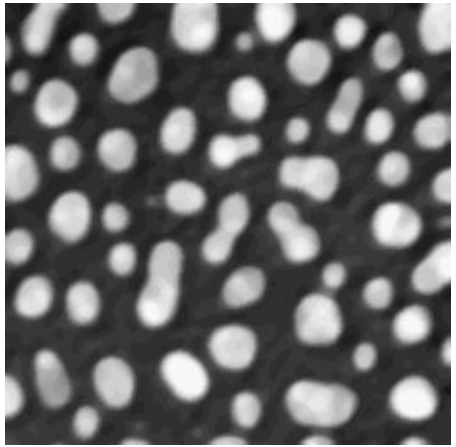


Segmentation

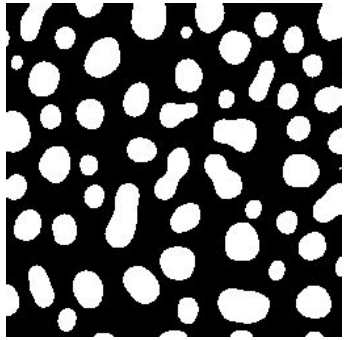
Separating ROI from background

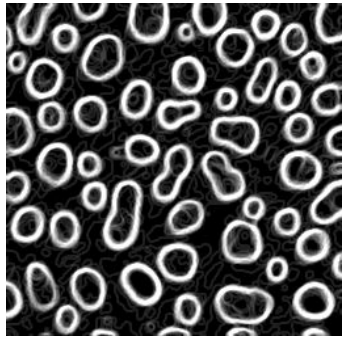
Methods

- Threshold
- Edges
- Clustering



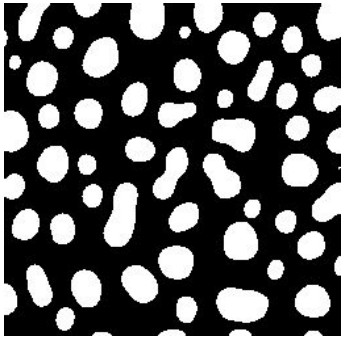
Binary (1bit) Image





Analyze

Measurements



Results

File Edit Font Results

	Area	XM	YM	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR
1	1	338.500	18.500	1.000	1.414	338	18	135	1	1.000
2	113	329.969	36.969	0.112	41.485	324	60	74.624	8.995	6.254
3	2	325.500	22.000	1.000	2.236	325	21	116.565	1.000	2.000
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7	1	345.500	27.500	1.000	1.414	345	27	135.000	1.000	1.000
8	2	348.000	28.000	0.785	2.828	347	29	45.000	1.414	2.646
9	7	335.357	32.357	0.621	4.472	335	30	116.565	3.000	1.697
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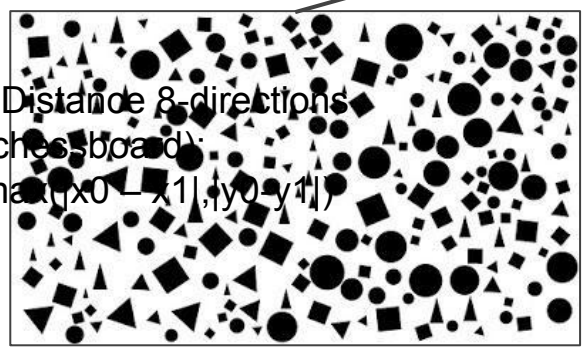
11	4	315.000	32.000	1.000	2.828	314	31	135.000	2.000	1.000
12	1	318.500	31.500	1.000	1.414	318	31	135.000	1.000	1.000

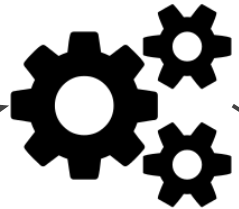
Analyze - Measurements

- Euclidian Distance :
√(x0 – x1) 2 + (y0 – y1) 2
Pixel connectivity
- Distance north-south-east-west
(city-block or Manhattan):
|x0 – x1| + |y0-y1|
0 1 2 3 4 5 6 7 8
9 0 1 2 3 4 5 6 7 8 9
8
7
6
5
4
3
2
1
0
- Distance 8-directions
(chessboard):
max(|x0 – x1|,|y0-y1|)

Principle

1. Learning Step with a labelled dataset (measurements/features + labels).
2. Prediction Step with an unknown dataset (measurements).





Results

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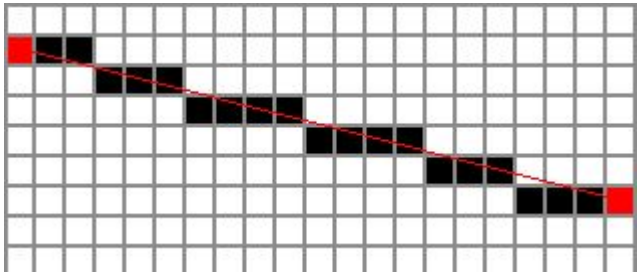
226	36	0.832	1.040	0.962	0.847
227	358	0.968	1.015	0.986	0.957
228	24	0.702	1.152	0.868	0.828
229	92	0.897	1.019	0.981	0.958
230	86	0.980	1.056	0.947	0.925
231	34	0.654	1.015	0.985	0.773
232	85	0.604	1.023	0.977	0.821
233	52	1.000	1.022	0.979	0.920
234	98	0.801	1.072	0.933	0.875
235	126	0.948	1.032	0.969	0.913
236	20	0.717	1.138	0.879	0.769
237	20	0.717	1.057	0.946	0.800
238	33	0.810	1.104	0.906	0.776
239	64	0.998	1.034	0.968	0.921

Analyze - Measurements

Distance

- Euclidean Distance :

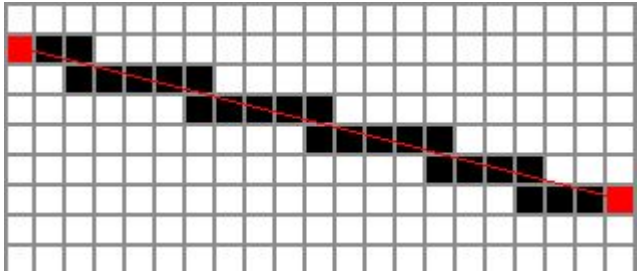
$\sqrt{(x0 - x1)^2 + (y0 - y1)^2}$



Pixel connectivity

- Distance north-south-east-west (city-block or Manhattan):

$|x0 - x1| + |y0-y1|$



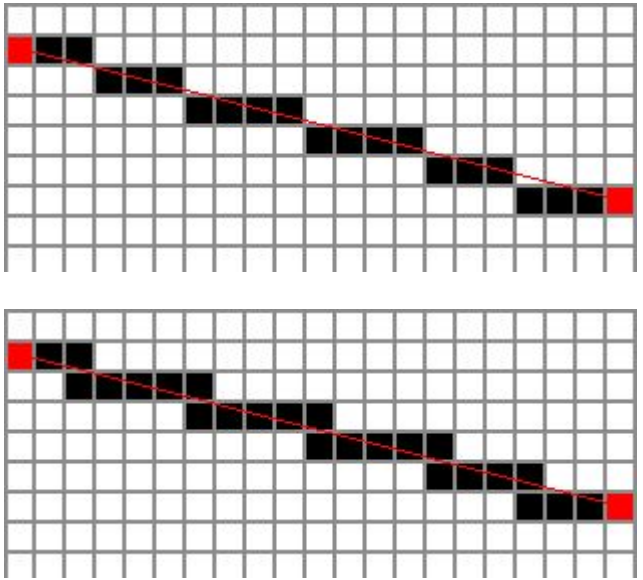
- Distance 8-directions (chessboard):

$max(|x0 - x1|,|y0-y1|)$

Analyze - Measurements

Distance

A(0,0) ⇔ B(20,5)

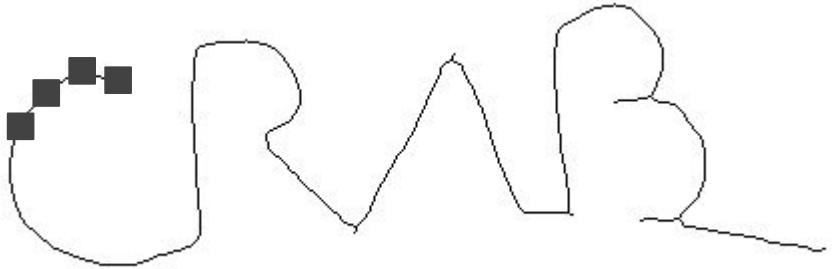


Pixel connectivity

- Distance 4-pixel connectivity: factor = 1.273
- Distance 8-pixel connectivity: factor = 0.9
- Factor = NSEW (1.0) + Diagonals (√2)

Analyze - Measurements

Object Length

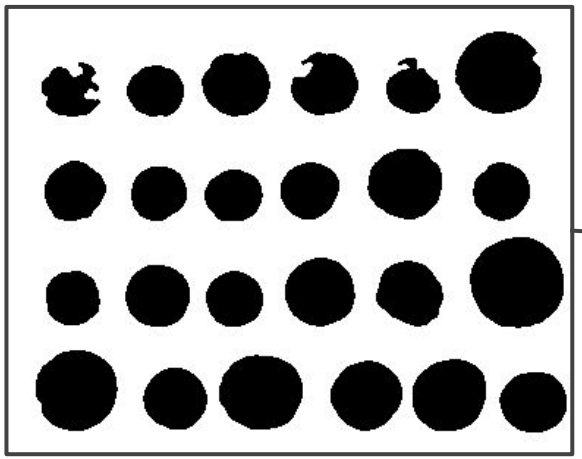


Length = Pixel_Number / connectivity_factor

Analyze - Measurements

Counting

Segmented Image



Convolution

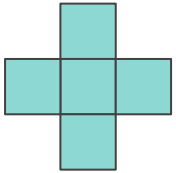


Table K	
X	Y
Xn	Yn
Xi	Yi
Xj	Yj
Xw	**Yw**

Table L	
Xi	Yi
Xj	Yj

Analyze - Measurements

Counting

Convolution

①

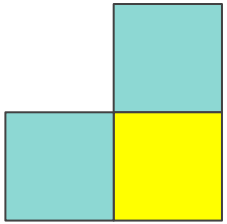


Table K	
Xm	**Ym**

②

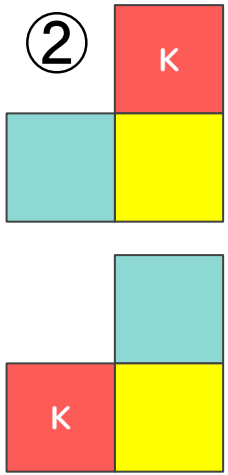


Table K	
X	Y
Xn	**Yn**

③

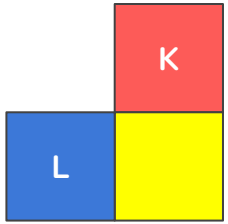


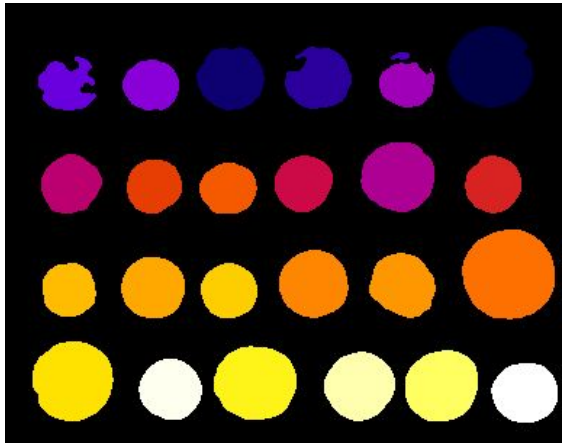
Table K	
X	Y
Xn	Yn

Table L	
Xi	Yi
Xj	Yj

Table K	
X	Y
Xn	Yn
Xi	Yi
Xj	Yj
Xw	**Yw**

Analyze - Measurements

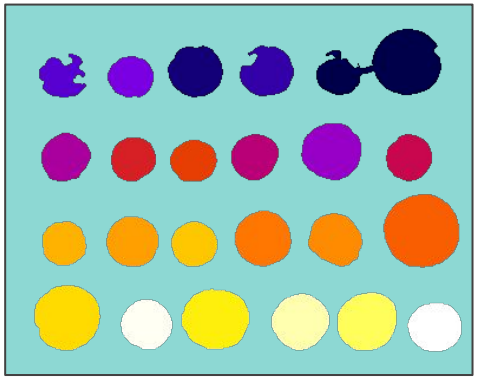
Counting



◂ 25 Objects

Table K	
X	Y
Xn	Yn
Xi	Yi
Xj	Yj
Xw	**Yw**

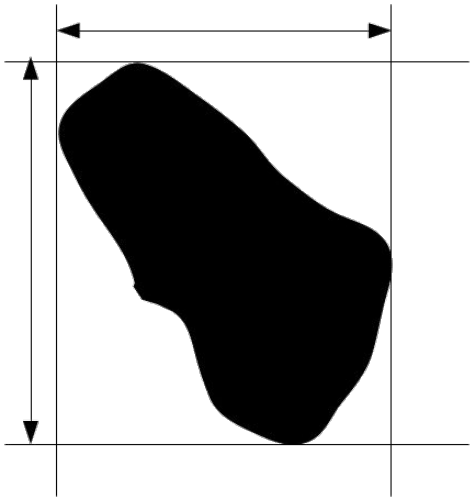
Table L	
Xi	Yi
Xj	Yj



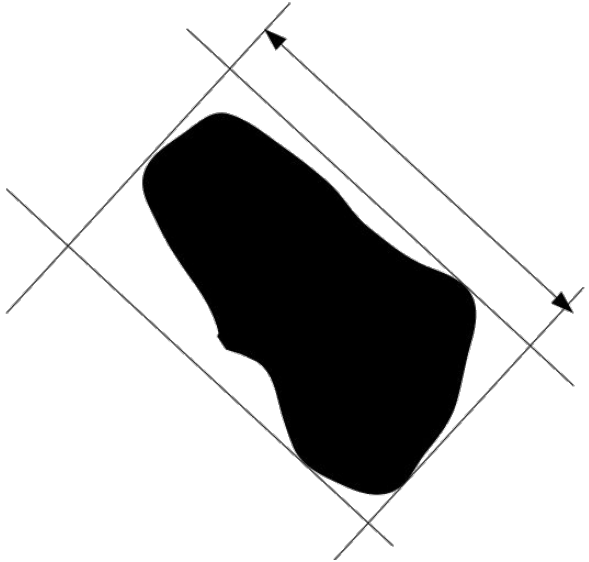
23 Objects ▸

Analyze - Measurements

Bounding Box - Size



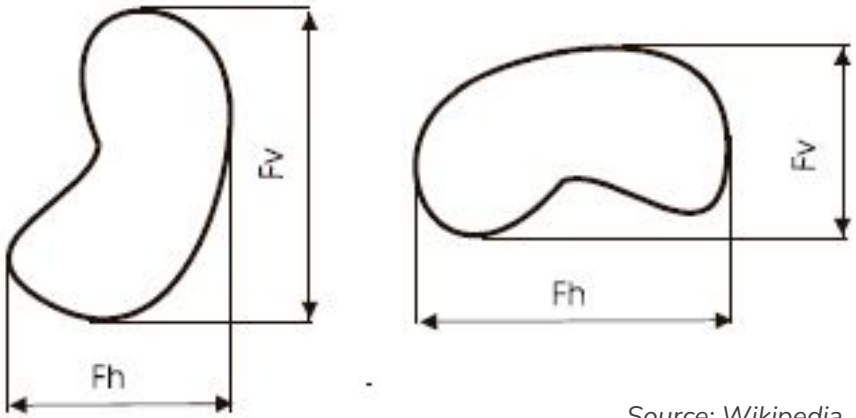
Axis-Aligned Bounding Box



Oriented Bounding Box

Analyze - Measurements

Size - Feret's Diameters



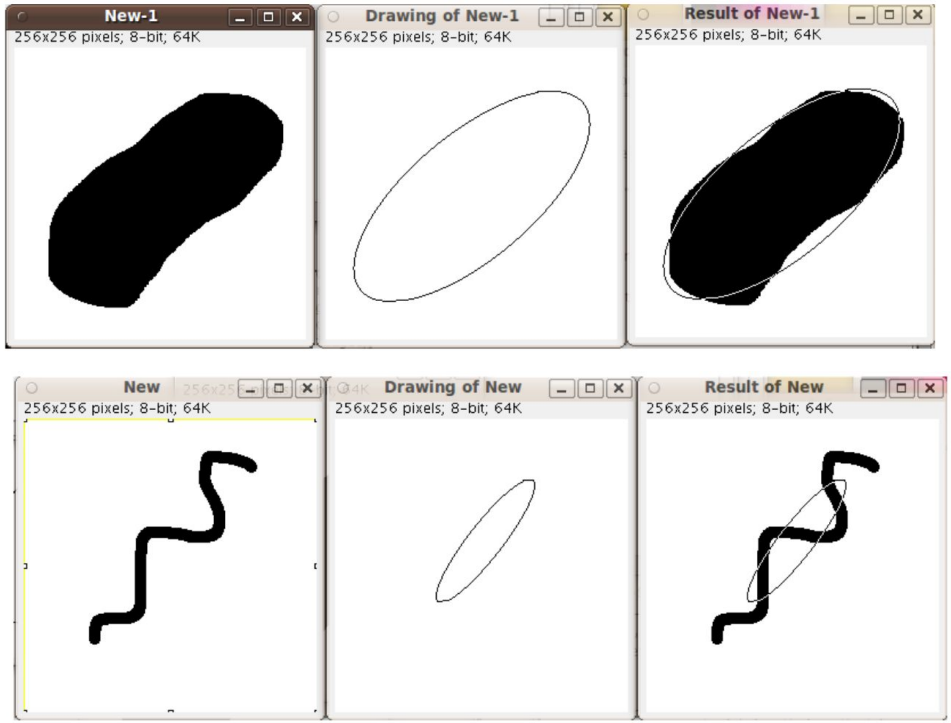
Source: Wikipedia

Size: Max. Feret Diameter x Min. Feret Diameter

Analyze - Measurements

Size - Ellipse

Ellipse
→ Major Axis
→ Minor Axis
→ Angle
→ Centroid



Analyze - Measurements

Shape Descriptors

Circularity = (4 . Area) / √ (Perimeter)

Roundness = 4. area / (Max_diameter . 2)

Shape Factor = Perim . 2 / (4 . area)

Aspect ratio = Max_diameter / Min_diameter

Compacity = √ (4 / Area) / Max_diameter

Analyze - Measurements

Shape Descriptors

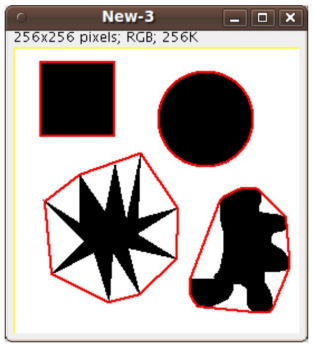
Circularity: 4π*area/sqrt(perimeter)

- A value of 1.0 indicates a perfect circle.
- As the value approaches 0.0, it indicates an increasingly elongated shape.
- Values may not be valid for very small particles.

Aspect ratio: major axis/minor axis.

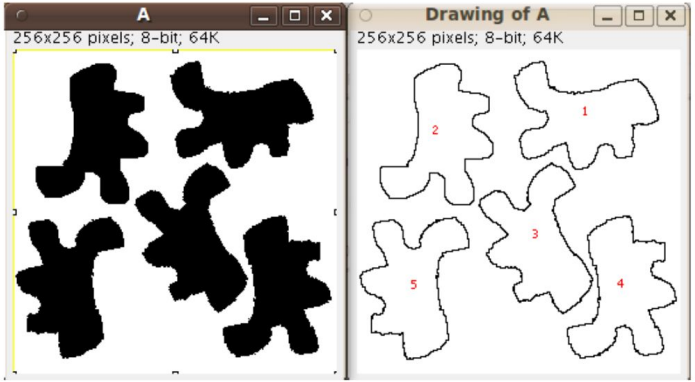
Roundness: 4 . area / (π*sqrt(major axis))

Solidity: area/convex area.



Analyze - Measurements

Shape Descriptors

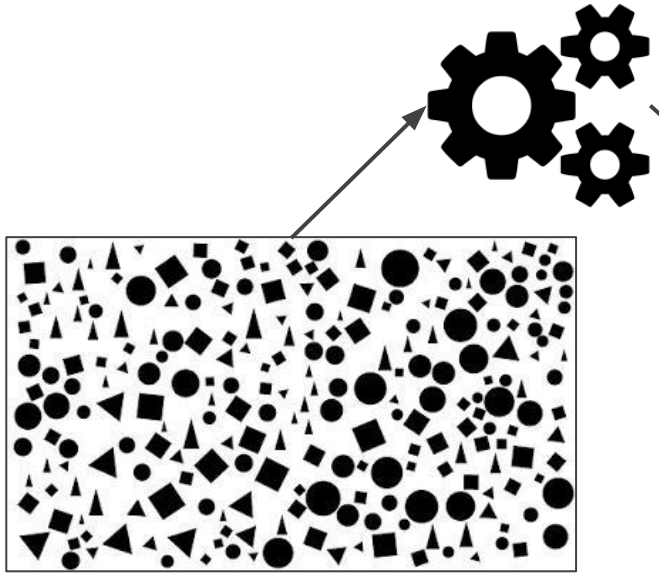


#	Label	Area	Circ.	AR	Round	Solidity
1	A	5312	0.335	1.604	0.624	0.701
2	A	5327	0.369	1.605	0.623	0.706
3	A	5304	0.328	1.603	0.624	0.699
4	A	5325	0.314	1.604	0.624	0.703
5	A	5322	0.325	1.601	0.625	0.702

Analyze - Machine Learning

Principle

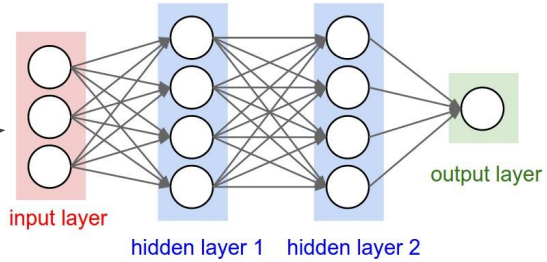
1. Learning Step with a labelled dataset (measurements/features + labels).
2. Prediction Step with an unknown dataset (measurements).



Results

File Edit Font Results

	Area	Circ.	AR	Round	Solidity
224	43	0.671	1.012	0.988	0.827
225	63	0.983	1.056	0.947	0.913
226	36	0.832	1.040	0.962	0.847
227	358	0.968	1.015	0.986	0.957
228	24	0.702	1.152	0.868	0.828
229	92	0.897	1.019	0.981	0.958
230	86	0.980	1.056	0.947	0.925
231	34	0.654	1.015	0.985	0.773
232	85	0.604	1.023	0.977	0.821
233	52	1.000	1.022	0.979	0.920
234	98	0.801	1.072	0.933	0.875
235	126	0.948	1.032	0.969	0.913
236	20	0.717	1.138	0.879	0.769
237	20	0.717	1.057	0.946	0.800
238	33	0.810	1.104	0.906	0.776
239	64	0.998	1.034	0.968	0.921



Analyze - Machine Learning

Deep Learning - End to End Approach