Part 1:

The process flow in the code implementation for this part looks like this:

1. Read dataset
2. Normalize dataset
3. Generate 5 random splits of the normalized dataset
4. Apply KNN or PCA + KNN
5. Output average accuracy, standard deviation and computation times

Outputs:

1. Simple KNN, using Cosine Similarity as distance measure, and 3 as the k value

```
Results without applying PCA and using Cosine Similarity as the distance measure in KNN (k = 3)

Average Accuracy: 0.974
Standard Deviation: 0.022449944320643667
Computation Times: [5.587595701217651, 4.330857992172241, 4.5508198738098145, 5.296854257583618, 4.248044490814209]
```

2. Simple KNN, using Euclidean as distance measure, and 3 as the k value

```
Results without applying PCA and using Euclidean as the distance measure in KNN (k = 3)

Average Accuracy: 0.9629999999999999
Standard Deviation: 0.02088061301782112
Computation Times: [3.5628442764282227, 4.799268484115601, 3.548143148422241, 3.496863603591919, 4.569430351257324]
```

The noticeable difference here is that with Euclidean as the distance measure, the computation time was reduces without any significant difference in the accuracy or standard deviation values

1. Simple KNN, using Euclidean as distance measure, 3 as the k value, and 5 as the classes/subjects values

```
Results without applying PCA and using Euclidean as the distance measure in KNN (k = 3, classes = 5)

Average Accuracy: 0.9960000000000001
Standard Deviation: 0.008000000000000007
Computation Times: [1.5010950565338135, 1.259225845336914, 0.8696529865264893, 0.8786160945892334, 0.8958480358123779]
```

2. Simple KNN, using Euclidean as distance measure, 3 as the k value, and 7 as the classes/subjects values

```
Results without applying PCA and using Euclidean as the distance measure in KNN (k = 3, classes = 7)

Average Accuracy: 0.9857142857142858
Standard Deviation: 0.018070158058105048
Computation Times: [1.7510974407196045, 1.7083961963653564, 1.715033769607544, 1.979337453842163, 2.705024003982544]
```

The thing to notice here is that not only computation times and standard deviation decreased depending on the number of classes but accuracy also increased since overall data decreased and the test data was now able to further improve the accuracy of the model

1. Simple KNN, using Euclidean as distance measure, 3 as the k value, 100 images per class for training and 70 images per class for testing

```
Results without applying PCA and using Euclidean as the distance measure in KNN (k = 3, train_images = 100, train_images = 70)

Average Accuracy: 0.9719999999999999
Standard Deviation: 0.006975174637562104
Computation Times: [8.219520330429077, 9.312226057052612, 9.275583028793335, 8.192786693572998, 9.231021165847778]
```

2. Simple KNN, using Euclidean as distance measure, 3 as the k value, 120 images per class for training and 50 images per class for testing

```
Results without applying PCA and using Euclidean as the distance measure in KNN (k = 3, train_images = 120, train_images = 50)

Average Accuracy: 0.9747999999999999
Standard Deviation: 0.010166612021711076
Computation Times: [7.626052141189575, 7.450585603713989, 8.082390069961548, 7.036544322967529, 8.016955614089966]
```

As can be seen here, computation times increase with test data and standard deviation decreases. No noticeable change in accuracy could be noticed since it was already really high.

1. Simple KNN, using Euclidean as distance measure, 5 as the k value

```
Results without applying PCA and using Euclidean as the distance measure in KNN (k = 5)

Average Accuracy: 0.9720000000000001
Standard Deviation: 0.021118712081942857
Computation Times: [3.564552068710327, 4.754005193710327, 3.4697628021240234, 3.3950891494750977, 4.628009796142578]
```

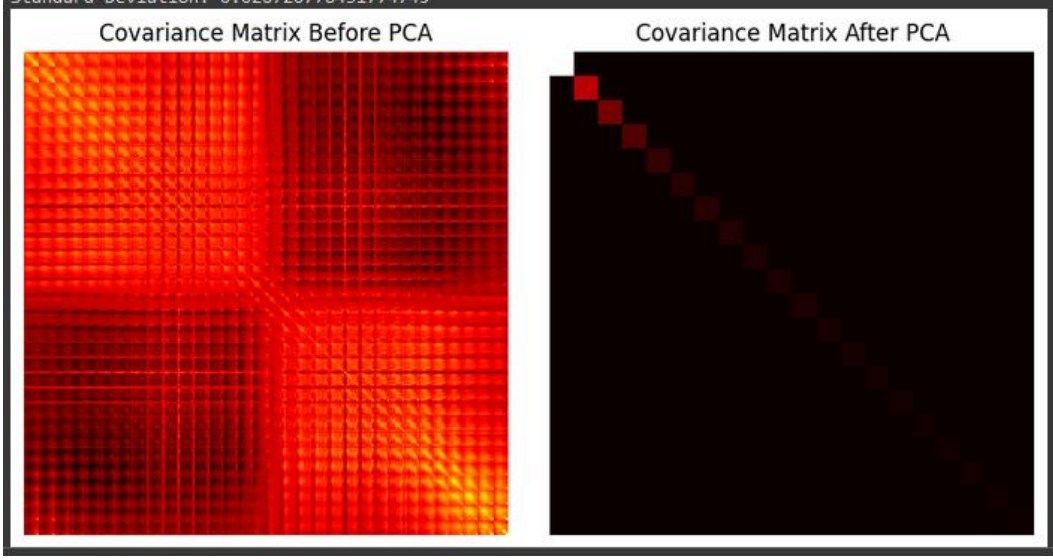
2. Simple KNN, using Euclidean as distance measure, 7 as the k value

```
Results without applying PCA and using Euclidean as the distance measure in KNN (k = 7)

Average Accuracy: 0.9640000000000001
Standard Deviation: 0.027640549922170497
Computation Times: [5.102294683456421, 3.5381381511688232, 3.531188488006592, 4.6829657554626465, 3.554135799407959]
```

No major noticeable trend here, but increasing k further would have adversely affected the accuracy of the model

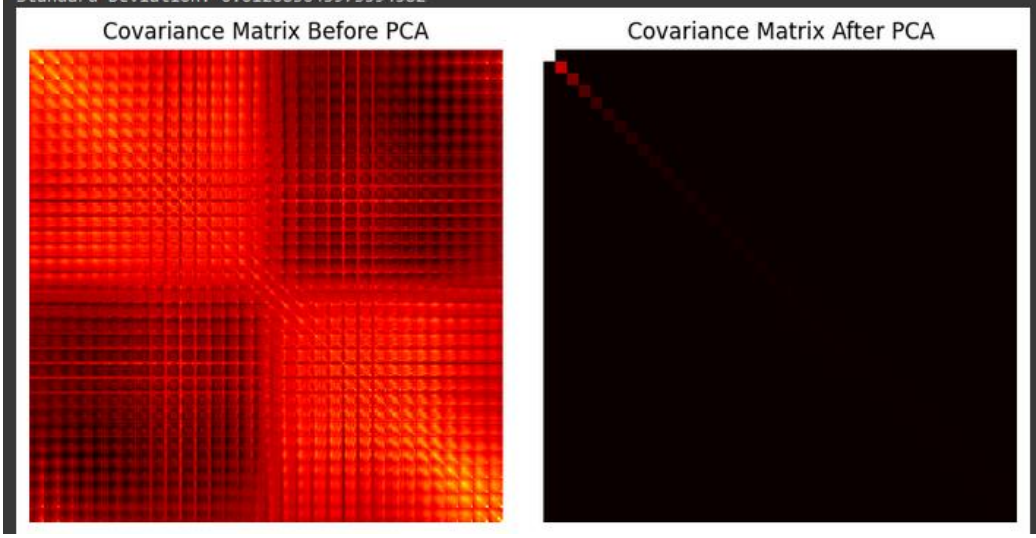
1. PCA + KNN with Euclidean as the distance measure, k=3 and principal components set to 20

```
Results PCA + KNN using Euclidean as the distance measure (k = 3, principal components = 20)

Number of Principal Components: 20
Average Accuracy Scores: [0.975, 0.965, 0.92, 0.93, 0.99]
Computation Times: [2.8001370429992676, 3.989873170852661, 2.8264241218566895, 2.8416635990142822, 2.807130813598633]
Average Accuracy: 0.9560000000000001
Standard Deviation: 0.026720778431774745
```



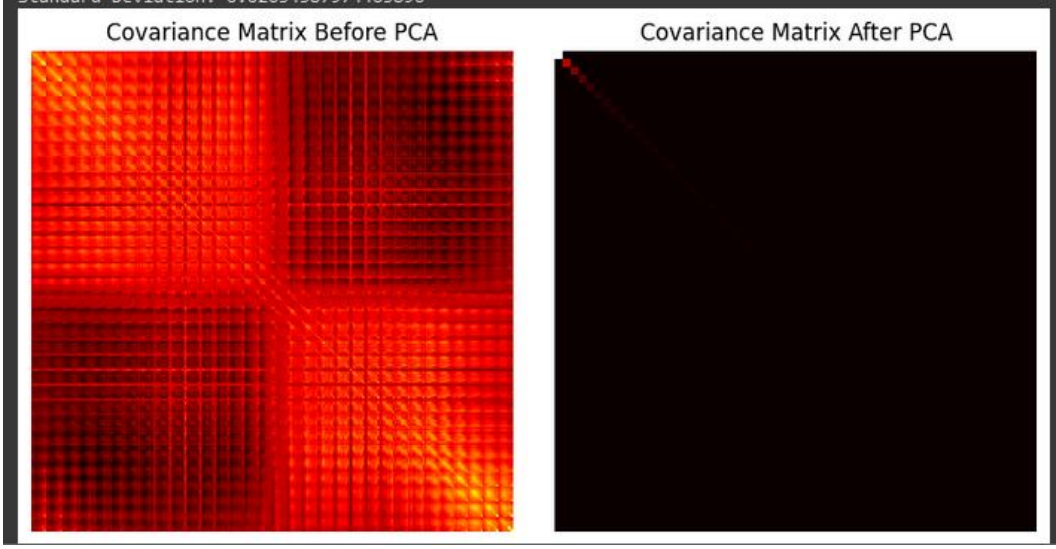
2. PCA + KNN with Euclidean as the distance measure, k=3 and principal components set to 40

```
Number of Principal Components: 40
Average Accuracy Scores: [0.995, 1.0, 0.99, 0.985, 0.965]
Computation Times: [3.5858778953552246, 2.9038233757019043, 2.8052456378936768, 4.070815324783325, 2.8363375663757324]
Average Accuracy: 0.9870000000000001
Standard Deviation: 0.012083045973594582
```



3. PCA + KNN with Euclidean as the distance measure, k=3 and principal components set to 60

```
Results PCA + KNN using Euclidean as the distance measure (k = 3, principal components = 60)

Number of Principal Components: 60
Average Accuracy Scores: [0.985, 0.925, 1.0, 0.99, 0.98]
Computation Times: [2.8489444255828857, 2.9051504135131836, 3.901599645614624, 2.871384859085083, 2.9673986434936523]
Average Accuracy: 0.9760000000000002
Standard Deviation: 0.02634387974463896
```



As can be noticed, uncorrelated covariance matrices were produced after applying PCA. Secondly, using 40 as the principal components values produced the best accuracy. Lastly, applying PCA on the data before apply KNN did reduce the computation time as now there was less data for KNN to process.

Part 2:

The process flow in the code for this part looks like this:

1. Read the normal and corresponding auxiliary image
2. Identify coordinates of seed foreground and background pixels from the auxiliary image
3. Extract the identified foreground and background pixels from the normal image
4. Apply KMeans Clustering algorithm on the extracted pixels (choose either the built-in function or the custom one)
5. Calculate class likelihoods of the identified foreground and background pixels from step 3
6. Output accuracies of the models (custom and built-in)

There were certain ambiguities in the task description:

a. Was the likelihood calculation to be carried out inside the kmeans algorithm or separately (code implementation assumes latter)
b. Was the likelihood calculation to be carried out for all pixels in the image or only the identified foreground and background pixels (code implementation assumes latter)

<u>Outputs:</u>

A. Normal image: lady.png Auxiliary Image: lady_stroke_1.png

1. Built-in KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  1283
Total pixels labeled 'Background':  63
Accuracy:  95.31946508172364
Foreground class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([138,  93,  66], dtype=uint8), a
Background class:  [array([181, 131,  98], dtype=uint8), array([190, 146, 115], dtype=uint8), array([172, 128,  97], dtype=uint8), a


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  56
Total pixels labeled 'Background':  1983
Accuracy:  97.25355566454145
Foreground class:  [array([129,  97,  73], dtype=uint8), array([158, 124,  98], dtype=uint8), array([114,  81,  52], dtype=uint8), a
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), a
```

2. Built-in KMeans algorithm, N = 75

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=75)
Total pixels labeled 'Foreground':  1289
Total pixels labeled 'Background':  57
Accuracy:  95.76523031203567
Foreground class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([138,  93,  66], dtype=uint8), array
Background class:  [array([181, 131,  98], dtype=uint8), array([181, 133, 103], dtype=uint8), array([190, 146, 115], dtype=uint8), array


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=75)
Total pixels labeled 'Foreground':  53
Total pixels labeled 'Background':  1986
Accuracy:  97.40068661108387
Foreground class:  [array([129,  97,  73], dtype=uint8), array([148, 112,  87], dtype=uint8), array([146, 110,  84], dtype=uint8), array
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), array
```

3. Built-in KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  1297
Total pixels labeled 'Background':  49
Accuracy:  96.35958395245171
Foreground class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([153, 100,  70], dtype=uint8),
Background class:  [array([138,  93,  66], dtype=uint8), array([190, 146, 115], dtype=uint8), array([110,  76,  50], dtype=uint8),


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  37
Total pixels labeled 'Background':  2002
Accuracy:  98.18538499264345
Foreground class:  [array([123,  92,  71], dtype=uint8), array([124,  94,  70], dtype=uint8), array([114,  81,  52], dtype=uint8),
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8),
```

Thing to be noticed here is the N=88 offered the best accuracy. Increasing N further produced similar accuracy.

1. Custom KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  752
Total pixels labeled 'Background':  594
Accuracy:  55.86924219910847
Foreground class:  [array([133,  82,  49], dtype=uint8), array([120,  72,  44], dtype=uint8), array([98, 66, 44], dt
Background class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([138,  93,  66],


Class likelihood of background seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  225
Total pixels labeled 'Background':  1814
Accuracy:  88.96517900931829
Foreground class:  [array([64, 52, 41], dtype=uint8), array([48, 37, 26], dtype=uint8), array([55, 39, 26], dtype=ui
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123],
```

2. Custom KMeans algorithm, N = 75

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=75)
Total pixels labeled 'Foreground':  789
Total pixels labeled 'Background':  557
Accuracy:  58.618127786032694
Foreground class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([153, 100,  70], dtype=uint8), array([1
Background class:  [array([138,  93,  66], dtype=uint8), array([183, 132,  98], dtype=uint8), array([169, 117,  82], dtype=uint8), array([1


Class likelihood of background seed pixels, using custom KMeans algorithm (N=75)
Total pixels labeled 'Foreground':  229
Total pixels labeled 'Background':  1810
Accuracy:  88.7690044139284
Foreground class:  [array([64, 52, 41], dtype=uint8), array([48, 37, 26], dtype=uint8), array([55, 39, 26], dtype=uint8), array([60, 40, 26
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), array([1
```

3. Custom KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  752
Total pixels labeled 'Background':  594
Accuracy:  55.86924219910847
Foreground class:  [array([133,  82,  49], dtype=uint8), array([120,  72,  44], dtype=uint8), array([98, 66, 44], dtype=uint8), array([
Background class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([138,  93,  66], dtype=uint8), arra


Class likelihood of background seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  255
Total pixels labeled 'Background':  1784
Accuracy:  87.49386954389406
Foreground class:  [array([64, 52, 41], dtype=uint8), array([55, 39, 26], dtype=uint8), array([60, 40, 26], dtype=uint8), array([85, 66
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), arra
```

Noticeable trend here is that the custom KMeans performed bad on the foreground pixels across all N values. Moreover, changing N values in this case produced no big change.

B. Normal image: lady.png Auxiliary Image: lady_stroke_2.png

1. Built-in KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  1287
Total pixels labeled 'Background':  59
Accuracy:  95.61664190193166
Foreground class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([138,  93,  66], dtype=uint8), array([15
Background class:  [array([183, 132,  98], dtype=uint8), array([181, 131,  98], dtype=uint8), array([181, 133, 103], dtype=uint8), array([19


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  60
Total pixels labeled 'Background':  1826
Accuracy:  96.8186638388123
Foreground class:  [array([129,  97,  73], dtype=uint8), array([131, 101,  76], dtype=uint8), array([148, 112,  87], dtype=uint8), array([14
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), array([17
```

2. Built-in KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  1297
Total pixels labeled 'Background':  49
Accuracy:  96.35958395245171
Foreground class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([153, 100,  70], dtype=uint8), arr
Background class:  [array([138,  93,  66], dtype=uint8), array([120,  72,  44], dtype=uint8), array([190, 146, 115], dtype=uint8), arr


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  42
Total pixels labeled 'Background':  1844
Accuracy:  97.77306468716861
Foreground class:  [array([123,  92,  71], dtype=uint8), array([124,  94,  70], dtype=uint8), array([114,  81,  52], dtype=uint8), arr
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), arr
```

Changing N value in this case couldn't affect the accuracy significantly since it was already pretty high

1. Custom KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  629
Total pixels labeled 'Background':  717
Accuracy:  46.731054977711736
Foreground class:  [array([133,  82,  49], dtype=uint8), array([87, 55, 36], dtype=uint8), array([80, 50, 28], dtype=uint8), array([85, 51
Background class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([138,  93,  66], dtype=uint8), array([


Class likelihood of background seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  142
Total pixels labeled 'Background':  1744
Accuracy:  92.47083775185578
Foreground class:  [array([64, 52, 41], dtype=uint8), array([72, 57, 37], dtype=uint8), array([74, 61, 42], dtype=uint8), array([66, 52, 3
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), array([
```

2. Custom KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  793
Total pixels labeled 'Background':  553
Accuracy:  58.91530460624072
Foreground class:  [array([153, 100,  70], dtype=uint8), array([133,  82,  49], dtype=uint8), array([120,  72,  44], dtype=uint8), array(
Background class:  [array([165, 111,  78], dtype=uint8), array([157, 108,  82], dtype=uint8), array([138,  93,  66], dtype=uint8), array(


Class likelihood of background seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  159
Total pixels labeled 'Background':  1727
Accuracy:  91.56945917285259
Foreground class:  [array([64, 52, 41], dtype=uint8), array([48, 37, 26], dtype=uint8), array([55, 39, 26], dtype=uint8), array([60, 40,
Background class:  [array([185, 164, 146], dtype=uint8), array([200, 176, 158], dtype=uint8), array([164, 139, 123], dtype=uint8), array(
```

Performance on background pixel identification remained high while performance on foreground pixel identification remained low.

C. Normal image: Mona-lisa.png Auxiliary Image: Mona-lisa_1.png

1. Built-in KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  1757
Total pixels labeled 'Background':  142
Accuracy:  92.52238020010532
Foreground class:  [array([235, 201, 123], dtype=uint8), array([255, 227, 150], dtype=uint8), array([225, 185, 111], dtype=uint8), ar
Background class:  [array([105,  81,  45], dtype=uint8), array([84, 55, 33], dtype=uint8), array([81, 62, 40], dtype=uint8), array([5


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  334
Total pixels labeled 'Background':  2587
Accuracy:  88.56555973981514
Foreground class:  [array([98, 87, 38], dtype=uint8), array([84, 70, 24], dtype=uint8), array([77, 63, 23], dtype=uint8), array([71,
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint8), ar
```

2. Built-in KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  1773
Total pixels labeled 'Background':  126
Accuracy:  93.36492890995261
Foreground class:  [array([235, 201, 123], dtype=uint8), array([255, 227, 150], dtype=uint8), array([225, 185, 111], dtype=uint8), array
Background class:  [array([105,  76,  39], dtype=uint8), array([84, 55, 33], dtype=uint8), array([81, 62, 40], dtype=uint8), array([59,


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  297
Total pixels labeled 'Background':  2624
Accuracy:  89.83224922971586
Foreground class:  [array([116, 104,  49], dtype=uint8), array([84, 70, 24], dtype=uint8), array([66, 51, 16], dtype=uint8), array([71,
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint8), array
```

In this case, changing N did not have any significant effect

1. Custom KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  924
Total pixels labeled 'Background':  975
Accuracy:  48.657187993680886
Foreground class:  [array([228, 163,  79], dtype=uint8), array([229, 162,  78], dtype=uint8), array([223, 170,  77], dtype=uint8), arr
Background class:  [array([235, 201, 123], dtype=uint8), array([255, 227, 150], dtype=uint8), array([225, 185, 111], dtype=uint8), arr


Class likelihood of background seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  921
Total pixels labeled 'Background':  2000
Accuracy:  68.46970215679562
Foreground class:  [array([154, 132,  80], dtype=uint8), array([129, 115,  60], dtype=uint8), array([153, 136,  72], dtype=uint8), arr
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint8), arr
```

2. Custom KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  1515
Total pixels labeled 'Background':  384
Accuracy:  79.77883096366509
Foreground class:  [array([235, 201, 123], dtype=uint8), array([225, 185, 111], dtype=uint8), array([251, 216, 138], dtype=uint8), array(
Background class:  [array([255, 227, 150], dtype=uint8), array([255, 223, 145], dtype=uint8), array([249, 220, 141], dtype=uint8), array(


Class likelihood of background seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  858
Total pixels labeled 'Background':  2063
Accuracy:  70.62649777473467
Foreground class:  [array([157, 147,  81], dtype=uint8), array([157, 140,  86], dtype=uint8), array([154, 132,  80], dtype=uint8), array(
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint8), array(
```

Changing N seemed to have a huge effect for foreground pixel identification in this case

D. Normal image: Mona-lisa.png Auxiliary Image: Mona-lisa_2.png

1. Built-in KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  935
Total pixels labeled 'Background':  8
Accuracy:  99.15164369034994
Foreground class:  [array([235, 201, 123], dtype=uint8), array([255, 227, 150], dtype=uint8), array([225, 185, 111], dtype=uint
Background class:  [array([77, 60, 25], dtype=uint8), array([57, 51, 40], dtype=uint8), array([100,  86,  46], dtype=uint8), ar


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  10
Total pixels labeled 'Background':  1934
Accuracy:  99.48559670781893
Foreground class:  [array([109,  98,  39], dtype=uint8), array([98, 87, 38], dtype=uint8), array([112,  96,  48], dtype=uint8),
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint
```

2. Built-in KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  940
Total pixels labeled 'Background':  3
Accuracy:  99.68186638388123
Foreground class:  [array([235, 201, 123], dtype=uint8), array([255, 227, 150], dtype=uint8), array([225, 185, 111], dtype=uint8)
Background class:  [array([57, 51, 40], dtype=uint8), array([100,  86,  46], dtype=uint8), array([108,  95,  47], dtype=uint8)]


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  10
Total pixels labeled 'Background':  1934
Accuracy:  99.48559670781893
Foreground class:  [array([116, 104,  49], dtype=uint8), array([95, 88, 30], dtype=uint8), array([84, 70, 24], dtype=uint8), arra
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint8)
```

Accuracy was extremely high in this case and hence changing N could not have any significant effect

1. Custom KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  929
Total pixels labeled 'Background':  14
Accuracy:  98.5153764581124
Foreground class:  [array([235, 201, 123], dtype=uint8), array([255, 227, 150], dtype=uint8), array([225, 185, 111], dtype=uint8), array([
Background class:  [array([128,  91,  17], dtype=uint8), array([127,  90,  21], dtype=uint8), array([142,  84,   7], dtype=uint8), array([


Class likelihood of background seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  480
Total pixels labeled 'Background':  1464
Accuracy:  75.30864197530865
Foreground class:  [array([162, 144,  77], dtype=uint8), array([161, 142,  77], dtype=uint8), array([155, 138,  83], dtype=uint8), array([
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint8), array([
```

2. Custom KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  850
Total pixels labeled 'Background':  93
Accuracy:  90.13785790031812
Foreground class:  [array([235, 201, 123], dtype=uint8), array([255, 227, 150], dtype=uint8), array([225, 185, 111], dtype=uint8), array(
Background class:  [array([128,  91,  17], dtype=uint8), array([127,  90,  21], dtype=uint8), array([125,  86,  27], dtype=uint8), array(


Class likelihood of background seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  130
Total pixels labeled 'Background':  1814
Accuracy:  93.3127572016461
Foreground class:  [array([141, 131,  62], dtype=uint8), array([157, 140,  86], dtype=uint8), array([138, 122,  59], dtype=uint8), array(
Background class:  [array([143, 195, 139], dtype=uint8), array([130, 171, 114], dtype=uint8), array([130, 153,  94], dtype=uint8), array(
```

The overall best results of the custom Kmeans model

E. Normal image: Van_Gogh.png Auxiliary Image: Van_Gogh.png

1. Built-in KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  5599
Total pixels labeled 'Background':  1927
Accuracy:  74.39542917884665
Foreground class:  [array([196, 178, 144], dtype=uint8), array([251, 234, 200], dtype=uint8), array([255, 252, 216], dtype=uint8), a
Background class:  [array([224, 220, 203], dtype=uint8), array([221, 213, 200], dtype=uint8), array([198, 198, 173], dtype=uint8), a


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  1429
Total pixels labeled 'Background':  7795
Accuracy:  84.50780572419775
Foreground class:  [array([134, 179, 175], dtype=uint8), array([140, 203, 191], dtype=uint8), array([164, 206, 194], dtype=uint8), a
Background class:  [array([213, 224, 216], dtype=uint8), array([229, 238, 229], dtype=uint8), array([230, 240, 231], dtype=uint8), a
```

2. Built-in KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  5634
Total pixels labeled 'Background':  1892
Accuracy:  74.86048365665692
Foreground class:  [array([196, 178, 144], dtype=uint8), array([251, 234, 200], dtype=uint8), array([255, 252, 216], dtype=uint8), a
Background class:  [array([186, 192, 168], dtype=uint8), array([189, 203, 167], dtype=uint8), array([128, 134, 107], dtype=uint8), a


Class likelihood of background seed pixels, using builtin KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  1453
Total pixels labeled 'Background':  7771
Accuracy:  84.24761491760624
Foreground class:  [array([ 60, 105, 111], dtype=uint8), array([140, 203, 191], dtype=uint8), array([129, 179, 167], dtype=uint8), a
Background class:  [array([213, 224, 216], dtype=uint8), array([229, 238, 229], dtype=uint8), array([230, 240, 231], dtype=uint8), a
```

No significant change in accuracy by changing N value

1. Custom KMeans algorithm, N = 64

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  4355
Total pixels labeled 'Background':  3171
Accuracy:  57.86606431039064
Foreground class:  [array([196, 178, 144], dtype=uint8), array([207, 191, 156], dtype=uint8), array([214, 200, 165], dtype=uint8), array([22
Background class:  [array([251, 234, 200], dtype=uint8), array([255, 252, 216], dtype=uint8), array([241, 233, 202], dtype=uint8), array([25


Class likelihood of background seed pixels, using custom KMeans algorithm (N=64)
Total pixels labeled 'Foreground':  1645
Total pixels labeled 'Background':  7579
Accuracy:  82.16608846487425
Foreground class:  [array([120, 153, 146], dtype=uint8), array([134, 179, 175], dtype=uint8), array([129, 179, 167], dtype=uint8), array([12
Background class:  [array([213, 224, 216], dtype=uint8), array([229, 238, 229], dtype=uint8), array([230, 240, 231], dtype=uint8), array([22
```

2. Custom KMeans algorithm, N = 88

```
Class likelihood of foreground seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  4005
Total pixels labeled 'Background':  3521
Accuracy:  53.21551953228807
Foreground class:  [array([196, 178, 144], dtype=uint8), array([207, 191, 156], dtype=uint8), array([214, 200, 165], dtype=uint8), array(
Background class:  [array([251, 234, 200], dtype=uint8), array([255, 252, 216], dtype=uint8), array([241, 233, 202], dtype=uint8), array(


Class likelihood of background seed pixels, using custom KMeans algorithm (N=88)
Total pixels labeled 'Foreground':  1285
Total pixels labeled 'Background':  7939
Accuracy:  86.06895056374675
Foreground class:  [array([120, 153, 146], dtype=uint8), array([129, 179, 167], dtype=uint8), array([129, 167, 156], dtype=uint8), array(
Background class:  [array([213, 224, 216], dtype=uint8), array([229, 238, 229], dtype=uint8), array([230, 240, 231], dtype=uint8), array(
```

Same trend as with the lady.png image. Good accuracy with background pixel identification but bad accuracy with the foreground pixel identification

Overall, the built-in KMeans algorithm performed faster and more accurately than the custom algorithm for all three images.