

Brennan Hall
861198641
CS171 - 18S
Late Days Used: 0
Total Late Days: 2

Assignment 1

Q1)

Calculate and plot equi-width histograms for the values of the attribute across the given class. You should parametrize your implementation with the number of histogram bins and create plots for b = 5, 10, 50, and 100 bins. In your report you should show all the plots organized by 1) dataset 2) attribute, 3) class, 4) bin size.

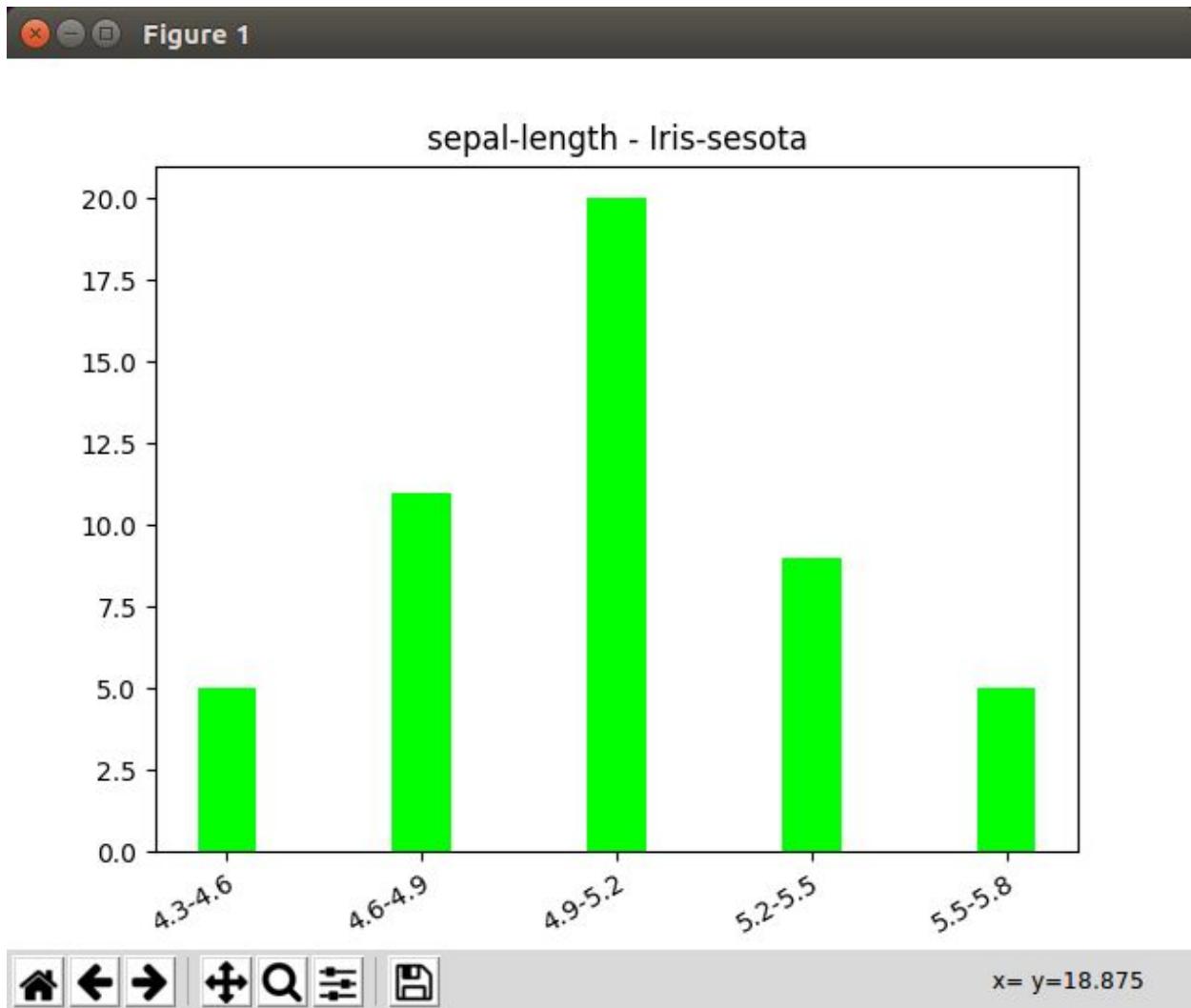




Figure 1

sepal-length - Iris-sesota

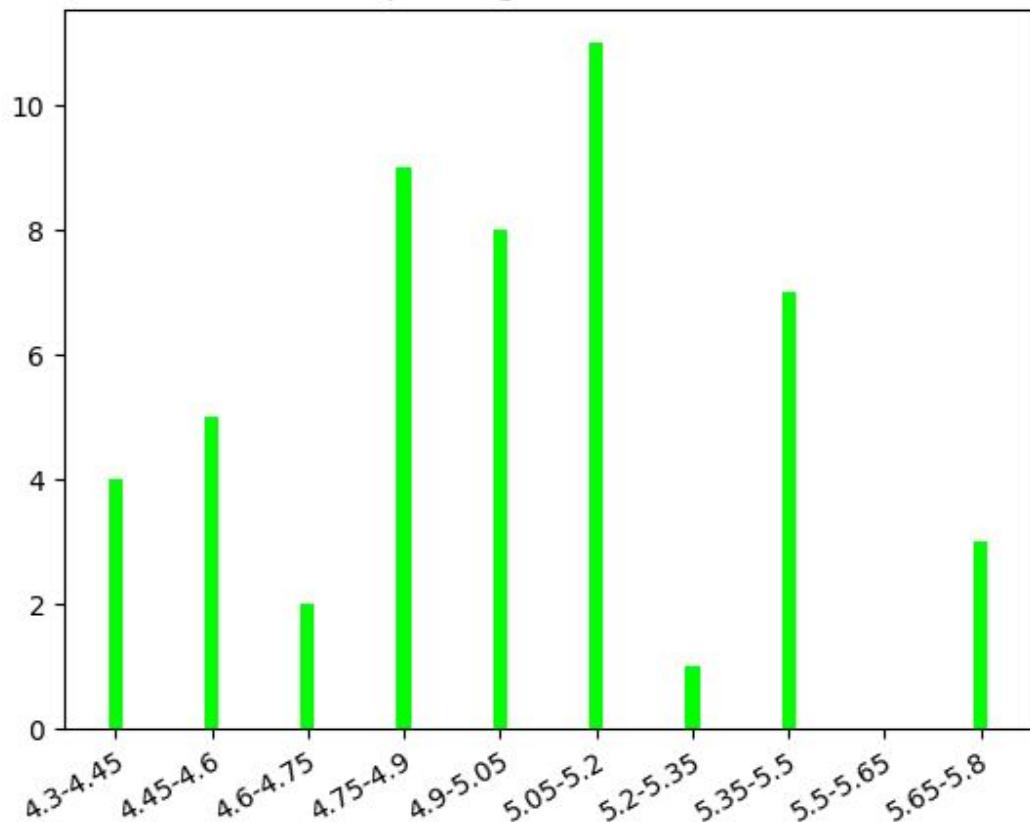
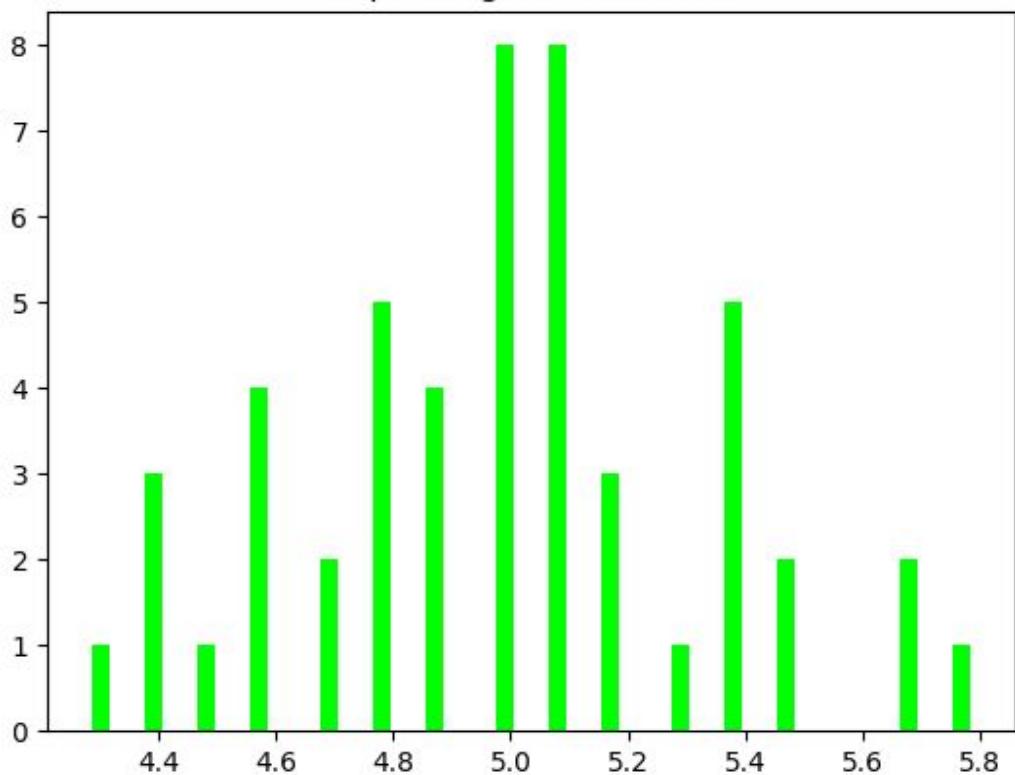




Figure 1

sepal-length - Iris-sesota

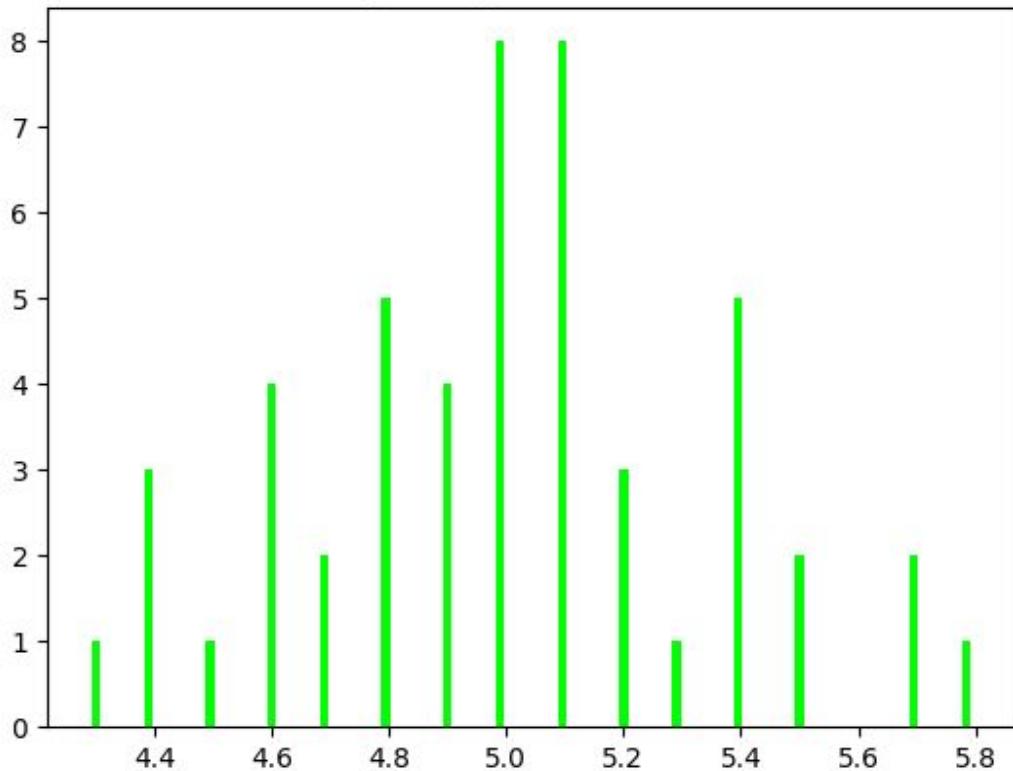


x=5.22794 y=7.09545



Figure 1

sepal-length - Iris-sesota



x=4.8928

y=8.20909



Figure 1

sepal-length - Iris-versicolor

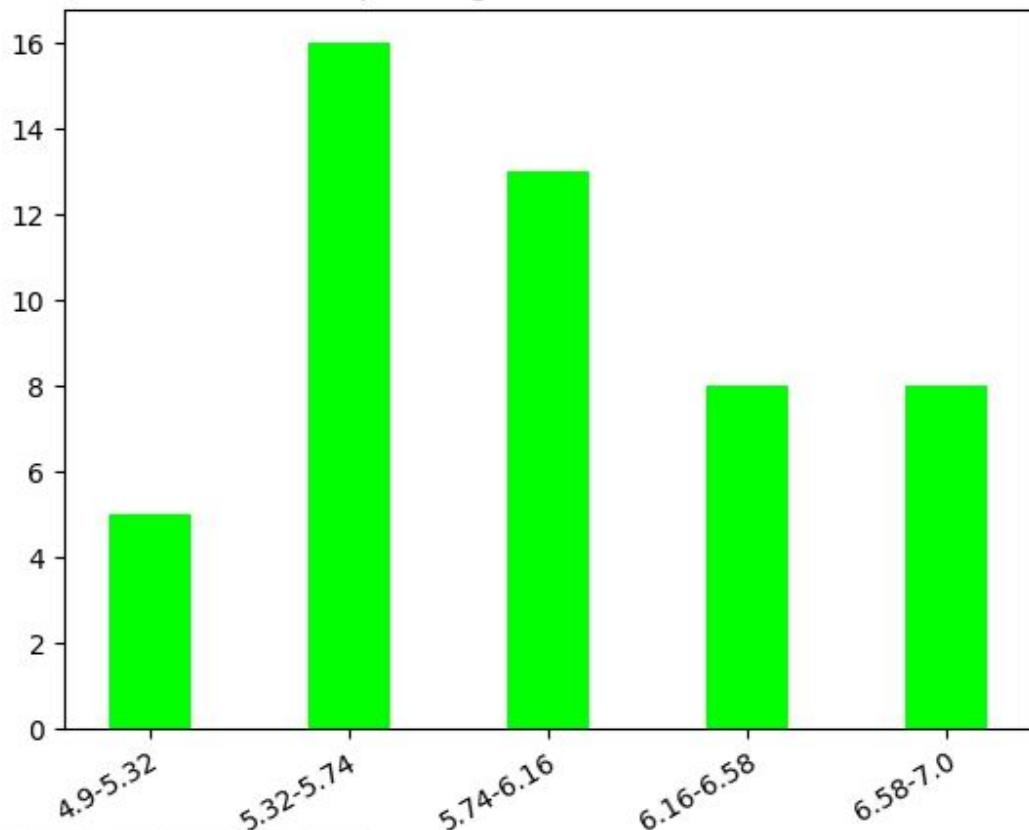
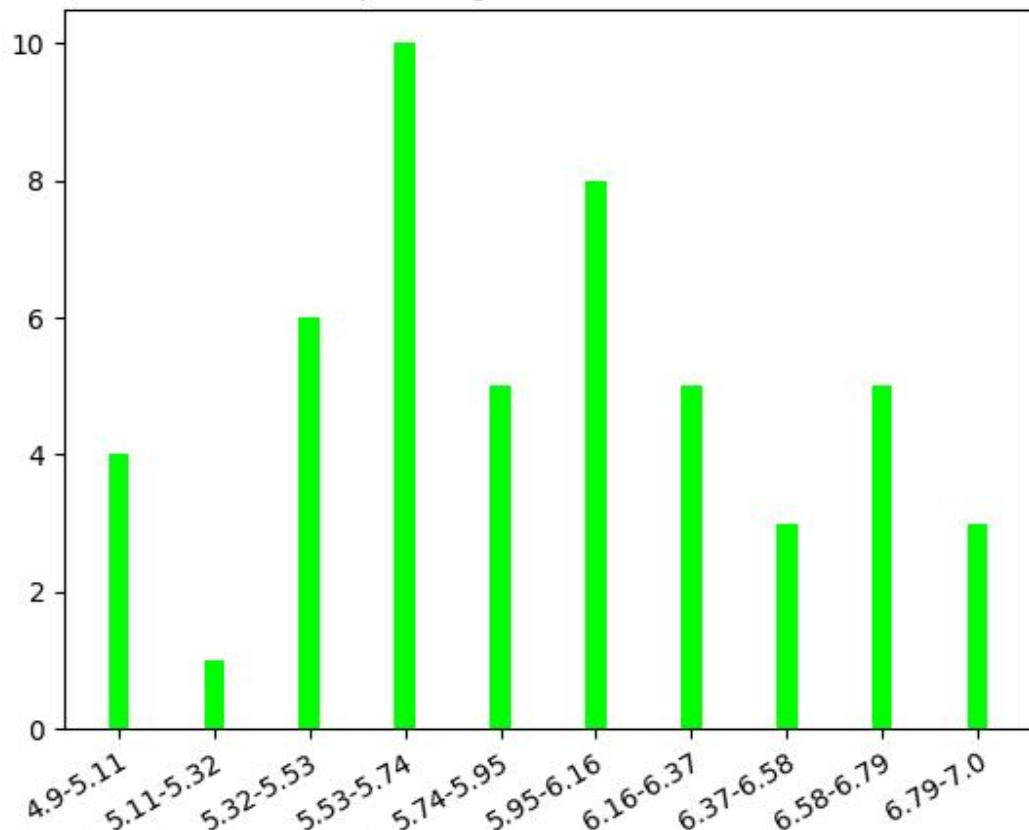




Figure 1

sepal-length - Iris-versicolor



x = y = 8.84091



Figure 1

sepal-length - Iris-versicolor

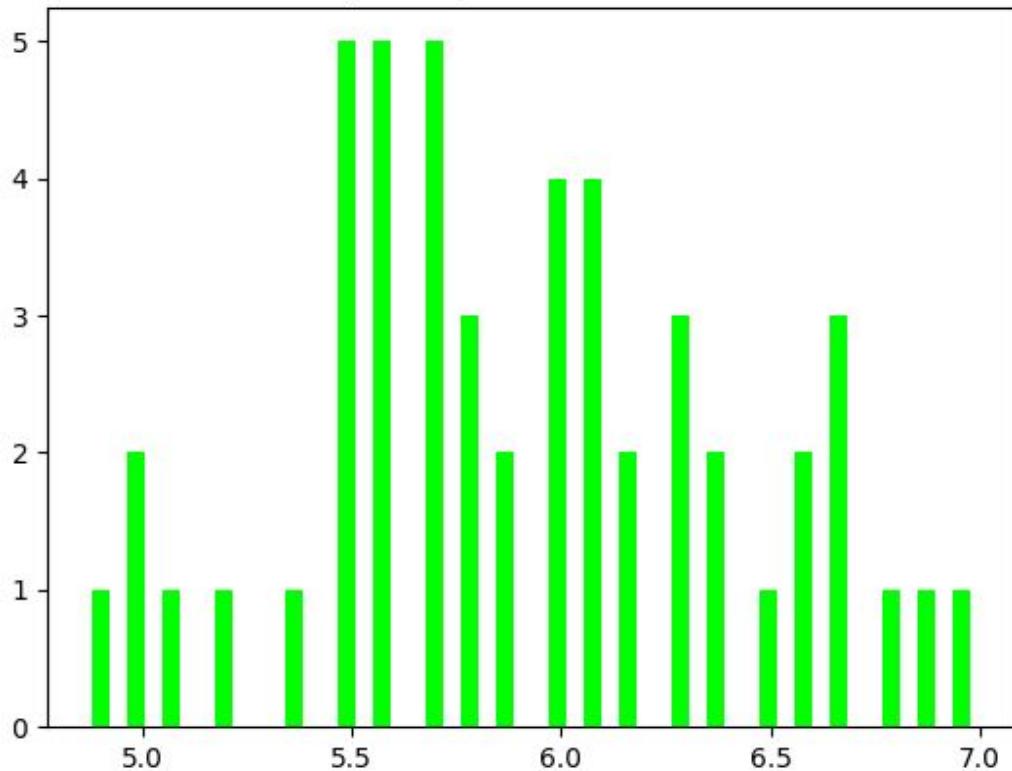
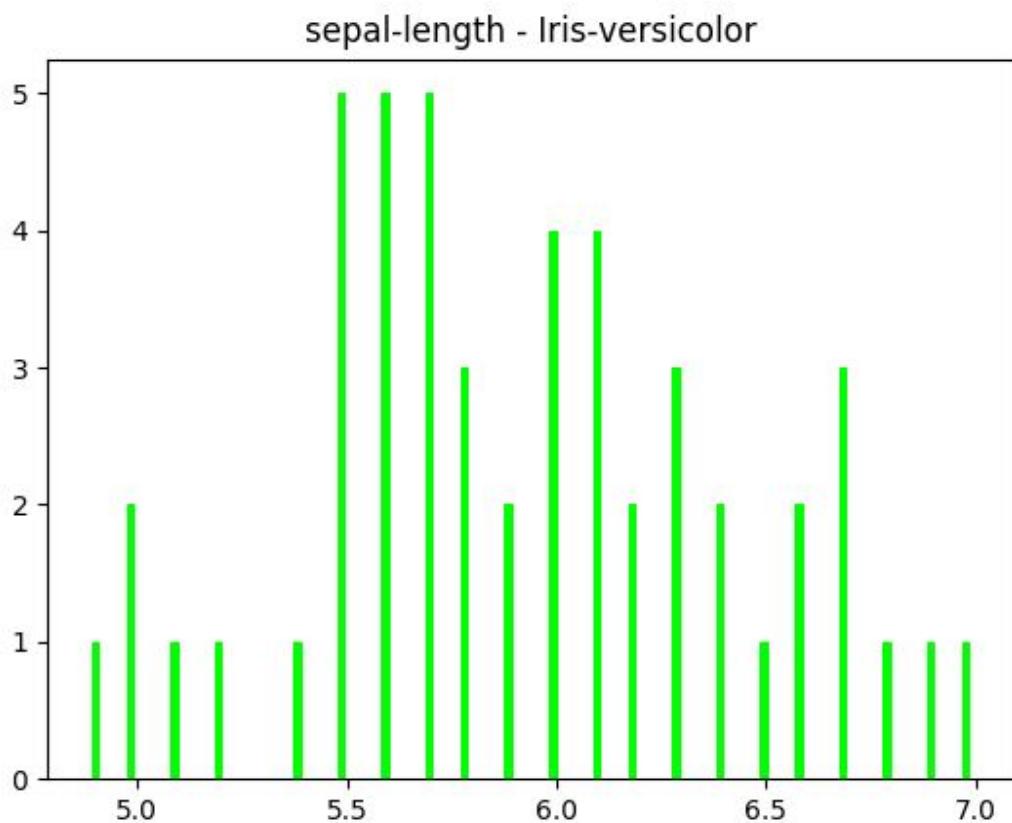




Figure 1



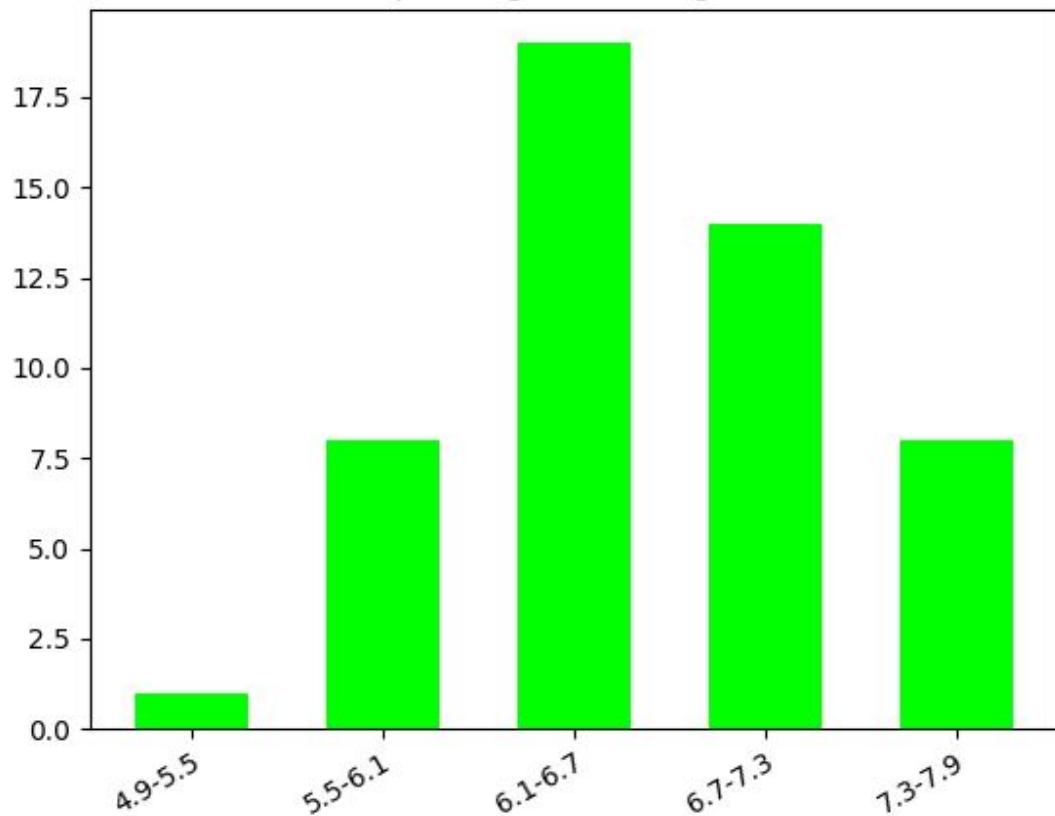
x=5.73924

y=4.90341



Figure 1

sepal-length - Iris-virginica

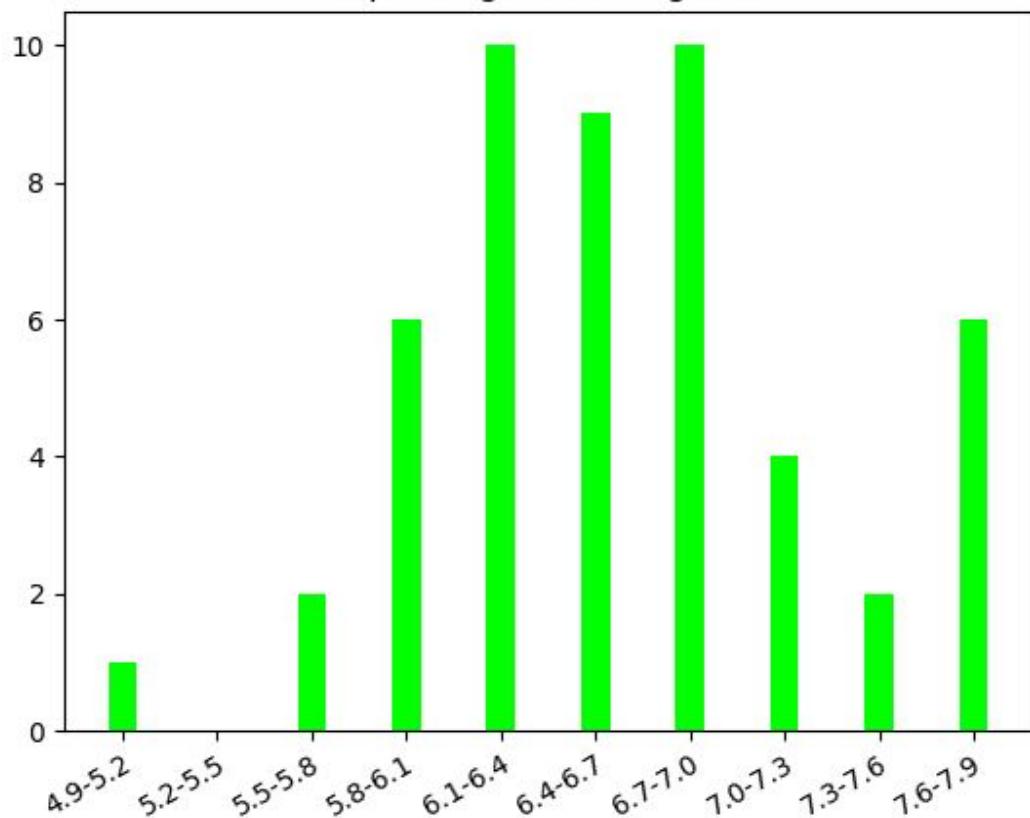


x = y = 15.7182



Figure 1

sepal-length - Iris-virginica

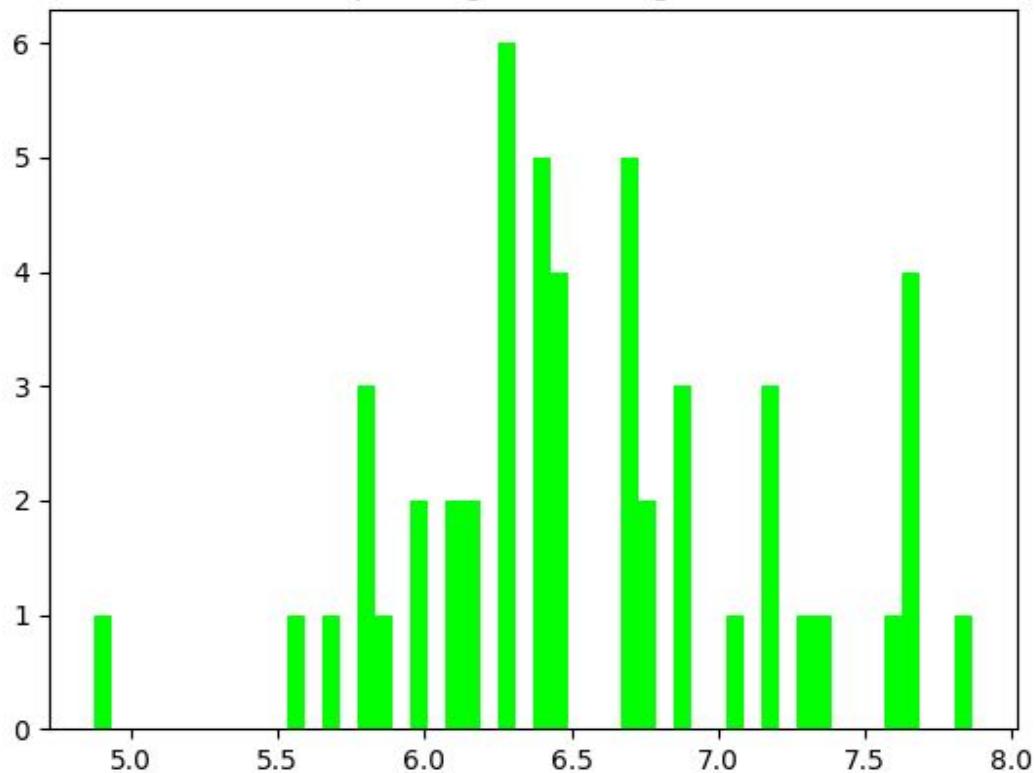


x = y = 7.90341



Figure 1

sepal-length - Iris-virginica

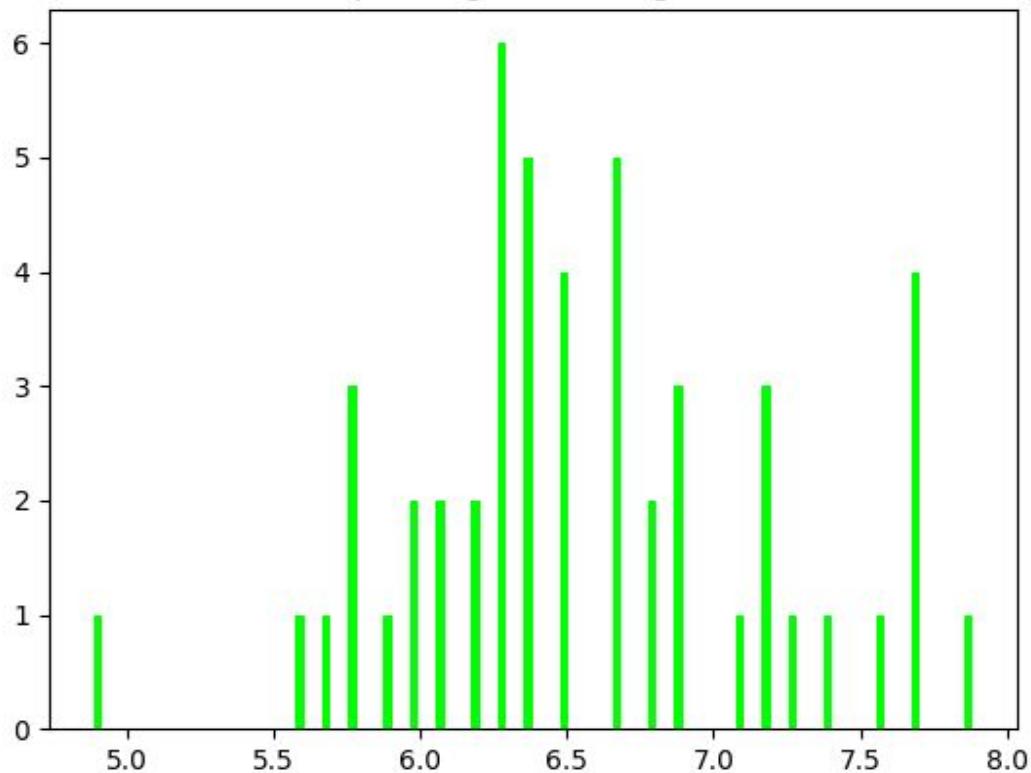


x=6.50306 y=5.56023



Figure 1

sepal-length - Iris-virginica

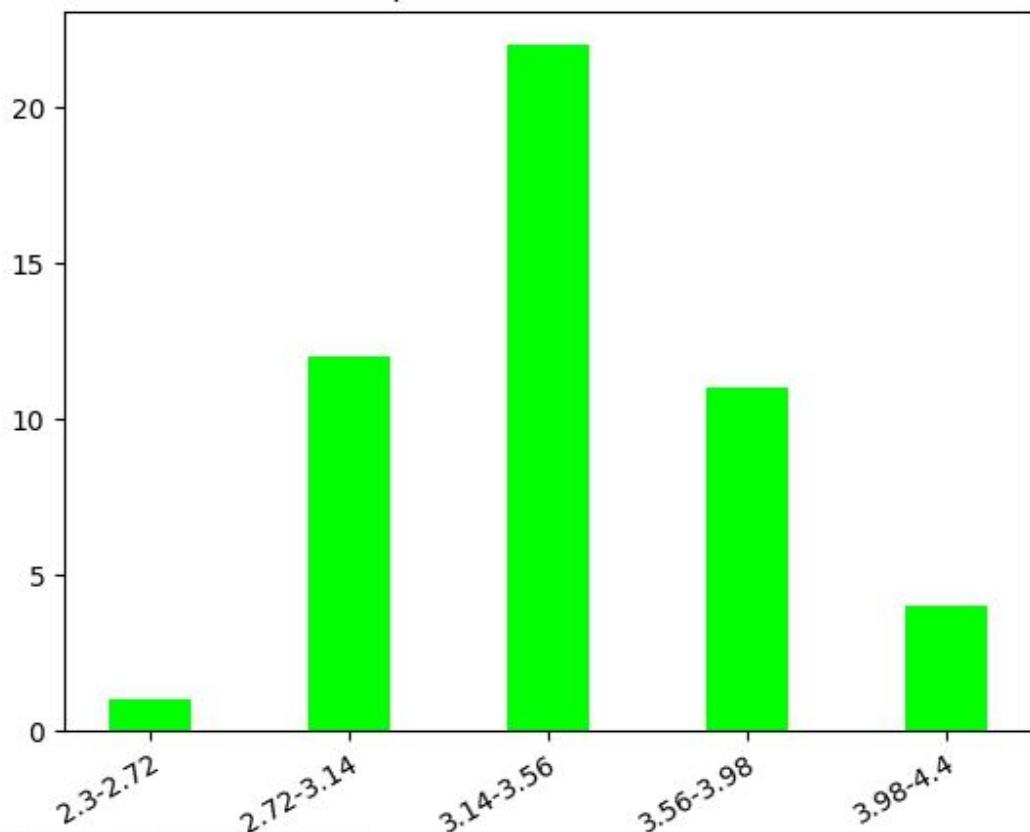


x=6.5979 y=5.88409



Figure 1

sepal-width - Iris-sesota

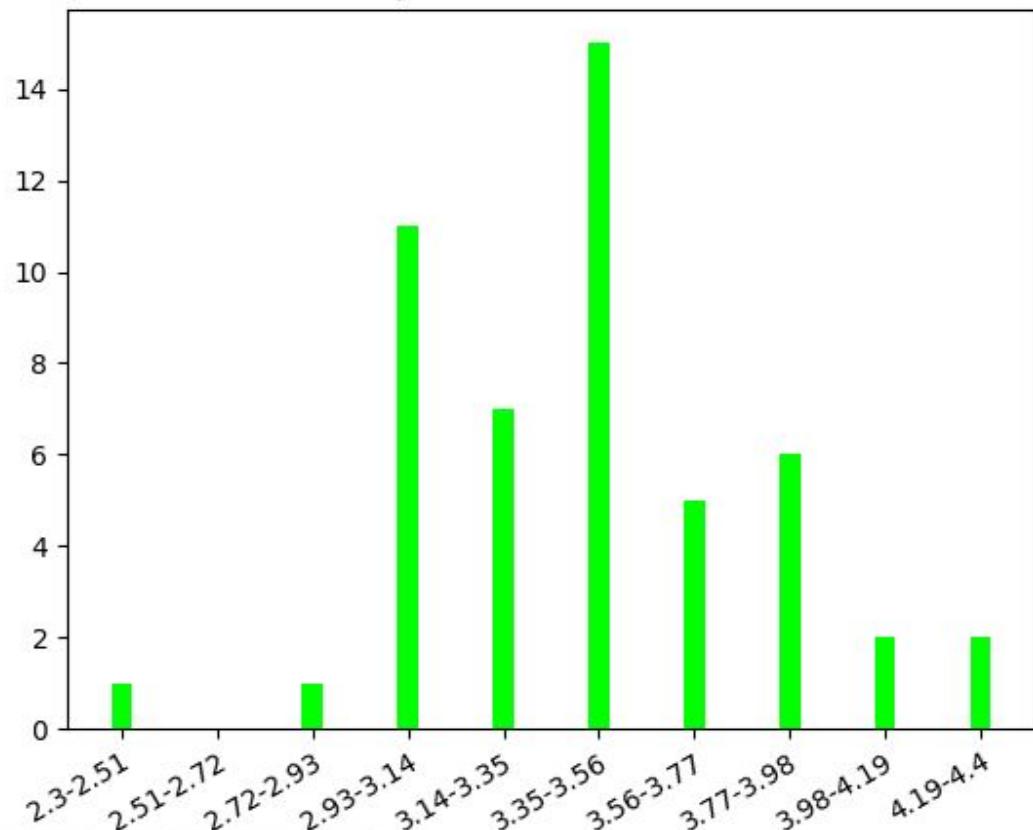


x = y = 18.3875



Figure 1

sepal-width - Iris-sesota

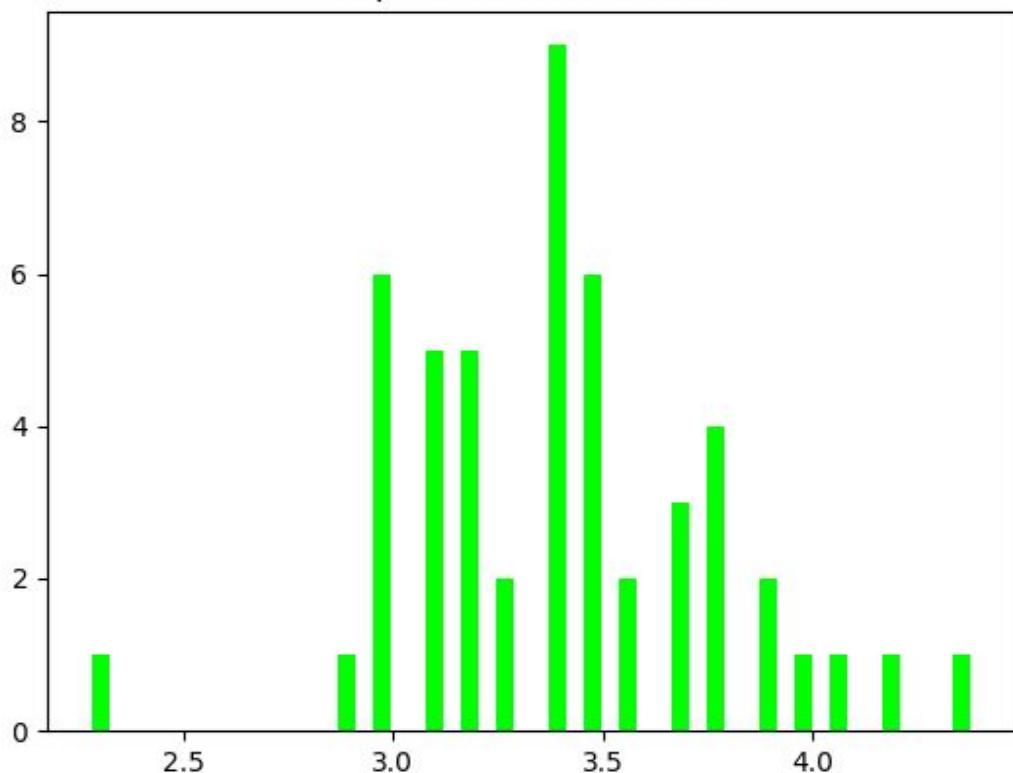


x = y = 8.57386



Figure 1

sepal-width - Iris-sesota



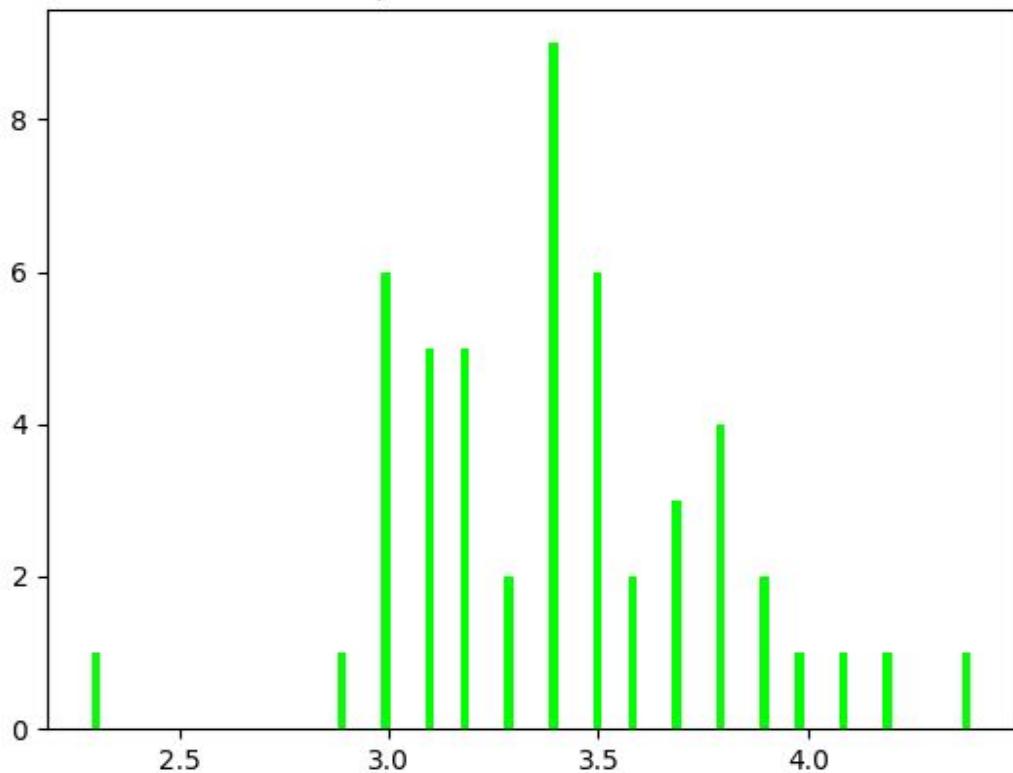
x=3.31037

y=8.44261



Figure 1

sepal-width - Iris-sesota



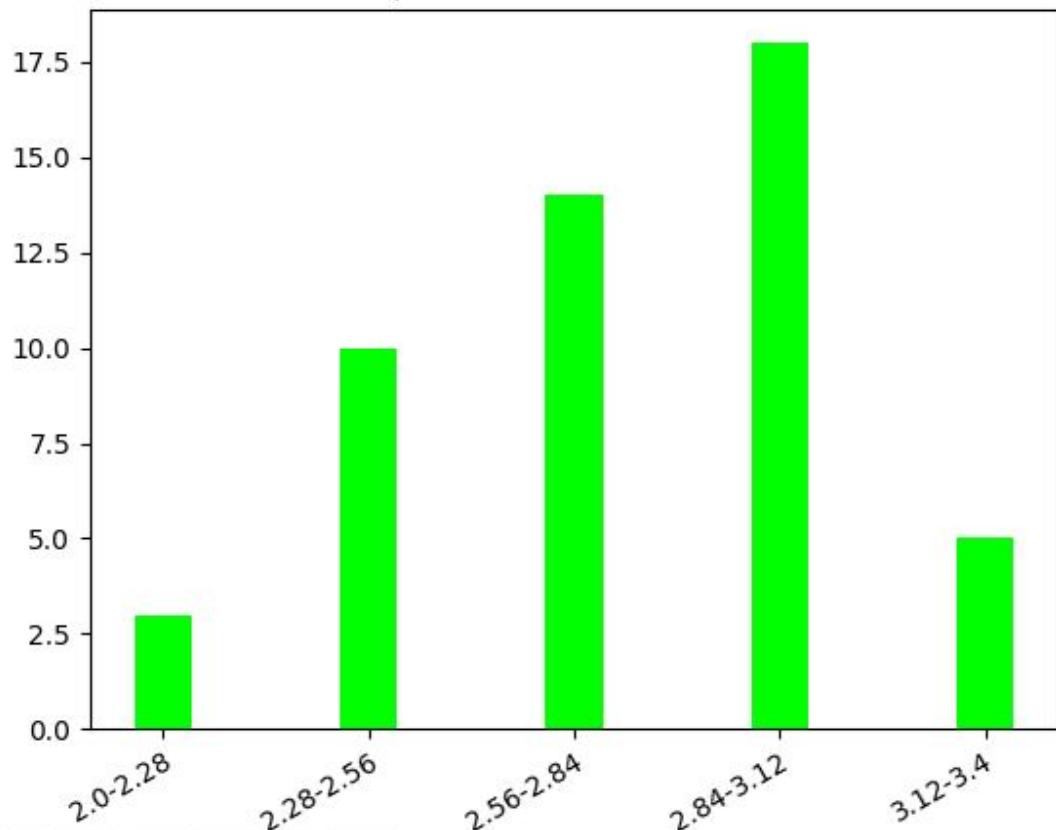
x=3.26033

y=7.1642



Figure 1

sepal-width - Iris-versicolor

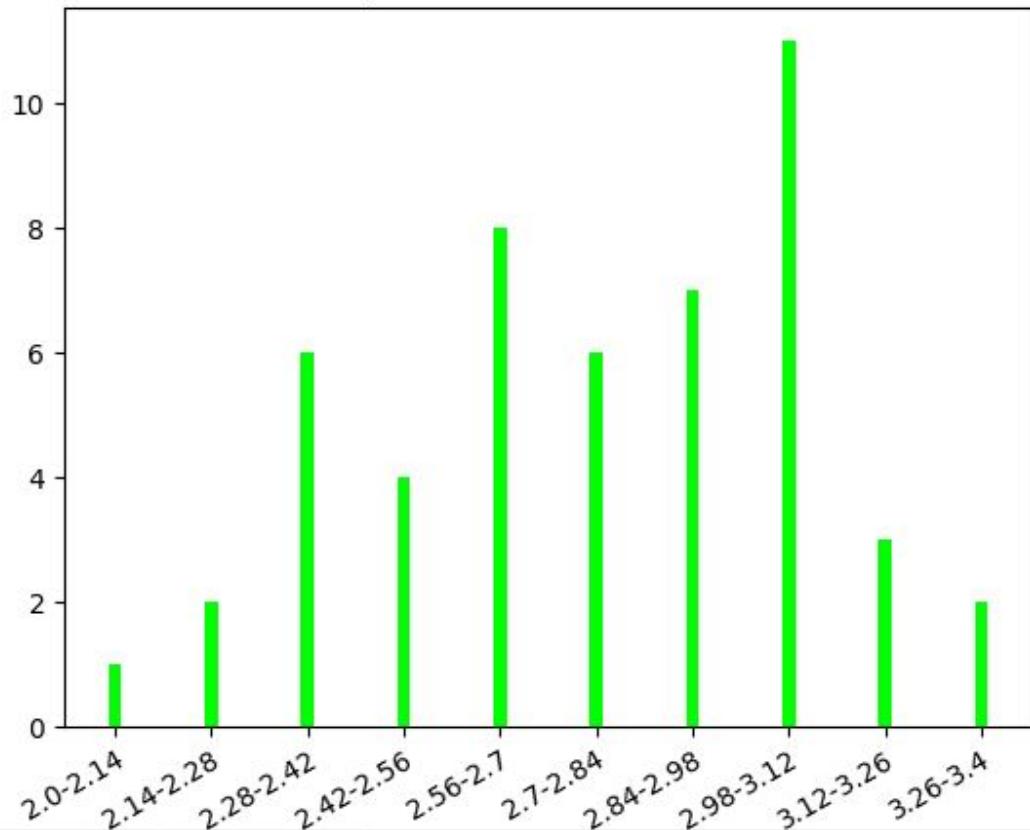


x = y = 15.1466



Figure 1

sepal-width - Iris-versicolor

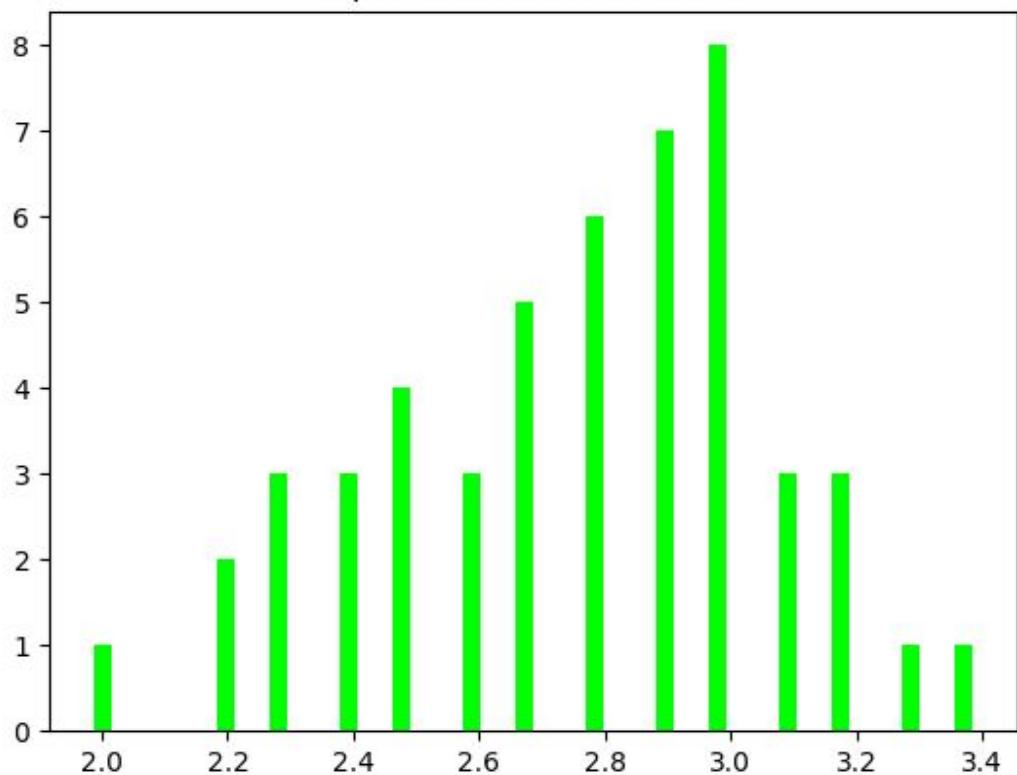


x = y = 9.0375



Figure 1

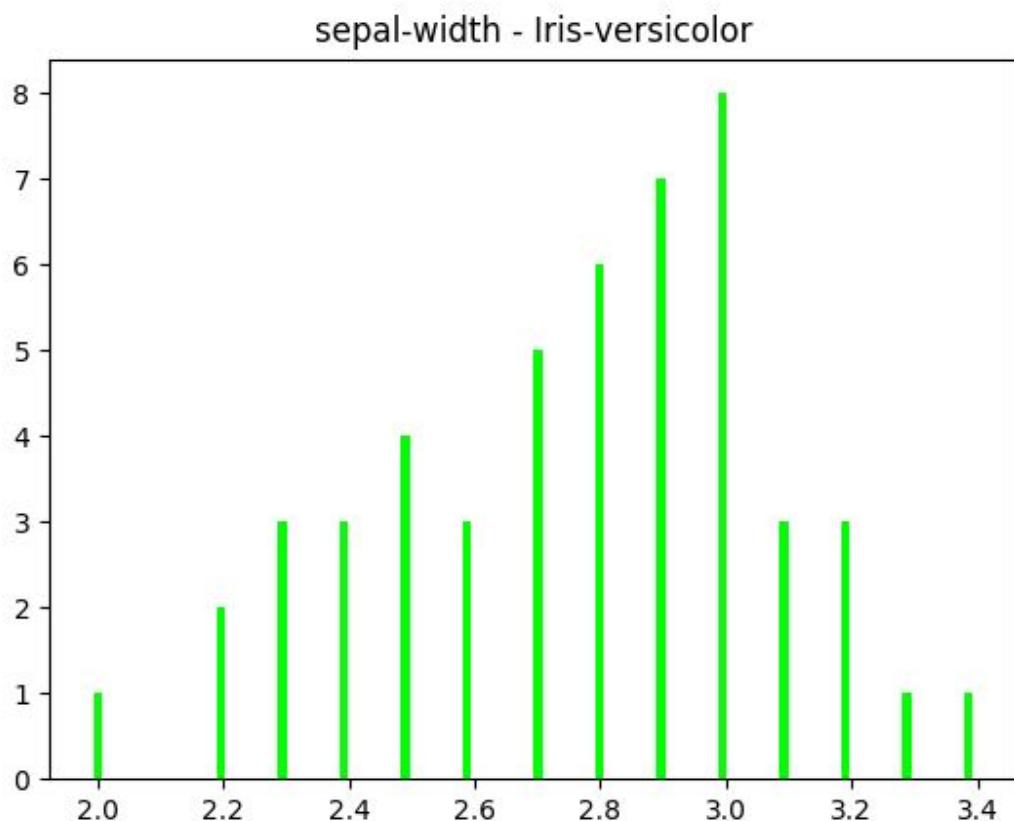
sepal-width - Iris-versicolor



x=3.01201 y=5.98182



Figure 1



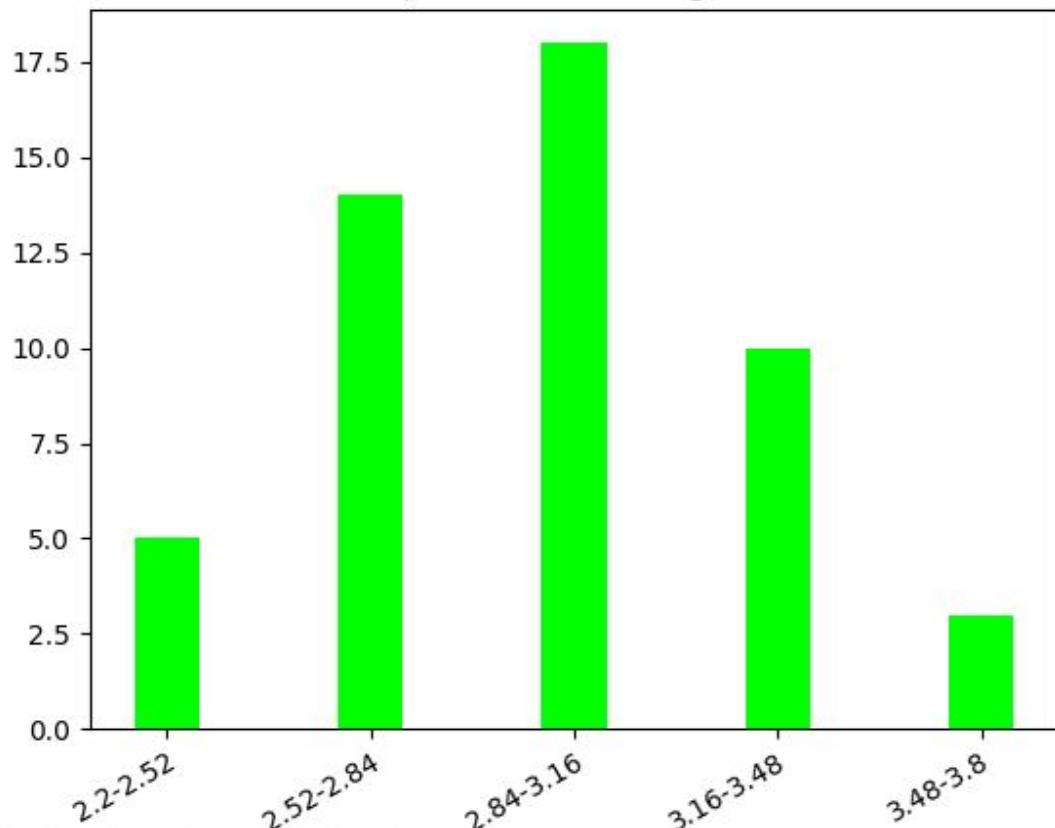
x=2.6309

y=6.64091



Figure 1

sepal-width - Iris-virginica

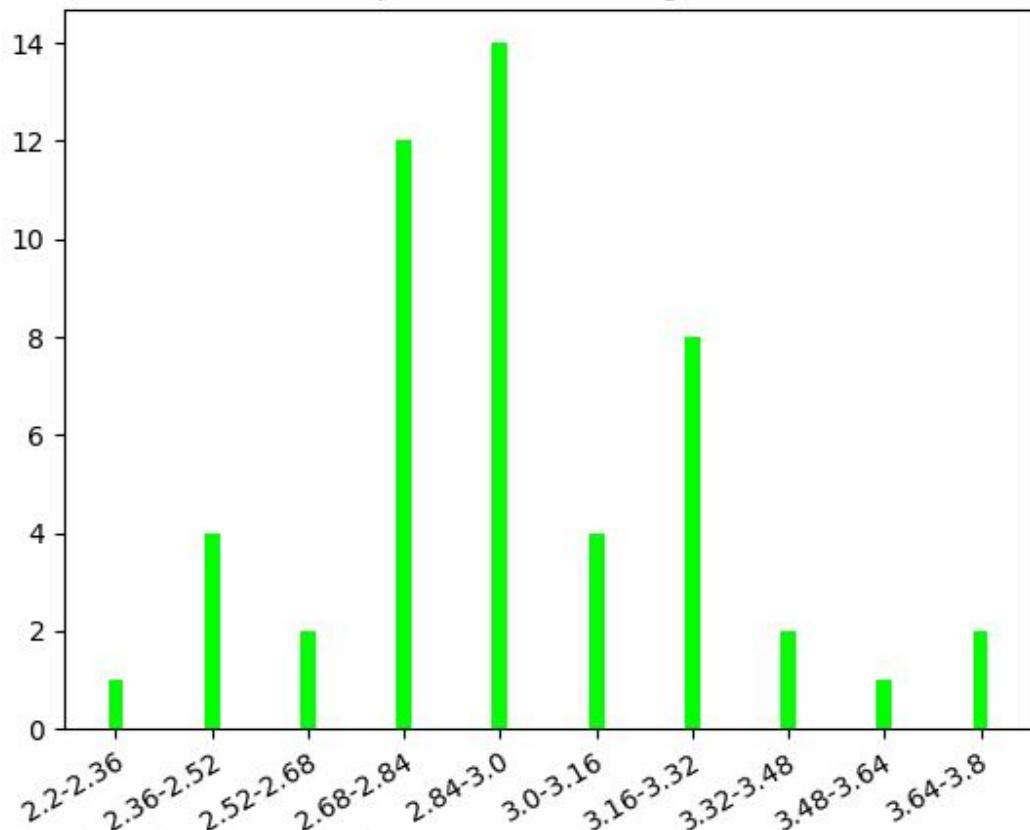


x = y = 17.8057



Figure 1

sepal-width - Iris-virginica

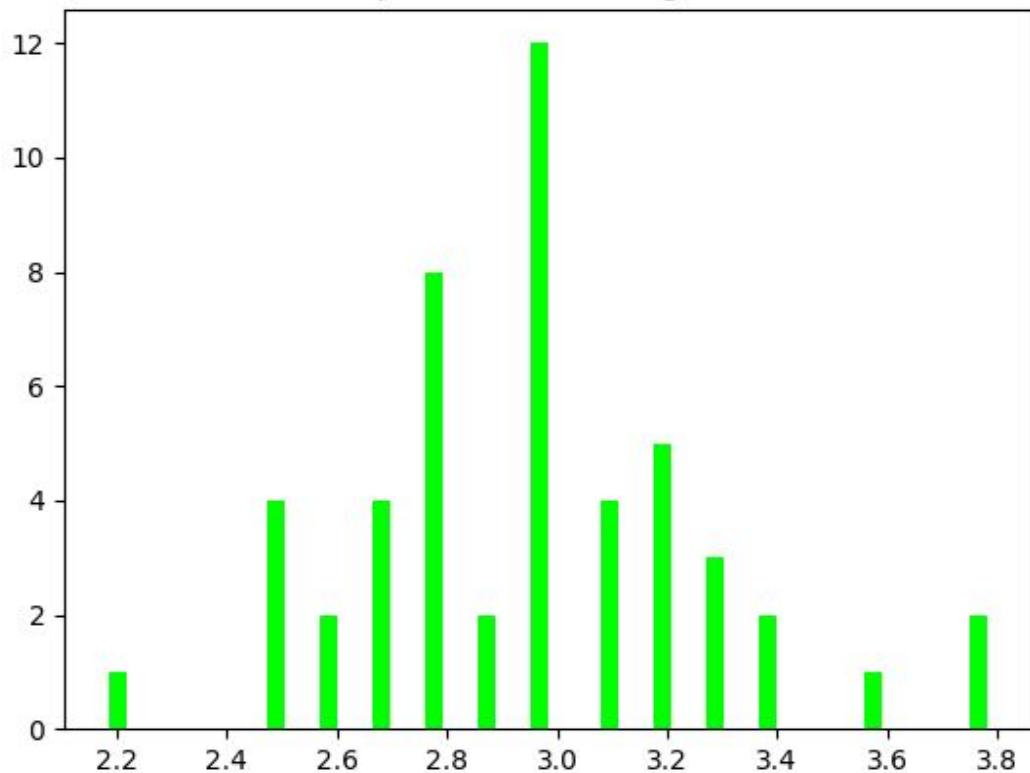


x = y = 10.1102



Figure 1

sepal-width - Iris-virginica

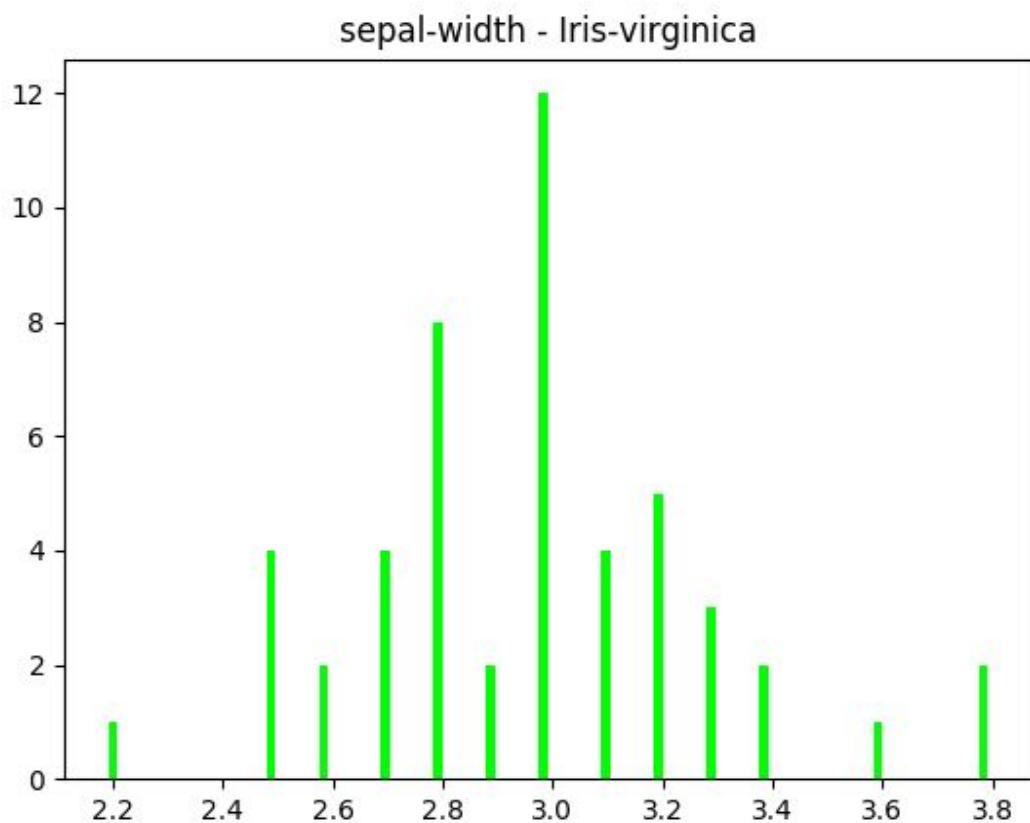


x=3.24658

y=7.67727



Figure 1



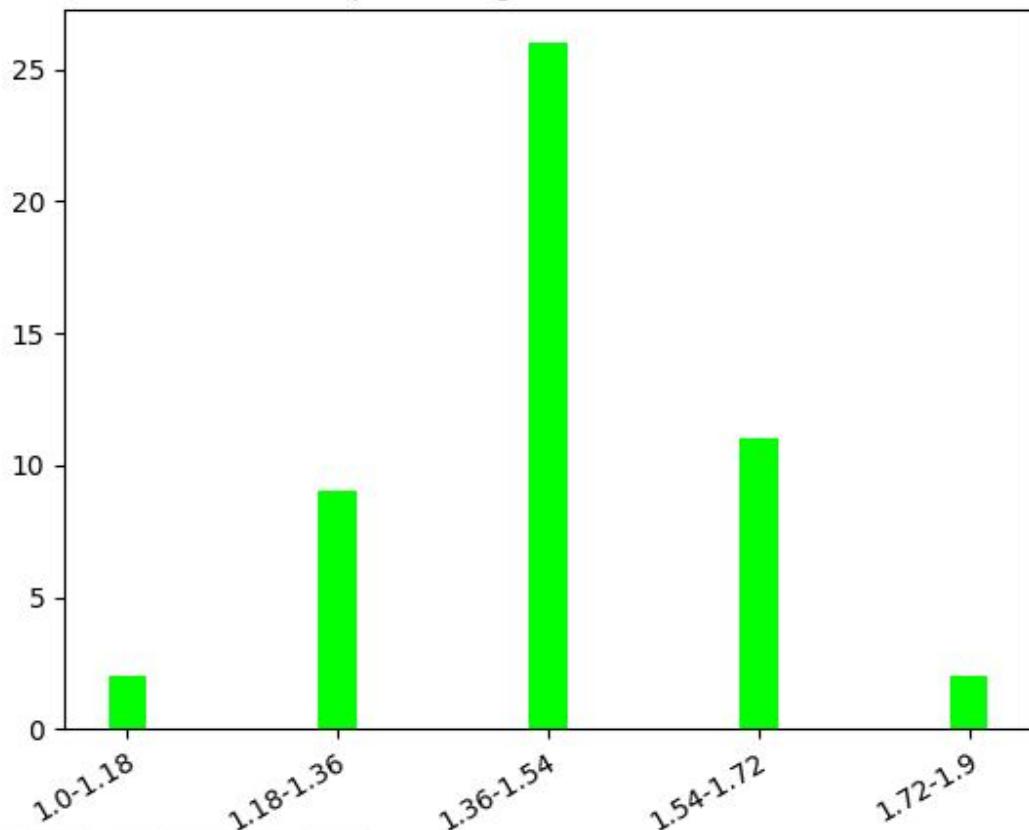
x=2.83587

y=9.41591



Figure 1

petal-length - Iris-sesota

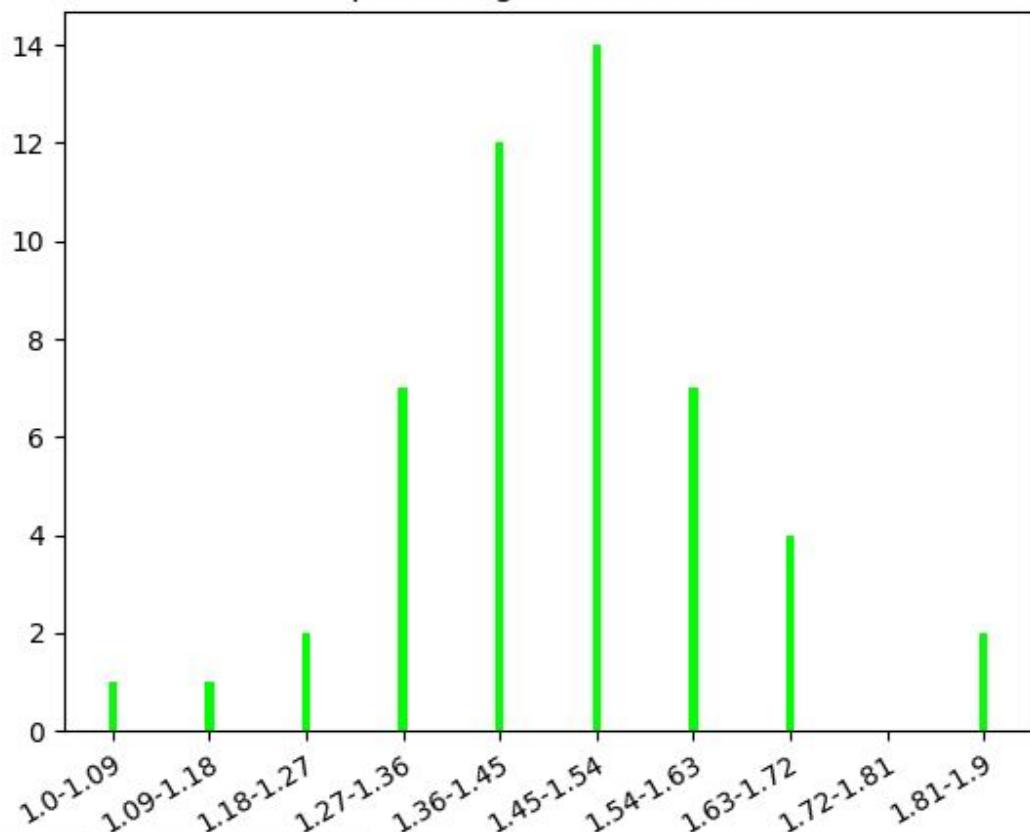


x = y = 21.7307



Figure 1

petal-length - Iris-sesota

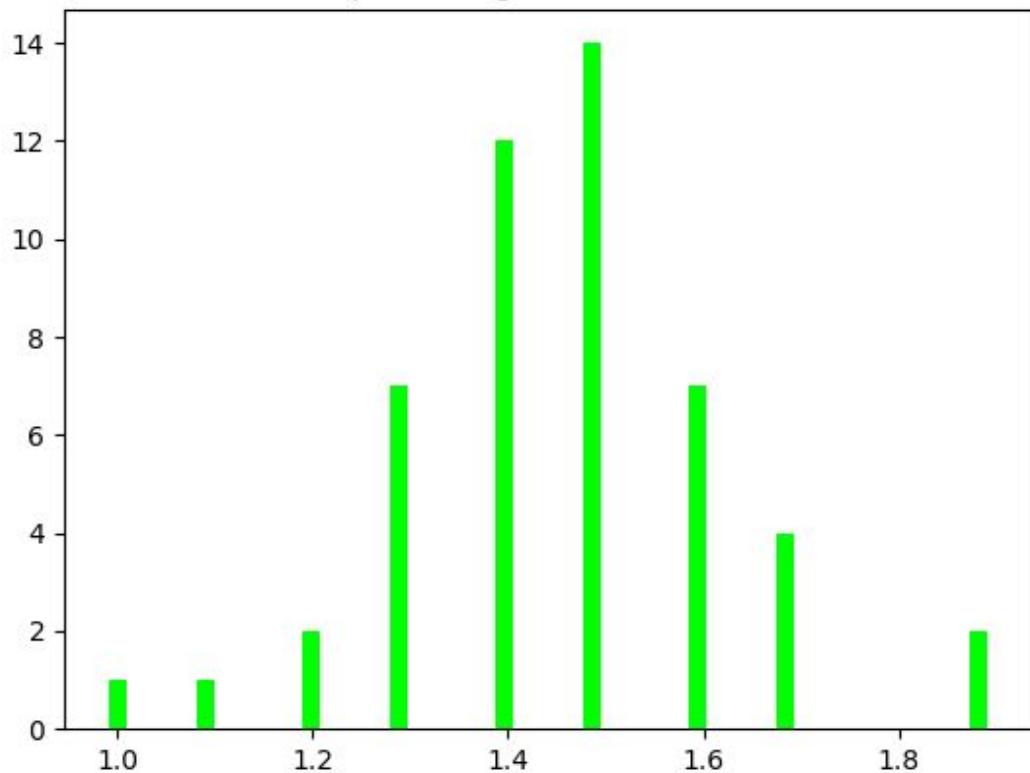


x = y = 10.2693



Figure 1

petal-length - Iris-sesota



x=1.54878 y=9.7125



Figure 1

petal-length - Iris-sesota

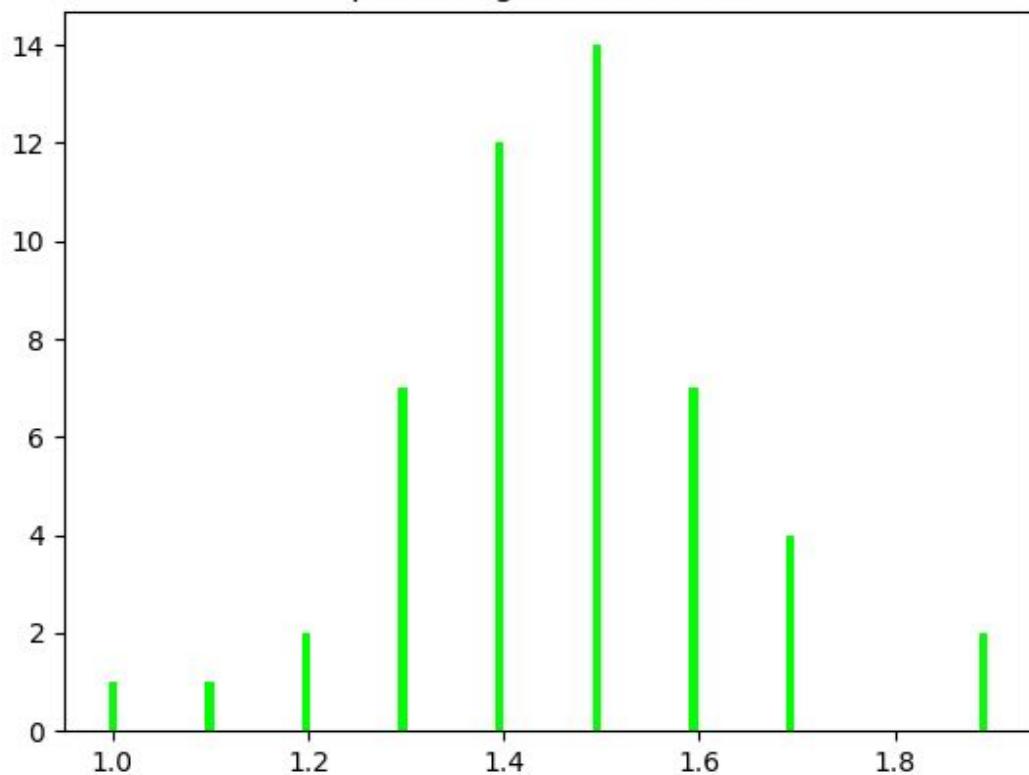
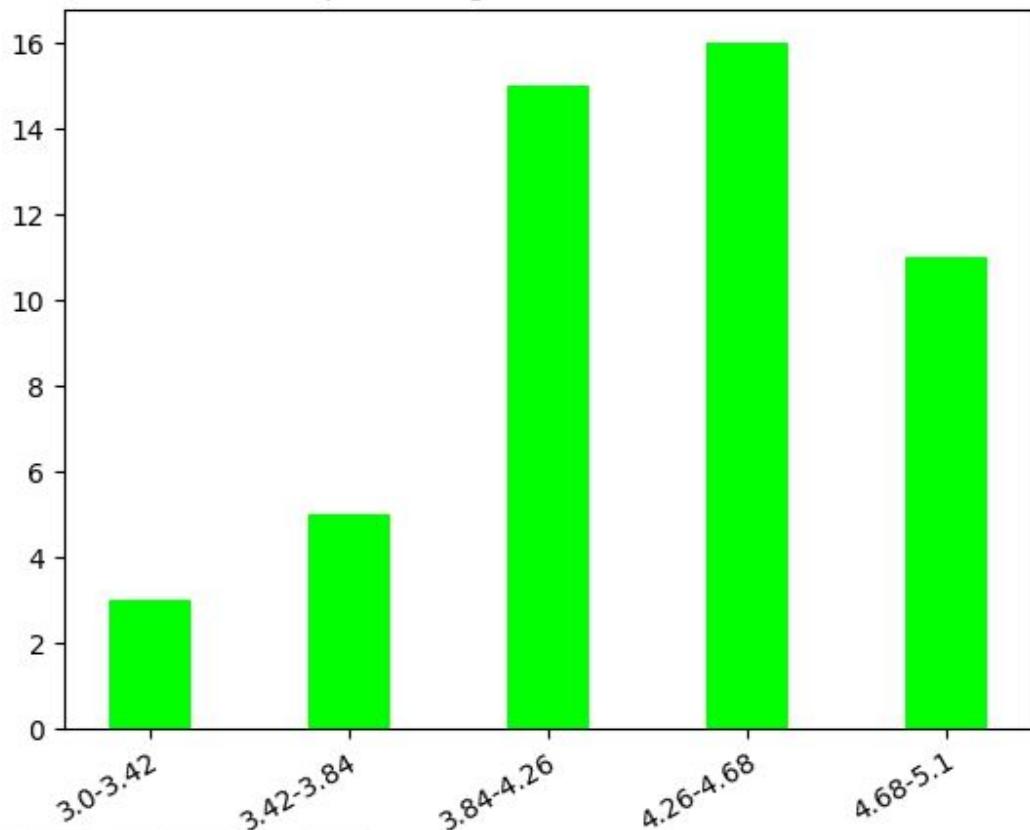




Figure 1

petal-length - Iris-versicolor

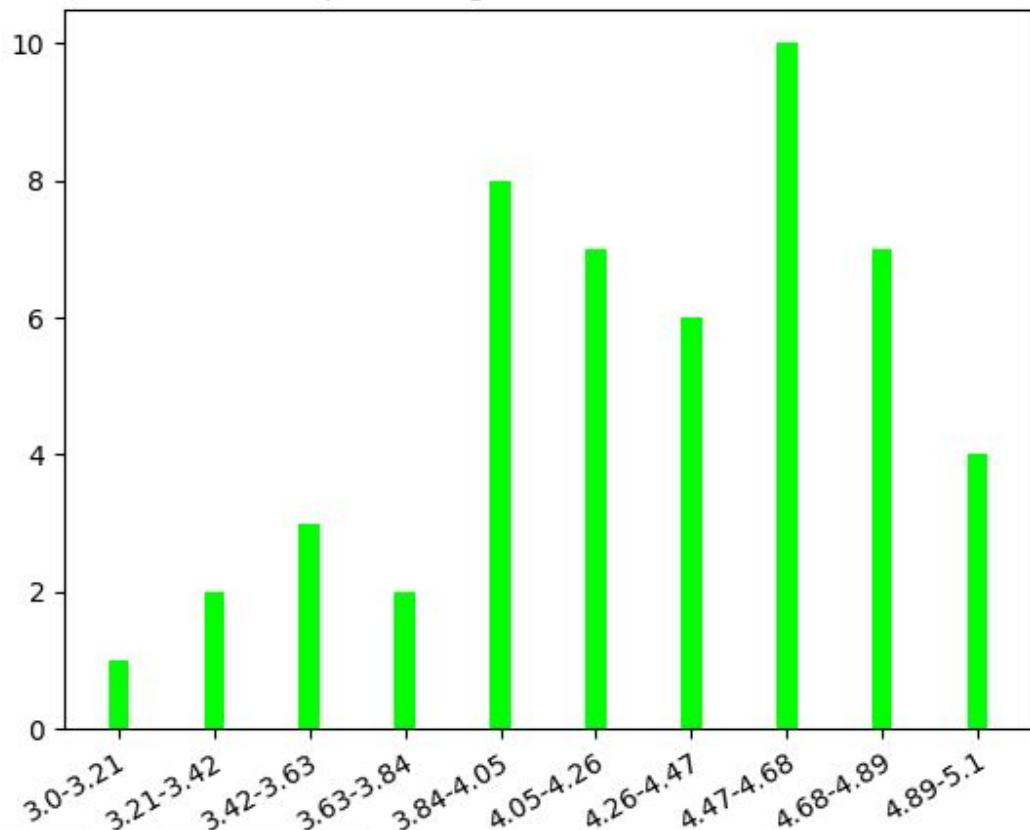


x = y = 10.7364



Figure 1

petal-length - Iris-versicolor

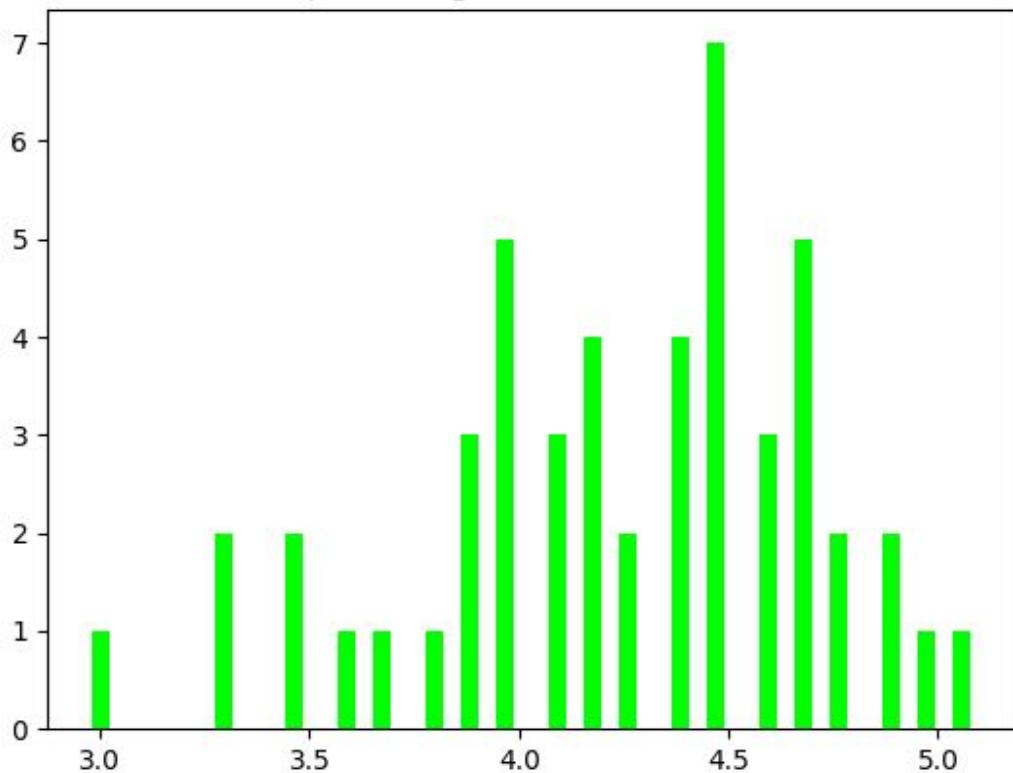


x = y = 8.13068



Figure 1

petal-length - Iris-versicolor

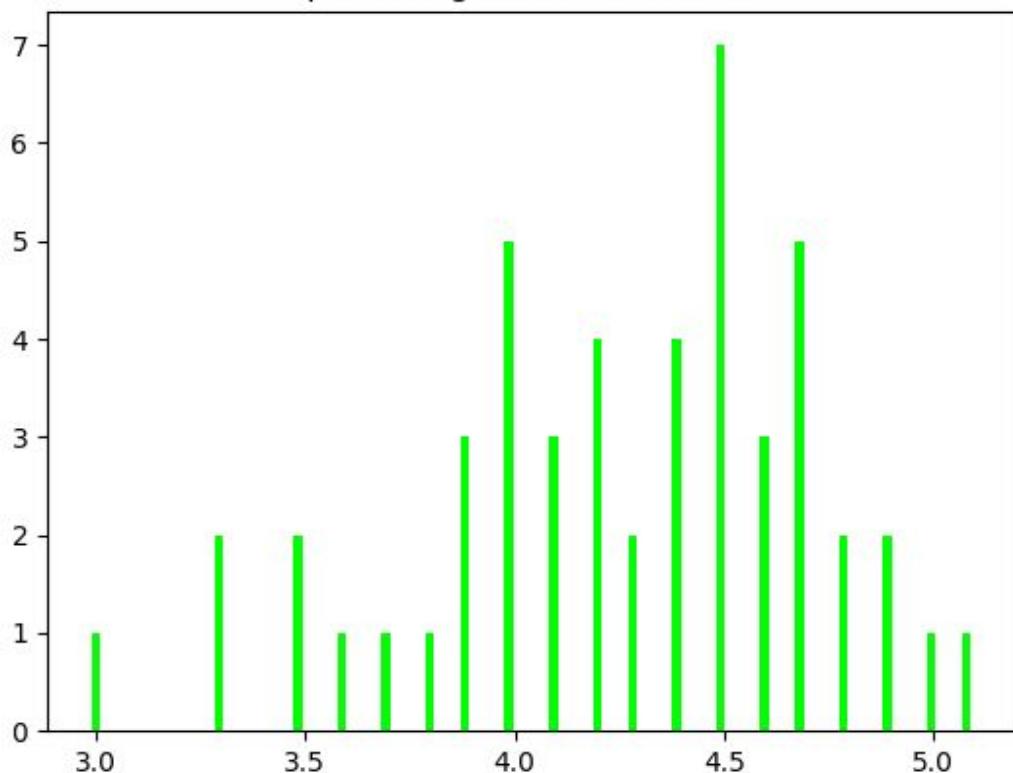


x=4.15009 y=4.85625



Figure 1

petal-length - Iris-versicolor



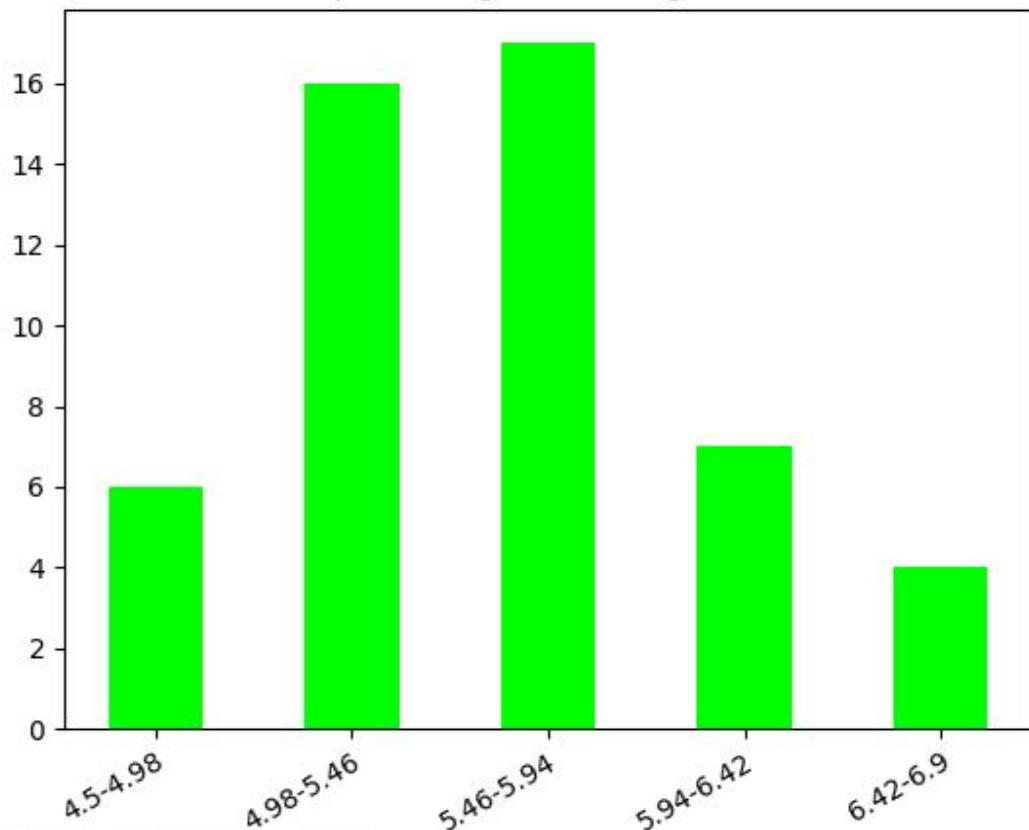
x=4.0395

y=5.01534



Figure 1

petal-length - Iris-virginica

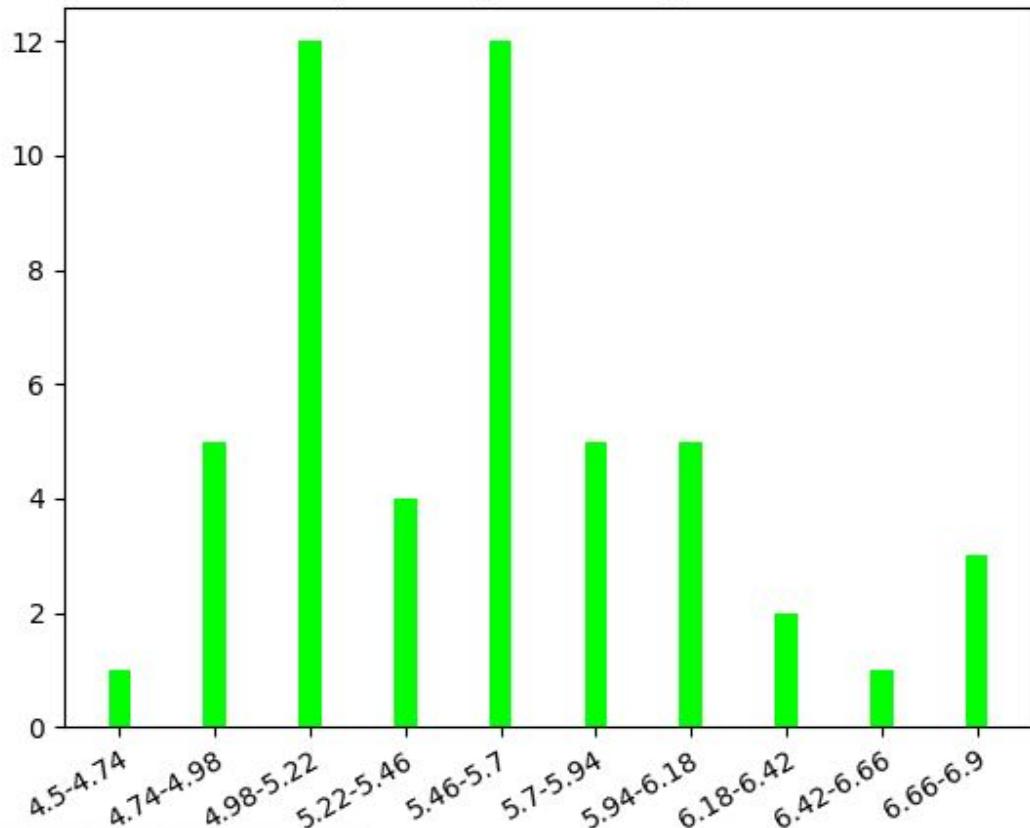


x = y = 11.6972



Figure 1

petal-length - Iris-virginica

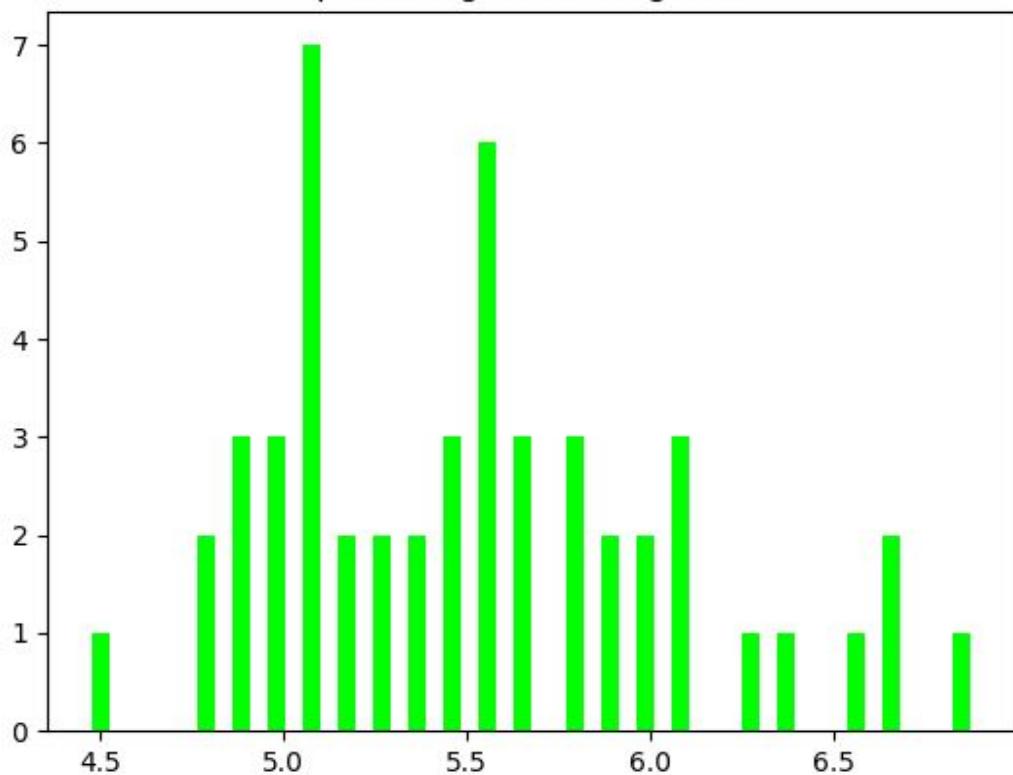


x = y = 8.56364



Figure 1

petal-length - Iris-virginica



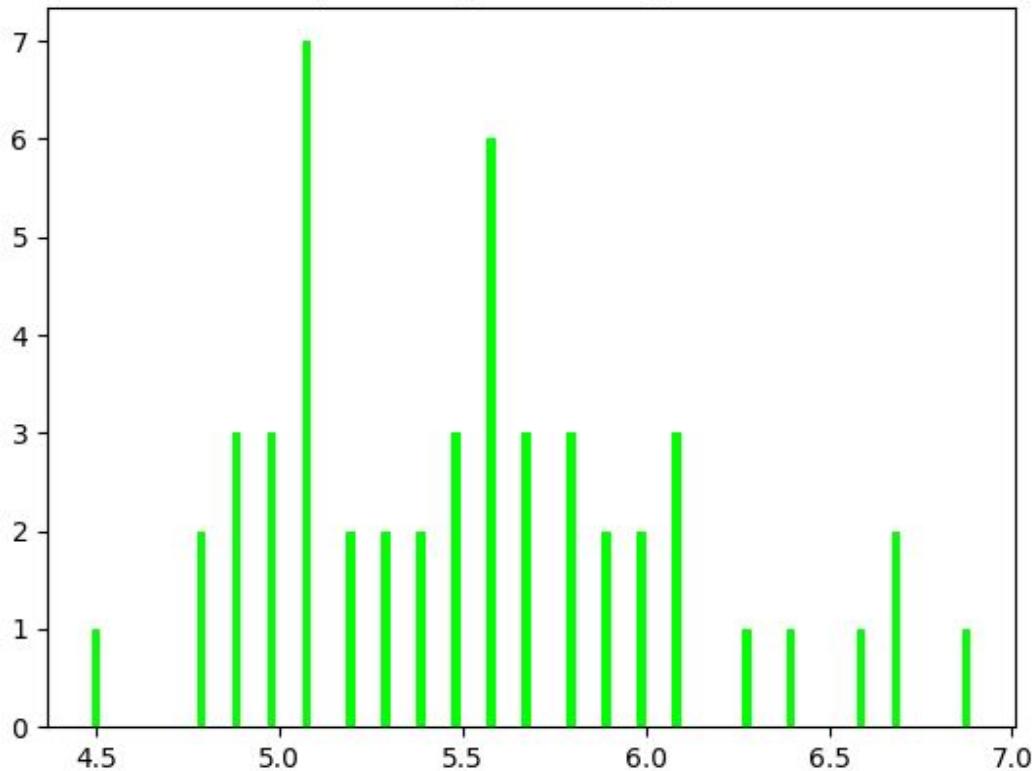
x=6.35729

y=4.61761



Figure 1

petal-length - Iris-virginica



x=6.08187 y=5.11477



Figure 1

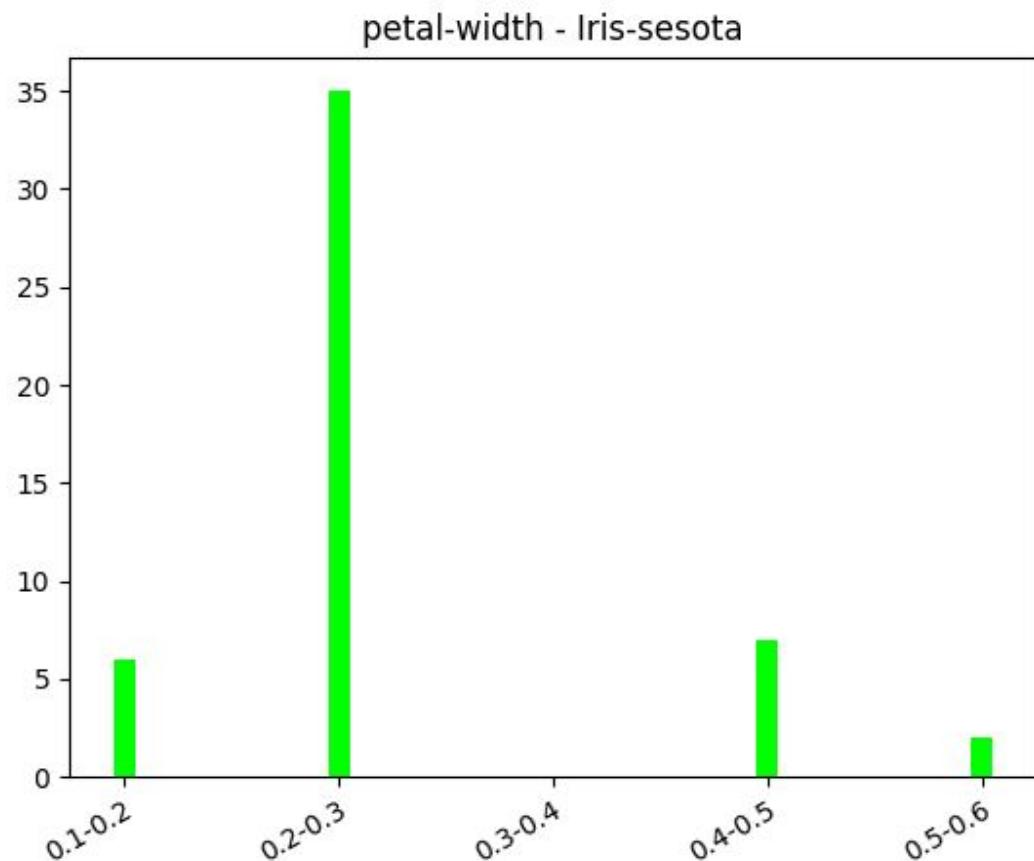
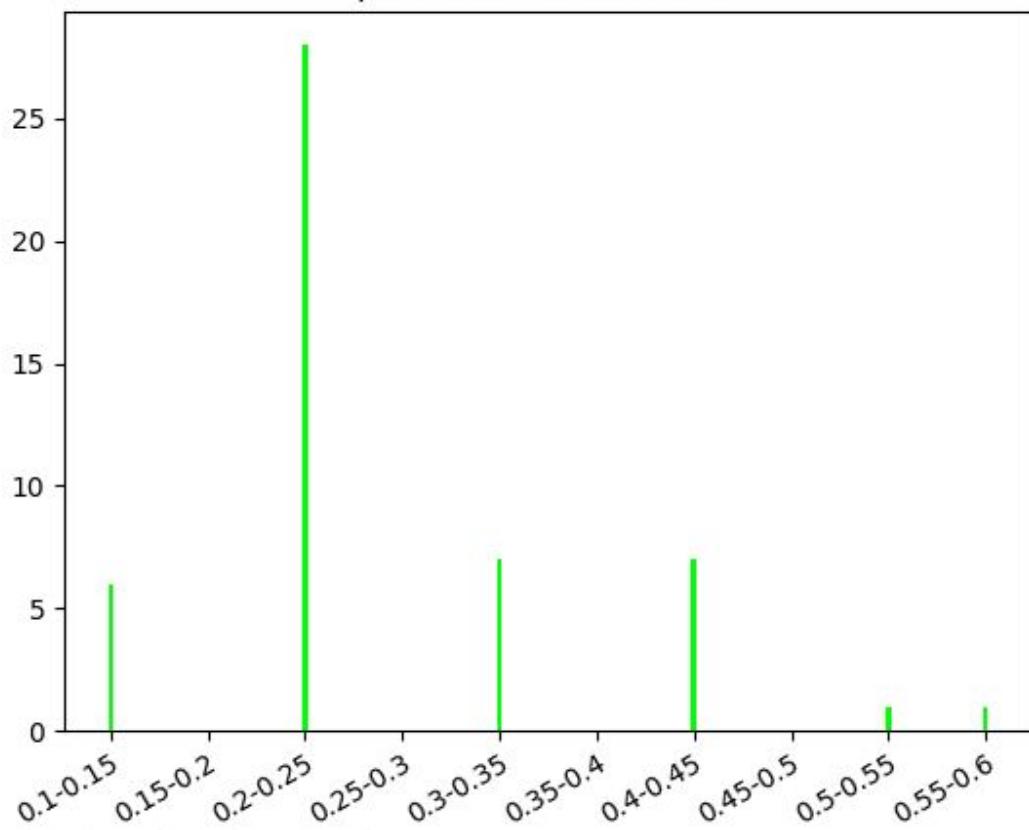




Figure 1

petal-width - Iris-sesota

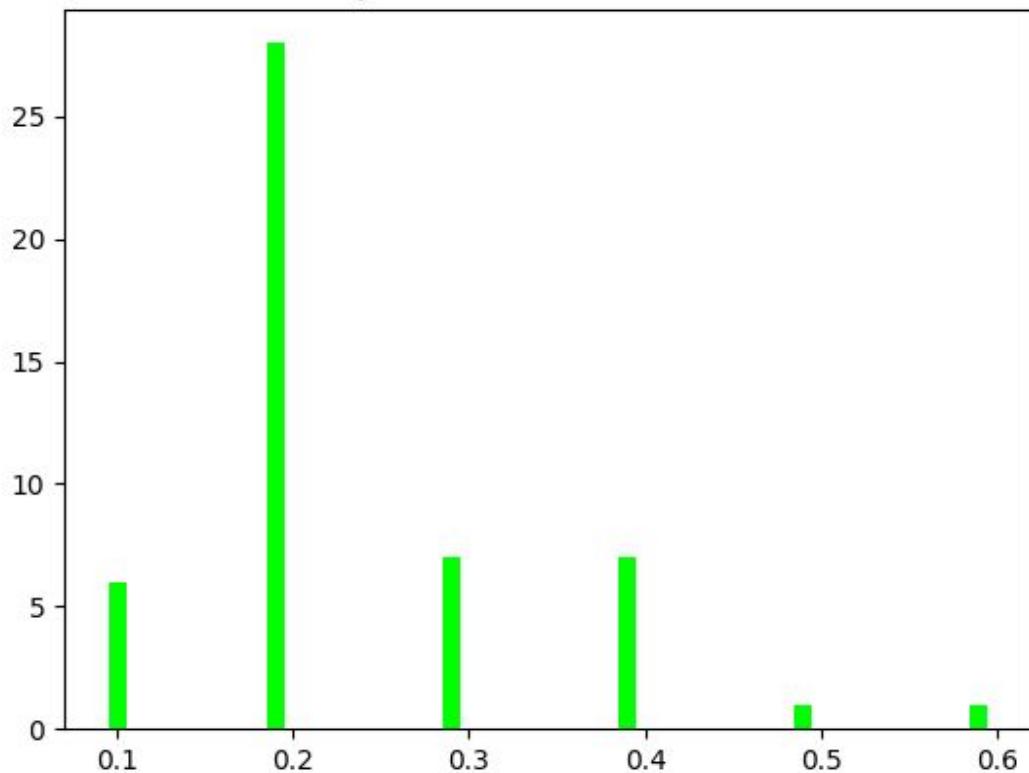


x = y = 21.7318



Figure 1

petal-width - Iris-sesota

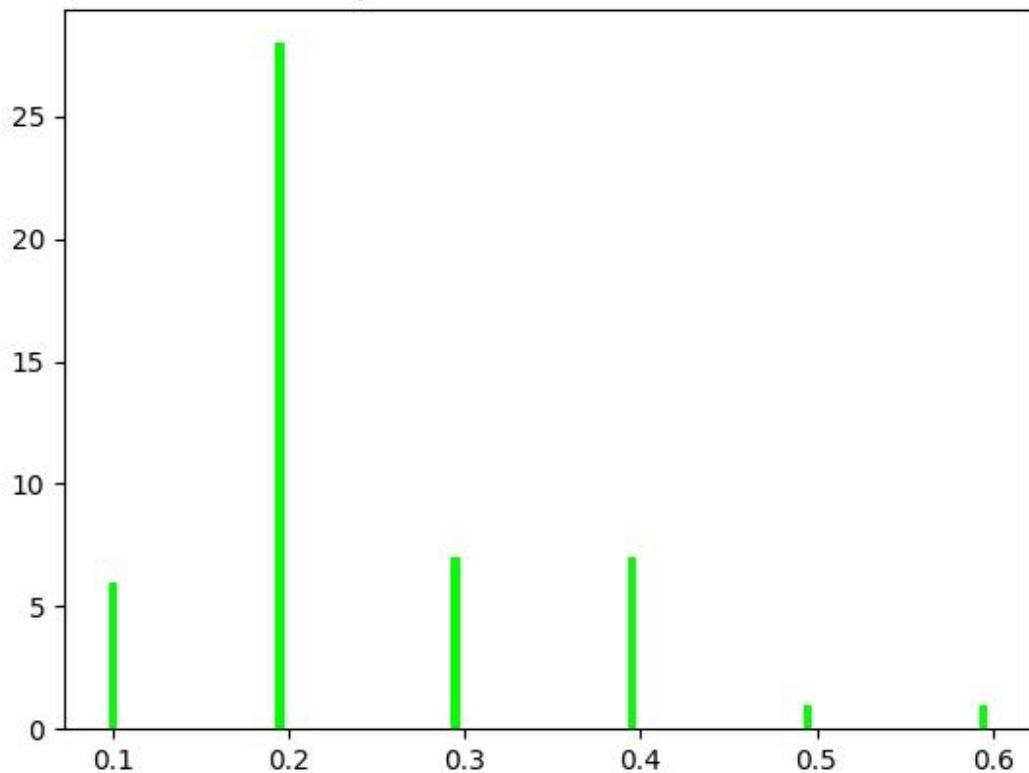


x=0.440363 y=19.5841



Figure 1

petal-width - Iris-sesota

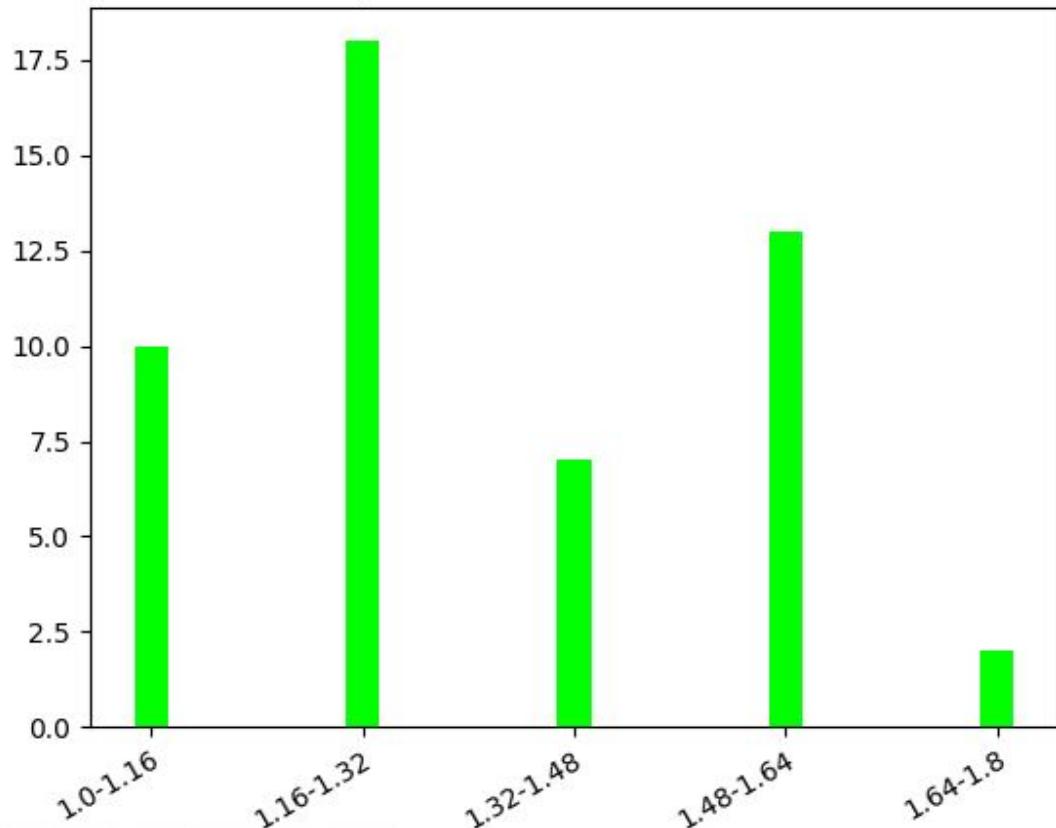


x=0.303145 y=19.3455



Figure 1

petal-width - Iris-versicolor

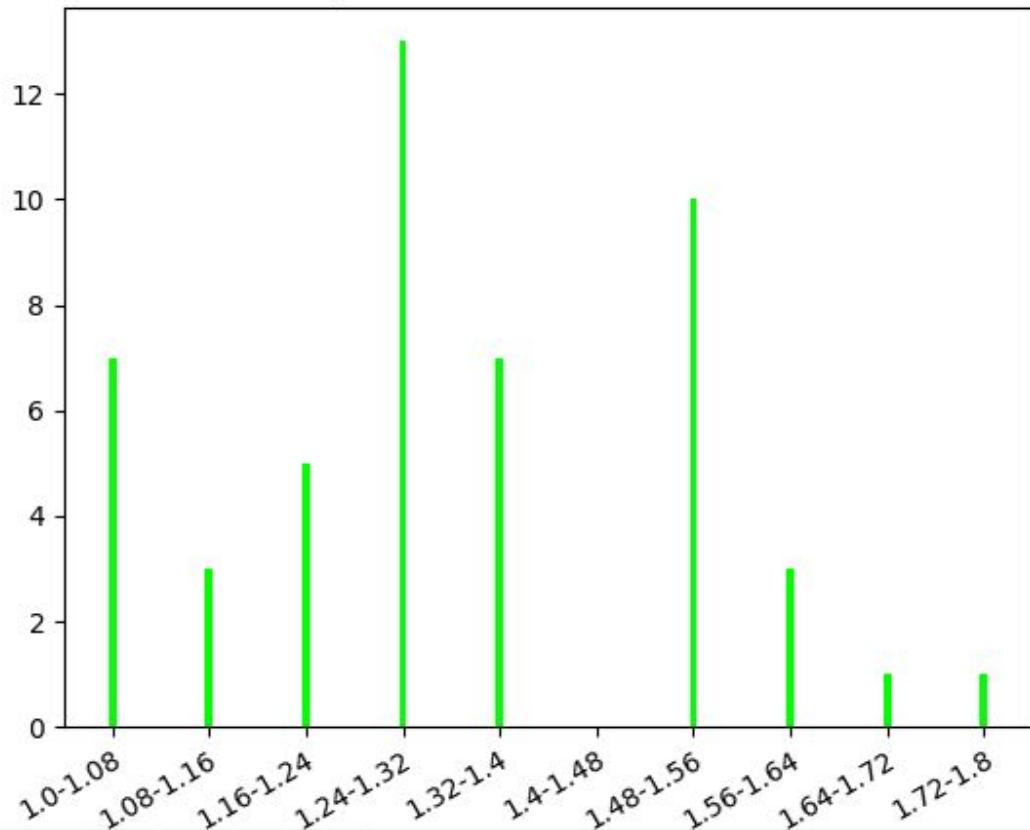


x = y = 15.4534



Figure 1

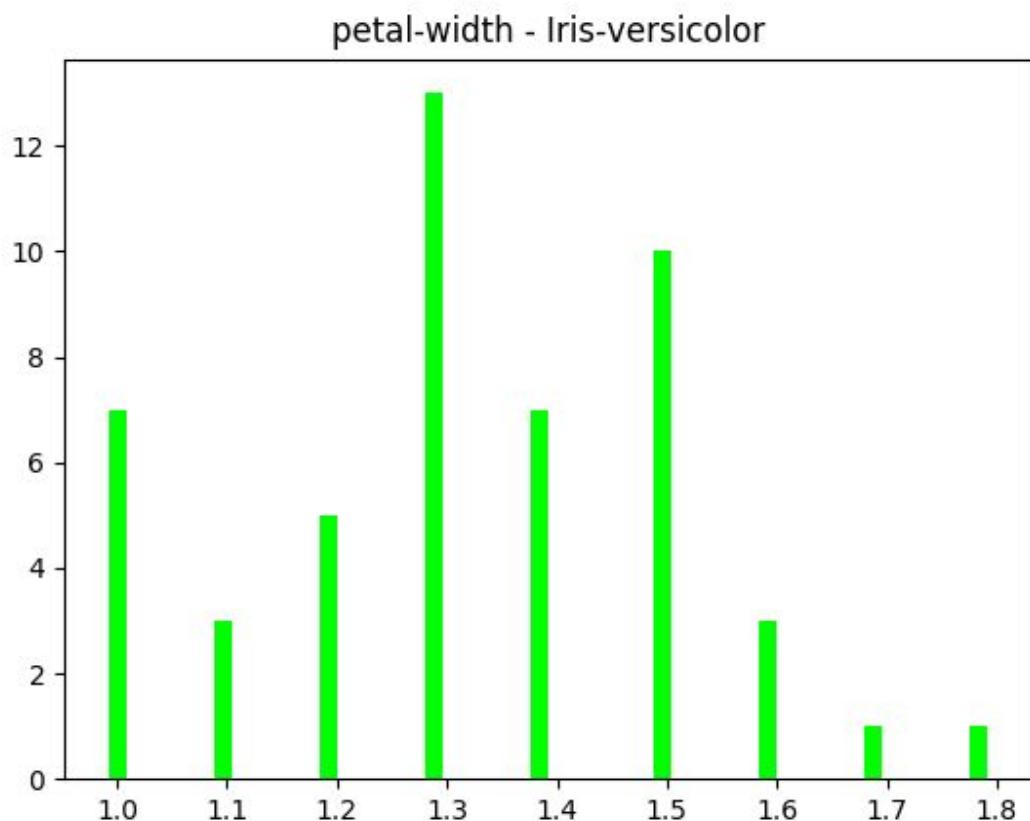
petal-width - Iris-versicolor



x = y = 9.01875



Figure 1



x=1.25894

y=10.5699



Figure 1

petal-width - Iris-versicolor

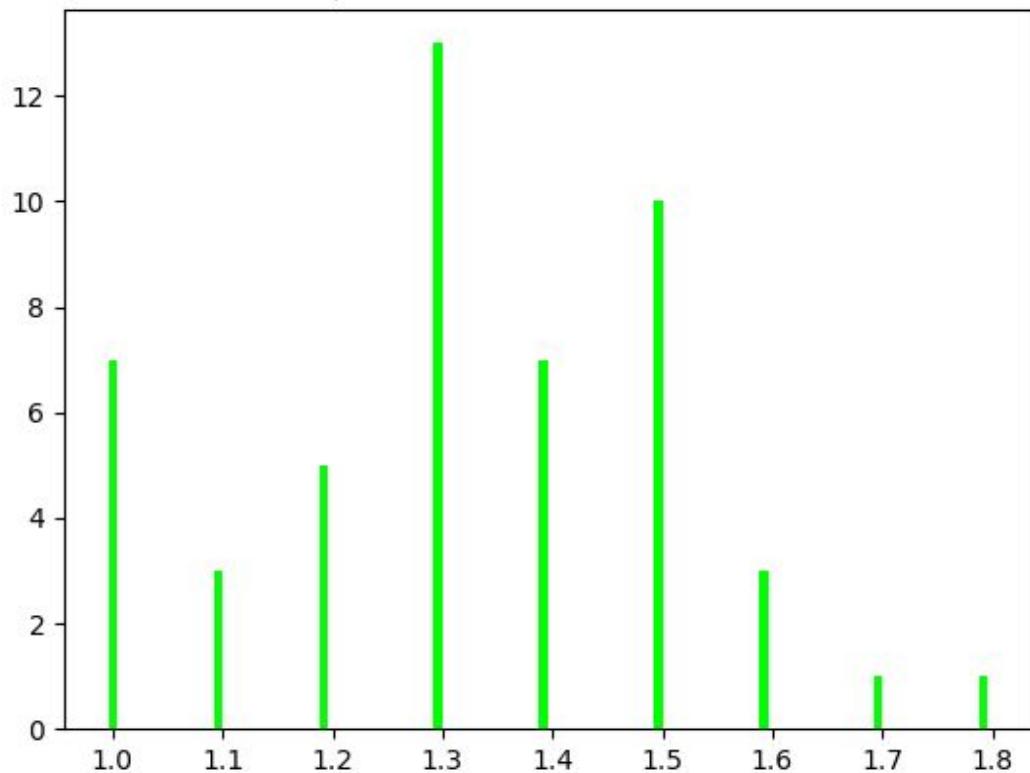
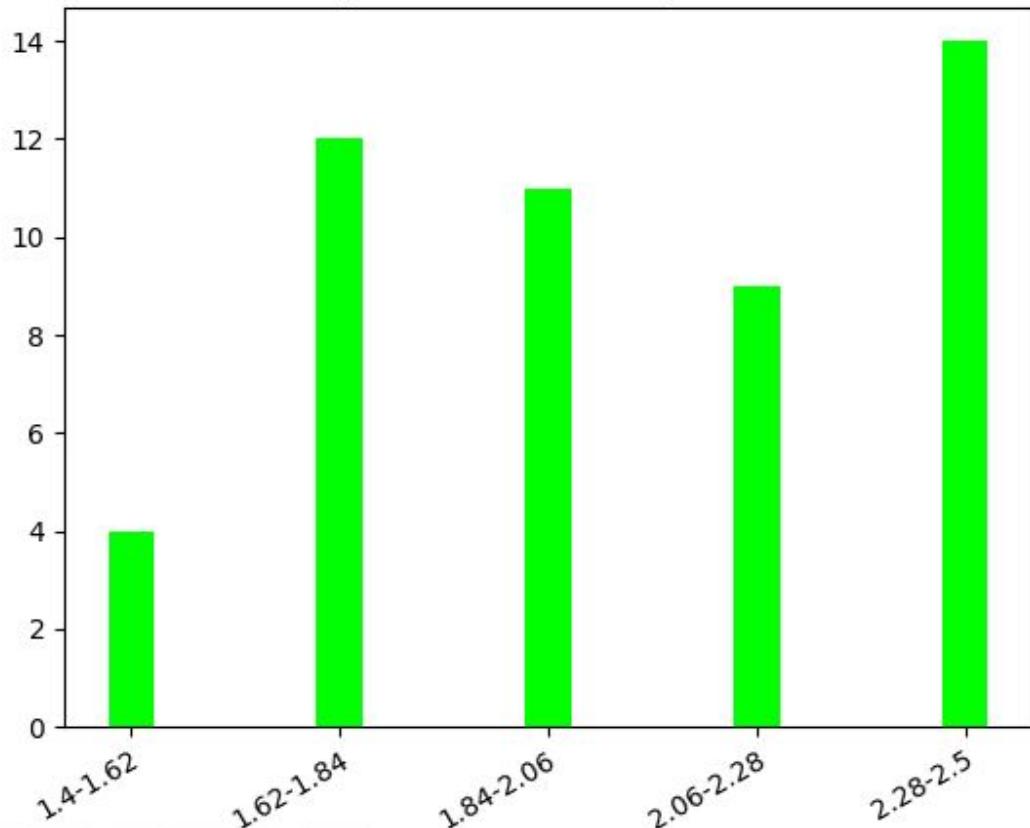




Figure 1

petal-width - Iris-virginica

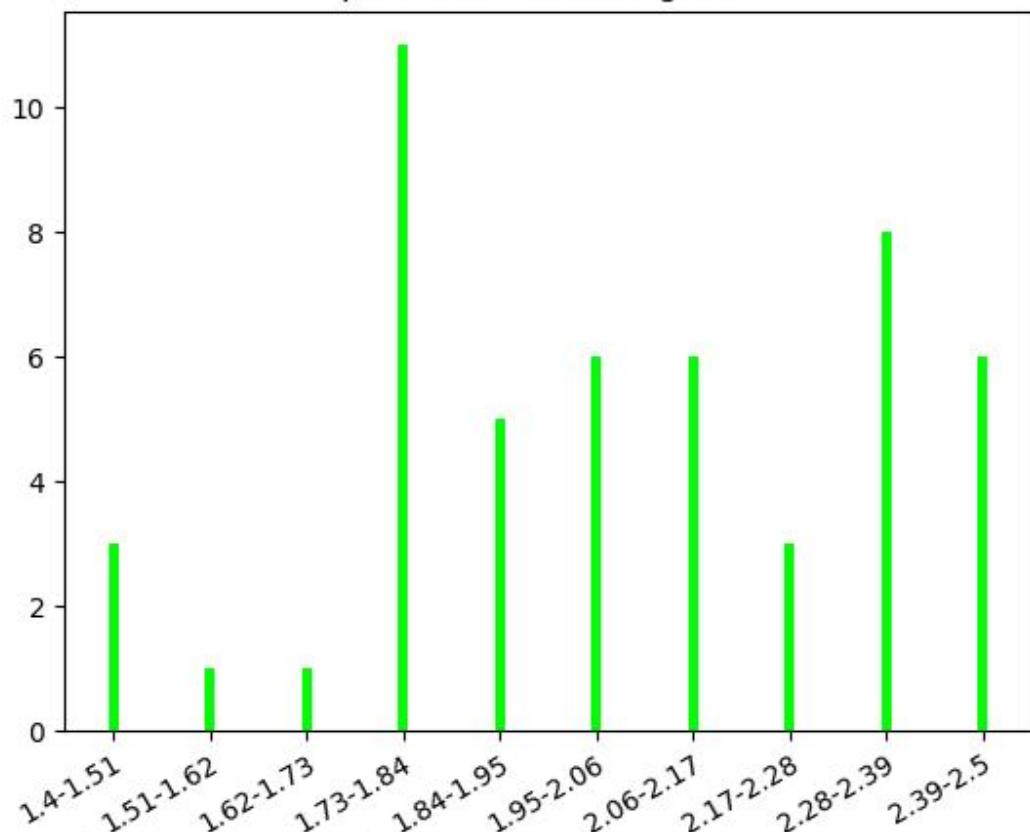


x = y = 10.7466



Figure 1

petal-width - Iris-virginica

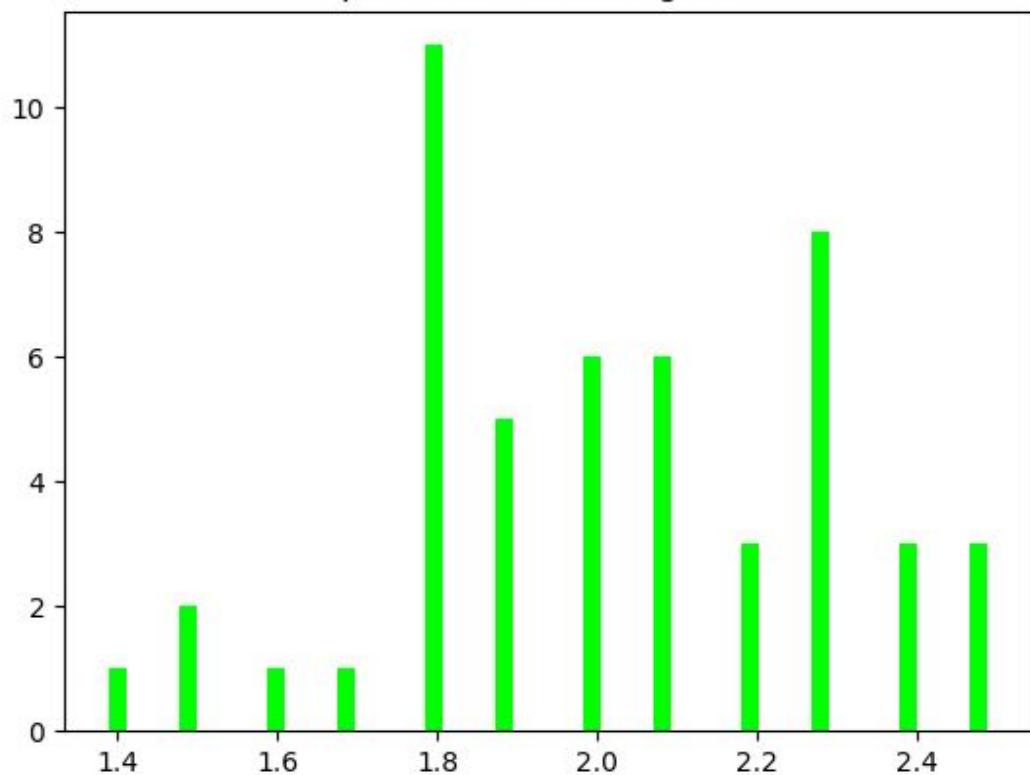


x = y = 8.31875



Figure 1

petal-width - Iris-virginica

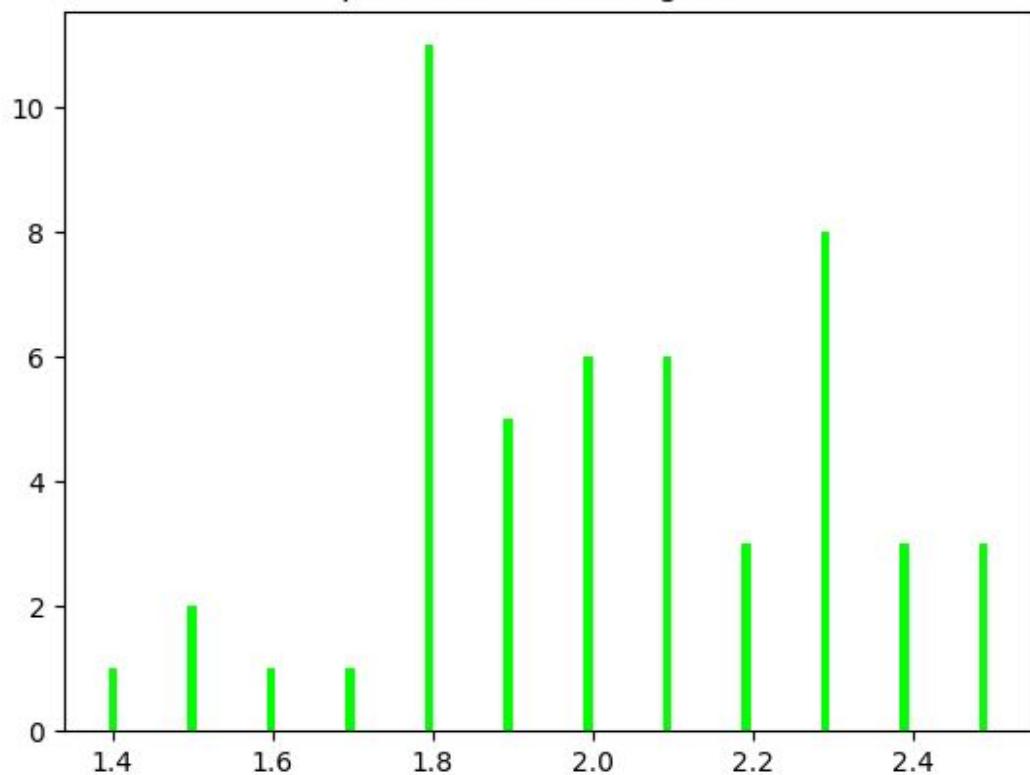


x=1.88289 y=7.88125



Figure 1

petal-width - Iris-virginica

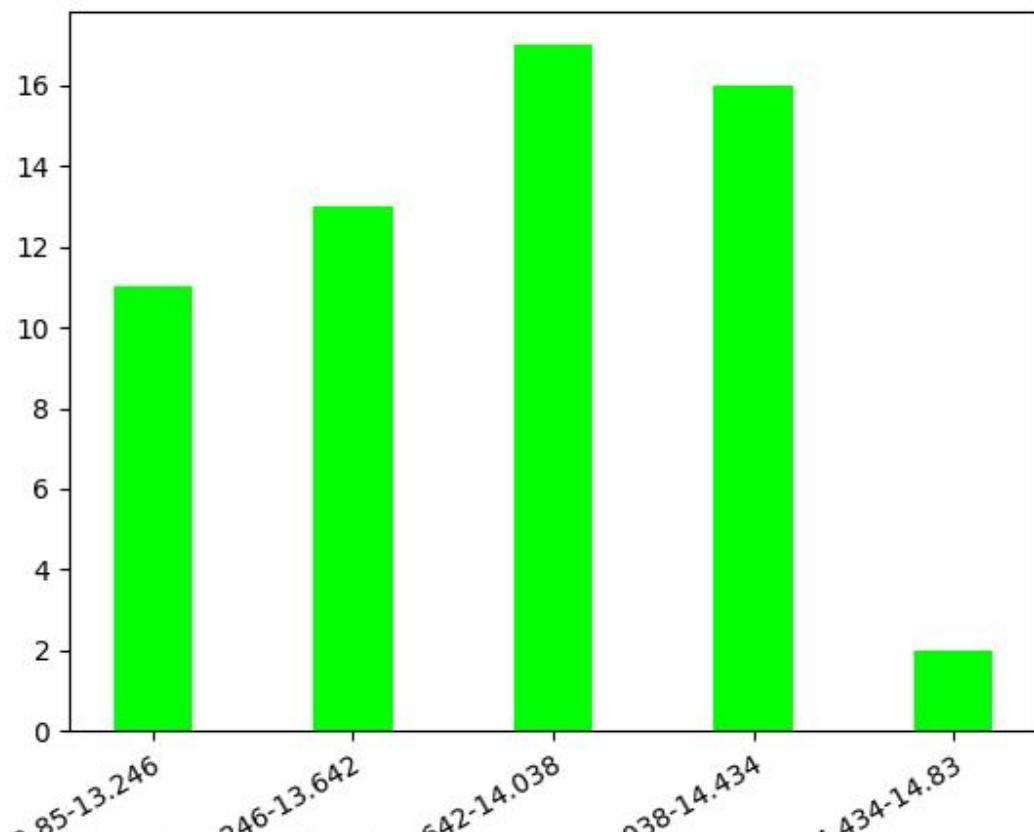


x=2.07135 y=6.85



Figure 1

alcohol - Wine Class 1

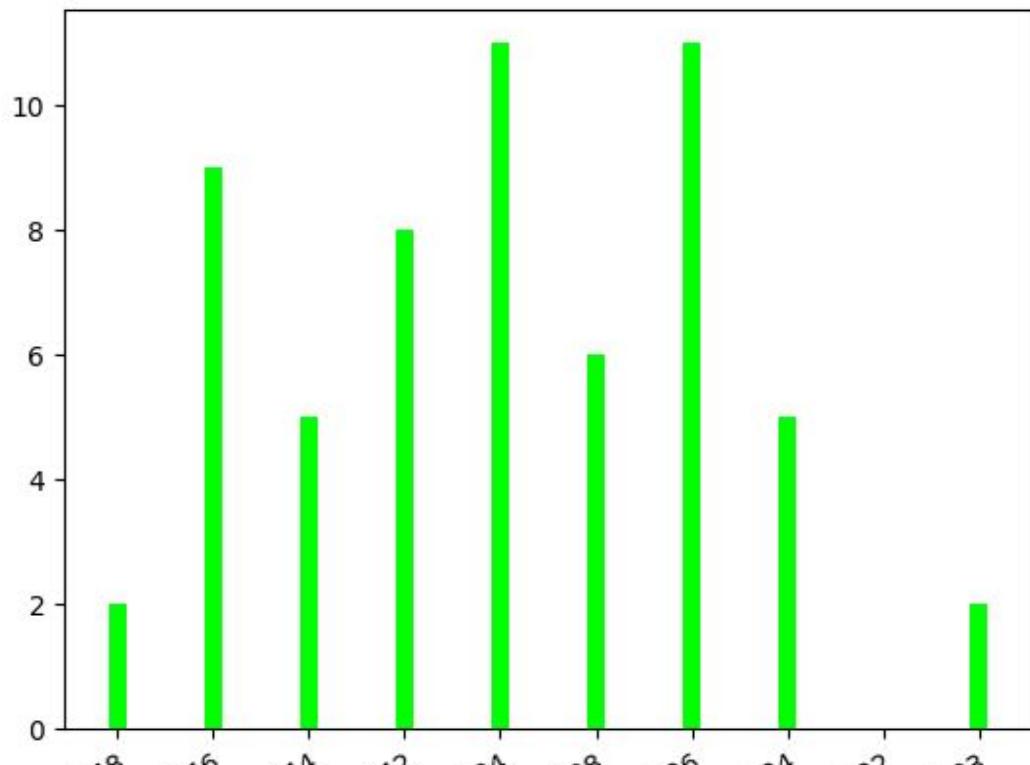


x = y = 12.325



Figure 1

alcohol - Wine Class 1

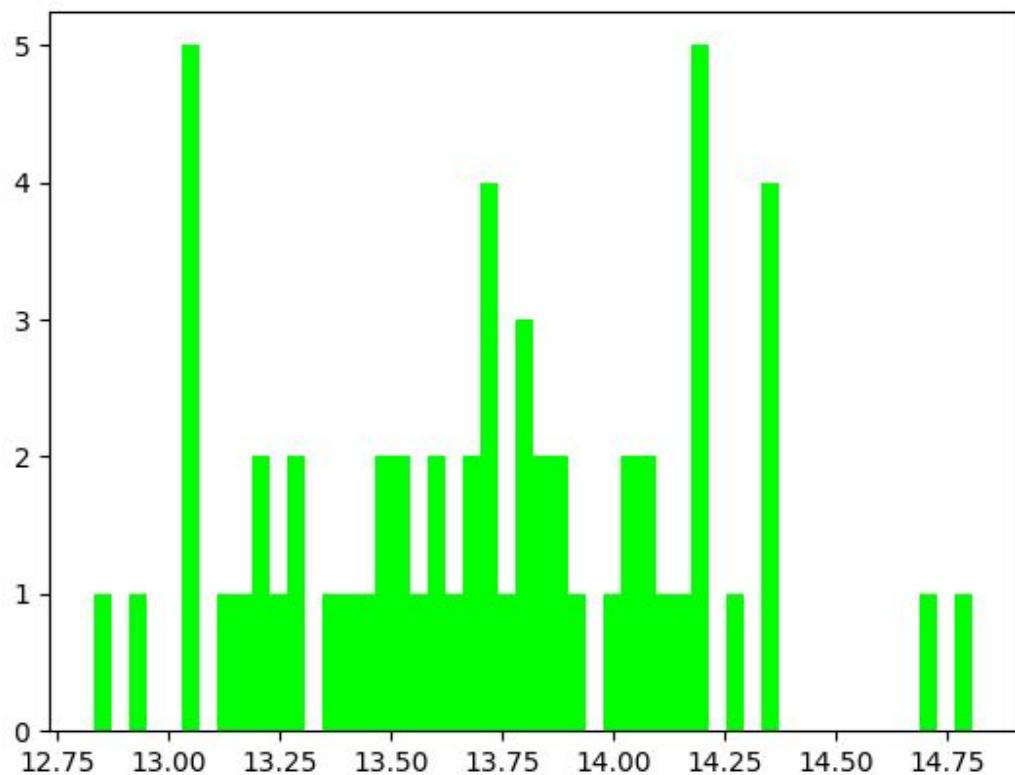


x = y = 8.00625



Figure 1

alcohol - Wine Class 1



x=13.9651 y=4.02273



Figure 1

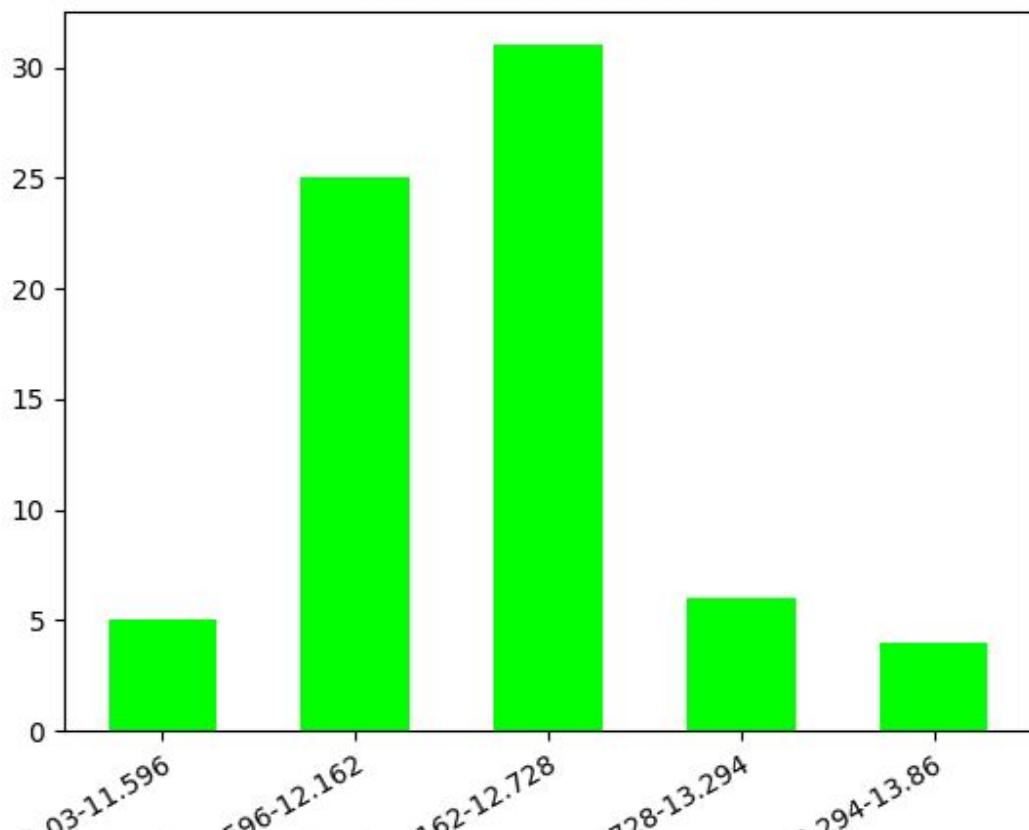


x=13.8652 y=2.63864



Figure 1

alcohol - Wine Class 2



x = y = 16.2222



Figure 1

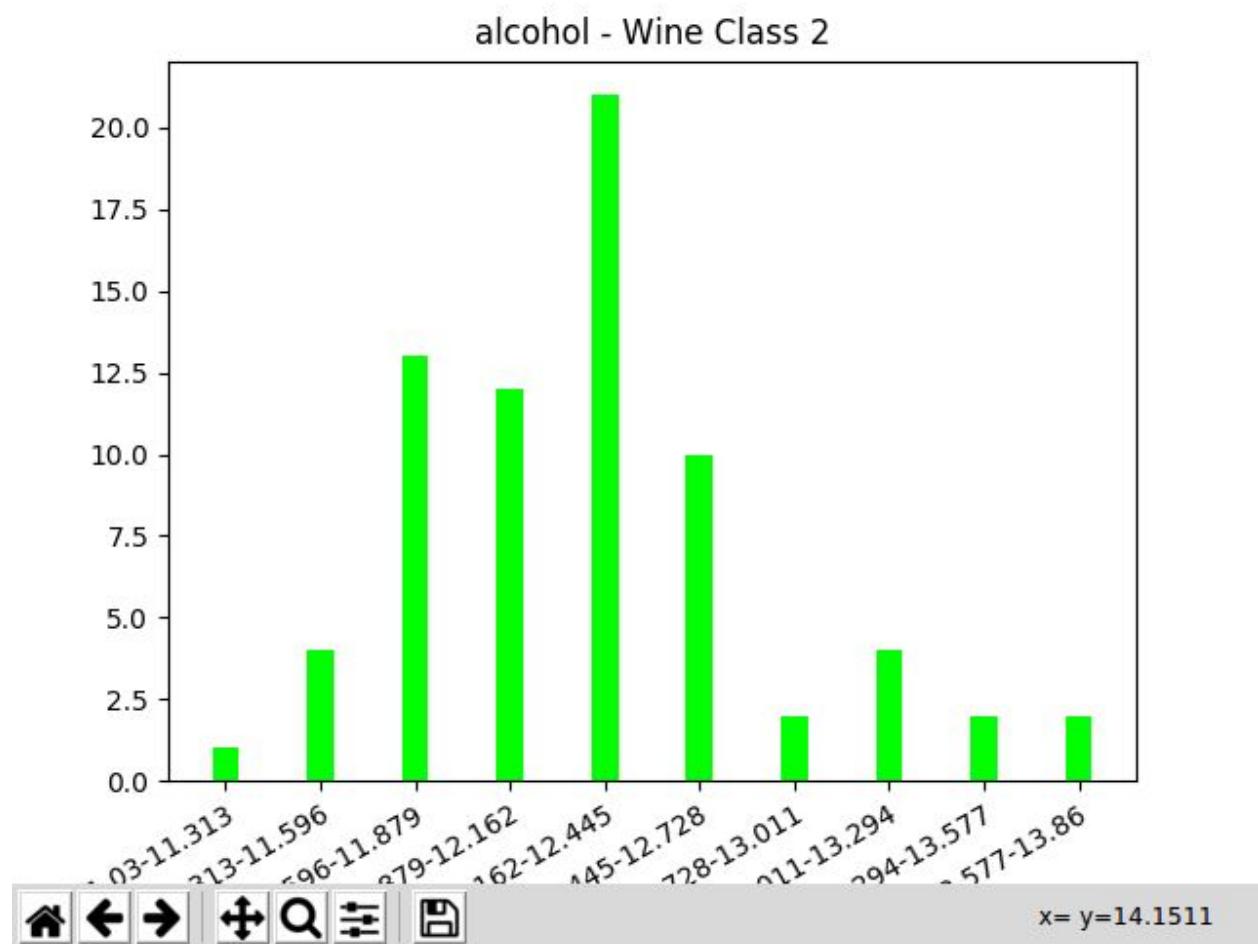
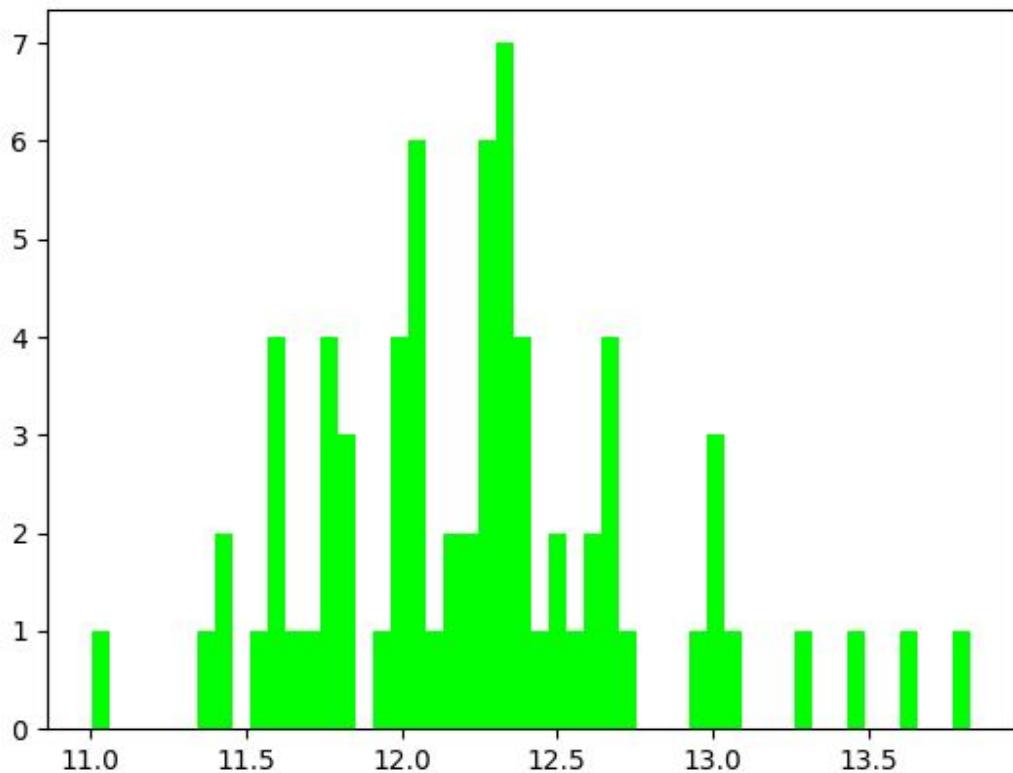




Figure 1

alcohol - Wine Class 2

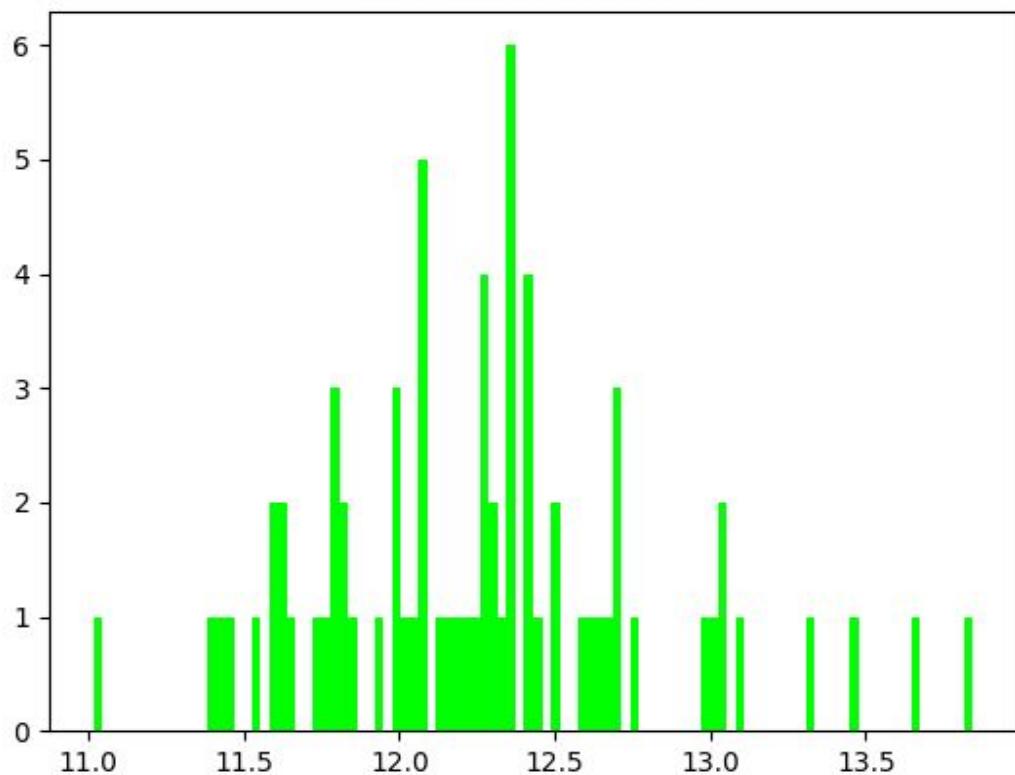


x=12.9878 y=4.59773



Figure 1

alcohol - Wine Class 2

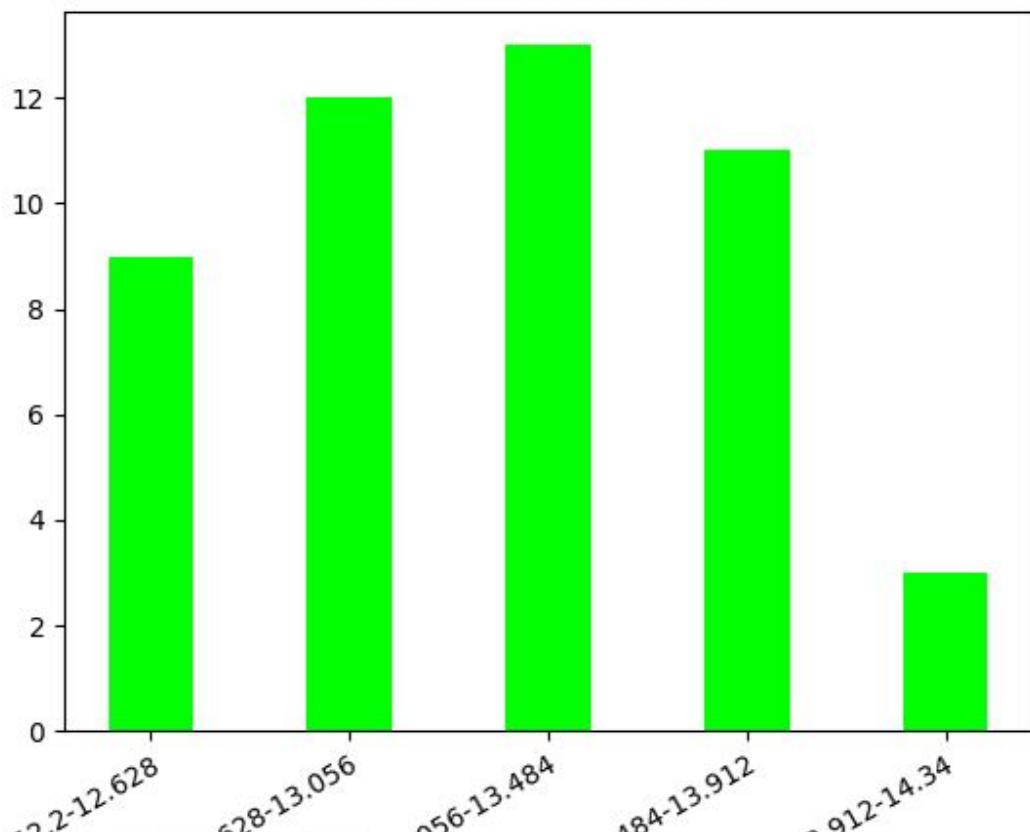


x=12.8011 y=3.36136



Figure 1

alcohol - Wine Class 3

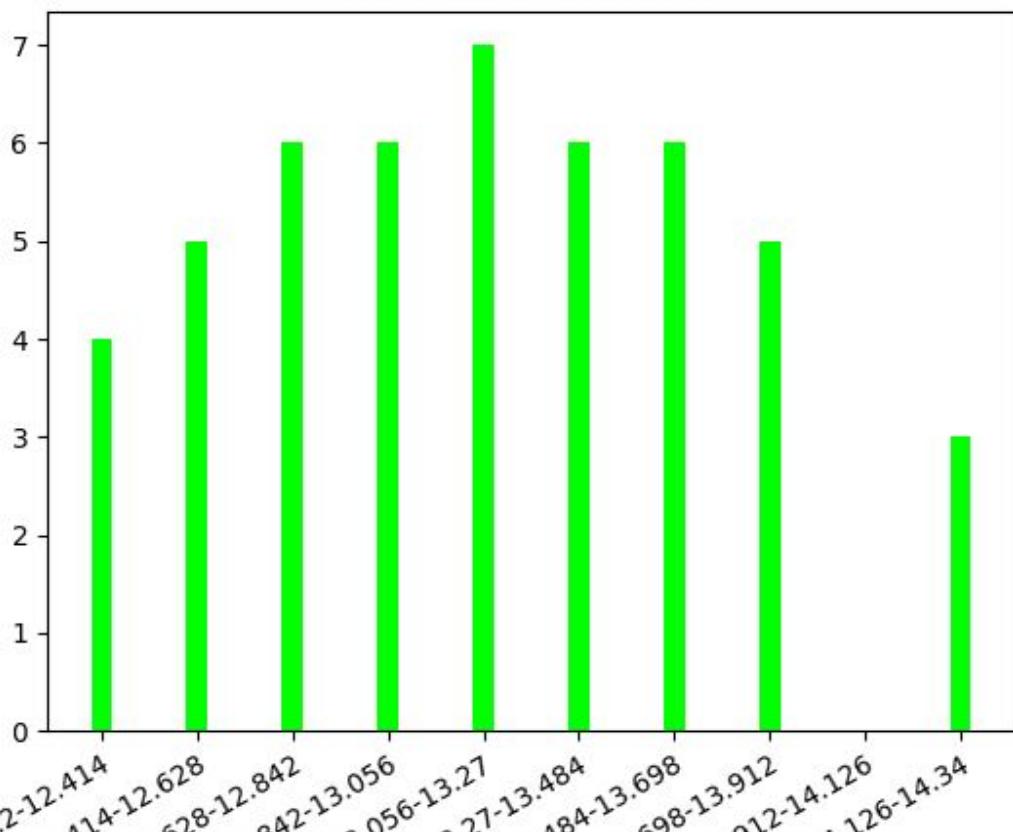


x = y = 8.02159



Figure 1

alcohol - Wine Class 3



x = y = 2.82784



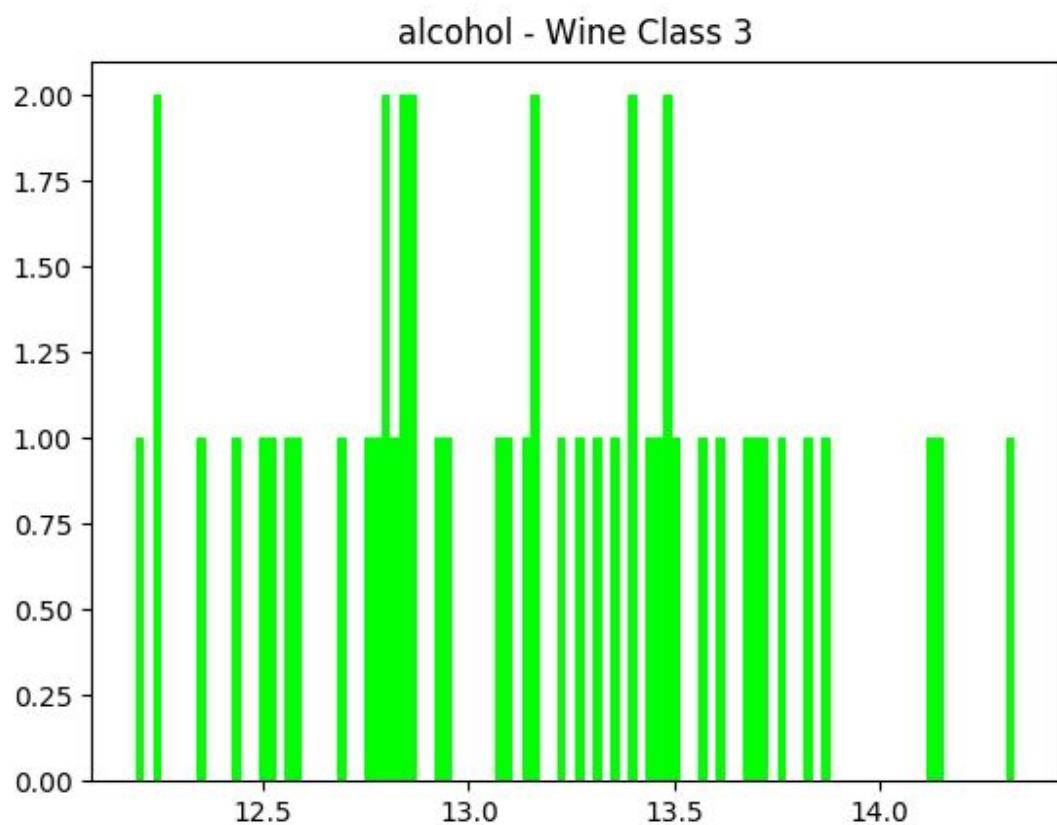
Figure 1



x=13.6093 y=1.61591



Figure 1



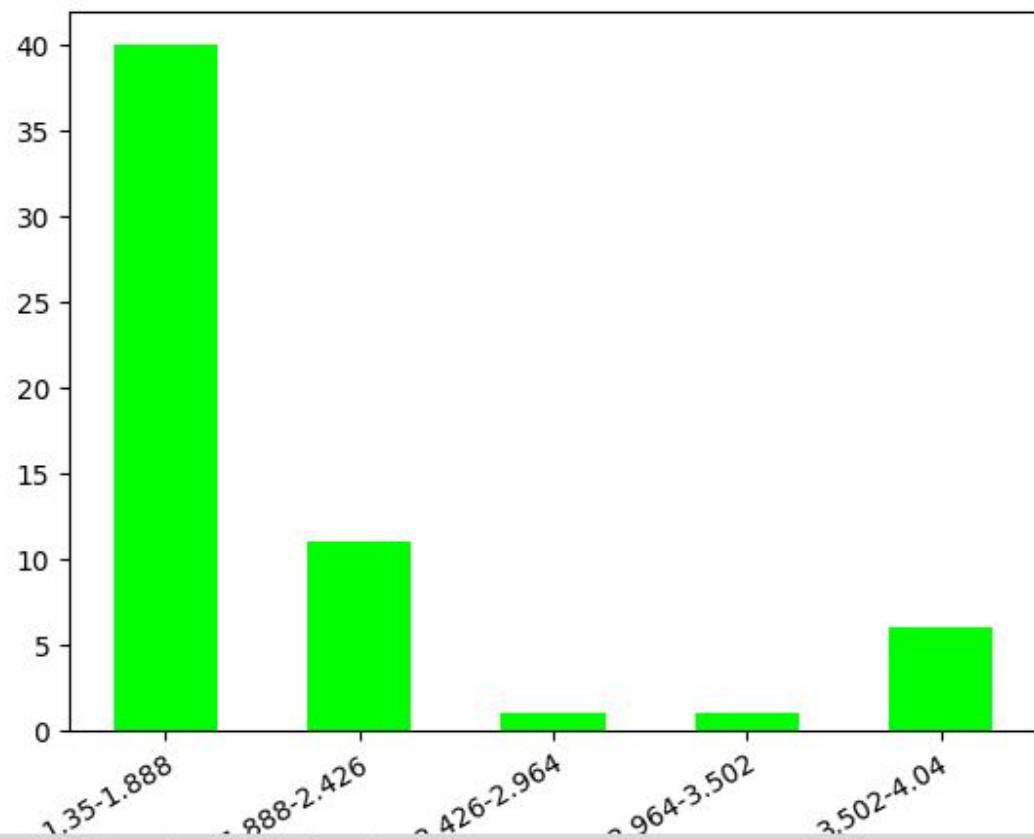
x=13.5061

y=1.2625



Figure 1

malic-acid - Wine Class 1

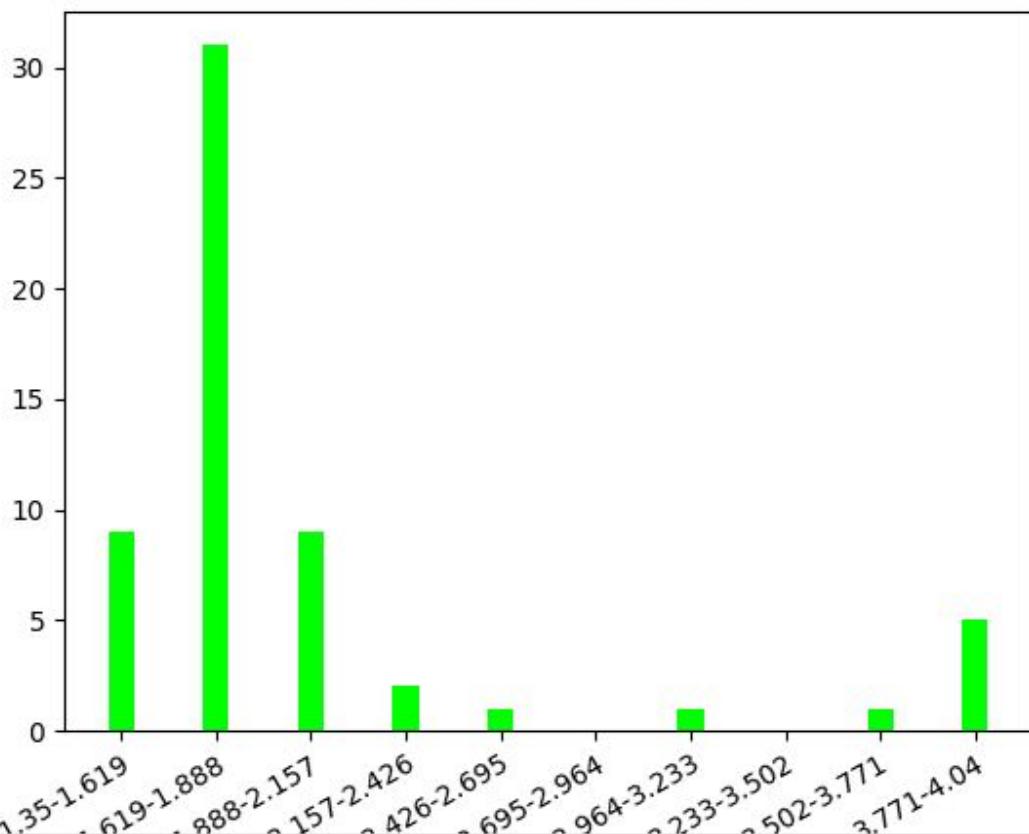


x = y = 19.5682



Figure 1

malic-acid - Wine Class 1

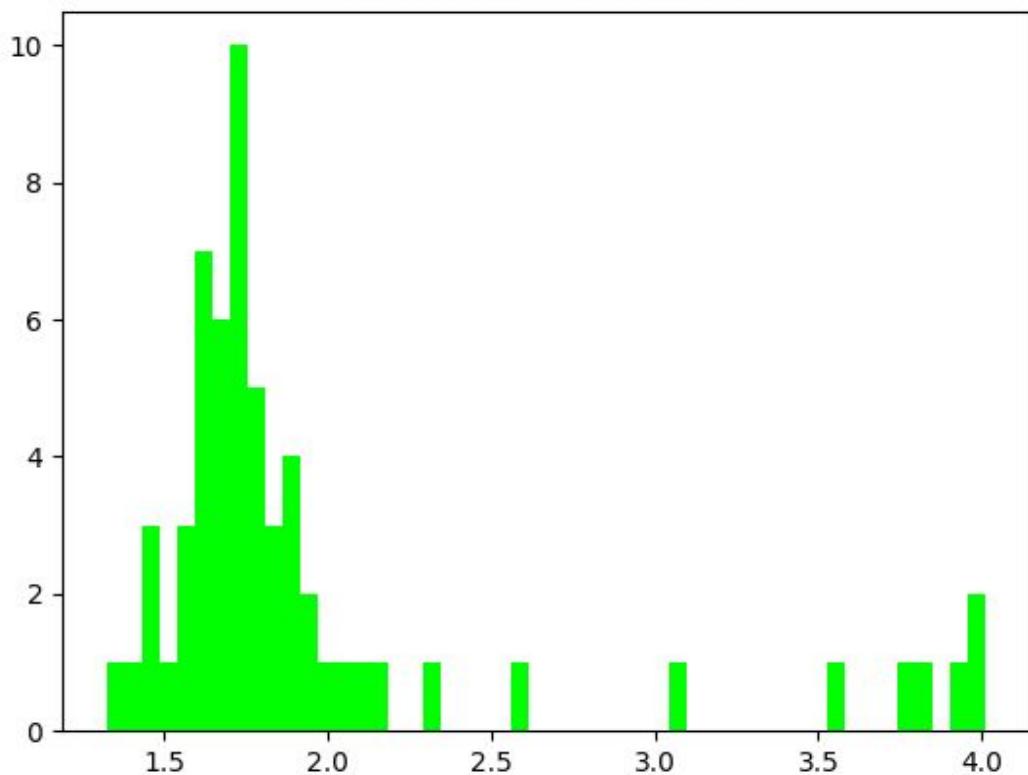


x = y = 14.725



Figure 1

malic-acid - Wine Class 1



x=2.8948 y=7.61932



Figure 1

malic-acid - Wine Class 1

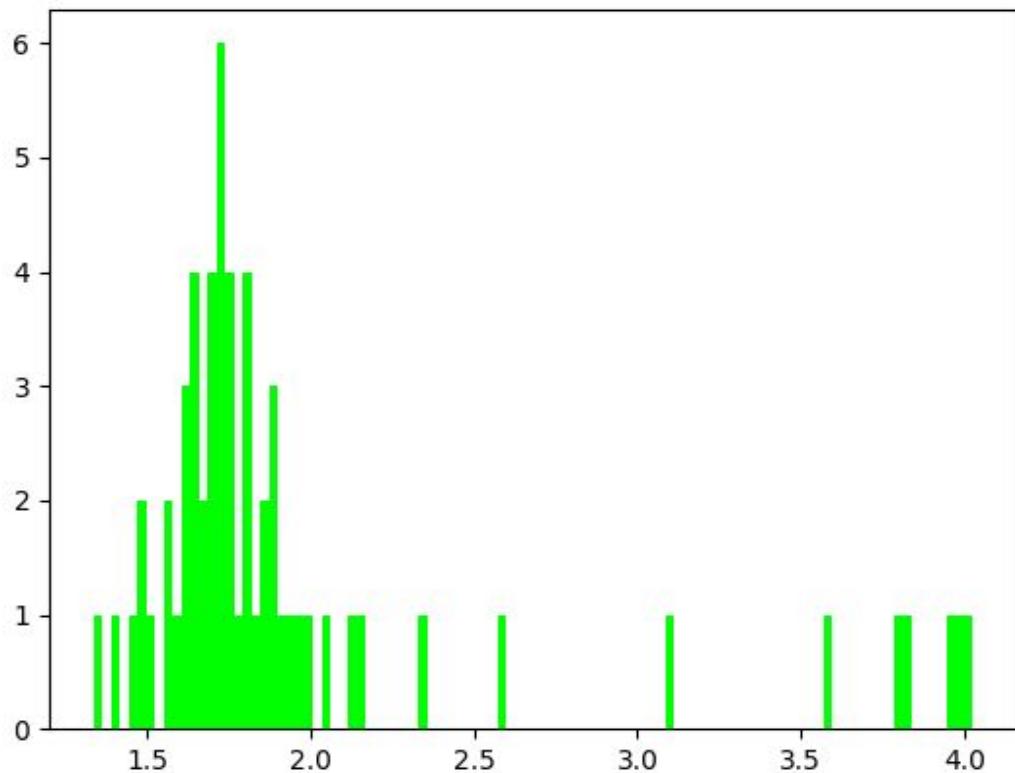
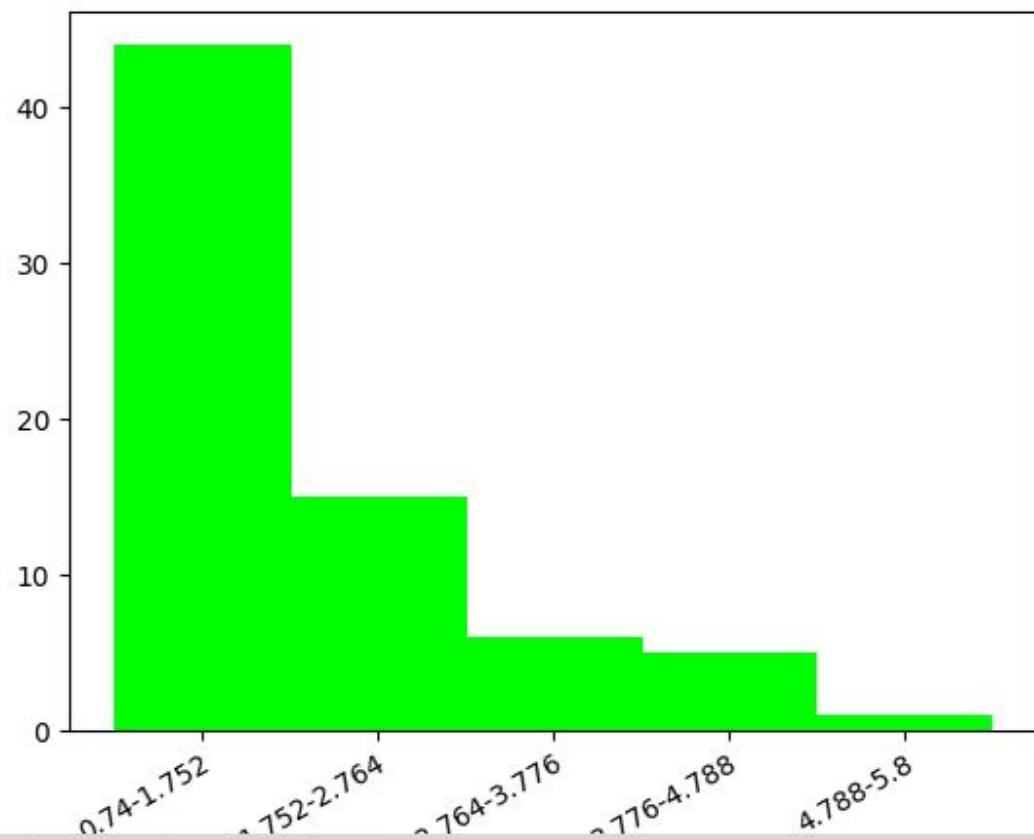




Figure 1

malic-acid - Wine Class 2

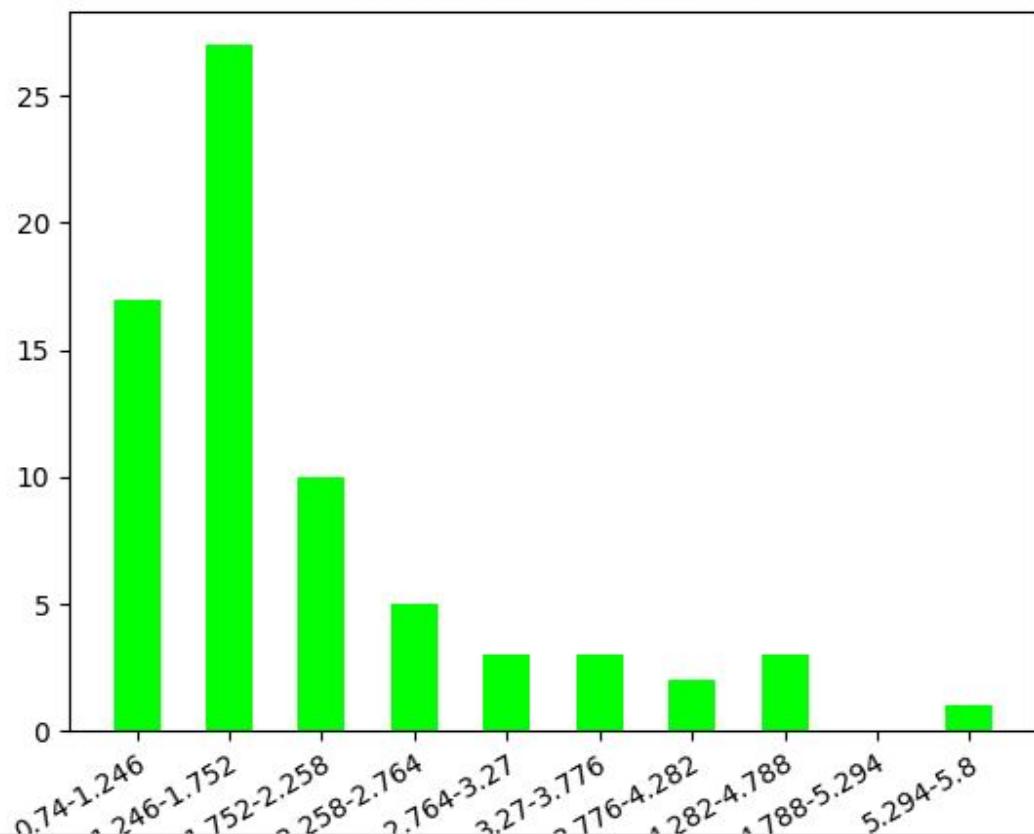


x = y = 32.275



Figure 1

malic-acid - Wine Class 2

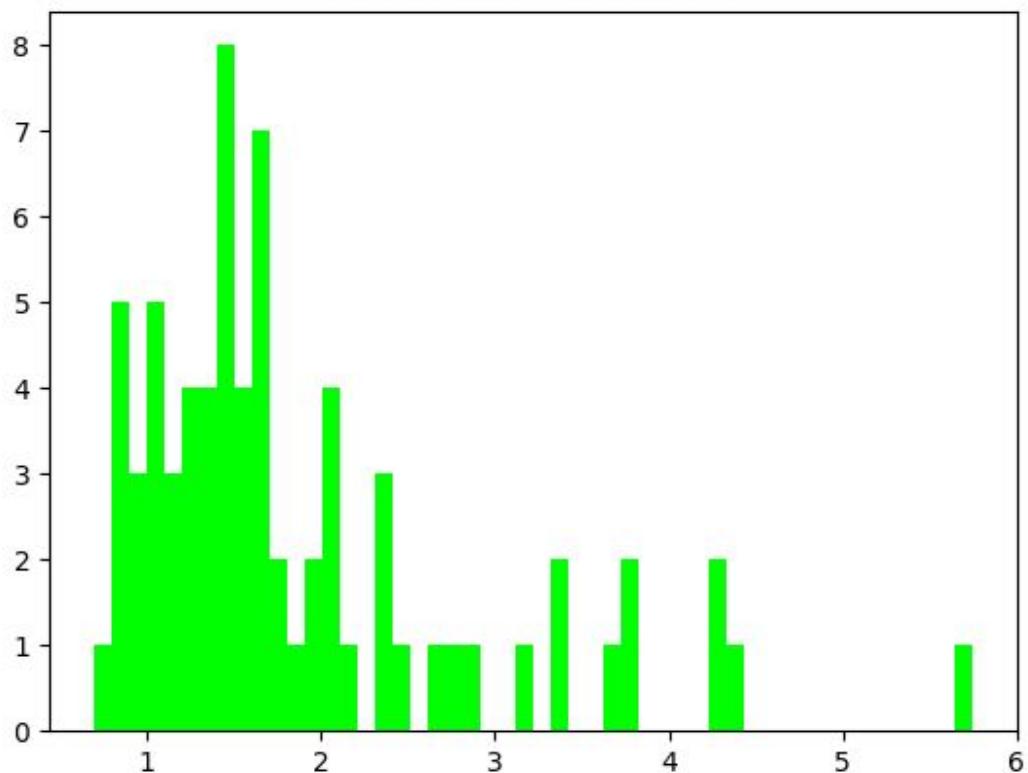


x = y = 17.5807



Figure 1

malic-acid - Wine Class 2



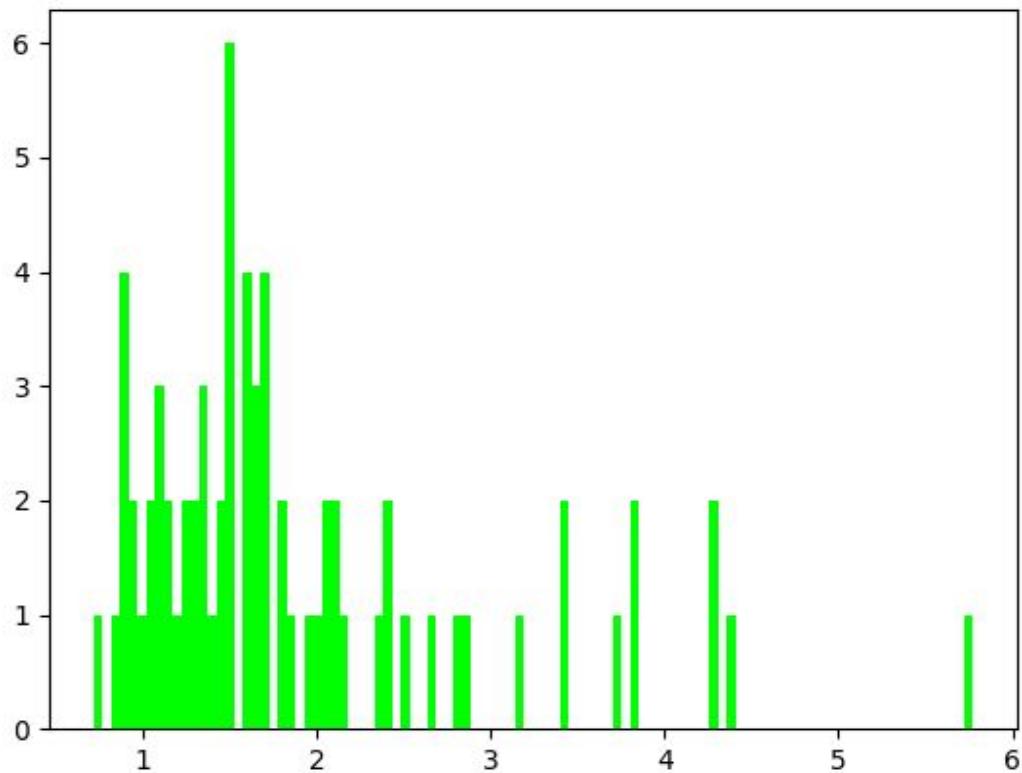
x=2.81542

y=6.09545



Figure 1

malic-acid - Wine Class 2

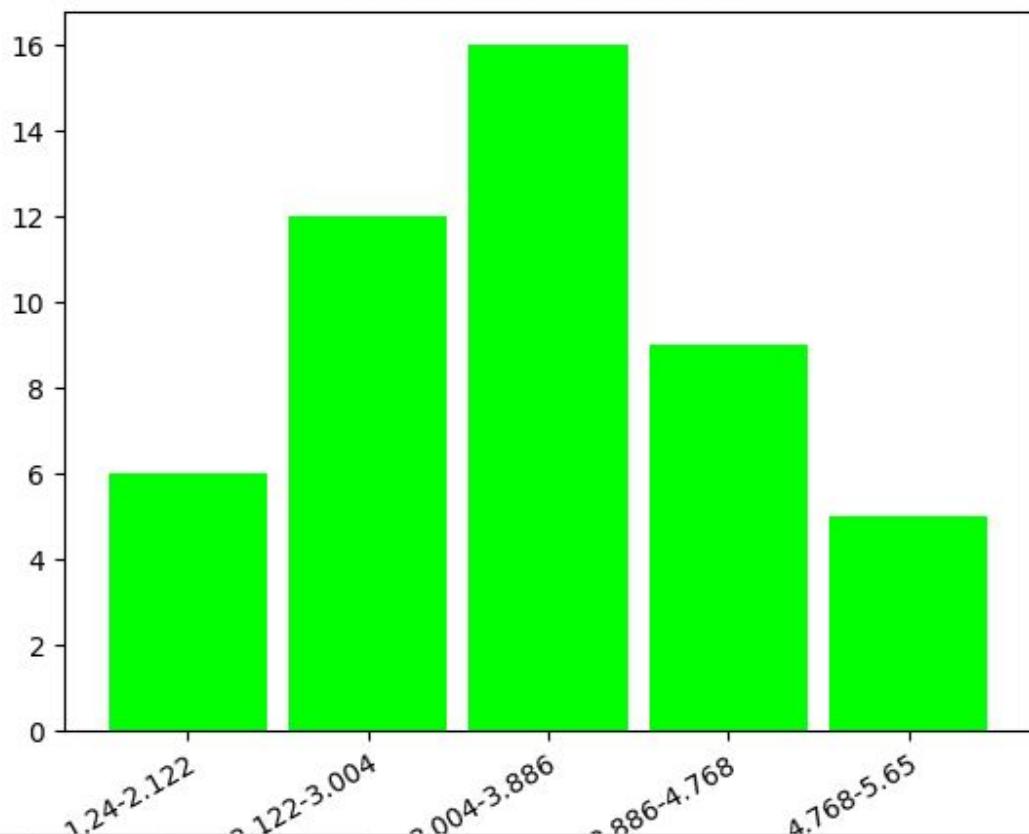


x=3.63746 y=4.5375



Figure 1

malic-acid - Wine Class 3



x = y = 11.8273



Figure 1

malic-acid - Wine Class 3

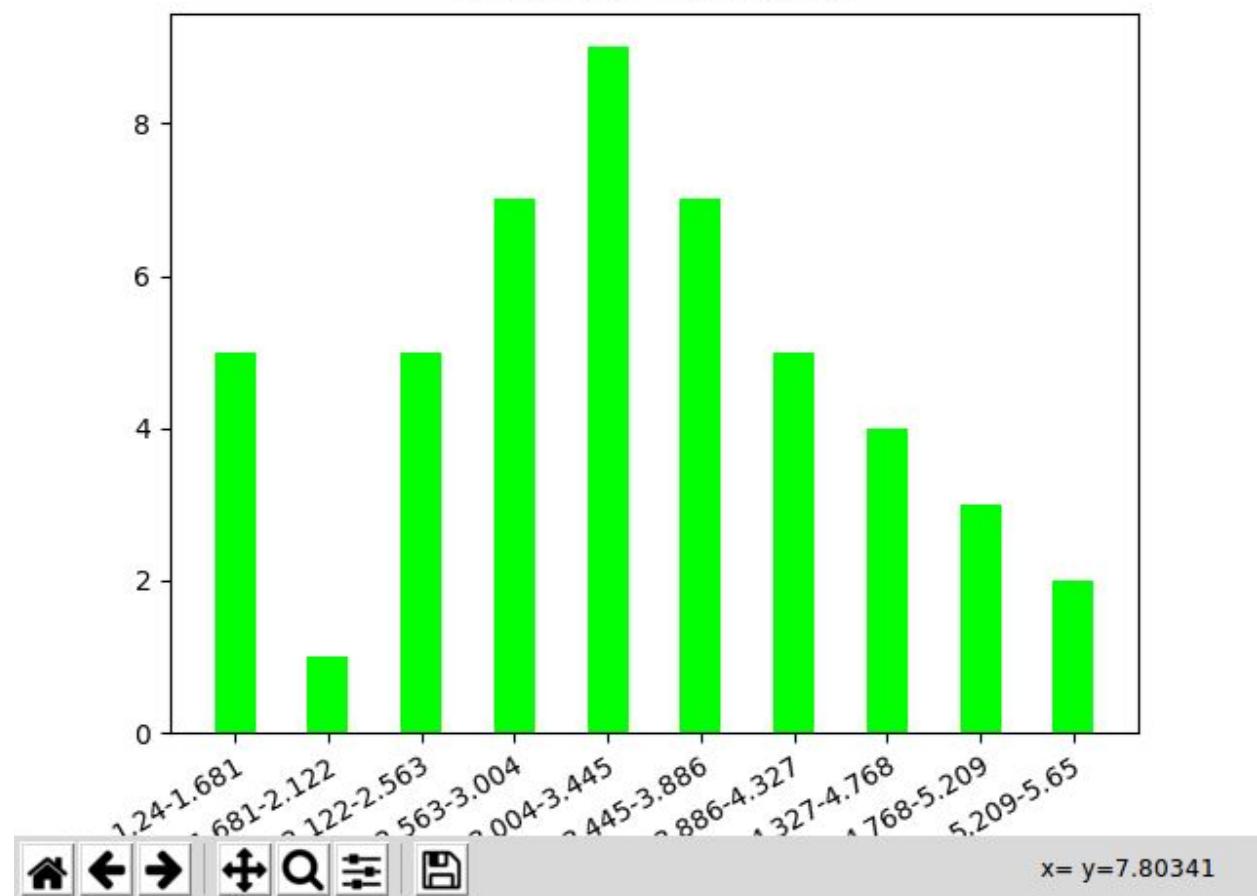
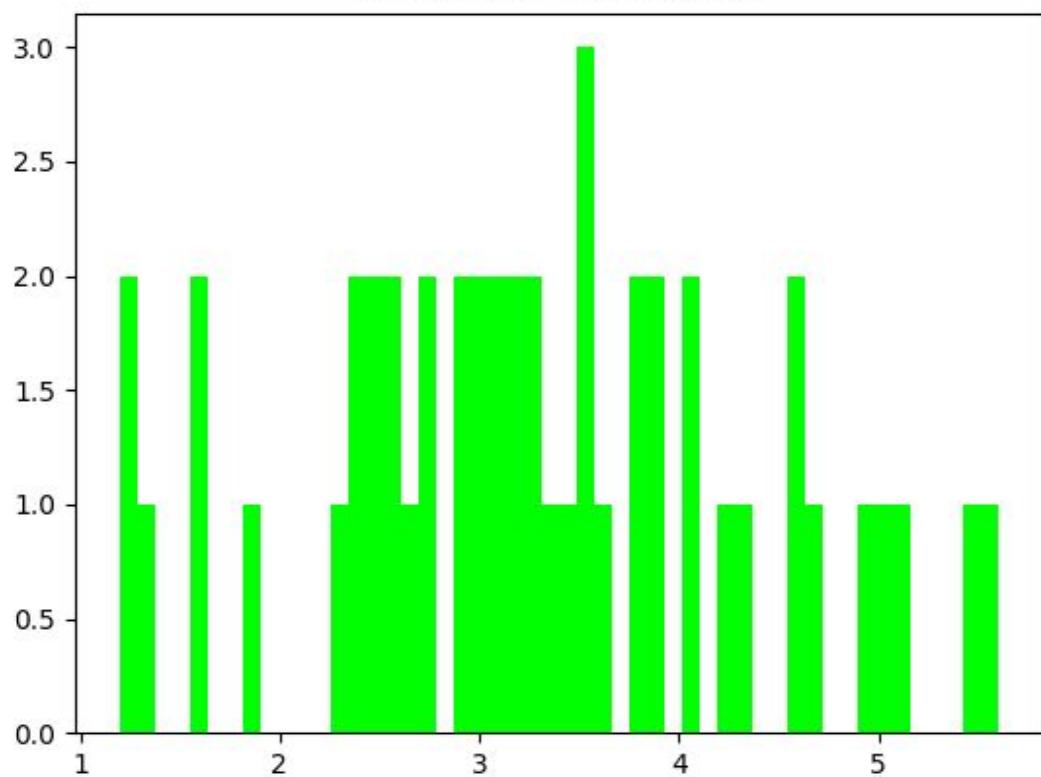




Figure 1

malic-acid - Wine Class 3

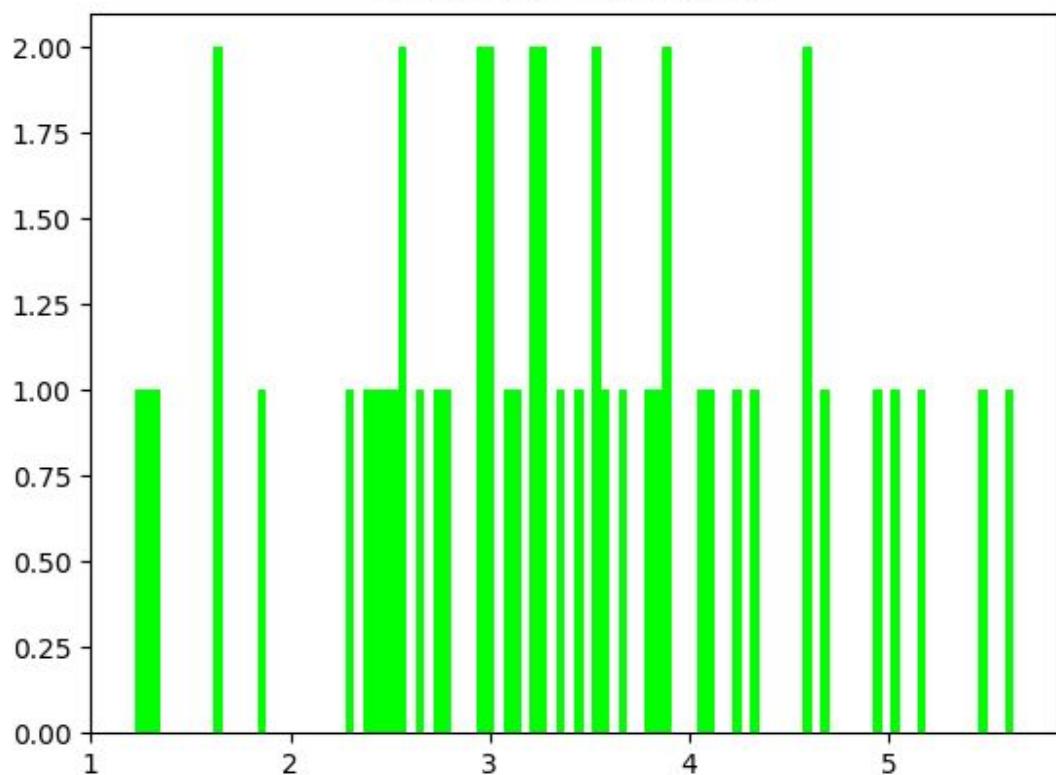


x=3.63563 y=2.22614



Figure 1

malic-acid - Wine Class 3

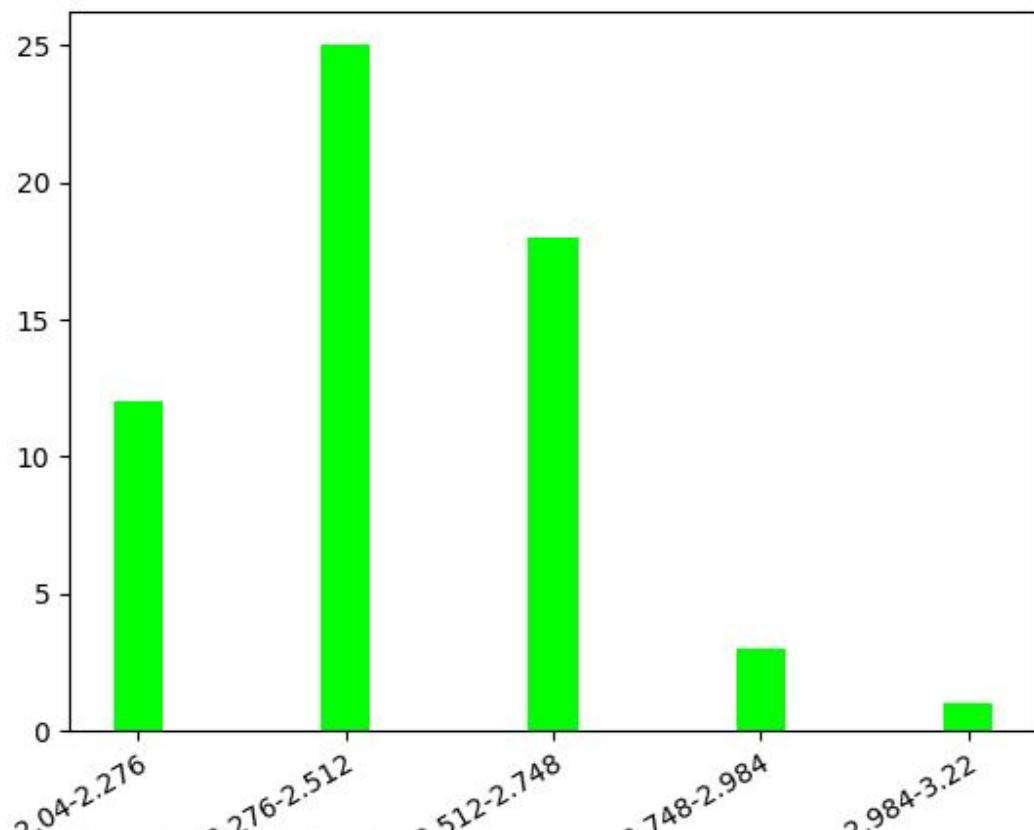


x=2.71877 y=1.79091



Figure 1

ash - Wine Class 1

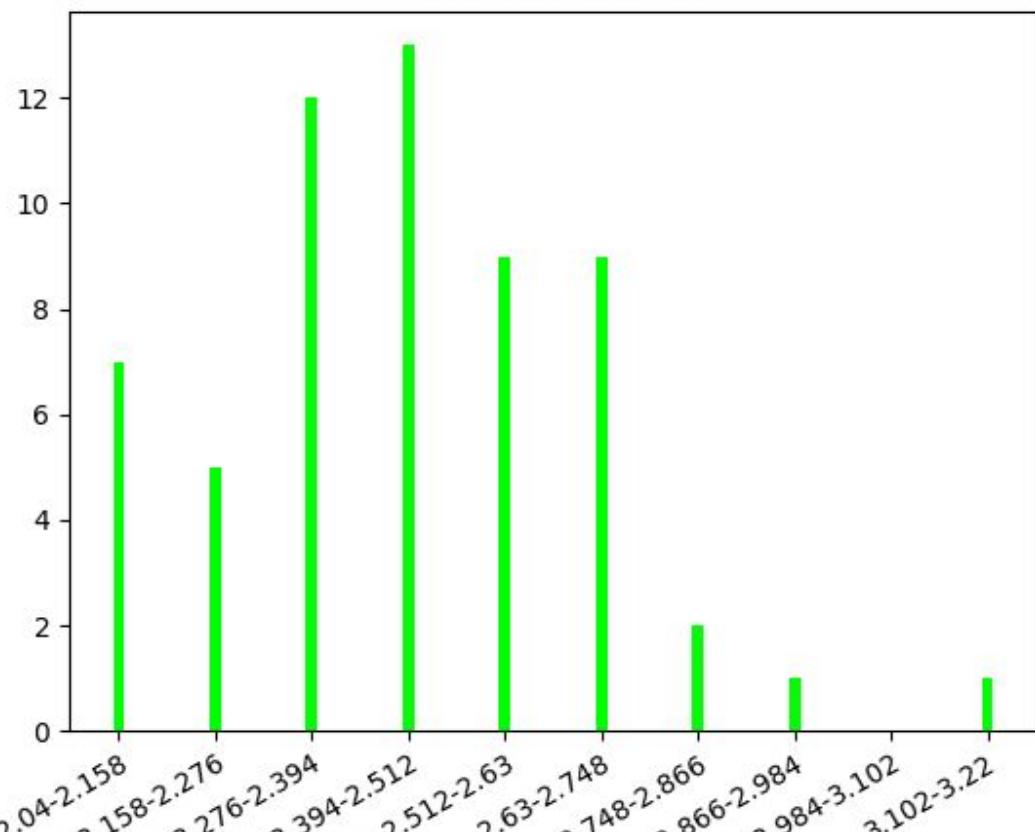


x = y = 18.9062



Figure 1

ash - Wine Class 1

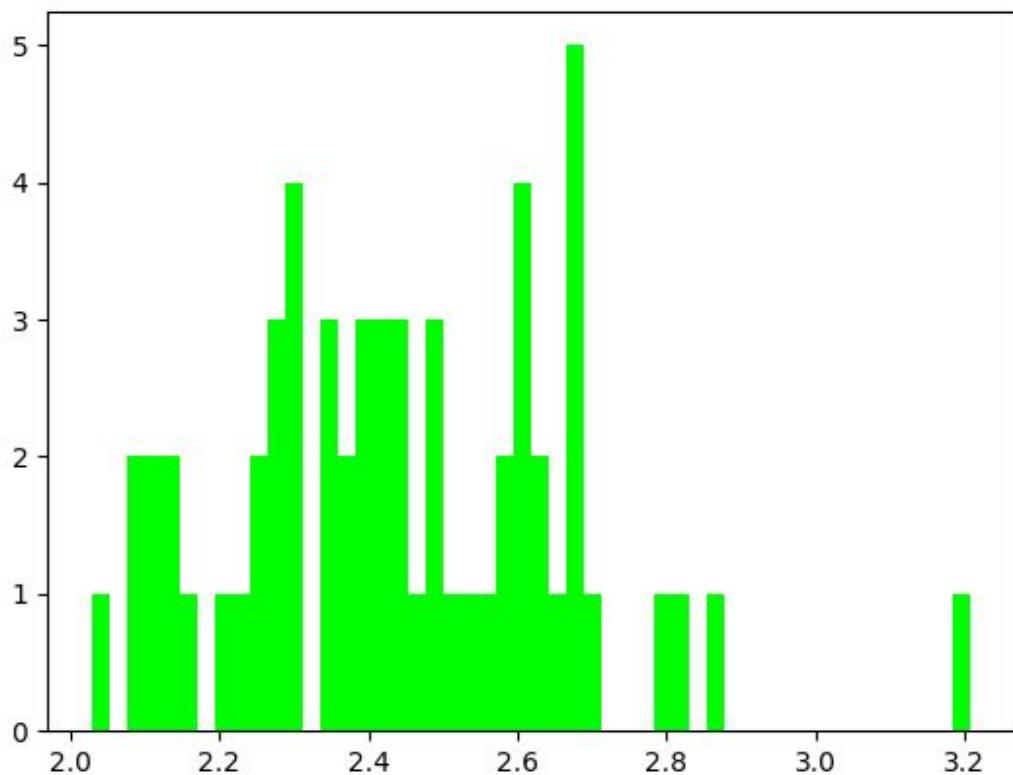


x = y = 10.0528



Figure 1

ash - Wine Class 1



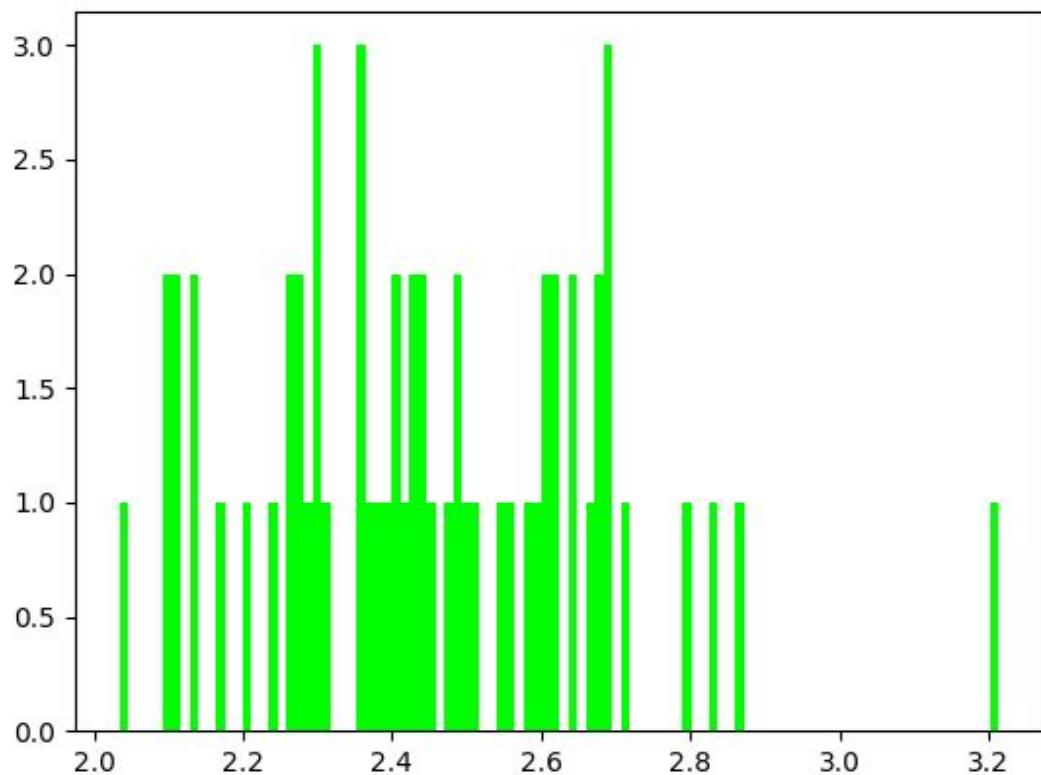
x=3.14682

y=2.34659



Figure 1

ash - Wine Class 1

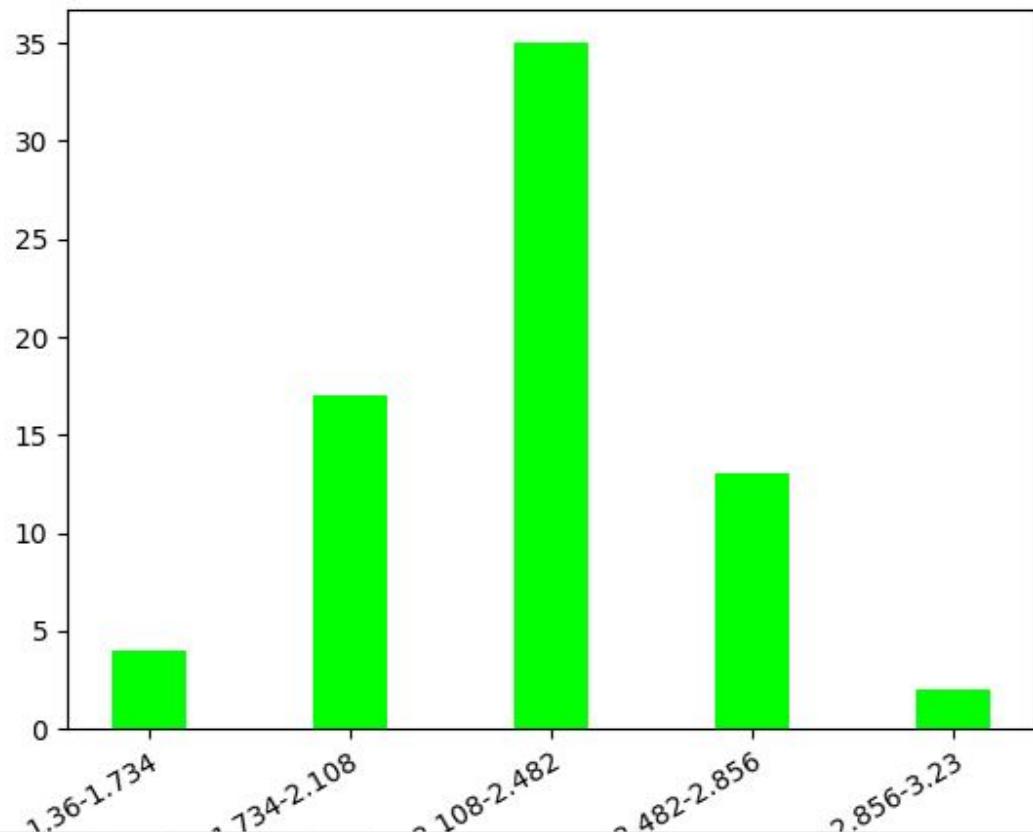


x=3.22861 y=1.66364



Figure 1

ash - Wine Class 2

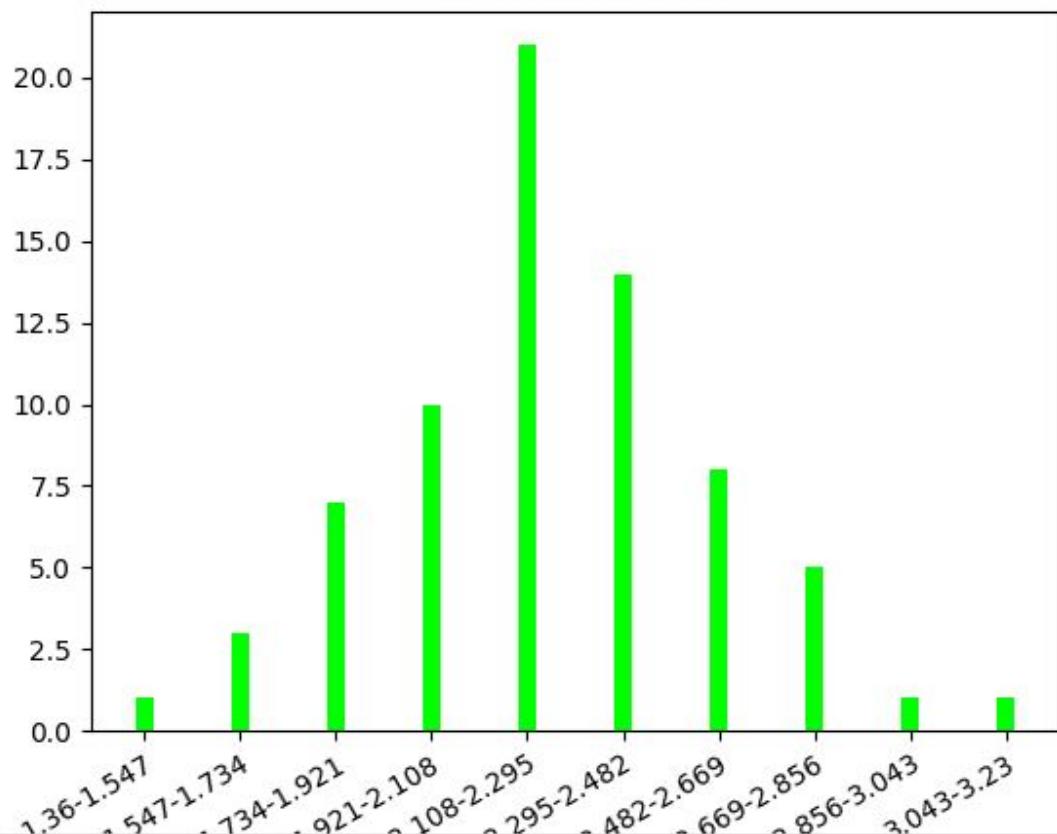


x = y = 28.8551



Figure 1

ash - Wine Class 2

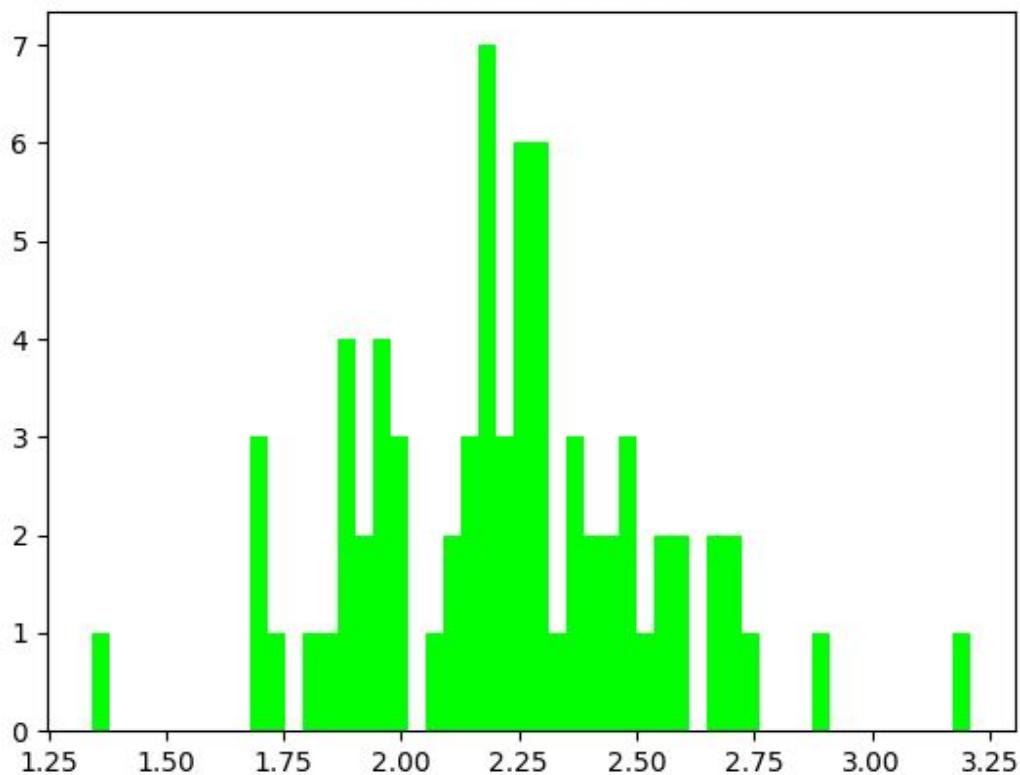


x = y = 16.4778



Figure 1

ash - Wine Class 2



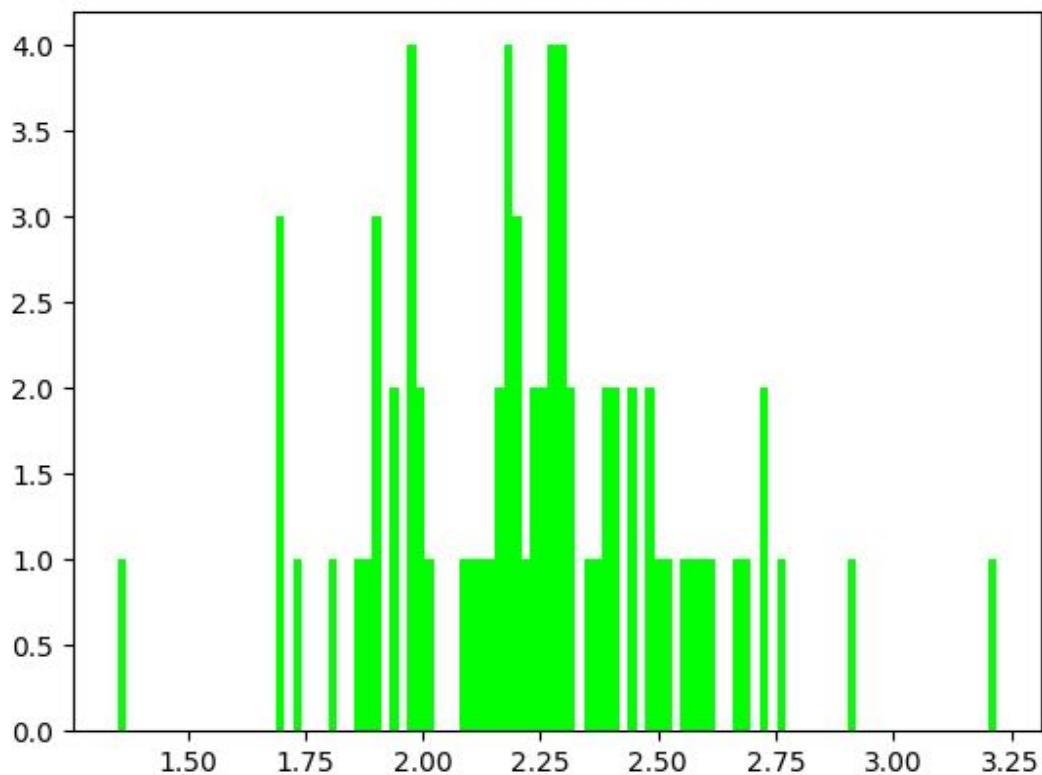
x=2.08968

y=4.79659



Figure 1

ash - Wine Class 2



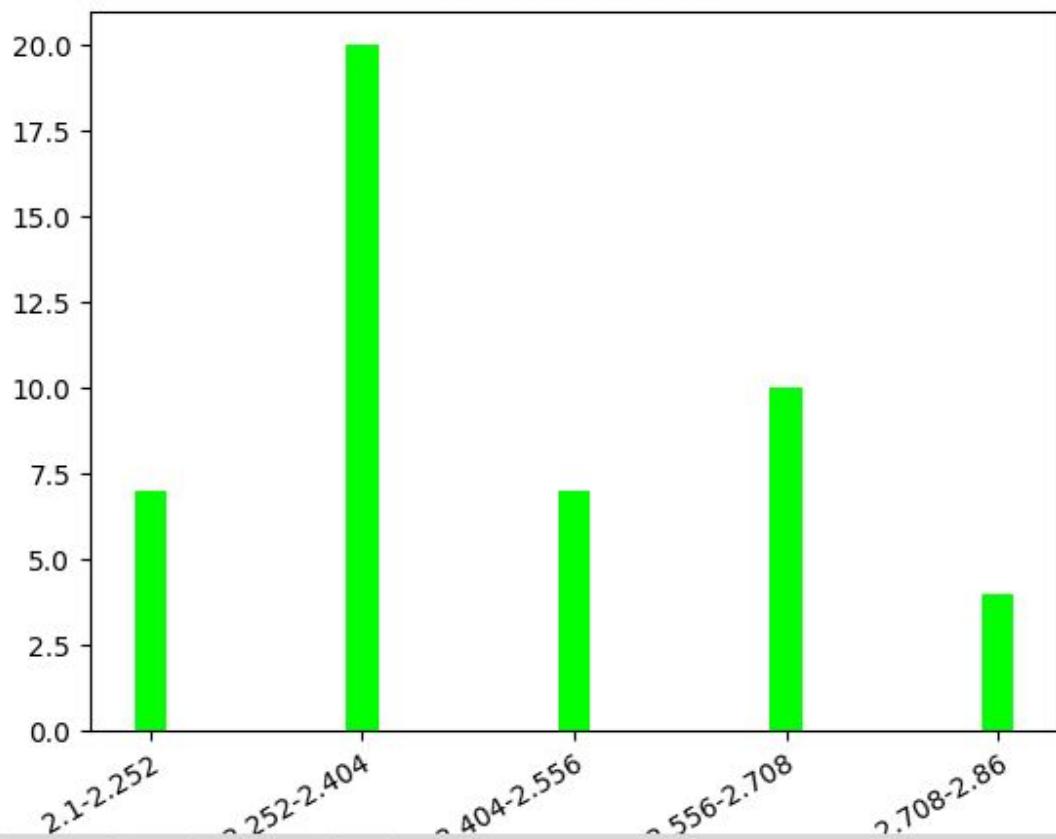
x=2.14879

y=3.08182



Figure 1

ash - Wine Class 3

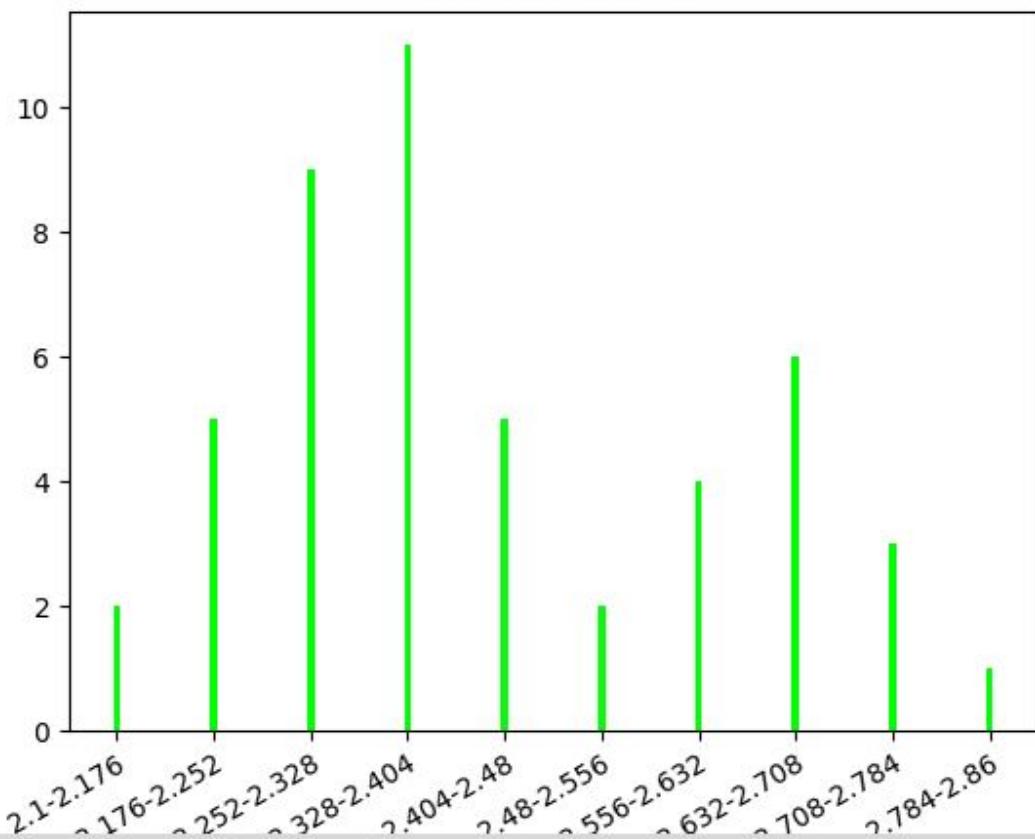


x = y = 13.3068



Figure 1

ash - Wine Class 3

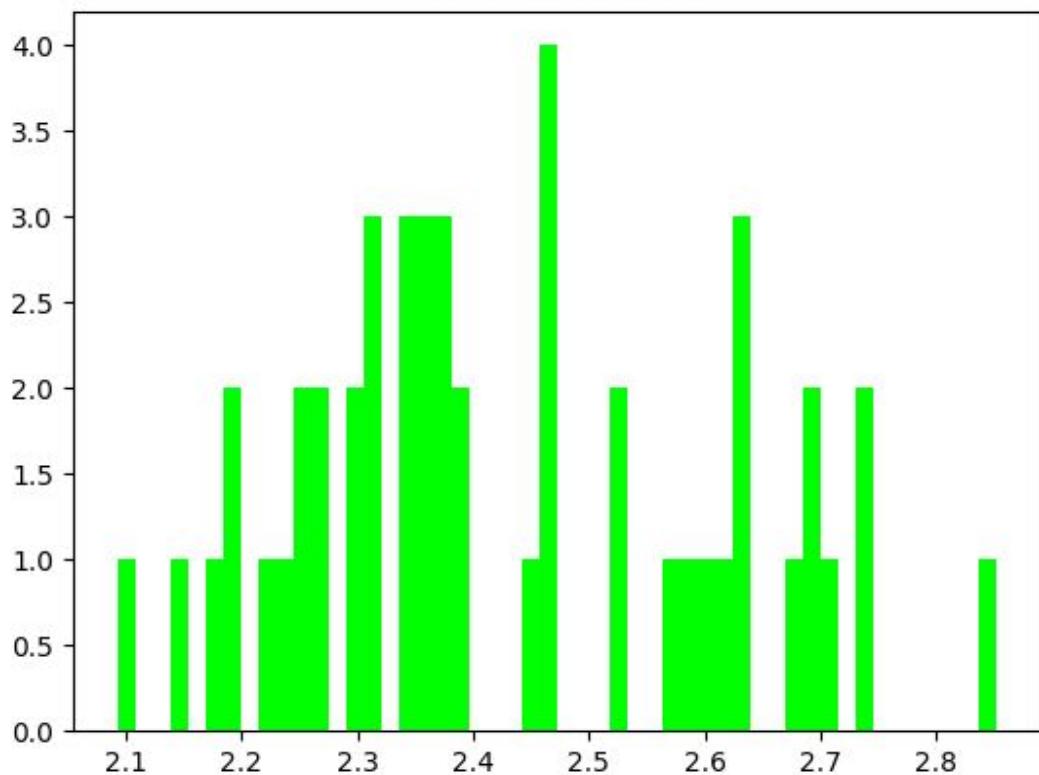


x = y = 8.35



Figure 1

ash - Wine Class 3



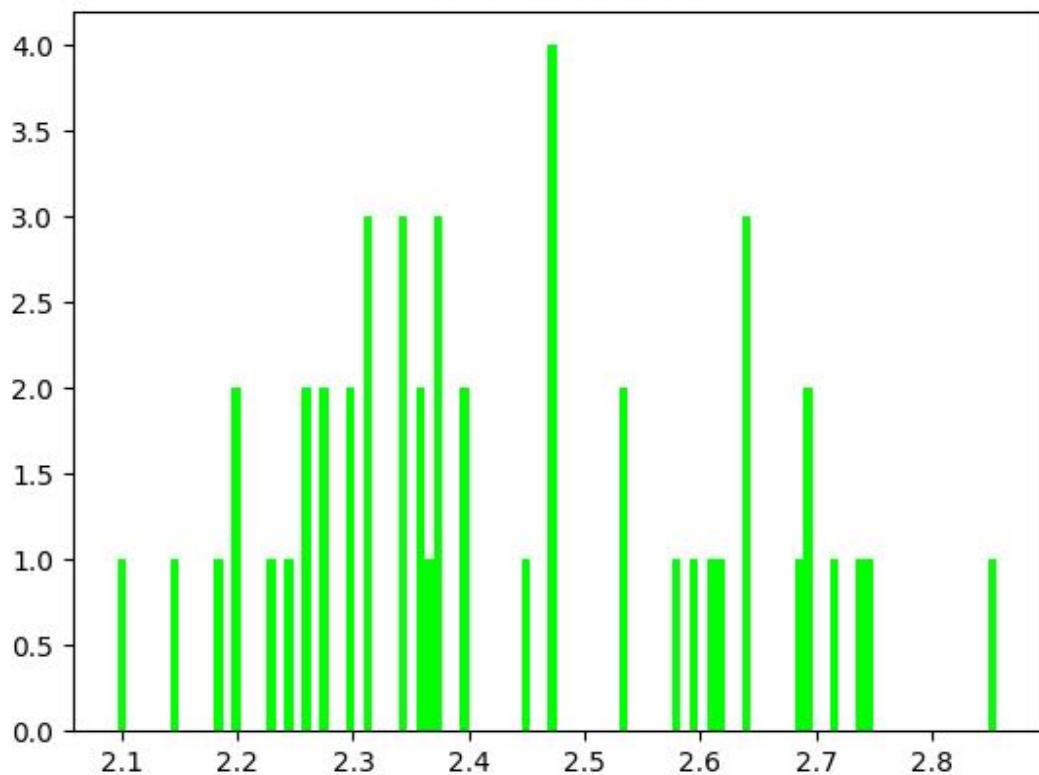
x=2.66455

y=2.84318



Figure 1

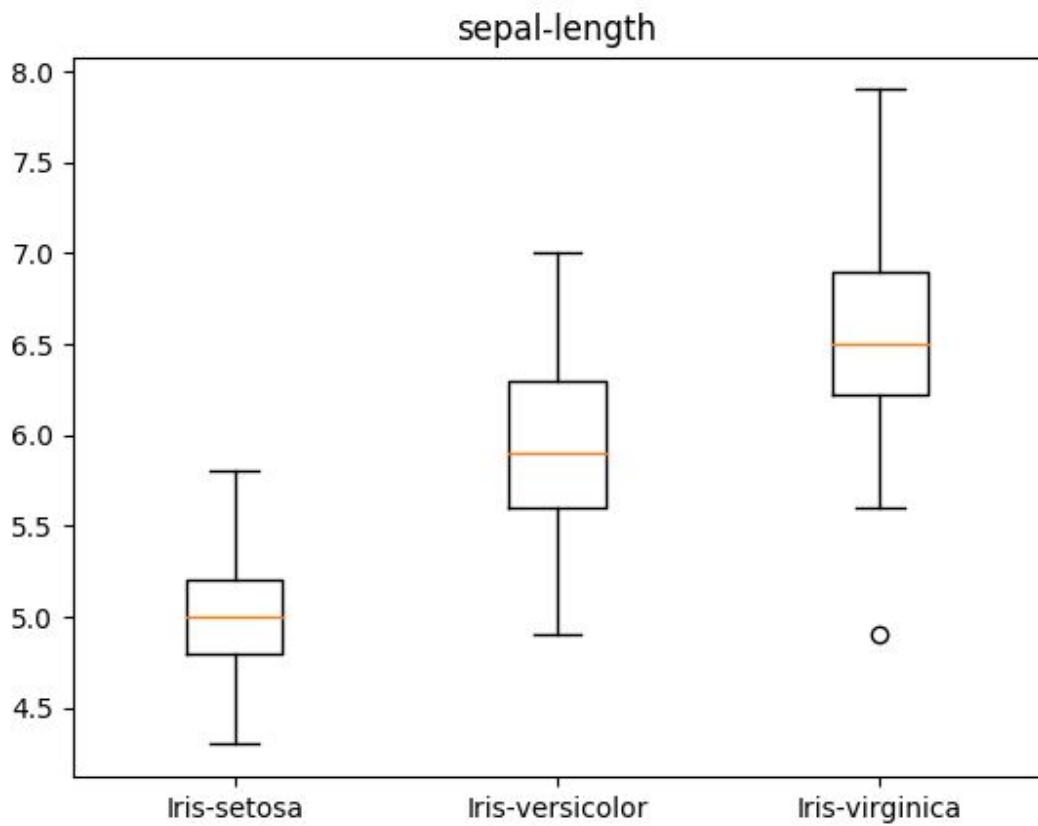
ash - Wine Class 3



x=2.43912 y=3.68409

2.

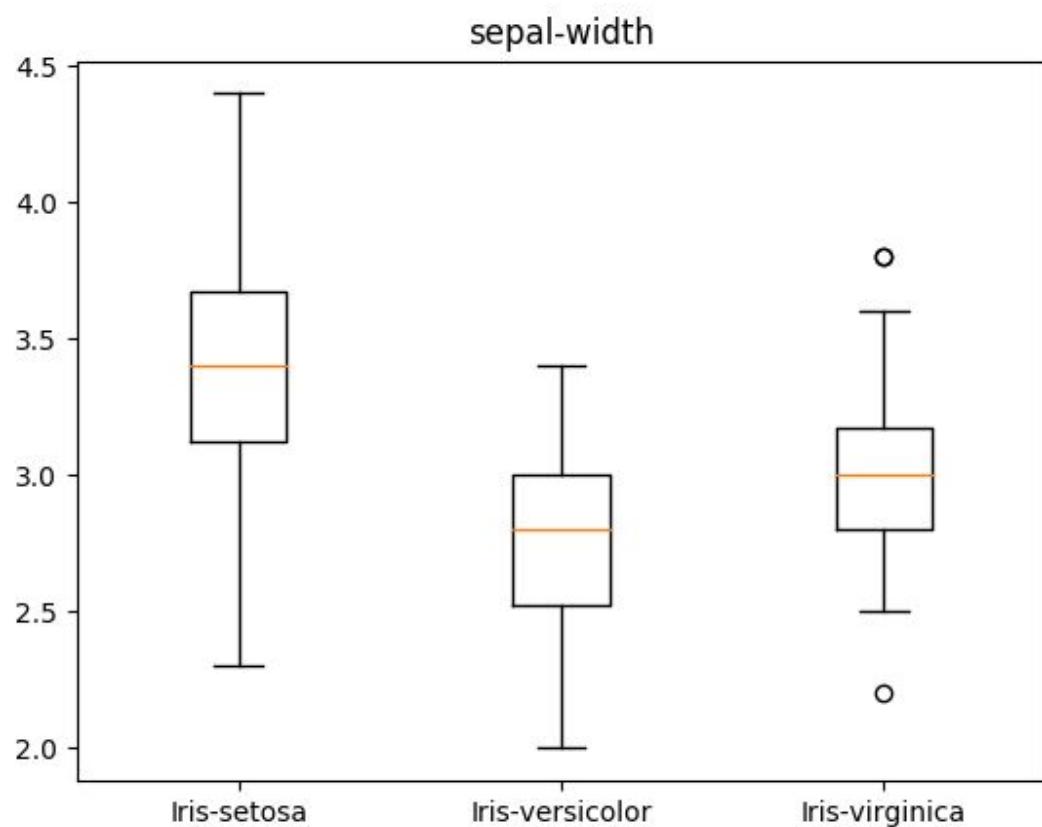
Figure 1



x= y=5.665



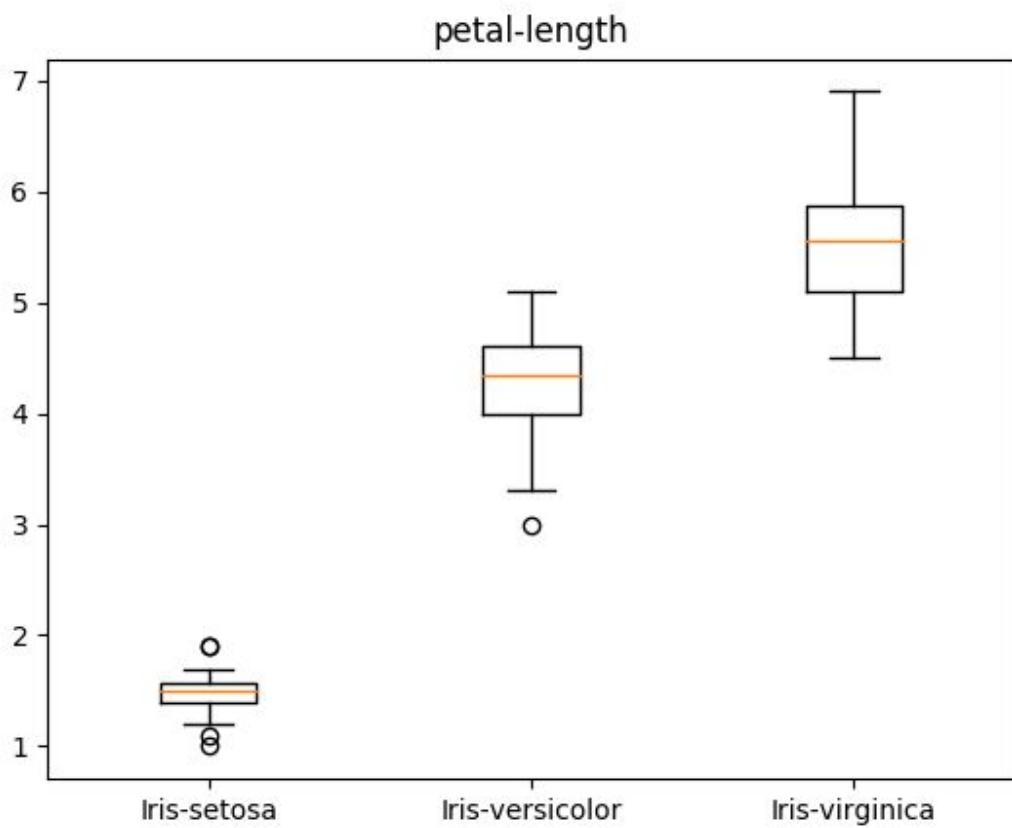
Figure 1



x = y = 3.79571



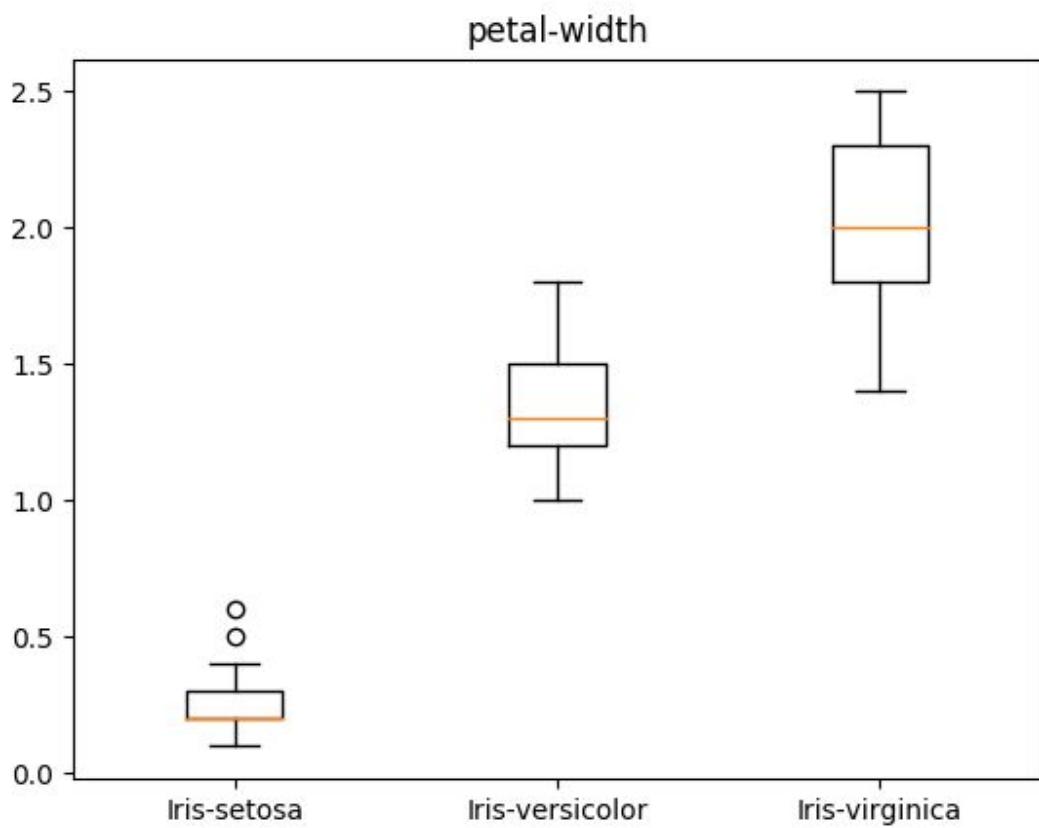
Figure 1



x = y = 6.01149



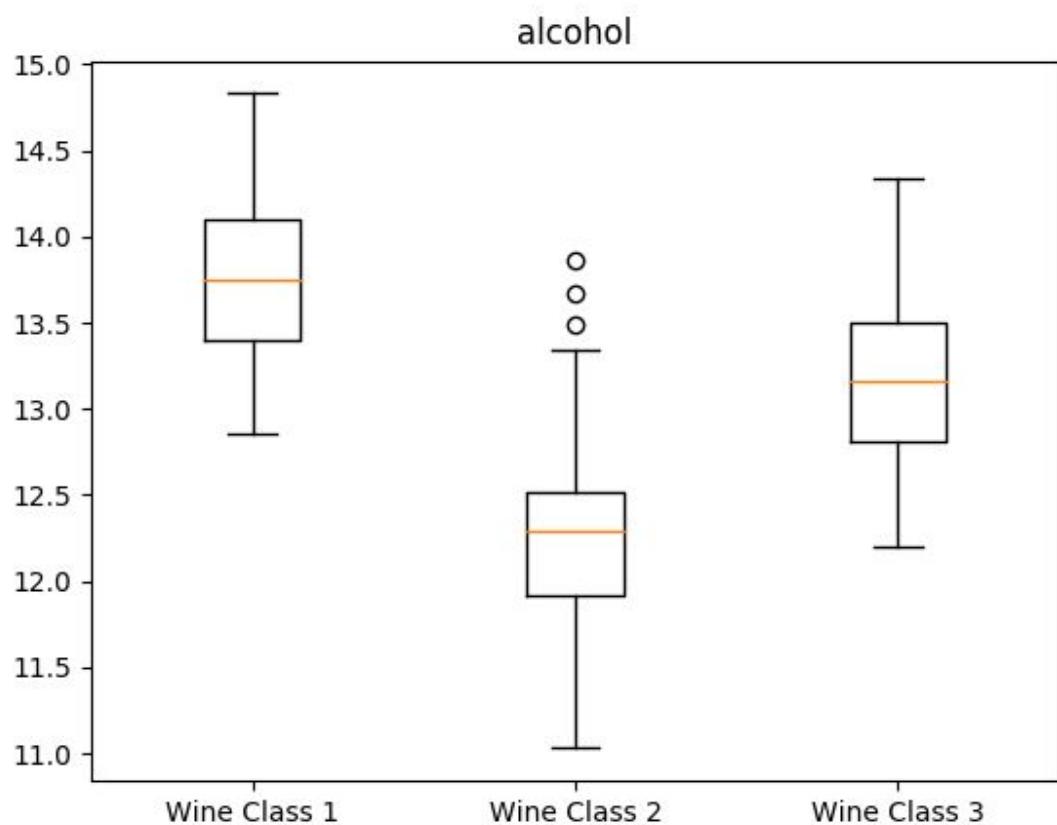
Figure 1



x = y = 1.77429



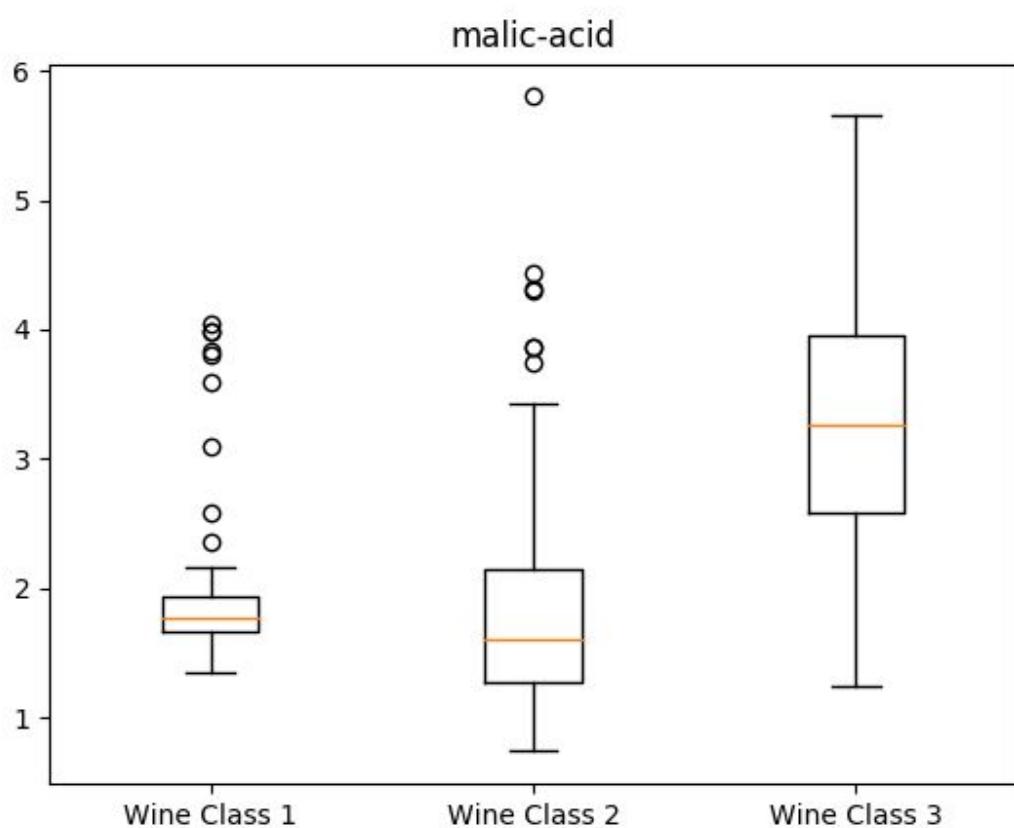
Figure 1



$x = y = 14.0655$



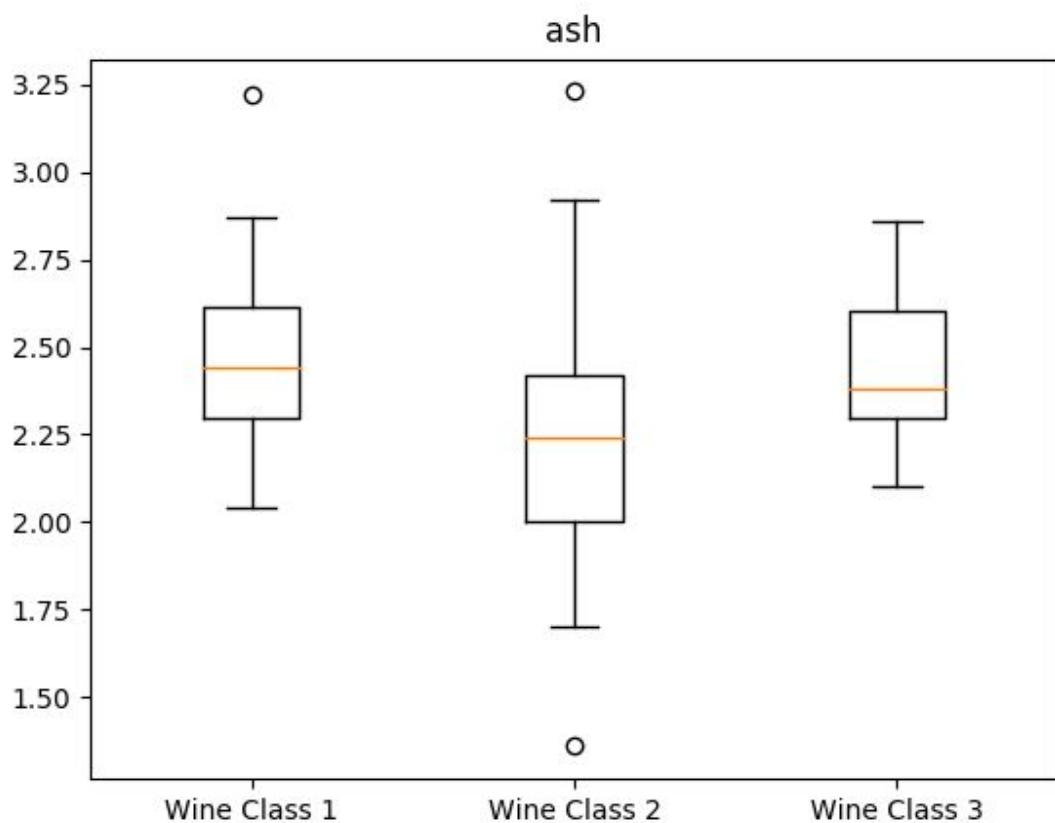
Figure 1



x = y = 5.47471



Figure 1



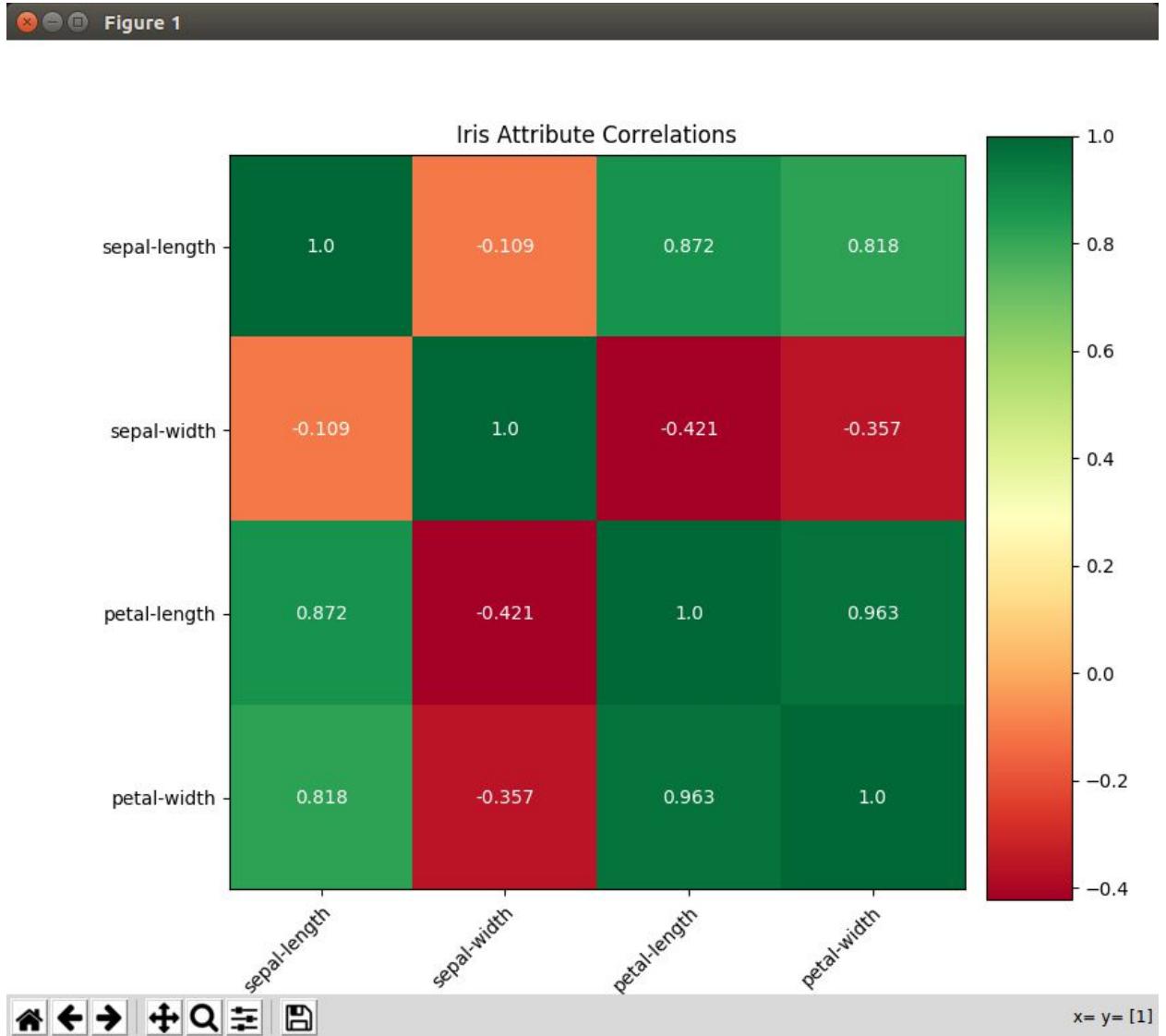
x = y = 2.98178

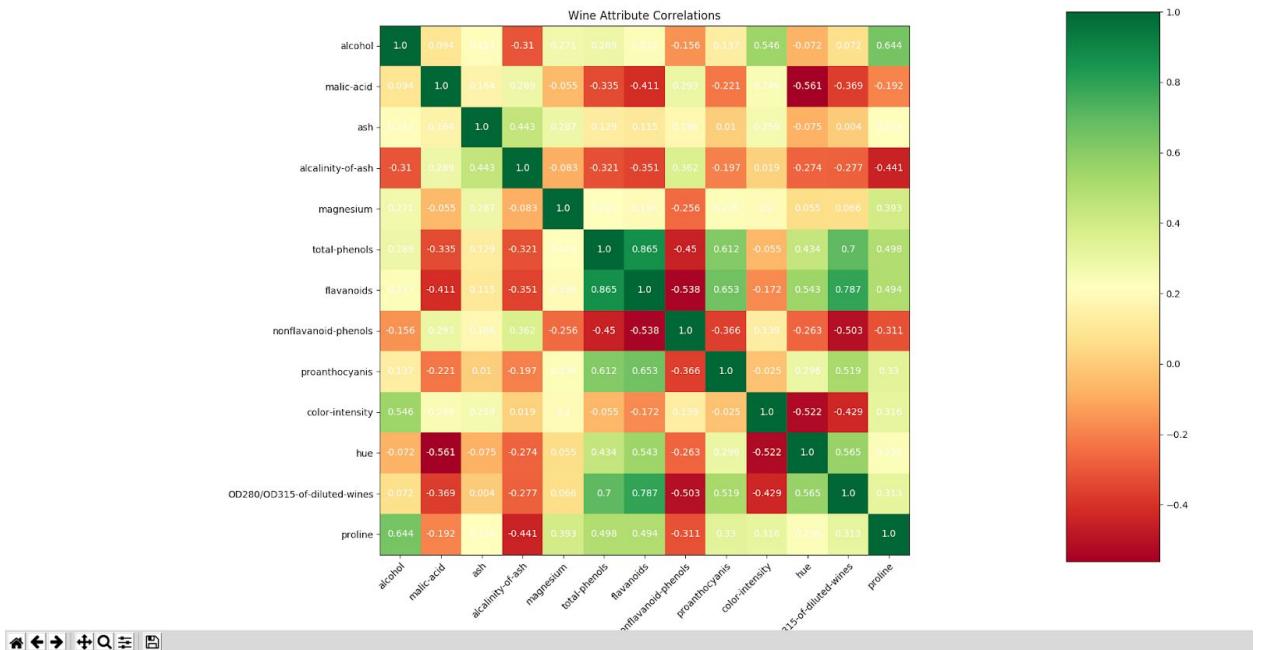
Question 2 Part 1:

- a) Compute the Pearson correlation coefficient between pairs of features by implementing a “correlation(x,y)” function according to the definition.

When trying to understand the Pearson correlation coefficient, I came across a helpful website that I ended up referencing when implementing the function. It was easiest to test the function by breaking up Data Points into sets of attributes and plugging them in as X and Y.

b) Plot the Feature-by-Feature correlation matrix





c) What is the absolute minimum number of calls to the correlation(x,y) function in order to fill in this matrix?

The absolute minimum number of calls needed to a **dataset of size n** would be $n/2(n-1)$. The full matrix by itself would be size n^2 , but for every element in the matrix that makes a comparison between some A and B, there is an identical element on the opposite side of the matrix that compares B and A. This alone halves the number of calls to correlation(x, y). Also, for n features, there are exactly n elements in the matrix in which some feature is compared to itself. This means that there are n less elements to worry about, but since we already split the workload in half, this essentially means that there are only n/2 less **non-trivial** elements to worry about. So the total number of necessary calls would be $(n^2)/2 - (n/2)$, which reduces to the final answer above.

d) Do you observe any correlated features? How can this information be useful?
 Compute the pearson correlation across features and plot the correlogram (i.e., the heatmap of the Feature-by-Feature correlation matrix).

On both pictures above, squares in green represent features that are correlated to a degree. As seen in the Iris correlogram, there is a very strong correlation between petal-length and petal-width. As seen in the wine correlogram, there is a relatively strong correlation between the amount of flavonoids and the amount of total phenols. This information can be useful when making predictions about other data points without knowing all the data, and it can also be useful when categorizing different flowers that may or may not be irises.

Question 2 Part 2:

a) Plot scatterplots for pairs of attributes, and color the points according to their label.

 **Figure 1**

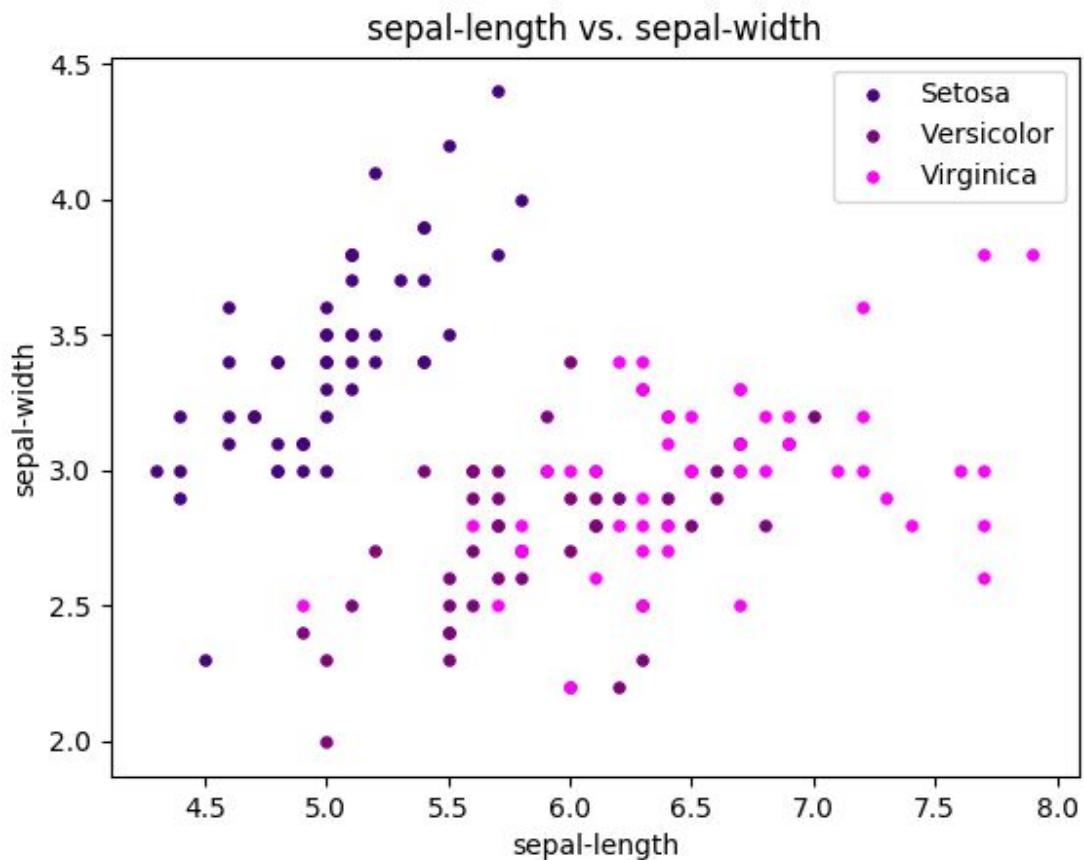




Figure 1

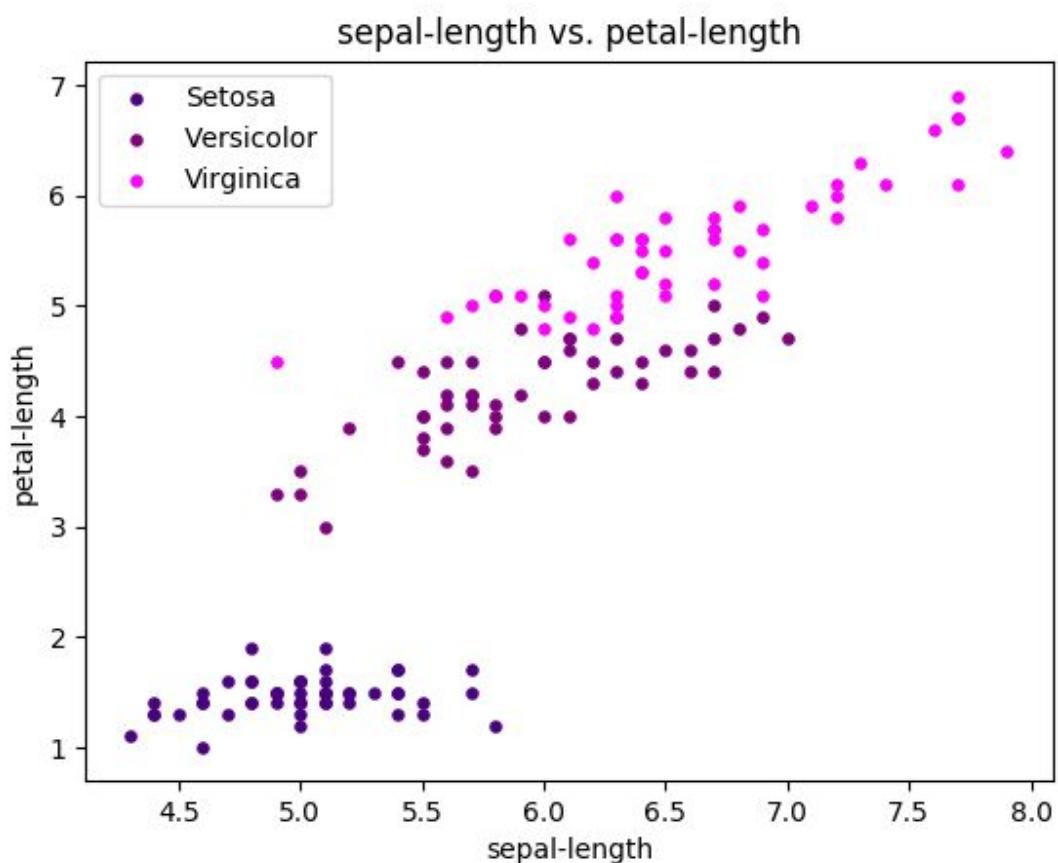




Figure 1

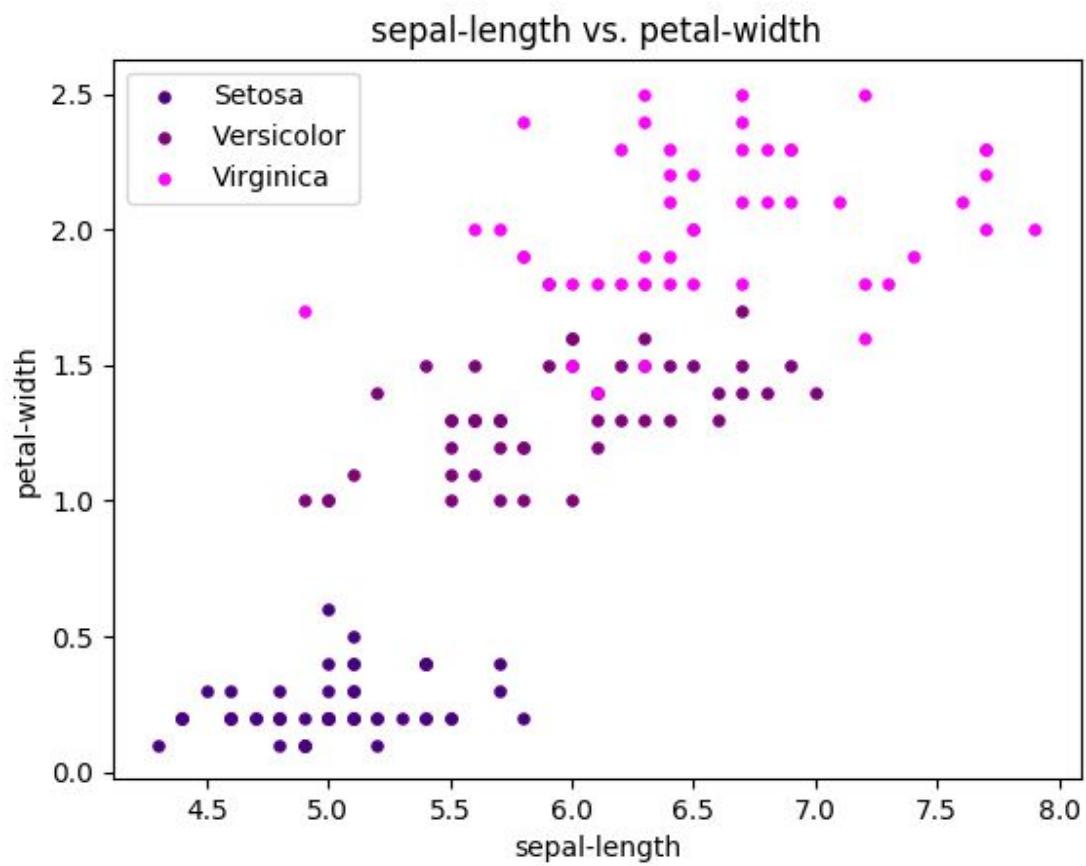




Figure 1

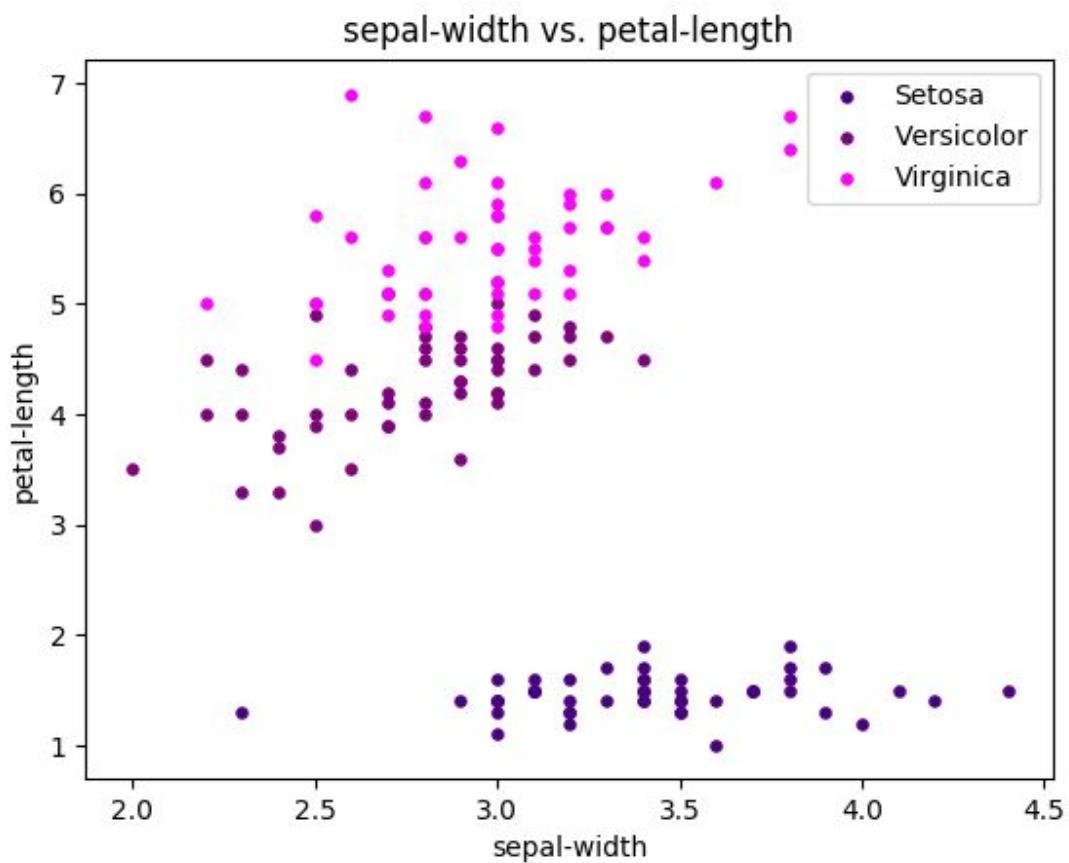




Figure 1

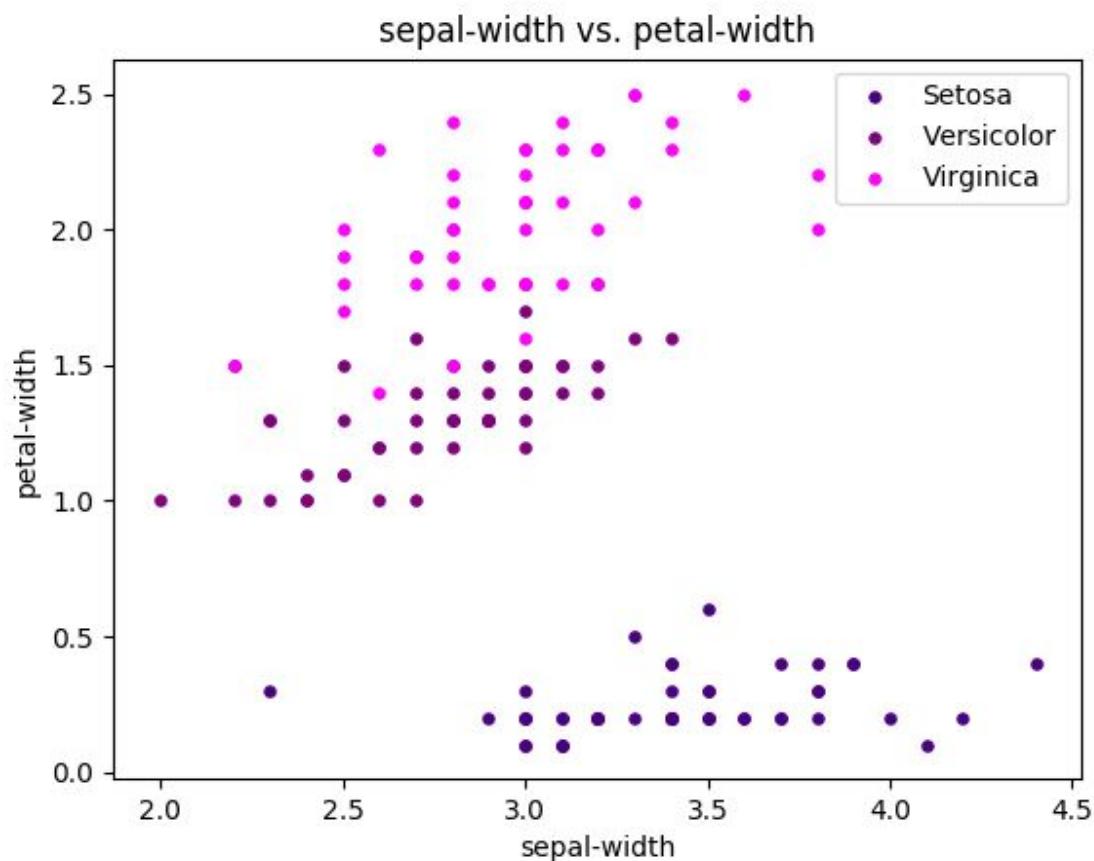
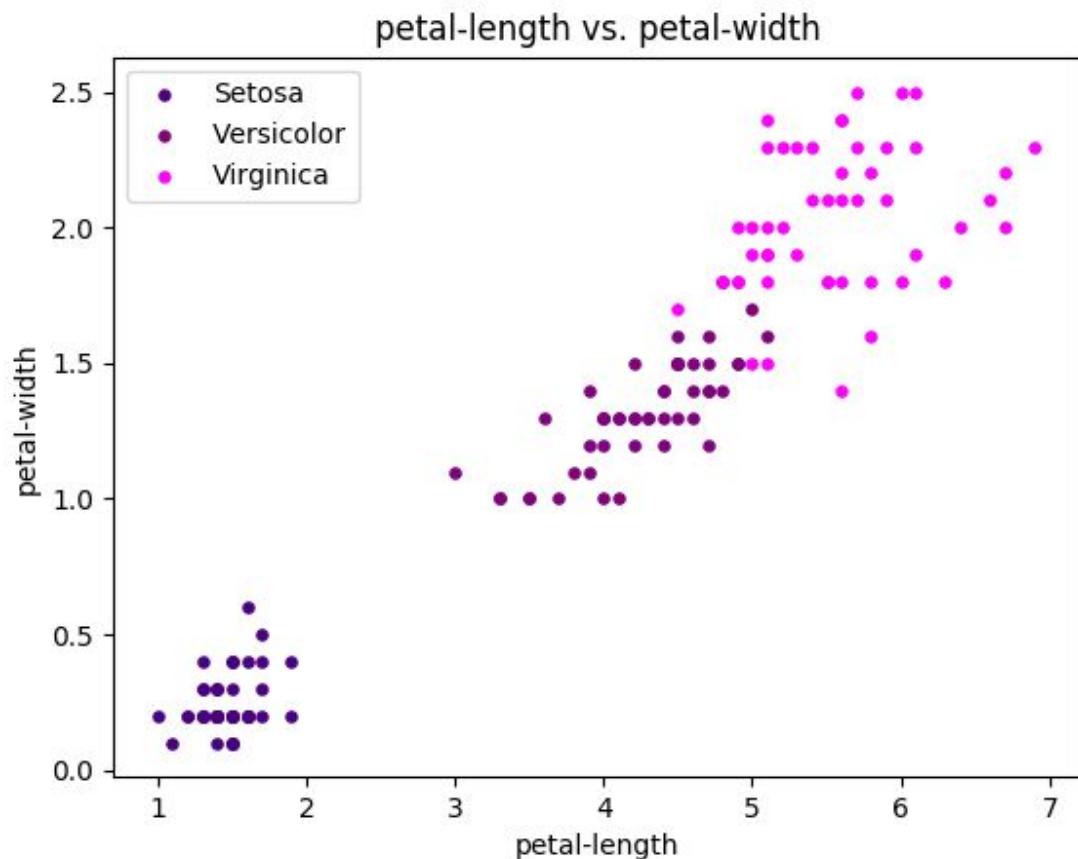




Figure 1



I decided against plotting **trivial** scatterplots such as B vs. A when I already graphed A vs. B, as well as graphing A vs. A.

b) Do you observe any pairs of features being discriminative? By “discriminative” we mean pairs of features that show good separation of the two classes in the 2D space defined by those features.

Most of the graphs above show that most pairs of features are discriminative by some degree, as many objects of the same label are clustered together, especially in the ‘petal-width vs petal-length’ graph.

c) Do you observe any pairs of features being non-disc

Although most graphs are relatively discriminative, the ‘sepal-width vs. sepal-length’ graph isn’t very discriminative between the versicolor and virginica classes, and without the colors, it would be hard to discriminate between them.

Question 2 Part 3:

- a) Implement a distance function “distance(x,y,p)” that computes the L_p norm.
- b) For each dataset compute the distance using p=1 and 2 between all data points and fill in an Data Point x Data Point matrix.

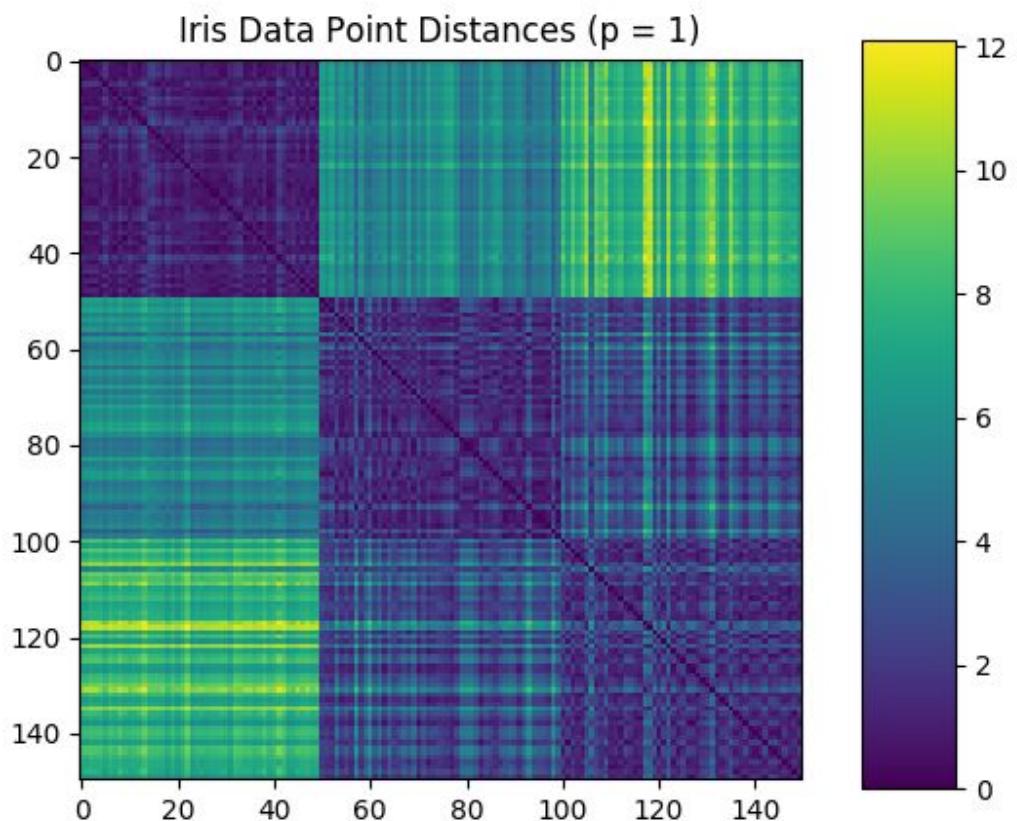
Both a) and b) are implicitly answered in the next few graphs and descriptions.

- c) What is the absolute minimum number of calls to the distance function you need to do to fill in this matrix?

The absolute minimum number of calls needed to a **dataset of size n** would be **n/2(n-1)**. The full matrix by itself would be size n^2 , but for every element in the matrix that makes a comparison between some A and B, there is an identical element on the opposite side of the matrix that compares B and A. This alone halves the number of calls to $\text{distance}(x, y, p)$. Also, for n features, there are exactly n elements in the matrix in which some feature is compared to itself. This means that there are n less elements to worry about, but since we already split the workload in half, this essentially means that there are only $n/2$ less **non-trivial** elements to worry about. So the total number of necessary calls would be $(n^2)/2 - (n/2)$, which reduces to the final answer above.

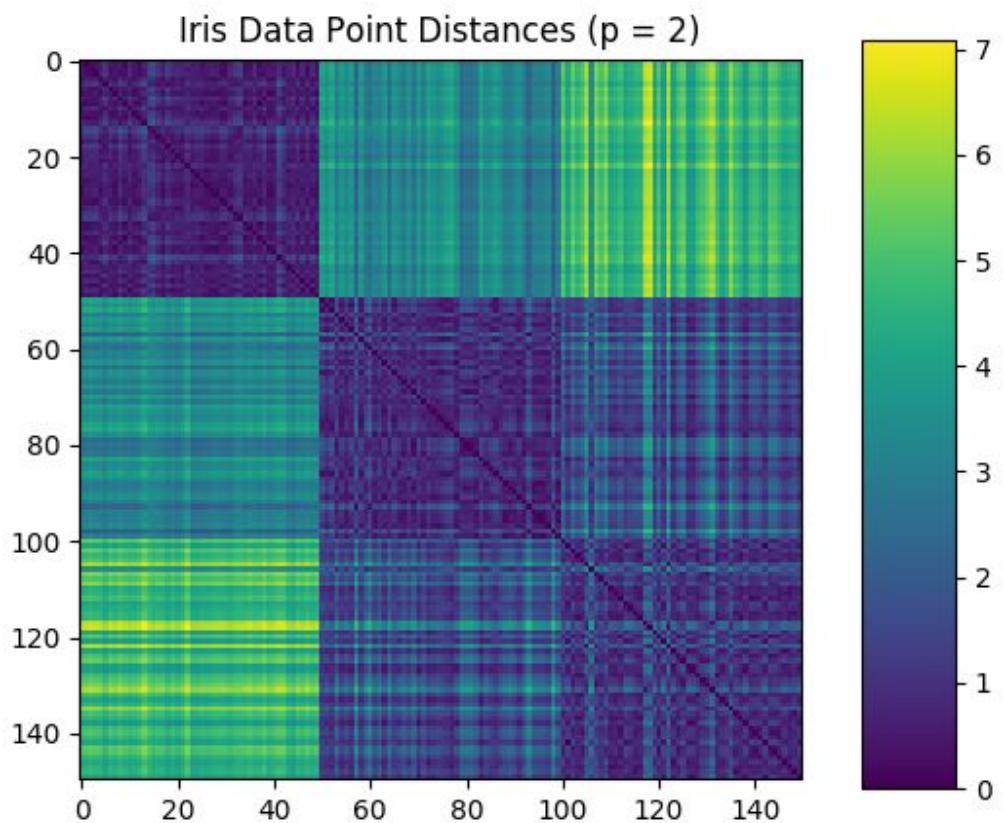
- d) Plot the matrix as a heatmap where the intensity is proportional to the distance

Figure 1



x=95.6039 y=52.4221 [2.3]

Figure 1



x=115.084 y=90.1656 [1.79]

Figure 1

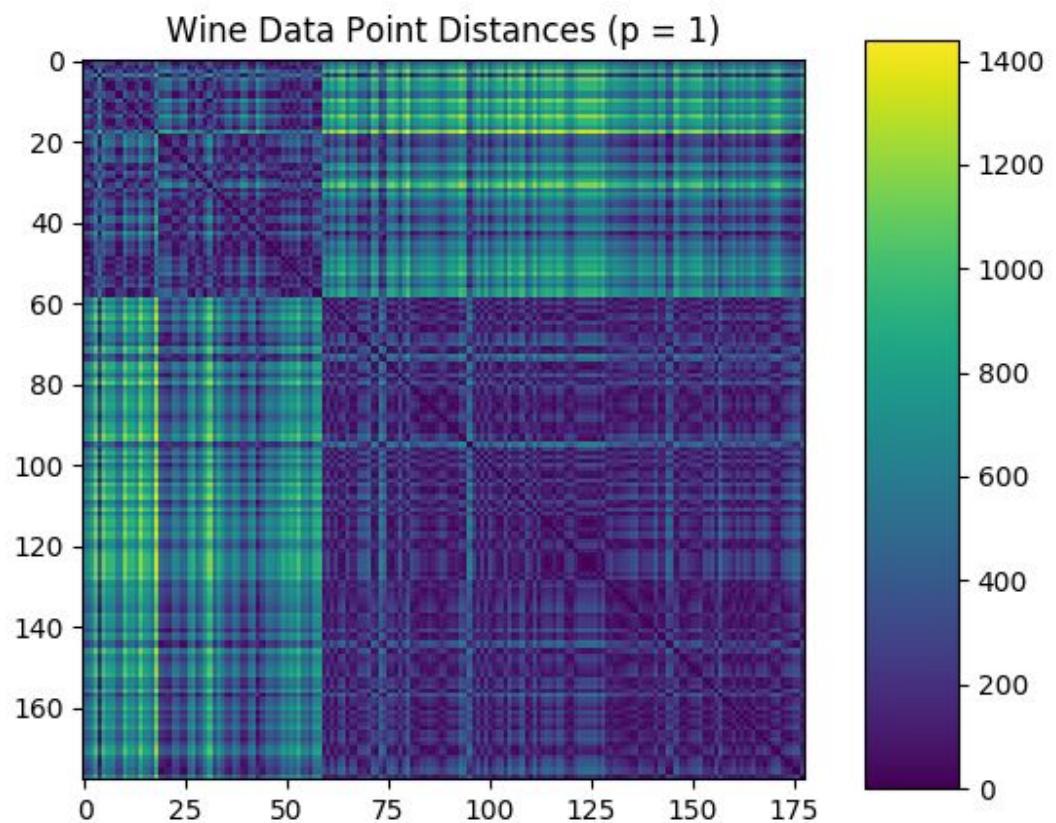
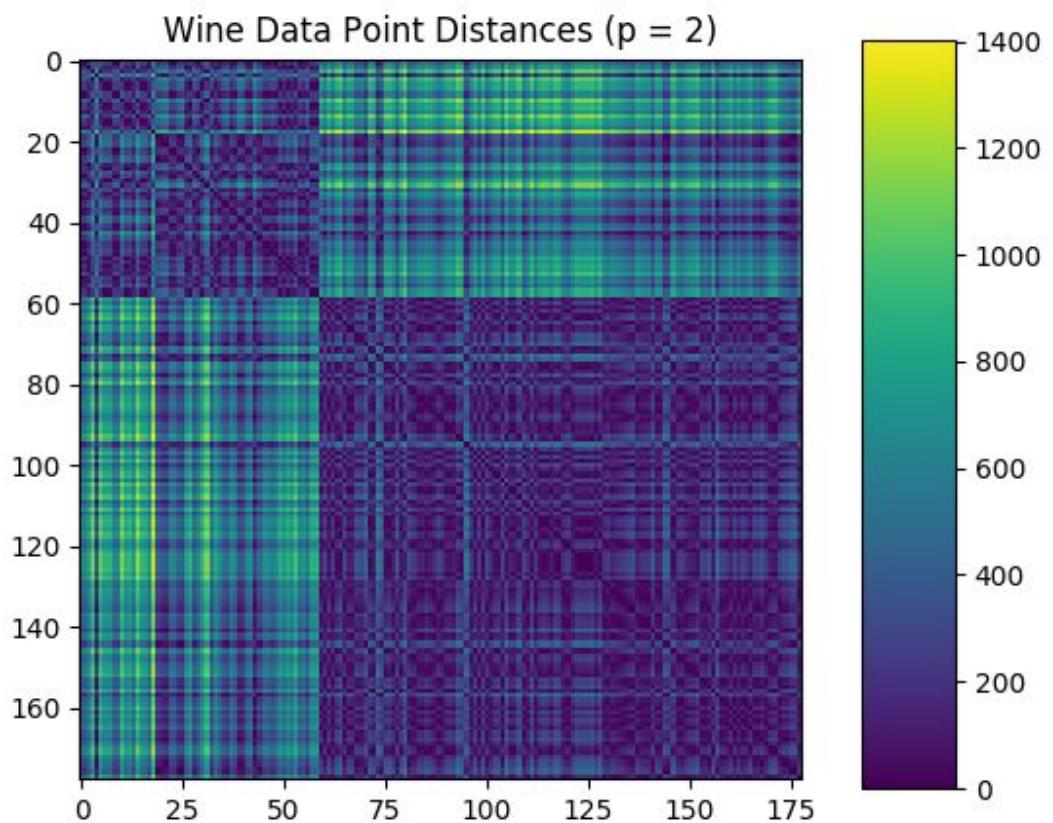


Figure 1



x=72.1255 y=52.1872 [718]

- e) For each data point, find its non-trivial nearest data point (e.g., the point that is not the same point). What is the label of the nearest point? Is it the same? Does the answer change for different values of p ?

For the majority of both irises and wines, the label of the nearest point is the same as the point in question, with a few exceptions. The answers do change noticeably for different values of p .

Irises for p=1


```
posh@posh-GF62-7RE: ~/Desktop/cs171/machine-learning-spr2018$ █
```

Irises for p=2:

Wines for p=1:

```
posh@posh-GF62-7RE: ~/Desktop/cs171/machine-learning-spr2018
Wine 0's (Class: 1) Nearest Wine: Wine 54 (Class: 1)
Wine 1's (Class: 1) Nearest Wine: Wine 8 (Class: 1)
Wine 2's (Class: 1) Nearest Wine: Wine 26 (Class: 1)
Wine 3's (Class: 1) Nearest Wine: Wine 5 (Class: 1)
Wine 4's (Class: 1) Nearest Wine: Wine 68 (Class: 2)
Wine 5's (Class: 1) Nearest Wine: Wine 3 (Class: 1)
Wine 6's (Class: 1) Nearest Wine: Wine 27 (Class: 1)
Wine 7's (Class: 1) Nearest Wine: Wine 16 (Class: 1)
Wine 8's (Class: 1) Nearest Wine: Wine 9 (Class: 1)
Wine 9's (Class: 1) Nearest Wine: Wine 8 (Class: 1)
Wine 10's (Class: 1) Nearest Wine: Wine 31 (Class: 1)
Wine 11's (Class: 1) Nearest Wine: Wine 27 (Class: 1)
Wine 12's (Class: 1) Nearest Wine: Wine 15 (Class: 1)
Wine 13's (Class: 1) Nearest Wine: Wine 50 (Class: 1)
Wine 14's (Class: 1) Nearest Wine: Wine 31 (Class: 1)
Wine 15's (Class: 1) Nearest Wine: Wine 7 (Class: 1)
Wine 16's (Class: 1) Nearest Wine: Wine 7 (Class: 1)
Wine 17's (Class: 1) Nearest Wine: Wine 55 (Class: 1)
Wine 18's (Class: 1) Nearest Wine: Wine 14 (Class: 1)
Wine 19's (Class: 1) Nearest Wine: Wine 176 (Class: 3)
Wine 20's (Class: 1) Nearest Wine: Wine 40 (Class: 1)
Wine 21's (Class: 1) Nearest Wine: Wine 141 (Class: 3)
Wine 22's (Class: 1) Nearest Wine: Wine 29 (Class: 1)
Wine 23's (Class: 1) Nearest Wine: Wine 38 (Class: 1)
Wine 24's (Class: 1) Nearest Wine: Wine 19 (Class: 1)
Wine 25's (Class: 1) Nearest Wine: Wine 175 (Class: 3)
Wine 26's (Class: 1) Nearest Wine: Wine 2 (Class: 1)
Wine 27's (Class: 1) Nearest Wine: Wine 11 (Class: 1)
Wine 28's (Class: 1) Nearest Wine: Wine 35 (Class: 1)
Wine 29's (Class: 1) Nearest Wine: Wine 22 (Class: 1)
Wine 30's (Class: 1) Nearest Wine: Wine 58 (Class: 1)
Wine 31's (Class: 1) Nearest Wine: Wine 10 (Class: 1)
Wine 32's (Class: 1) Nearest Wine: Wine 47 (Class: 1)
Wine 33's (Class: 1) Nearest Wine: Wine 49 (Class: 1)
Wine 34's (Class: 1) Nearest Wine: Wine 42 (Class: 1)
Wine 35's (Class: 1) Nearest Wine: Wine 28 (Class: 1)
Wine 36's (Class: 1) Nearest Wine: Wine 44 (Class: 1)
Wine 37's (Class: 1) Nearest Wine: Wine 42 (Class: 1)
Wine 38's (Class: 1) Nearest Wine: Wine 23 (Class: 1)
Wine 39's (Class: 1) Nearest Wine: Wine 20 (Class: 1)
Wine 40's (Class: 1) Nearest Wine: Wine 20 (Class: 1)
Wine 41's (Class: 1) Nearest Wine: Wine 29 (Class: 1)
Wine 42's (Class: 1) Nearest Wine: Wine 34 (Class: 1)
Wine 43's (Class: 1) Nearest Wine: Wine 65 (Class: 2)
Wine 44's (Class: 1) Nearest Wine: Wine 36 (Class: 1)
Wine 45's (Class: 1) Nearest Wine: Wine 34 (Class: 1)
Wine 46's (Class: 1) Nearest Wine: Wine 48 (Class: 1)
Wine 47's (Class: 1) Nearest Wine: Wine 32 (Class: 1)
Wine 48's (Class: 1) Nearest Wine: Wine 46 (Class: 1)
Wine 49's (Class: 1) Nearest Wine: Wine 57 (Class: 1)
Wine 50's (Class: 1) Nearest Wine: Wine 13 (Class: 1)
Wine 51's (Class: 1) Nearest Wine: Wine 57 (Class: 1)
Wine 52's (Class: 1) Nearest Wine: Wine 2 (Class: 1)
Wine 53's (Class: 1) Nearest Wine: Wine 15 (Class: 1)
Wine 54's (Class: 1) Nearest Wine: Wine 0 (Class: 1)
Wine 55's (Class: 1) Nearest Wine: Wine 17 (Class: 1)
Wine 56's (Class: 1) Nearest Wine: Wine 47 (Class: 1)
Wine 57's (Class: 1) Nearest Wine: Wine 51 (Class: 1)
Wine 58's (Class: 1) Nearest Wine: Wine 30 (Class: 1)
Wine 59's (Class: 2) Nearest Wine: Wine 84 (Class: 2)
```

```
posh@posh-GF62-7RE: ~/Desktop/cs171/machine-learning-spr2018
Wine 60's (Class: 2) Nearest Wine: Wine 65 (Class: 2)
Wine 61's (Class: 2) Nearest Wine: Wine 85 (Class: 2)
Wine 62's (Class: 2) Nearest Wine: Wine 120 (Class: 2)
Wine 63's (Class: 2) Nearest Wine: Wine 103 (Class: 2)
Wine 64's (Class: 2) Nearest Wine: Wine 117 (Class: 2)
Wine 65's (Class: 2) Nearest Wine: Wine 109 (Class: 2)
Wine 66's (Class: 2) Nearest Wine: Wine 67 (Class: 2)
Wine 67's (Class: 2) Nearest Wine: Wine 106 (Class: 2)
Wine 68's (Class: 2) Nearest Wine: Wine 168 (Class: 3)
Wine 69's (Class: 2) Nearest Wine: Wine 78 (Class: 2)
Wine 70's (Class: 2) Nearest Wine: Wine 74 (Class: 2)
Wine 71's (Class: 2) Nearest Wine: Wine 115 (Class: 2)
Wine 72's (Class: 2) Nearest Wine: Wine 171 (Class: 3)
Wine 73's (Class: 2) Nearest Wine: Wine 56 (Class: 1)
Wine 74's (Class: 2) Nearest Wine: Wine 44 (Class: 1)
Wine 75's (Class: 2) Nearest Wine: Wine 97 (Class: 2)
Wine 76's (Class: 2) Nearest Wine: Wine 114 (Class: 2)
Wine 77's (Class: 2) Nearest Wine: Wine 150 (Class: 3)
Wine 78's (Class: 2) Nearest Wine: Wine 39 (Class: 1)
Wine 79's (Class: 2) Nearest Wine: Wine 127 (Class: 2)
Wine 80's (Class: 2) Nearest Wine: Wine 93 (Class: 2)
Wine 81's (Class: 2) Nearest Wine: Wine 100 (Class: 2)
Wine 82's (Class: 2) Nearest Wine: Wine 89 (Class: 2)
Wine 83's (Class: 2) Nearest Wine: Wine 165 (Class: 3)
Wine 84's (Class: 2) Nearest Wine: Wine 142 (Class: 3)
Wine 85's (Class: 2) Nearest Wine: Wine 61 (Class: 2)
Wine 86's (Class: 2) Nearest Wine: Wine 116 (Class: 2)
Wine 87's (Class: 2) Nearest Wine: Wine 101 (Class: 2)
Wine 88's (Class: 2) Nearest Wine: Wine 104 (Class: 2)
Wine 89's (Class: 2) Nearest Wine: Wine 82 (Class: 2)
Wine 90's (Class: 2) Nearest Wine: Wine 107 (Class: 2)
Wine 91's (Class: 2) Nearest Wine: Wine 85 (Class: 2)
Wine 92's (Class: 2) Nearest Wine: Wine 116 (Class: 2)
Wine 93's (Class: 2) Nearest Wine: Wine 80 (Class: 2)
Wine 94's (Class: 2) Nearest Wine: Wine 117 (Class: 2)
Wine 95's (Class: 2) Nearest Wine: Wine 28 (Class: 1)
Wine 96's (Class: 2) Nearest Wine: Wine 130 (Class: 3)
Wine 97's (Class: 2) Nearest Wine: Wine 63 (Class: 2)
Wine 98's (Class: 2) Nearest Wine: Wine 172 (Class: 3)
Wine 99's (Class: 2) Nearest Wine: Wine 115 (Class: 2)
Wine 100's (Class: 2) Nearest Wine: Wine 81 (Class: 2)
Wine 101's (Class: 2) Nearest Wine: Wine 119 (Class: 2)
Wine 102's (Class: 2) Nearest Wine: Wine 113 (Class: 2)
Wine 103's (Class: 2) Nearest Wine: Wine 63 (Class: 2)
Wine 104's (Class: 2) Nearest Wine: Wine 88 (Class: 2)
Wine 105's (Class: 2) Nearest Wine: Wine 108 (Class: 2)
Wine 106's (Class: 2) Nearest Wine: Wine 67 (Class: 2)
Wine 107's (Class: 2) Nearest Wine: Wine 92 (Class: 2)
Wine 108's (Class: 2) Nearest Wine: Wine 105 (Class: 2)
Wine 109's (Class: 2) Nearest Wine: Wine 65 (Class: 2)
Wine 110's (Class: 2) Nearest Wine: Wine 162 (Class: 3)
Wine 111's (Class: 2) Nearest Wine: Wine 105 (Class: 2)
Wine 112's (Class: 2) Nearest Wine: Wine 133 (Class: 3)
Wine 113's (Class: 2) Nearest Wine: Wine 97 (Class: 2)
Wine 114's (Class: 2) Nearest Wine: Wine 125 (Class: 2)
Wine 115's (Class: 2) Nearest Wine: Wine 99 (Class: 2)
Wine 116's (Class: 2) Nearest Wine: Wine 86 (Class: 2)
Wine 117's (Class: 2) Nearest Wine: Wine 94 (Class: 2)
Wine 118's (Class: 2) Nearest Wine: Wine 125 (Class: 2)
Wine 119's (Class: 2) Nearest Wine: Wine 101 (Class: 2)
```

```
posh@posh-GF62-7RE: ~/Desktop/cs171/machine-learning-spr2018
Wine 119's (Class: 2) Nearest Wine: Wine 101 (Class: 2)
Wine 120's (Class: 2) Nearest Wine: Wine 62 (Class: 2)
Wine 121's (Class: 2) Nearest Wine: Wine 79 (Class: 2)
Wine 122's (Class: 2) Nearest Wine: Wine 64 (Class: 2)
Wine 123's (Class: 2) Nearest Wine: Wine 125 (Class: 2)
Wine 124's (Class: 2) Nearest Wine: Wine 123 (Class: 2)
Wine 125's (Class: 2) Nearest Wine: Wine 123 (Class: 2)
Wine 126's (Class: 2) Nearest Wine: Wine 128 (Class: 2)
Wine 127's (Class: 2) Nearest Wine: Wine 72 (Class: 2)
Wine 128's (Class: 2) Nearest Wine: Wine 126 (Class: 2)
Wine 129's (Class: 2) Nearest Wine: Wine 138 (Class: 3)
Wine 130's (Class: 3) Nearest Wine: Wine 96 (Class: 2)
Wine 131's (Class: 3) Nearest Wine: Wine 142 (Class: 3)
Wine 132's (Class: 3) Nearest Wine: Wine 177 (Class: 3)
Wine 133's (Class: 3) Nearest Wine: Wine 140 (Class: 3)
Wine 134's (Class: 3) Nearest Wine: Wine 148 (Class: 3)
Wine 135's (Class: 3) Nearest Wine: Wine 167 (Class: 3)
Wine 136's (Class: 3) Nearest Wine: Wine 155 (Class: 3)
Wine 137's (Class: 3) Nearest Wine: Wine 142 (Class: 3)
Wine 138's (Class: 3) Nearest Wine: Wine 129 (Class: 2)
Wine 139's (Class: 3) Nearest Wine: Wine 140 (Class: 3)
Wine 140's (Class: 3) Nearest Wine: Wine 133 (Class: 3)
Wine 141's (Class: 3) Nearest Wine: Wine 21 (Class: 1)
Wine 142's (Class: 3) Nearest Wine: Wine 137 (Class: 3)
Wine 143's (Class: 3) Nearest Wine: Wine 177 (Class: 3)
Wine 144's (Class: 3) Nearest Wine: Wine 19 (Class: 1)
Wine 145's (Class: 3) Nearest Wine: Wine 24 (Class: 1)
Wine 146's (Class: 3) Nearest Wine: Wine 103 (Class: 2)
Wine 147's (Class: 3) Nearest Wine: Wine 159 (Class: 3)
Wine 148's (Class: 3) Nearest Wine: Wine 172 (Class: 3)
Wine 149's (Class: 3) Nearest Wine: Wine 143 (Class: 3)
Wine 150's (Class: 3) Nearest Wine: Wine 77 (Class: 2)
Wine 151's (Class: 3) Nearest Wine: Wine 156 (Class: 3)
Wine 152's (Class: 3) Nearest Wine: Wine 75 (Class: 2)
Wine 153's (Class: 3) Nearest Wine: Wine 163 (Class: 3)
Wine 154's (Class: 3) Nearest Wine: Wine 148 (Class: 3)
Wine 155's (Class: 3) Nearest Wine: Wine 136 (Class: 3)
Wine 156's (Class: 3) Nearest Wine: Wine 171 (Class: 3)
Wine 157's (Class: 3) Nearest Wine: Wine 74 (Class: 2)
Wine 158's (Class: 3) Nearest Wine: Wine 172 (Class: 3)
Wine 159's (Class: 3) Nearest Wine: Wine 164 (Class: 3)
Wine 160's (Class: 3) Nearest Wine: Wine 165 (Class: 3)
Wine 161's (Class: 3) Nearest Wine: Wine 163 (Class: 3)
Wine 162's (Class: 3) Nearest Wine: Wine 132 (Class: 3)
Wine 163's (Class: 3) Nearest Wine: Wine 161 (Class: 3)
Wine 164's (Class: 3) Nearest Wine: Wine 159 (Class: 3)
Wine 165's (Class: 3) Nearest Wine: Wine 160 (Class: 3)
Wine 166's (Class: 3) Nearest Wine: Wine 135 (Class: 3)
Wine 167's (Class: 3) Nearest Wine: Wine 135 (Class: 3)
Wine 168's (Class: 3) Nearest Wine: Wine 174 (Class: 3)
Wine 169's (Class: 3) Nearest Wine: Wine 130 (Class: 3)
Wine 170's (Class: 3) Nearest Wine: Wine 137 (Class: 3)
Wine 171's (Class: 3) Nearest Wine: Wine 156 (Class: 3)
Wine 172's (Class: 3) Nearest Wine: Wine 148 (Class: 3)
Wine 173's (Class: 3) Nearest Wine: Wine 155 (Class: 3)
Wine 174's (Class: 3) Nearest Wine: Wine 168 (Class: 3)
Wine 175's (Class: 3) Nearest Wine: Wine 176 (Class: 3)
Wine 176's (Class: 3) Nearest Wine: Wine 175 (Class: 3)
Wine 177's (Class: 3) Nearest Wine: Wine 132 (Class: 3)
```

```
posh@posh-GF62-7RE:~/Desktop/cs171/machine-learning-spr2018$ █
```

Wines for p=2:

```
posh@posh-GF62-7RE: ~/Desktop/cs171/machine-learning-spr2018
Wine 0's (Class: 1) Nearest Wine: Wine 54 (Class: 1)
Wine 1's (Class: 1) Nearest Wine: Wine 8 (Class: 1)
Wine 2's (Class: 1) Nearest Wine: Wine 52 (Class: 1)
Wine 3's (Class: 1) Nearest Wine: Wine 5 (Class: 1)
Wine 4's (Class: 1) Nearest Wine: Wine 68 (Class: 2)
Wine 5's (Class: 1) Nearest Wine: Wine 3 (Class: 1)
Wine 6's (Class: 1) Nearest Wine: Wine 27 (Class: 1)
Wine 7's (Class: 1) Nearest Wine: Wine 16 (Class: 1)
Wine 8's (Class: 1) Nearest Wine: Wine 9 (Class: 1)
Wine 9's (Class: 1) Nearest Wine: Wine 8 (Class: 1)
Wine 10's (Class: 1) Nearest Wine: Wine 31 (Class: 1)
Wine 11's (Class: 1) Nearest Wine: Wine 27 (Class: 1)
Wine 12's (Class: 1) Nearest Wine: Wine 15 (Class: 1)
Wine 13's (Class: 1) Nearest Wine: Wine 50 (Class: 1)
Wine 14's (Class: 1) Nearest Wine: Wine 31 (Class: 1)
Wine 15's (Class: 1) Nearest Wine: Wine 7 (Class: 1)
Wine 16's (Class: 1) Nearest Wine: Wine 58 (Class: 1)
Wine 17's (Class: 1) Nearest Wine: Wine 55 (Class: 1)
Wine 18's (Class: 1) Nearest Wine: Wine 14 (Class: 1)
Wine 19's (Class: 1) Nearest Wine: Wine 176 (Class: 3)
Wine 20's (Class: 1) Nearest Wine: Wine 40 (Class: 1)
Wine 21's (Class: 1) Nearest Wine: Wine 141 (Class: 3)
Wine 22's (Class: 1) Nearest Wine: Wine 29 (Class: 1)
Wine 23's (Class: 1) Nearest Wine: Wine 38 (Class: 1)
Wine 24's (Class: 1) Nearest Wine: Wine 145 (Class: 3)
Wine 25's (Class: 1) Nearest Wine: Wine 175 (Class: 3)
Wine 26's (Class: 1) Nearest Wine: Wine 2 (Class: 1)
Wine 27's (Class: 1) Nearest Wine: Wine 11 (Class: 1)
Wine 28's (Class: 1) Nearest Wine: Wine 35 (Class: 1)
Wine 29's (Class: 1) Nearest Wine: Wine 22 (Class: 1)
Wine 30's (Class: 1) Nearest Wine: Wine 58 (Class: 1)
Wine 31's (Class: 1) Nearest Wine: Wine 10 (Class: 1)
Wine 32's (Class: 1) Nearest Wine: Wine 47 (Class: 1)
Wine 33's (Class: 1) Nearest Wine: Wine 49 (Class: 1)
Wine 34's (Class: 1) Nearest Wine: Wine 42 (Class: 1)
Wine 35's (Class: 1) Nearest Wine: Wine 28 (Class: 1)
Wine 36's (Class: 1) Nearest Wine: Wine 44 (Class: 1)
Wine 37's (Class: 1) Nearest Wine: Wine 42 (Class: 1)
Wine 38's (Class: 1) Nearest Wine: Wine 23 (Class: 1)
Wine 39's (Class: 1) Nearest Wine: Wine 78 (Class: 2)
Wine 40's (Class: 1) Nearest Wine: Wine 20 (Class: 1)
Wine 41's (Class: 1) Nearest Wine: Wine 29 (Class: 1)
Wine 42's (Class: 1) Nearest Wine: Wine 34 (Class: 1)
Wine 43's (Class: 1) Nearest Wine: Wine 60 (Class: 2)
Wine 44's (Class: 1) Nearest Wine: Wine 36 (Class: 1)
Wine 45's (Class: 1) Nearest Wine: Wine 34 (Class: 1)
Wine 46's (Class: 1) Nearest Wine: Wine 48 (Class: 1)
Wine 47's (Class: 1) Nearest Wine: Wine 32 (Class: 1)
Wine 48's (Class: 1) Nearest Wine: Wine 46 (Class: 1)
Wine 49's (Class: 1) Nearest Wine: Wine 57 (Class: 1)
Wine 50's (Class: 1) Nearest Wine: Wine 13 (Class: 1)
Wine 51's (Class: 1) Nearest Wine: Wine 57 (Class: 1)
Wine 52's (Class: 1) Nearest Wine: Wine 2 (Class: 1)
Wine 53's (Class: 1) Nearest Wine: Wine 12 (Class: 1)
Wine 54's (Class: 1) Nearest Wine: Wine 0 (Class: 1)
Wine 55's (Class: 1) Nearest Wine: Wine 17 (Class: 1)
Wine 56's (Class: 1) Nearest Wine: Wine 47 (Class: 1)
Wine 57's (Class: 1) Nearest Wine: Wine 51 (Class: 1)
Wine 58's (Class: 1) Nearest Wine: Wine 30 (Class: 1)
Wine 59's (Class: 2) Nearest Wine: Wine 84 (Class: 2)
```

```
posh@posh-GF62-7RE: ~/Desktop/cs171/machine-learning-spr2018
Wine 60's (Class: 2) Nearest Wine: Wine 43 (Class: 1)
Wine 61's (Class: 2) Nearest Wine: Wine 85 (Class: 2)
Wine 62's (Class: 2) Nearest Wine: Wine 120 (Class: 2)
Wine 63's (Class: 2) Nearest Wine: Wine 103 (Class: 2)
Wine 64's (Class: 2) Nearest Wine: Wine 117 (Class: 2)
Wine 65's (Class: 2) Nearest Wine: Wine 60 (Class: 2)
Wine 66's (Class: 2) Nearest Wine: Wine 67 (Class: 2)
Wine 67's (Class: 2) Nearest Wine: Wine 106 (Class: 2)
Wine 68's (Class: 2) Nearest Wine: Wine 168 (Class: 3)
Wine 69's (Class: 2) Nearest Wine: Wine 78 (Class: 2)
Wine 70's (Class: 2) Nearest Wine: Wine 36 (Class: 1)
Wine 71's (Class: 2) Nearest Wine: Wine 115 (Class: 2)
Wine 72's (Class: 2) Nearest Wine: Wine 171 (Class: 3)
Wine 73's (Class: 2) Nearest Wine: Wine 56 (Class: 1)
Wine 74's (Class: 2) Nearest Wine: Wine 44 (Class: 1)
Wine 75's (Class: 2) Nearest Wine: Wine 102 (Class: 2)
Wine 76's (Class: 2) Nearest Wine: Wine 114 (Class: 2)
Wine 77's (Class: 2) Nearest Wine: Wine 150 (Class: 3)
Wine 78's (Class: 2) Nearest Wine: Wine 39 (Class: 1)
Wine 79's (Class: 2) Nearest Wine: Wine 127 (Class: 2)
Wine 80's (Class: 2) Nearest Wine: Wine 93 (Class: 2)
Wine 81's (Class: 2) Nearest Wine: Wine 136 (Class: 3)
Wine 82's (Class: 2) Nearest Wine: Wine 89 (Class: 2)
Wine 83's (Class: 2) Nearest Wine: Wine 165 (Class: 3)
Wine 84's (Class: 2) Nearest Wine: Wine 142 (Class: 3)
Wine 85's (Class: 2) Nearest Wine: Wine 61 (Class: 2)
Wine 86's (Class: 2) Nearest Wine: Wine 116 (Class: 2)
Wine 87's (Class: 2) Nearest Wine: Wine 101 (Class: 2)
Wine 88's (Class: 2) Nearest Wine: Wine 104 (Class: 2)
Wine 89's (Class: 2) Nearest Wine: Wine 82 (Class: 2)
Wine 90's (Class: 2) Nearest Wine: Wine 107 (Class: 2)
Wine 91's (Class: 2) Nearest Wine: Wine 85 (Class: 2)
Wine 92's (Class: 2) Nearest Wine: Wine 116 (Class: 2)
Wine 93's (Class: 2) Nearest Wine: Wine 80 (Class: 2)
Wine 94's (Class: 2) Nearest Wine: Wine 117 (Class: 2)
Wine 95's (Class: 2) Nearest Wine: Wine 73 (Class: 2)
Wine 96's (Class: 2) Nearest Wine: Wine 130 (Class: 3)
Wine 97's (Class: 2) Nearest Wine: Wine 113 (Class: 2)
Wine 98's (Class: 2) Nearest Wine: Wine 172 (Class: 3)
Wine 99's (Class: 2) Nearest Wine: Wine 115 (Class: 2)
Wine 100's (Class: 2) Nearest Wine: Wine 81 (Class: 2)
Wine 101's (Class: 2) Nearest Wine: Wine 119 (Class: 2)
Wine 102's (Class: 2) Nearest Wine: Wine 113 (Class: 2)
Wine 103's (Class: 2) Nearest Wine: Wine 63 (Class: 2)
Wine 104's (Class: 2) Nearest Wine: Wine 88 (Class: 2)
Wine 105's (Class: 2) Nearest Wine: Wine 108 (Class: 2)
Wine 106's (Class: 2) Nearest Wine: Wine 67 (Class: 2)
Wine 107's (Class: 2) Nearest Wine: Wine 116 (Class: 2)
Wine 108's (Class: 2) Nearest Wine: Wine 105 (Class: 2)
Wine 109's (Class: 2) Nearest Wine: Wine 65 (Class: 2)
Wine 110's (Class: 2) Nearest Wine: Wine 162 (Class: 3)
Wine 111's (Class: 2) Nearest Wine: Wine 105 (Class: 2)
Wine 112's (Class: 2) Nearest Wine: Wine 133 (Class: 3)
Wine 113's (Class: 2) Nearest Wine: Wine 97 (Class: 2)
Wine 114's (Class: 2) Nearest Wine: Wine 124 (Class: 2)
Wine 115's (Class: 2) Nearest Wine: Wine 99 (Class: 2)
Wine 116's (Class: 2) Nearest Wine: Wine 86 (Class: 2)
Wine 117's (Class: 2) Nearest Wine: Wine 94 (Class: 2)
Wine 118's (Class: 2) Nearest Wine: Wine 125 (Class: 2)
Wine 119's (Class: 2) Nearest Wine: Wine 101 (Class: 2)
```

```
posh@posh-GF62-7RE: ~/Desktop/cs171/machine-learning-spr2018
Wine 119's (Class: 2) Nearest Wine: Wine 101 (Class: 2)
Wine 120's (Class: 2) Nearest Wine: Wine 62 (Class: 2)
Wine 121's (Class: 2) Nearest Wine: Wine 151 (Class: 3)
Wine 122's (Class: 2) Nearest Wine: Wine 64 (Class: 2)
Wine 123's (Class: 2) Nearest Wine: Wine 125 (Class: 2)
Wine 124's (Class: 2) Nearest Wine: Wine 125 (Class: 2)
Wine 125's (Class: 2) Nearest Wine: Wine 123 (Class: 2)
Wine 126's (Class: 2) Nearest Wine: Wine 128 (Class: 2)
Wine 127's (Class: 2) Nearest Wine: Wine 72 (Class: 2)
Wine 128's (Class: 2) Nearest Wine: Wine 126 (Class: 2)
Wine 129's (Class: 2) Nearest Wine: Wine 138 (Class: 3)
Wine 130's (Class: 3) Nearest Wine: Wine 169 (Class: 3)
Wine 131's (Class: 3) Nearest Wine: Wine 142 (Class: 3)
Wine 132's (Class: 3) Nearest Wine: Wine 177 (Class: 3)
Wine 133's (Class: 3) Nearest Wine: Wine 112 (Class: 2)
Wine 134's (Class: 3) Nearest Wine: Wine 148 (Class: 3)
Wine 135's (Class: 3) Nearest Wine: Wine 167 (Class: 3)
Wine 136's (Class: 3) Nearest Wine: Wine 155 (Class: 3)
Wine 137's (Class: 3) Nearest Wine: Wine 142 (Class: 3)
Wine 138's (Class: 3) Nearest Wine: Wine 129 (Class: 2)
Wine 139's (Class: 3) Nearest Wine: Wine 133 (Class: 3)
Wine 140's (Class: 3) Nearest Wine: Wine 133 (Class: 3)
Wine 141's (Class: 3) Nearest Wine: Wine 21 (Class: 1)
Wine 142's (Class: 3) Nearest Wine: Wine 137 (Class: 3)
Wine 143's (Class: 3) Nearest Wine: Wine 177 (Class: 3)
Wine 144's (Class: 3) Nearest Wine: Wine 19 (Class: 1)
Wine 145's (Class: 3) Nearest Wine: Wine 24 (Class: 1)
Wine 146's (Class: 3) Nearest Wine: Wine 103 (Class: 2)
Wine 147's (Class: 3) Nearest Wine: Wine 159 (Class: 3)
Wine 148's (Class: 3) Nearest Wine: Wine 134 (Class: 3)
Wine 149's (Class: 3) Nearest Wine: Wine 110 (Class: 2)
Wine 150's (Class: 3) Nearest Wine: Wine 77 (Class: 2)
Wine 151's (Class: 3) Nearest Wine: Wine 121 (Class: 2)
Wine 152's (Class: 3) Nearest Wine: Wine 75 (Class: 2)
Wine 153's (Class: 3) Nearest Wine: Wine 65 (Class: 2)
Wine 154's (Class: 3) Nearest Wine: Wine 62 (Class: 2)
Wine 155's (Class: 3) Nearest Wine: Wine 136 (Class: 3)
Wine 156's (Class: 3) Nearest Wine: Wine 171 (Class: 3)
Wine 157's (Class: 3) Nearest Wine: Wine 74 (Class: 2)
Wine 158's (Class: 3) Nearest Wine: Wine 172 (Class: 3)
Wine 159's (Class: 3) Nearest Wine: Wine 164 (Class: 3)
Wine 160's (Class: 3) Nearest Wine: Wine 165 (Class: 3)
Wine 161's (Class: 3) Nearest Wine: Wine 163 (Class: 3)
Wine 162's (Class: 3) Nearest Wine: Wine 110 (Class: 2)
Wine 163's (Class: 3) Nearest Wine: Wine 161 (Class: 3)
Wine 164's (Class: 3) Nearest Wine: Wine 159 (Class: 3)
Wine 165's (Class: 3) Nearest Wine: Wine 160 (Class: 3)
Wine 166's (Class: 3) Nearest Wine: Wine 161 (Class: 3)
Wine 167's (Class: 3) Nearest Wine: Wine 88 (Class: 2)
Wine 168's (Class: 3) Nearest Wine: Wine 174 (Class: 3)
Wine 169's (Class: 3) Nearest Wine: Wine 130 (Class: 3)
Wine 170's (Class: 3) Nearest Wine: Wine 137 (Class: 3)
Wine 171's (Class: 3) Nearest Wine: Wine 72 (Class: 2)
Wine 172's (Class: 3) Nearest Wine: Wine 98 (Class: 2)
Wine 173's (Class: 3) Nearest Wine: Wine 174 (Class: 3)
Wine 174's (Class: 3) Nearest Wine: Wine 168 (Class: 3)
Wine 175's (Class: 3) Nearest Wine: Wine 176 (Class: 3)
Wine 176's (Class: 3) Nearest Wine: Wine 175 (Class: 3)
Wine 177's (Class: 3) Nearest Wine: Wine 132 (Class: 3)
```

```
posh@posh-GF62-7RE:~/Desktop/cs171/machine-learning-spr2018$ █
```