

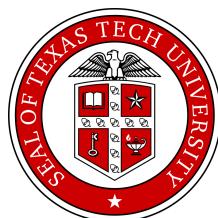
Pattern Recognition - ECE 5363

Project 1 Report

Classifying Fisher Iris Dataset using Perceptron and Least Square algorithms

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1 Introduction

Fisher Iris dataset was published in 1936 as a paper entitled as "The use of multiple measurements in taxonomic problems as an example of linear discriminant analysis" by Ronald Fisher who was a British statistician and biologist. (1)

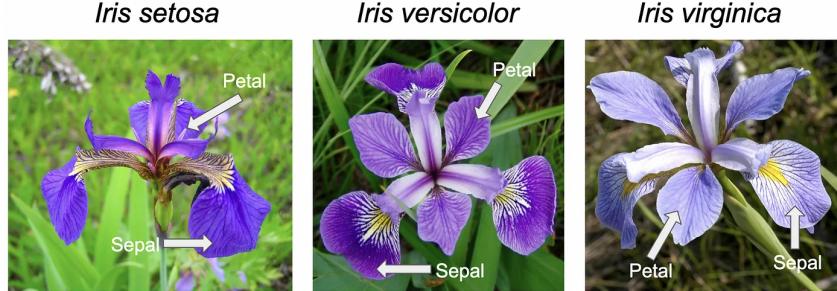


Figure 1: Petals and Sepals for Iris setosa, Iris versicolor, and Iris virginicas. (2)

About the Fisher Iris dataset:

Table 1: Study Summary and Feature Performance Expectation

Aspect	Details
(a) Number of Classes	3
(b) Number of Features	4
(c) Data Representation	It represents the sepal length and width, and petal length and width, of three flower species collected.
Feature Performance Expectation	Based on the Figure 1, we can visually notice the dimension difference between the sepal and petal of Setosa and Versicolor species. But for the specie Virginica, Petal and Sepal dimension are quite similar. We can expect from the classification task being possible if the 3 species sepal and petal length are numerically different from each other and on the next sections numerical analysis will be done.

2 Statistical Analysis of Iris Flower Features

	Sepal Length	Sepal Width	Petal Length	Petal Width
Minimum	4.30	2.00	1.00	0.10
Maximum	7.90	4.40	6.90	2.50
Mean	5.84	3.05	3.76	1.20
Variance	0.69	0.19	3.11	0.58
Within Class Variance	0.27	0.12	0.19	0.04
Between Class Variance	0.42	0.08	2.91	0.54

Table 2: Statistical analysis of Iris flower features

From Statistical Analysis table, we can notice that the 4 features has different minimum, maximum and means values which means that numerically each of the 4 features is differentiable from each other.

The variance metrics reveal that the Petal Length feature exhibits the highest overall variance among the four features. This observation suggests a significant spread of data points for Petal Length, indicating diverse measurements within this feature across all samples. To gain deeper insights into how this variance contributes to class differentiation, we need to take a look into within-class variance and between-class variance, since

$$\text{Total Variance} = \text{Within-Class Variance} + \text{Between-Class Variance}$$

The within class variance computed doesn't show high values for any of the species. A smaller within-class variance indicates that the data points in each class are closely clustered around their class mean. In the context of iris dataset classification, lower within-class variance is desirable as for each class, the data points are close to their own mean, making the class more distinguishable from others.

Finally, about the between class variance we can notice that only petal length has a high value. A larger between-class variance indicates that the classes are well-separated. In classification tasks, higher between-class variance is preferred because it suggests that classes are easily distinguishable based on their feature values. Therefore, sepal length and width are the hardest features to distinguish between classes and that's one of the reasons that the project chose feature 3 and 4 when doing binary classification.

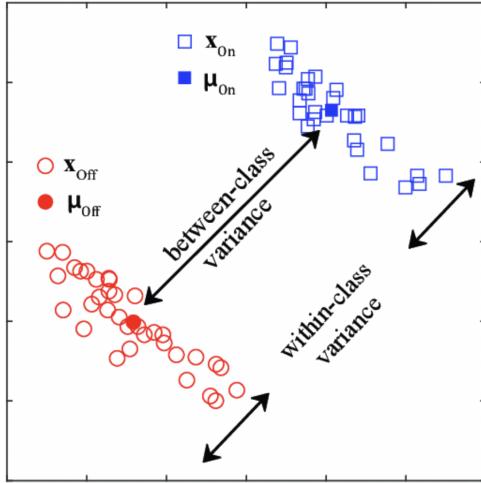


Figure 2: Difference between within and between variance. (3)

3 Correlation Coefficient

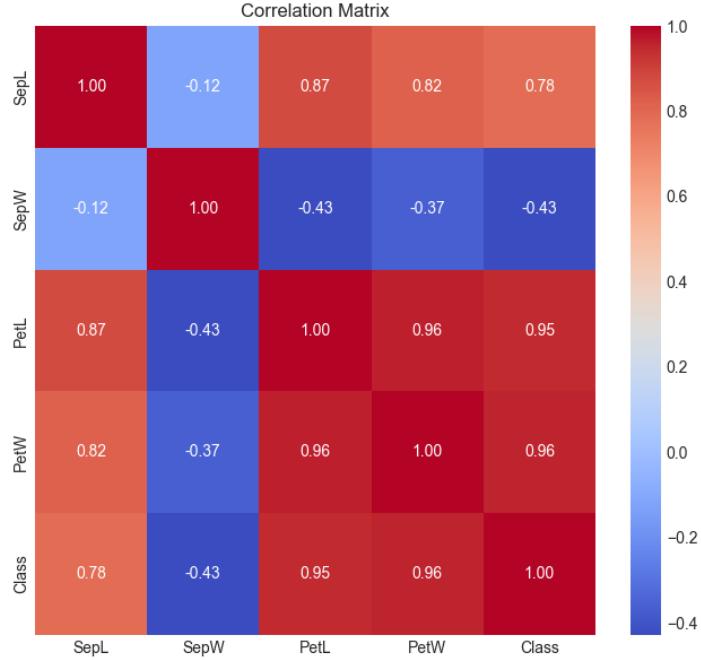


Figure 3: Correlation matrix of the dataset.

From the correlation matrix for the Iris dataset, we can see that petal length and petal width have high positive correlations with the class variable. This suggests that these features (petal length and width) are good predictors of the Iris species. In contrast, sepal length and sepal width show negative correlations, indicating they are less predictive of the species. From this matrix, we just found another reason of choosing petal length and width for the binary classification part.

4 Feature Vs Class

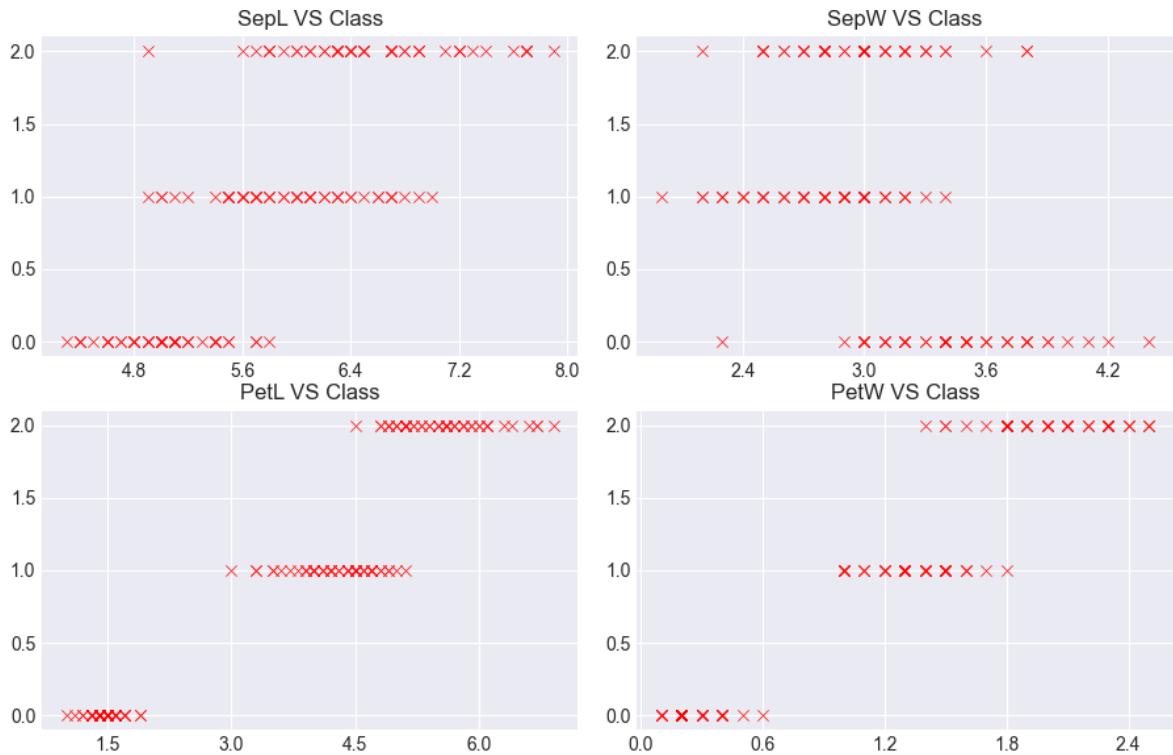


Figure 4: Feature Vs Class plot.

From feature vs. class plot we can notice that sepal length and width has more overlaps when compared to petal length and width. This image show us that it will be harder to differentiate the flower classes when using sepal features when compared to petal features due to the overlaps.

5 Results

5.1 Results Summary

For the ease of correction, here are the results summary.

Table 3: Classification Task Results

Type	Algorithm	Features	Converged?	No. Epochs	No. Miss or Accuracy
Setosa Vs. V+V	Batch P.	All Features	Yes	7	0
Setosa Vs. V+V	LS	All Features	-	-	1.000
Setosa Vs. V+V	Batch P.	Features 3 and 4	Yes	7	0
Setosa Vs. V+V	LS	Features 3 and 4	-	-	0.933
Virgi Vs. V+S	Batch P.	All Features	No	982	1
Virgi Vs. V+S	LS	All Features	-	-	0.927
Virgi Vs. V+S	Batch P.	Features 3 and 4	No	891	4
Virgi Vs. V+S	LS	Features 3 and 4	No	-	0.947
S. Vs. V Vs. Vi	MultiC LS	Features 3 and 4	-	-	0.773

* For the Batch P. that didn't converged, we tried to find the least missclassification as possible for epochs less than 1000.

* "No. Miss" stands for Number of missclassifications

Table 4: Weight, feature vectors and decision boundary results

Type	Algorithm	Features	Weight Vector	Feature Vector	Decision Boundary
Setosa Vs. V+V	Batch P.	All Features	page 9	page 9	-
Setosa Vs. V+V	LS	All Features	page 10	page 10	-
Setosa Vs. V+V	Batch P.	Features 3 and 4	page 14	page 12	page 11
Setosa Vs. V+V	LS	Features 3 and 4	page 14	page 13	page 13
Virgi Vs. V+S	Batch P.	All Features	page 16	page 16	-
Virgi Vs. V+S	LS	All Features	page 17	page 17	-
Virgi Vs. V+S	Batch P.	Features 3 and 4	page 19	page 19	page 18
Virgi Vs. V+S	LS	Features 3 and 4	page 21	page 20	page 20
S. Vs. V Vs. Vi	MultiC LS	Features 3 and 4	page 24	page 24	page 24

5.2 Comparison between the algorithms on features 3 and 4

Setosa Vs. V+V: See page 22.

Virgi Vs. V+S: See page 23.

5.3 [All features] Setosa Vs. Versi+Virigi: Batch Perceptron

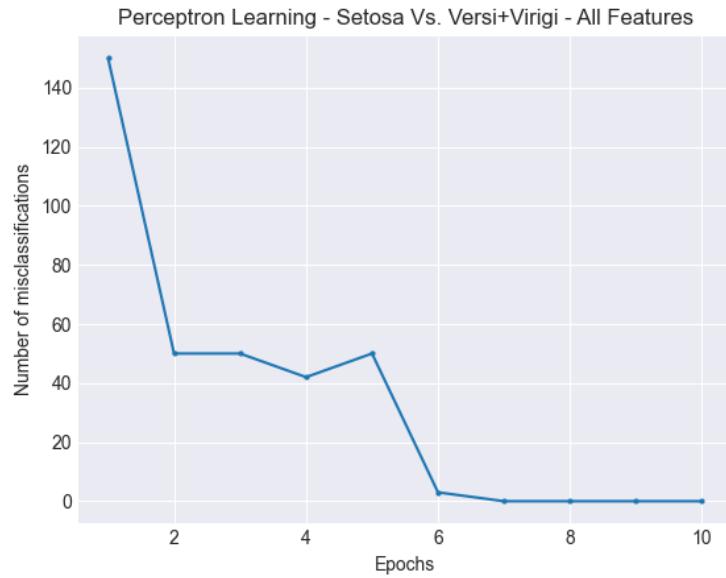


Figure 5: Miss classification over Epochs.

Epoch and Number of Miss classifications

```
1 Epoch 1, Number of missclassifications: 150
2 Epoch 2, Number of missclassifications: 50
3 Epoch 3, Number of missclassifications: 50
4 Epoch 4, Number of missclassifications: 42
5 Epoch 5, Number of missclassifications: 50
6 Epoch 6, Number of missclassifications: 3
7 Epoch 7, Number of missclassifications: 0
8 Epoch 8, Number of missclassifications: 0
9 Epoch 9, Number of missclassifications: 0
10 Epoch 10, Number of missclassifications: 0
```

5.3.1 Feature Vector

Feature Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1  array([[5.1,  3.5,  1.4,  0.2,  1. ],
2      [4.9,  3. ,  1.4,  0.2,  1. ],
3      [4.7,  3.2,  1.3,  0.2,  1. ],
4      [4.6,  3.1,  1.5,  0.2,  1. ],
5      [5. ,  3.6,  1.4,  0.2,  1. ],
6      [5.4,  3.9,  1.7,  0.4,  1. ],
7      [4.6,  3.4,  1.4,  0.3,  1. ],
8      [5. ,  3.4,  1.5,  0.2,  1. ],
9      [4.4,  2.9,  1.4,  0.2,  1. ],
10     [4.9,  3.1,  1.5,  0.1,  1. ],
11     [5.4,  3.7,  1.5,  0.2,  1. ],
12     [4.8,  3.4,  1.6,  0.2,  1. ],
13     [4.8,  3. ,  1.4,  0.1,  1. ],
14     [4.3,  3. ,  1.1,  0.1,  1. ],
15     [5.8,  4. ,  1.2,  0.2,  1. ],
16     [5.7,  4.4,  1.5,  0.4,  1. ],
17     [5.4,  3.9,  1.3,  0.4,  1. ],
18     [5.1,  3.5,  1.4,  0.3,  1. ],
19     [5.7,  3.8,  1.7,  0.3,  1. ],
20     [5.1,  3.8,  1.5,  0.3,  1. ],
21     [5.4,  3.4,  1.7,  0.2,  1. ],
22     [5.1,  3.7,  1.5,  0.4,  1. ],
23     [4.6,  3.6,  1. ,  0.2,  1. ],
24     [5.1,  3.3,  1.7,  0.5,  1. ],
25     [4.8,  3.4,  1.9,  0.2,  1. ],
26     ...
27     [6.7,  3. ,  5.2,  2.3,  1. ],
28     [6.3,  2.5,  5. ,  1.9,  1. ],
29     [6.5,  3. ,  5.2,  2. ,  1. ],
30     [6.2,  3.4,  5.4,  2.3,  1. ],
31     [5.9,  3. ,  5.1,  1.8,  1. ]])
```

5.3.2 Weight Vector

Weight Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1  array([ 1.101,  2.734, -3.837, -1.76 ,  0.55 ])
```

5.4 [All features] Setosa Vs. Versi+Virigi: Least Square

5.4.1 Feature vector

Feature Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1  array([[5.1,  3.5,  1.4,  0.2,  1. ],
2      [4.9,  3. ,  1.4,  0.2,  1. ],
3      [4.7,  3.2,  1.3,  0.2,  1. ],
4      [4.6,  3.1,  1.5,  0.2,  1. ],
5      [5. ,  3.6,  1.4,  0.2,  1. ],
6      [5.4,  3.9,  1.7,  0.4,  1. ],
7      [4.6,  3.4,  1.4,  0.3,  1. ],
8      [5. ,  3.4,  1.5,  0.2,  1. ],
9      [4.4,  2.9,  1.4,  0.2,  1. ],
10     [4.9,  3.1,  1.5,  0.1,  1. ],
11     [5.4,  3.7,  1.5,  0.2,  1. ],
12     [4.8,  3.4,  1.6,  0.2,  1. ],
13     [4.8,  3. ,  1.4,  0.1,  1. ],
14     [4.3,  3. ,  1.1,  0.1,  1. ],
15     [5.8,  4. ,  1.2,  0.2,  1. ],
16     [5.7,  4.4,  1.5,  0.4,  1. ],
17     [5.4,  3.9,  1.3,  0.4,  1. ],
18     [5.1,  3.5,  1.4,  0.3,  1. ],
19     [5.7,  3.8,  1.7,  0.3,  1. ],
20     [5.1,  3.8,  1.5,  0.3,  1. ],
21     [5.4,  3.4,  1.7,  0.2,  1. ],
22     [5.1,  3.7,  1.5,  0.4,  1. ],
23     [4.6,  3.6,  1. ,  0.2,  1. ],
24     [5.1,  3.3,  1.7,  0.5,  1. ],
25     [4.8,  3.4,  1.9,  0.2,  1. ],
26     ...
27     [6.7,  3. ,  5.2,  2.3,  1. ],
28     [6.3,  2.5,  5. ,  1.9,  1. ],
29     [6.5,  3. ,  5.2,  2. ,  1. ],
30     [6.2,  3.4,  5.4,  2.3,  1. ],
31     [5.9,  3. ,  5.1,  1.8,  1. ]])
```

5.4.2 Weight vector

Weight Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1  array([-0.26411908, -0.97139149,  0.89862846,  0.22989092,  1.52710844])
```

5.5 [3 and 4 features] Setosa Vs. Versi+Virigi: Batch Perceptron

- Number of Epochs: 10

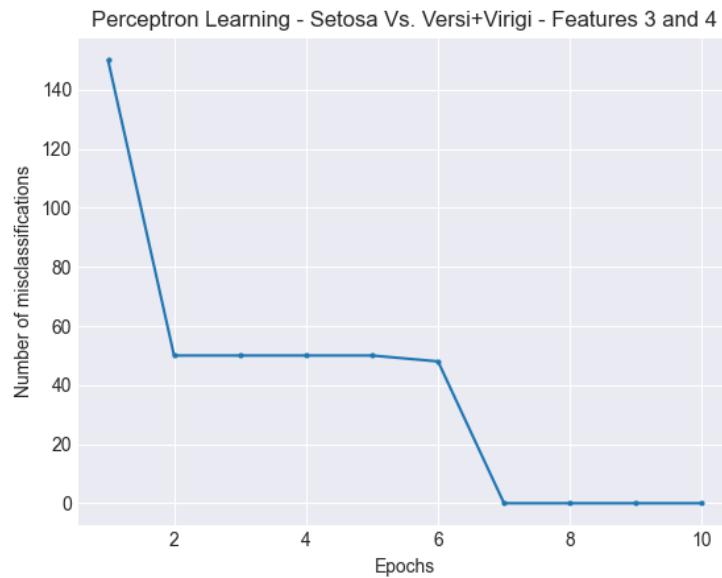


Figure 6: Miss classification over Epochs.

Epoch and Number of Miss classifications

```
1 Epoch 1, Number of missclassifications: 150
2 Epoch 2, Number of missclassifications: 50
3 Epoch 3, Number of missclassifications: 50
4 Epoch 4, Number of missclassifications: 50
5 Epoch 5, Number of missclassifications: 50
6 Epoch 6, Number of missclassifications: 48
7 Epoch 7, Number of missclassifications: 0
8 Epoch 8, Number of missclassifications: 0
9 Epoch 9, Number of missclassifications: 0
10 Epoch 10, Number of missclassifications: 0
```

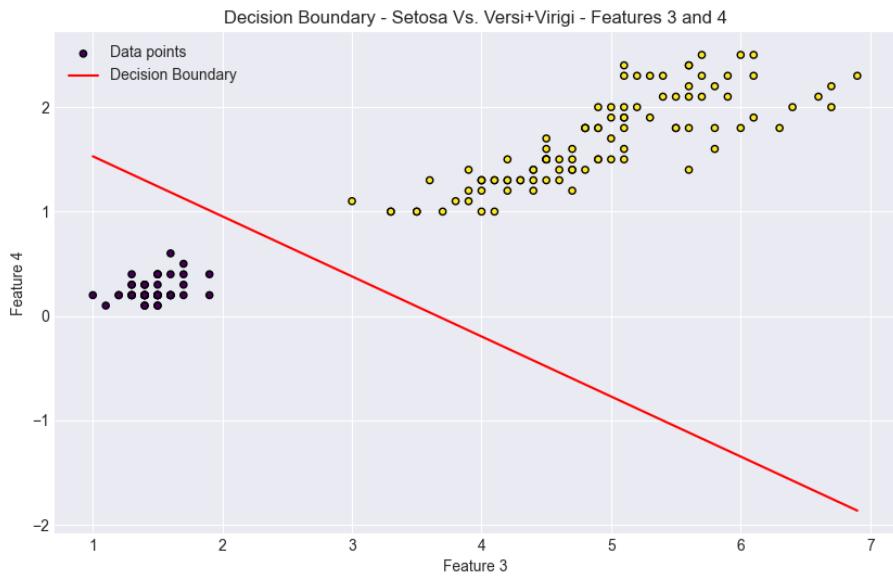


Figure 7: Computed decision boundary. Where the yellow data point refers to versi+virgi class and the black to setosa class.

5.5.1 Feature vector

Feature Vector [Petal Length, Petal Width, Bias]

```

1  array([[1.4,  0.2,  1. ],
2      [1.4,  0.2,  1. ],
3      [1.3,  0.2,  1. ],
4      [1.5,  0.2,  1. ],
5      [1.4,  0.2,  1. ],
6      [1.7,  0.4,  1. ],
7      [1.4,  0.3,  1. ],
8      [1.5,  0.2,  1. ],
9      [1.4,  0.2,  1. ],
10     [1.5,  0.1,  1. ],
11     [1.5,  0.2,  1. ],
12     [1.6,  0.2,  1. ],
13     [1.4,  0.1,  1. ],
14     [1.1,  0.1,  1. ],
15     [1.2,  0.2,  1. ],
16     [1.5,  0.4,  1. ],
17     [1.3,  0.4,  1. ],
18     [1.4,  0.3,  1. ],
19     [1.7,  0.3,  1. ],
20     [1.5,  0.3,  1. ],
21     [1.7,  0.2,  1. ],
22     [1.5,  0.4,  1. ],
23     [1.,  0.2,  1. ],
24     [1.7,  0.5,  1. ],
25     [1.9,  0.2,  1. ],
26     ...
27     [5.2,  2.3,  1. ],
28     [5.,  1.9,  1. ],
29     [5.2,  2.,  1. ],
30     [5.4,  2.3,  1. ],
31     [5.1,  1.8,  1. ]])

```

5.5.2 Weight vector

Weight Vector [Petal Length, Petal Width, Bias]

```

1  array([-0.541, -0.941,  1.98 ])

```

5.6 [3 and 4 features] Setosa Vs. Versi+Virigi: Least Square

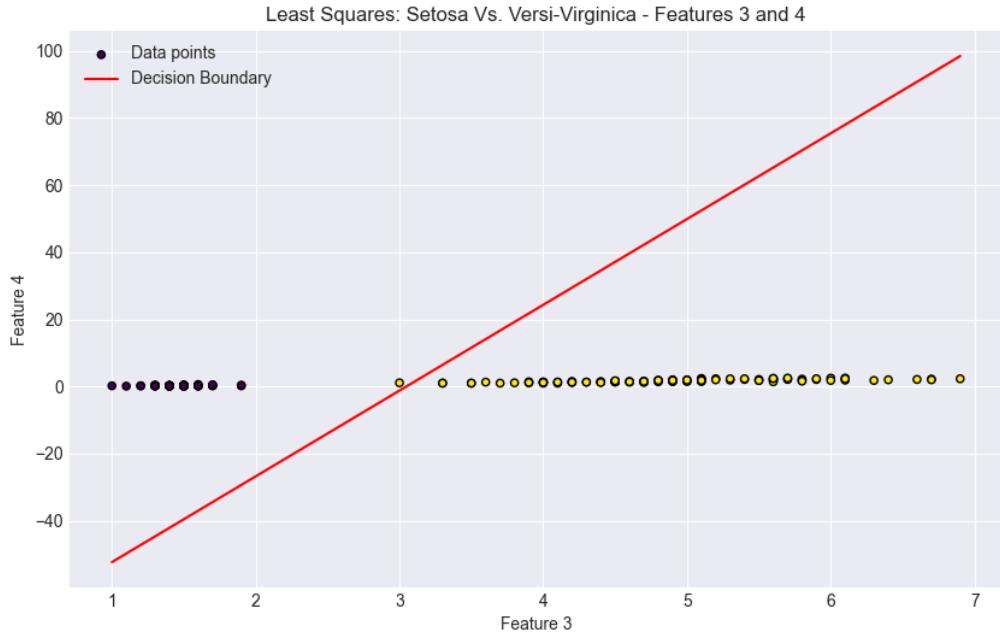


Figure 8: Computed decision boundary. Where the yellow data point refers to versi+virgi class and the black to setosa class.

5.6.1 Feature vector

Feature Vector [Petal Length, Petal Width, Bias]

```

1  array([[1.4,  0.2,  1. ],
2      [1.4,  0.2,  1. ],
3      [1.3,  0.2,  1. ],
4      [1.5,  0.2,  1. ],
5      [1.4,  0.2,  1. ],
6      [1.7,  0.4,  1. ],
7      [1.4,  0.3,  1. ],
8      [1.5,  0.2,  1. ],
9      [1.4,  0.2,  1. ],
10     [1.5,  0.1,  1. ],
11     [1.5,  0.2,  1. ],
12     [1.6,  0.2,  1. ],
13     [1.4,  0.1,  1. ],
14     [1.1,  0.1,  1. ],
15     [1.2,  0.2,  1. ],
16     [1.5,  0.4,  1. ],
17     [1.3,  0.4,  1. ],
18     [1.4,  0.3,  1. ],
19     [1.7,  0.3,  1. ],
20     [1.5,  0.3,  1. ],
21 ...
22     [5.2,  2.3,  1. ],
23     [5. ,  1.9,  1. ],
24     [5.2,  2. ,  1. ],
25     [5.4,  2.3,  1. ],
26     [5.1,  1.8,  1. ]])

```

5.6.2 Weight vector

Weight Vector [Petal Length, Petal Width, Bias]

```
1 array([ 1.00531621, -0.03933704, -3.06413342])
```

5.7 [All features] Virgi Vs. Versi+Setosa: Batch Perceptron

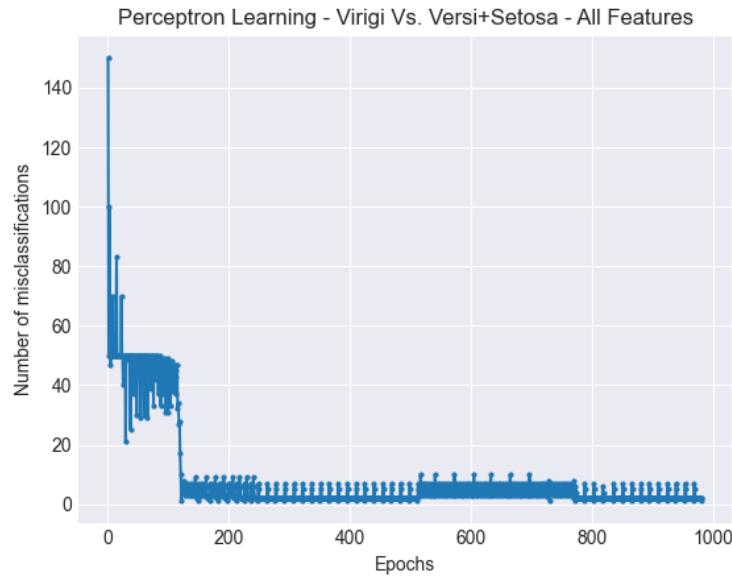


Figure 9: Miss classification over Epochs.

Epoch and Number of Miss classifications

```
1 Epoch 1, Number of misclassifications: 150
2 Epoch 2, Number of misclassifications: 50
3 Epoch 3, Number of misclassifications: 100
4 Epoch 4, Number of misclassifications: 50
5 Epoch 5, Number of misclassifications: 47
6 Epoch 6, Number of misclassifications: 50
7 Epoch 7, Number of misclassifications: 50
8 Epoch 8, Number of misclassifications: 50
9 Epoch 9, Number of misclassifications: 70
10 Epoch 10, Number of misclassifications: 50
11 Epoch 11, Number of misclassifications: 50
12 Epoch 12, Number of misclassifications: 50
13 Epoch 13, Number of misclassifications: 51
14 Epoch 14, Number of misclassifications: 50
15 Epoch 15, Number of misclassifications: 83
16 Epoch 16, Number of misclassifications: 50
17 Epoch 17, Number of misclassifications: 50
18 Epoch 18, Number of misclassifications: 50
19 Epoch 19, Number of misclassifications: 50
20 Epoch 20, Number of misclassifications: 50
21 Epoch 21, Number of misclassifications: 50
22 Epoch 22, Number of misclassifications: 50
23 Epoch 23, Number of misclassifications: 70
24 ...
25 Epoch 979, Number of misclassifications: 2
26 Epoch 980, Number of misclassifications: 2
27 Epoch 981, Number of misclassifications: 2
28 Epoch 982, Number of misclassifications: 1
```

5.7.1 Feature vector

Feature Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1 array([[5.1, 3.5, 1.4, 0.2, 1. ],
2        [4.9, 3., 1.4, 0.2, 1. ],
3        [4.7, 3.2, 1.3, 0.2, 1. ],
4        [4.6, 3.1, 1.5, 0.2, 1. ],
5        [5., 3.6, 1.4, 0.2, 1. ],
6        [5.4, 3.9, 1.7, 0.4, 1. ],
7        [4.6, 3.4, 1.4, 0.3, 1. ],
8        [5., 3.4, 1.5, 0.2, 1. ],
9        [4.4, 2.9, 1.4, 0.2, 1. ],
10       [4.9, 3.1, 1.5, 0.1, 1. ],
11       [5.4, 3.7, 1.5, 0.2, 1. ],
12       [4.8, 3.4, 1.6, 0.2, 1. ],
13       [4.8, 3., 1.4, 0.1, 1. ],
14       [4.3, 3., 1.1, 0.1, 1. ],
15       [5.8, 4., 1.2, 0.2, 1. ],
16       [5.7, 4.4, 1.5, 0.4, 1. ],
17       [5.4, 3.9, 1.3, 0.4, 1. ],
18       [5.1, 3.5, 1.4, 0.3, 1. ],
19       [5.7, 3.8, 1.7, 0.3, 1. ],
20       [5.1, 3.8, 1.5, 0.3, 1. ],
21       [5.4, 3.4, 1.7, 0.2, 1. ],
22       [5.1, 3.7, 1.5, 0.4, 1. ],
23       [4.6, 3.6, 1., 0.2, 1. ],
24       [5.1, 3.3, 1.7, 0.5, 1. ],
25       [4.8, 3.4, 1.9, 0.2, 1. ],
26       ...
27       [6.7, 3., 5.2, 2.3, 1. ],
28       [6.3, 2.5, 5., 1.9, 1. ],
29       [6.5, 3., 5.2, 2., 1. ],
30       [6.2, 3.4, 5.4, 2.3, 1. ],
31       [5.9, 3., 5.1, 1.8, 1. ]])
```

5.7.2 Weight vector

Weight Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1 array([ 0.9822,  0.8522, -1.43 , -1.2169,  0.619 ])
```

5.8 [All features] Virgi Vs. Versi+Setosa: Least Square

5.8.1 Feature vector

Feature Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1 array([[5.1, 3.5, 1.4, 0.2, 1. ],
2        [4.9, 3. , 1.4, 0.2, 1. ],
3        [4.7, 3.2, 1.3, 0.2, 1. ],
4        [4.6, 3.1, 1.5, 0.2, 1. ],
5        [5. , 3.6, 1.4, 0.2, 1. ],
6        [5.4, 3.9, 1.7, 0.4, 1. ],
7        [4.6, 3.4, 1.4, 0.3, 1. ],
8        [5. , 3.4, 1.5, 0.2, 1. ],
9        [4.4, 2.9, 1.4, 0.2, 1. ],
10       [4.9, 3.1, 1.5, 0.1, 1. ],
11       [5.4, 3.7, 1.5, 0.2, 1. ],
12       [4.8, 3.4, 1.6, 0.2, 1. ],
13       [4.8, 3. , 1.4, 0.1, 1. ],
14       [4.3, 3. , 1.1, 0.1, 1. ],
15       [5.8, 4. , 1.2, 0.2, 1. ],
16       [5.7, 4.4, 1.5, 0.4, 1. ],
17       [5.4, 3.9, 1.3, 0.4, 1. ],
18       [5.1, 3.5, 1.4, 0.3, 1. ],
19       [5.7, 3.8, 1.7, 0.3, 1. ],
20       [5.1, 3.8, 1.5, 0.3, 1. ],
21       [5.4, 3.4, 1.7, 0.2, 1. ],
22       [5.1, 3.7, 1.5, 0.4, 1. ],
23       [4.6, 3.6, 1. , 0.2, 1. ],
24       [5.1, 3.3, 1.7, 0.5, 1. ],
25       [4.8, 3.4, 1.9, 0.2, 1. ],
26       ...
27       [6.7, 3. , 5.2, 2.3, 1. ],
28       [6.3, 2.5, 5. , 1.9, 1. ],
29       [6.5, 3. , 5.2, 2. , 1. ],
30       [6.2, 3.4, 5.4, 2.3, 1. ],
31       [5.9, 3. , 5.1, 1.8, 1. ]])
```

5.8.2 Weight vector

Weight Vector [Sepal Length, Sepal Width, Petal Length, Petal Width, Bias]

```
1 array([-0.09175217,  0.40553677,  0.00797582,  1.10355865, -2.39056373])
```

5.9 [3 and 4 features] Virgi Vs. Versi+Setosa: Batch Perceptron

- Number of Epochs: 891

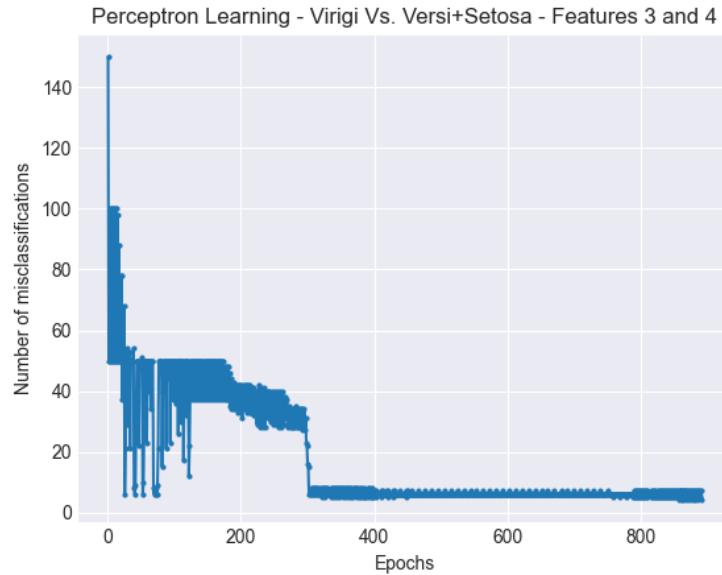


Figure 10: Miss classification over Epochs.

Epoch and Number of Miss classifications

```
1 Epoch 1, Number of misclassifications: 150
2 Epoch 2, Number of misclassifications: 50
3 Epoch 3, Number of misclassifications: 100
4 Epoch 4, Number of misclassifications: 50
5 Epoch 5, Number of misclassifications: 100
6 Epoch 6, Number of misclassifications: 50
7 Epoch 7, Number of misclassifications: 100
8 Epoch 8, Number of misclassifications: 50
9 Epoch 9, Number of misclassifications: 100
10 Epoch 10, Number of misclassifications: 50
11 Epoch 11, Number of misclassifications: 100
12 Epoch 12, Number of misclassifications: 50
13 Epoch 13, Number of misclassifications: 100
14 Epoch 14, Number of misclassifications: 50
15 Epoch 15, Number of misclassifications: 98
16 Epoch 16, Number of misclassifications: 50
17 Epoch 17, Number of misclassifications: 88
18 Epoch 18, Number of misclassifications: 50
19 Epoch 19, Number of misclassifications: 78
20 Epoch 20, Number of misclassifications: 50
21 Epoch 21, Number of misclassifications: 78
22 Epoch 22, Number of misclassifications: 37
23 Epoch 23, Number of misclassifications: 53
24 ...
25 Epoch 888, Number of misclassifications: 7
26 Epoch 889, Number of misclassifications: 5
27 Epoch 890, Number of misclassifications: 7
28 Epoch 891, Number of misclassifications: 4
```

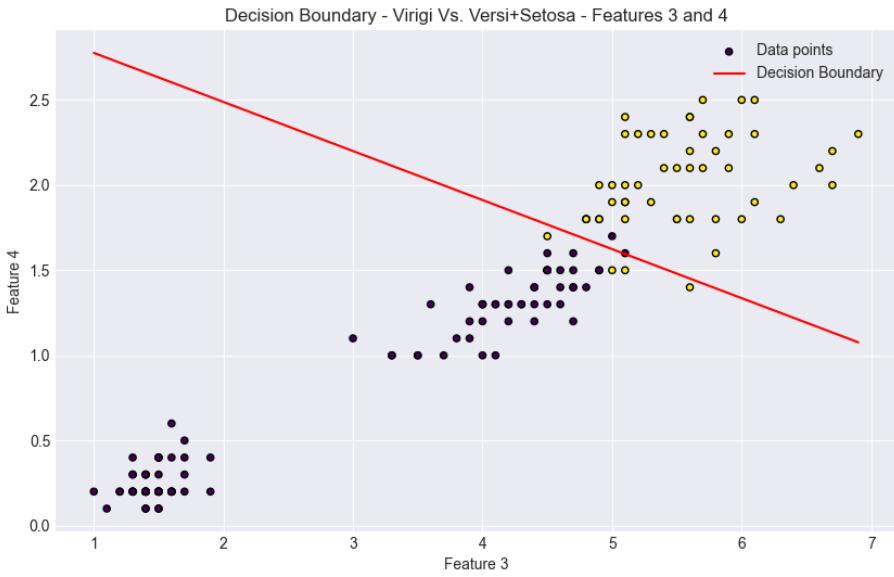


Figure 11: Computed decision boundary. Where the yellow data point refers to virigi class and the black to versi+setosa class.

5.9.1 Feature vector

Feature Vector [Petal Length, Petal Width, Bias]

```

1  array([[1.4,  0.2,  1. ],
2      [1.4,  0.2,  1. ],
3      [1.3,  0.2,  1. ],
4      [1.5,  0.2,  1. ],
5      [1.4,  0.2,  1. ],
6      [1.7,  0.4,  1. ],
7      [1.4,  0.3,  1. ],
8      [1.5,  0.2,  1. ],
9      [1.4,  0.2,  1. ],
10     [1.5,  0.1,  1. ],
11     [1.5,  0.2,  1. ],
12     [1.6,  0.2,  1. ],
13     [1.4,  0.1,  1. ],
14     [1.1,  0.1,  1. ],
15     [1.2,  0.2,  1. ],
16     [1.5,  0.4,  1. ],
17     [1.3,  0.4,  1. ],
18     [1.4,  0.3,  1. ],
19     [1.7,  0.3,  1. ],
20     [1.5,  0.3,  1. ],
21     [1.7,  0.2,  1. ],
22     [1.5,  0.4,  1. ],
23     [1.,  0.2,  1. ],
24     [1.7,  0.5,  1. ],
25     [1.9,  0.2,  1. ],
26     ...
27     [5.2,  2.3,  1. ],
28     [5.,  1.9,  1. ],
29     [5.2,  2.,  1. ],
30     [5.4,  2.3,  1. ],
31     [5.1,  1.8,  1. ]])

```

5.9.2 Weight vector

Weight Vector [Petal Length, Petal Width, Bias]

```

1  array([-1.725, -5.988, 18.35])

```

5.10 [3 and 4 features] Virgi Vs. Versi+Setosa: Least Square

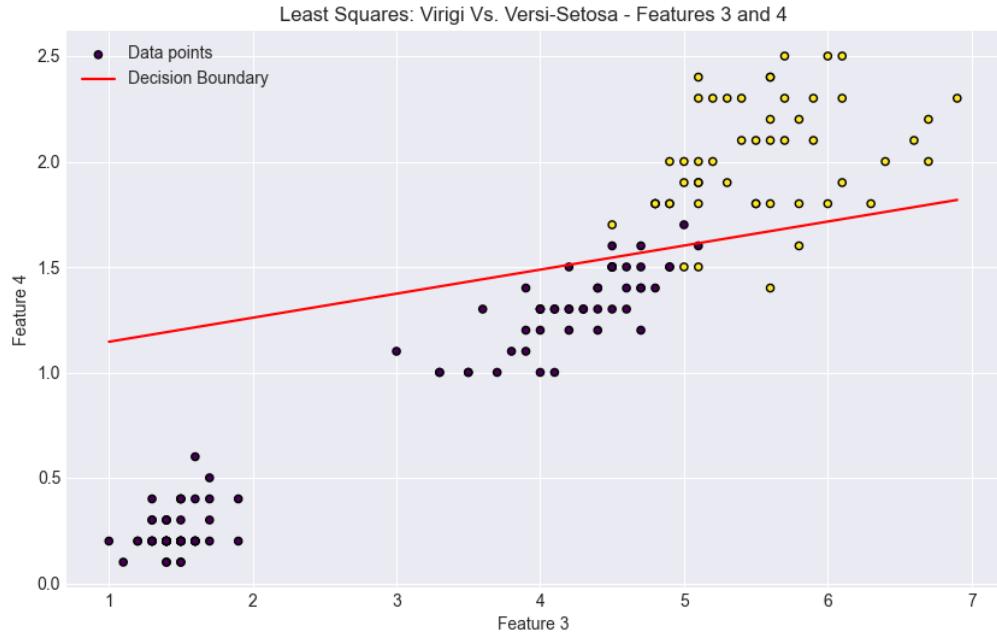


Figure 12: Computed decision boundary. Where the yellow data point refers to virgi class and the black to versi+setosa class.

5.10.1 Feature vector

Feature Vector [Petal Length, Petal Width, Bias]

```

1  array([[1.4,  0.2,  1. ],
2      [1.4,  0.2,  1. ],
3      [1.3,  0.2,  1. ],
4      [1.5,  0.2,  1. ],
5      [1.4,  0.2,  1. ],
6      [1.7,  0.4,  1. ],
7      [1.4,  0.3,  1. ],
8      [1.5,  0.2,  1. ],
9      [1.4,  0.2,  1. ],
10     [1.5,  0.1,  1. ],
11     [1.5,  0.2,  1. ],
12     [1.6,  0.2,  1. ],
13     [1.4,  0.1,  1. ],
14     [1.1,  0.1,  1. ],
15     [1.2,  0.2,  1. ],
16     [1.5,  0.4,  1. ],
17     [1.3,  0.4,  1. ],
18     [1.4,  0.3,  1. ],
19     [1.7,  0.3,  1. ],
20     [1.5,  0.3,  1. ],
21     [1.7,  0.2,  1. ],
22     ...
23     [5.2,  2.3,  1. ],
24     [5. ,  1.9,  1. ],
25     [5.2,  2. ,  1. ],
26     [5.4,  2.3,  1. ],
27     [5.1,  1.8,  1. ]])

```

5.10.2 Weight vector

Weight Vector [Petal Length, Petal Width, Bias]

```
1 array([-0.14601222,  1.28051055, -1.32037839])
```

5.11 Comparison between Least Square and Batch Perceptron Algorithm

5.11.1 Setosa vs. Versi+Virgi

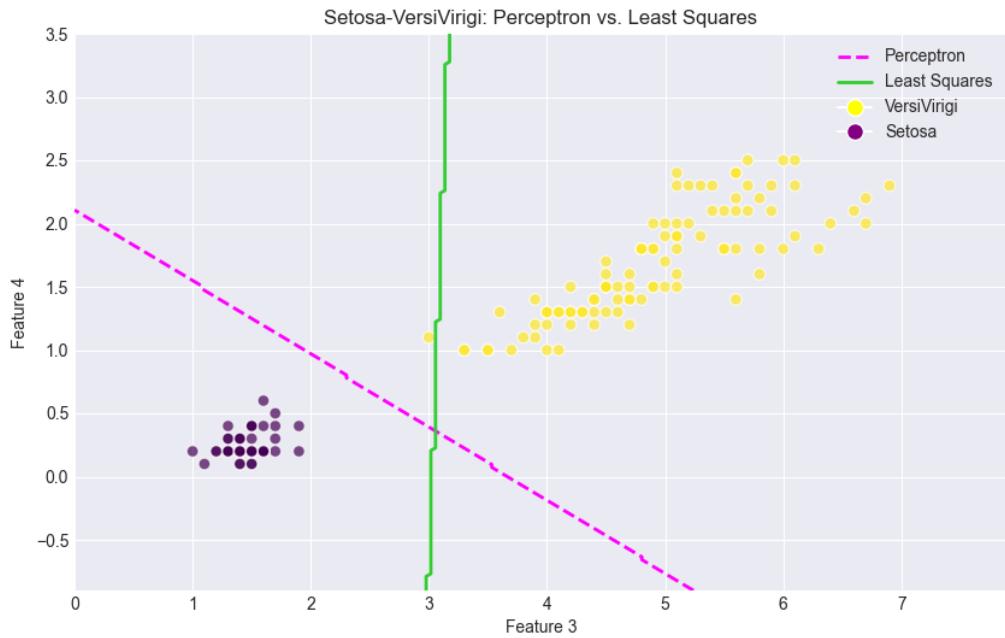


Figure 13: Computed decision boundary.

5.11.2 Virgi vs. Versi+Setosa

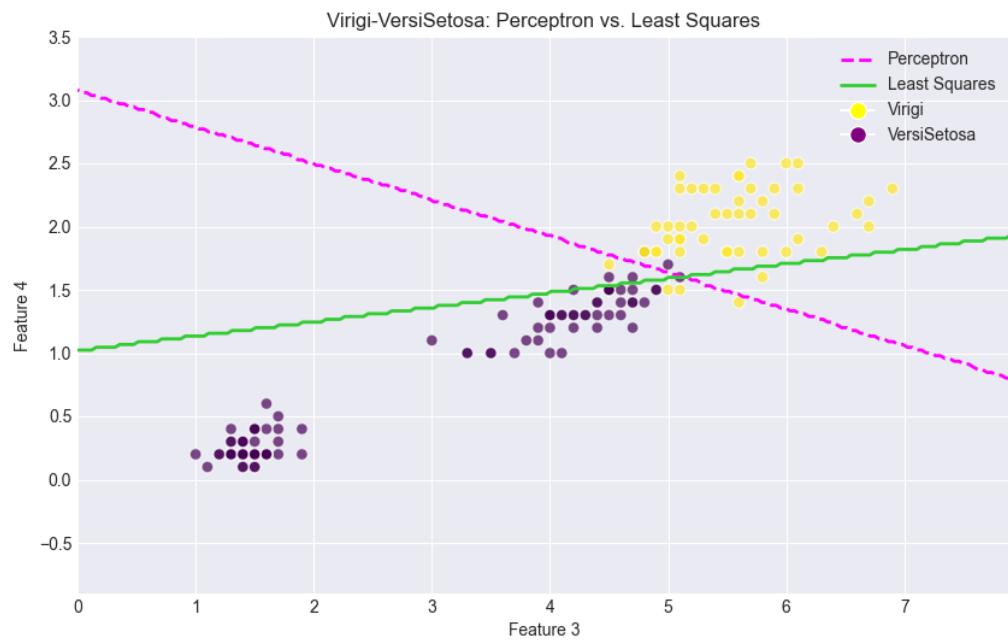


Figure 14: Computed decision boundary.

5.12 [3 and 4 features] Multiclass: Virgi Vs. Versi Vs. Setosa: Least Square

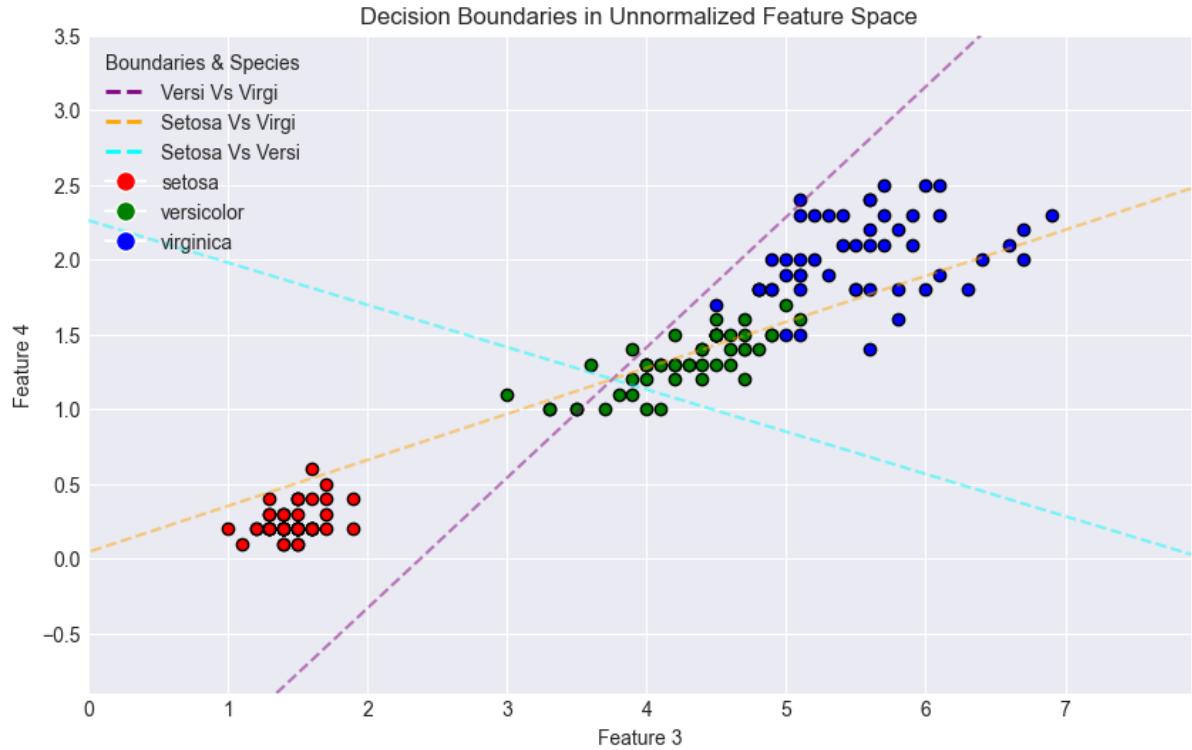


Figure 15: Multi-class computed decision boundary.

5.12.1 Feature vector

Feature Vector [Petal Length, Petal Width, Bias]

```

1 array([[1.4,  0.2,  1. ],
2      [1.4,  0.2,  1. ],
3      [1.3,  0.2,  1. ],
4      [1.5,  0.2,  1. ],
5      [1.4,  0.2,  1. ],
6      [1.7,  0.4,  1. ],
7      [1.4,  0.3,  1. ],
8      [1.5,  0.2,  1. ],
9      [1.4,  0.2,  1. ],
10     [1.5,  0.1,  1. ],
11     [1.5,  0.2,  1. ],
12     [1.6,  0.2,  1. ],
13     [1.4,  0.1,  1. ],
14     ...
15     [5.2,  2.3,  1. ],
16     [5. ,  1.9,  1. ],
17     [5.2,  2. ,  1. ],
18     [5.4,  2.3,  1. ],
19     [5.1,  1.8,  1. ]])

```

5.12.2 Weight vector

Weight Vector [Petal Length, Petal Width, Bias]

```

1 Unscaled Weight [[-0.25132905  0.32433516 -0.07300611] # d_1
2   [ 0.00983426 -0.65008953  0.64025527] # d_2
3   [ 1.26603335 -0.10584416 -0.16018919]] # d_3

```

References

- [1] Iris Flower Data Set, *Wikipedia*, Available at: https://en.wikipedia.org/wiki/Iris_flower_data_set
- [2] 'The Iris Dataset: A Little Bit of History and Biology', *Towards Data Science*, Available at: <https://towardsdatascience.com/the-iris-dataset-a-little-bit-of-history-and-biology-fb4812f5a7b5>
- [3] 'Between-class variance and within-class variance', *ResearchGate*, Available at: https://www.researchgate.net/figure/Between-class-variance-and-within-class-variance_fig4_338388512