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Report: Scikit-learn with PCA & LDA

I. Evaluation summary:

Task	Requirement Met(%)	Notes
Create CSV file	100%	
Describe data info in the report	100%	
Implement basic multivariate analysis	100%	
Apply PCA & LDA using Scikit-learn	70%	LDA is not completed
List comments for basic multivariate analysis	100%	
List comments for PCA & LDA implementation	100%	

II. List of funtion:

1. **print_mean_and_sd_by_group(variables, group_variable)**
2. **calc_within_groups_variance(variable, group_variable)**
3. **calc_between_groups_variance(variable, group_variable)**
4. **calc_separations(variables, group_variable)**
5. **calc_within_groups_covariance(variable1, variable2, group_variable)**
6. **calc_between_groups_covariance(variable1, variable2, group_variable)**
7. **most_highly_correlated(my_dataframe, num_to_report)**
8. **pca_summary(pca, standardised_data, out=True)**
9. **scree_plot(pca, standardised_values)**
10. **hinton(matrix, max_weight=None, ax=None)**

III. Function Summaries and Implementation

1. **print_mean_and_sd_by_group(variables, group_variable)**
    - **Summary**: Calculates the mean and standard deviation of variables grouped by a specified group variable and prints the results.
    - **Implementation**:
        - Divides the data into groups based on the **group_variable**.

- Computes the mean and standard deviation of each variable within each group.
- Prints the mean, standard deviation, and sample size for each group.

2. **calc_within_groups_variance(variable, group_variable)**
    - **Summary**: Computes within-group variance for a specific variable.
    - **Implementation**:
        - Divides the data into groups based on the **group_variable**.
        - Calculates the variance of the variable within each group.
        - Returns the within-group variance.
3. **calc_between_groups_variance(variable, group_variable)**
    - **Summary**: Computes between-group variance for a specific variable.
    - **Implementation**:
        - Compares the mean values of the variable between the groups defined by the **group_variable**.
        - Calculates the variance between these mean values.
        - Returns the between-group variance.
4. **calc_separations(variables, group_variable)**
    - **Summary**: Calculates separations between groups based on input variables.
    - **Implementation**:
        - Uses **calc_within_groups_variance()** and **calc_between_groups_variance()** functions to compute separation within a variable or between pairs of variables.
        - Returns the separation values for each variable.
5. **calc_within_groups_covariance(variable1, variable2, group_variable)**
    - **Summary**: Computes within-group covariance between two specific variables.
    - **Implementation**:
        - Divides the data into groups based on the **group_variable**.
        - Calculates the covariance between the two variables within each group.
        - Returns the within-group covariance.
6. **calc_between_groups_covariance(variable1, variable2, group_variable)**
    - **Summary**: Computes between-group covariance for two specific variables.
    - **Implementation**:

- Compares the mean values of the two variables between the groups defined by the **group_variable**.
- Calculates the covariance between these mean values.
- Returns the between-group covariance.

7. **most_highly_correlated(my_dataframe, num_to_report)**
    - **Summary**: Computes and returns the most highly correlated variable pairs from a DataFrame.
    - **Implementation**:
        - Calculates the correlation matrix using the **corr()** function.
        - Retrieves the variable pairs with the highest correlation and returns them.
8. **pca_summary(pca, standardised_data, out=True)**
    - **Summary**: Generates a summary table for Principal Component Analysis (PCA).
    - **Implementation**:
        - Computes the standard deviation, proportion of explained variance, and cumulative proportion of variance for each principal component.
        - Returns a DataFrame containing the summary statistics.
9. **scree_plot(pca, standardised_values)**
    - **Summary**: Plots a scree plot to show the distribution of variance explained by the principal components.
    - **Implementation**:
        - Uses the explained variance ratio from PCA to plot the graph.
10. **hinton(matrix, max_weight=None, ax=None)**
    - **Summary**: Plots a Hinton diagram to visualize a weight matrix.
    - **Implementation**:
        - Uses size and color to represent the value of each cell in the matrix.

V. The results:

Full image proof:

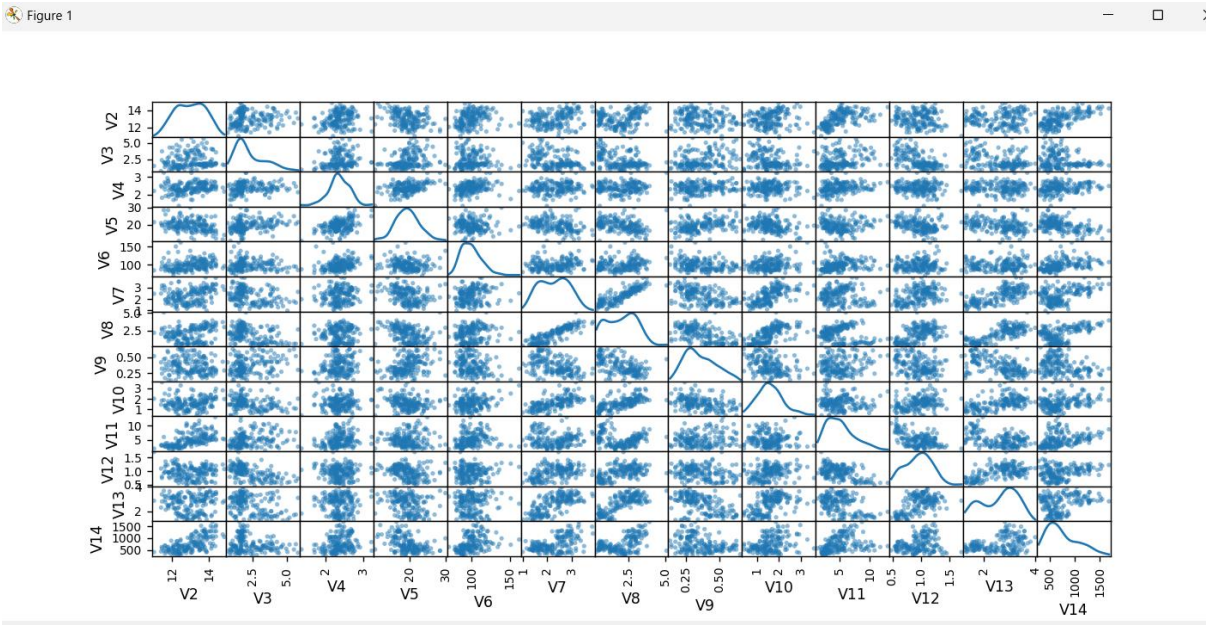
- Read data from the given sample CSV file

Output:

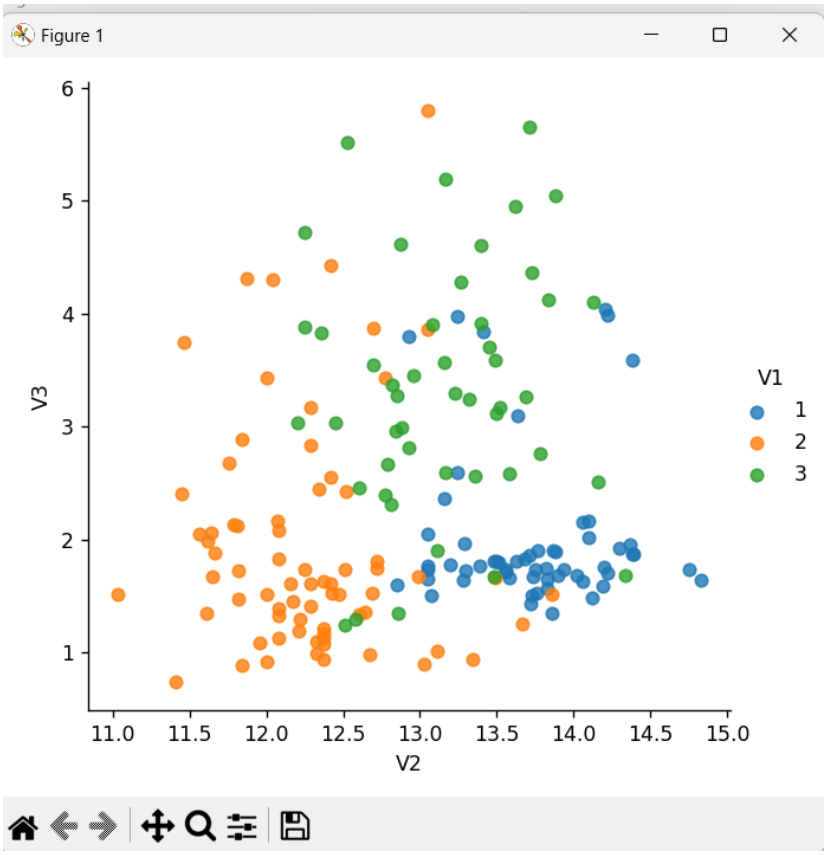
```
## Data:
     V1      V2    V3    V4    V5   V6  ...    V9   V10    V11
V12   V13   V14
0      1  13.20  1.78  2.14  11.2  100  ...  0.26  1.28   4.38
1.05  3.40  1050
1      1  13.16  2.36  2.67  18.6  101  ...  0.30  2.81   5.68
1.03  3.17  1185
2      1  14.37  1.95  2.50  16.8  113  ...  0.24  2.18   7.80
0.86  3.45  1480
3      1  13.24  2.59  2.87  21.0  118  ...  0.39  1.82   4.32
1.04  2.93   735
4      1  14.20  1.76  2.45  15.2  112  ...  0.34  1.97   6.75
1.05  2.85  1450
..   ..    ...   ...   ...   ...  ...  ...   ...   ...    ...
...   ...   ...
172    3  13.71  5.65  2.45  20.5   95  ...  0.52  1.06   7.70
0.64  1.74   740
173    3  13.40  3.91  2.48  23.0  102  ...  0.43  1.41   7.30
0.70  1.56   750
174    3  13.27  4.28  2.26  20.0  120  ...  0.43  1.35  10.20
0.59  1.56   835
175    3  13.17  2.59  2.37  20.0  120  ...  0.53  1.46   9.30
0.60  1.62   840
176    3  14.13  4.10  2.74  24.5   96  ...  0.56  1.35   9.20
0.61  1.60   560
[177 rows x 14 columns]
## Head:
   V1     V2    V3    V4    V5   V6  ...    V9   V10   V11
V12   V13   V14
0   1  13.20  1.78  2.14  11.2  100  ...  0.26  1.28  4.38
1.05  3.40  1050
1   1  13.16  2.36  2.67  18.6  101  ...  0.30  2.81  5.68
1.03  3.17  1185
2   1  14.37  1.95  2.50  16.8  113  ...  0.24  2.18  7.80
0.86  3.45  1480
3   1  13.24  2.59  2.87  21.0  118  ...  0.39  1.82  4.32
1.04  2.93   735
4   1  14.20  1.76  2.45  15.2  112  ...  0.34  1.97  6.75
1.05  2.85  1450
[5 rows x 14 columns]
## Tail:
     V1     V2    V3    V4    V5   V6  ...    V9   V10   V11
V12   V13  V14
172    3  13.71  5.65  2.45  20.5   95  ...  0.52  1.06   7.7
0.64  1.74  740
173    3  13.40  3.91  2.48  23.0  102  ...  0.43  1.41   7.3
0.70  1.56  750
174    3  13.27  4.28  2.26  20.0  120  ...  0.43  1.35  10.2
0.59  1.56  835
175    3  13.17  2.59  2.37  20.0  120  ...  0.53  1.46   9.3
0.60  1.62  840
176    3  14.13  4.10  2.74  24.5   96  ...  0.56  1.35   9.2
0.61  1.60  560
[5 rows x 14 columns]
## Info:
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 177 entries, 0 to 176
Data columns (total 14 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   V1      177 non-null    int64
 1   V2      177 non-null    float64
 2   V3      177 non-null    float64
 3   V4      177 non-null    float64
 4   V5      177 non-null    float64
 5   V6      177 non-null    int64
 6   V7      177 non-null    float64
 7   V8      177 non-null    float64
 8   V9      177 non-null    float64
 9   V10     177 non-null    float64
 10  V11     177 non-null    float64
 11  V12     177 non-null    float64
 12  V13     177 non-null    float64
 13  V14     177 non-null    int64
dtypes: float64(11), int64(3)
```

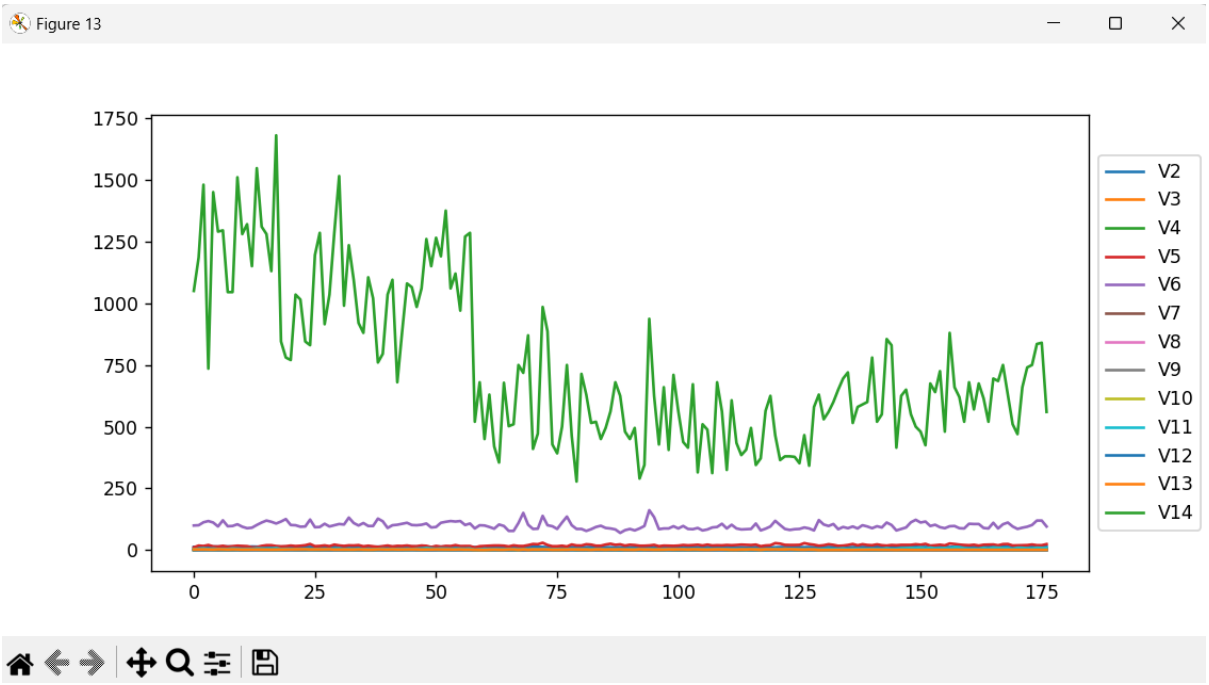
- Plot data for visualization



- Scatterplot with the data points labelled by their Group



- Profile plot, used to shows the variation in each of the variables, by plotting the value of each of the variables for each of the samples



- Calculating summary statistics for multivariate data

Output: → Mean

```
V2       12.993672
V3        2.339887
V4        2.366158
V5       19.516949
V6       99.587571
V7        2.292260
V8        2.023446
V9        0.362316
V10       1.586949
V11       5.054802
V12       0.956983
V13       2.604294
V14     745.096045
```

→ Standard deviation

```
V2        0.806520
V3        1.116148
V4        0.274302
V5        3.326634
V6       14.133922
V7        0.624693
V8        0.995833
V9        0.124300
V10       0.569928
V11       2.317871
V12       0.228487
V13       0.703108
V14     313.993283
```

→ Max

```
V2       14.83
V3        5.80
V4        3.23
V5       30.00
V6      162.00
V7        3.88
V8        5.08
V9        0.66
V10       3.58
V11      13.00
V12       1.71
V13       4.00
V14    1680.00
```

- Means and variances per group

```
## Means:
          V2        V3        V4  ...       V12       V13
V14
V1                                  ...
1   13.736379  2.015862  2.456034  ...  1.062414  3.144655
1116.586207
2   12.278732  1.932676  2.244789  ...  1.056282  2.785352
519.507042
3   13.153750  3.333750  2.437083  ...  0.682708  1.683542
629.895833

[3 rows x 13 columns]

## Standard deviations:
          V2        V3        V4  ...       V12       V13
V14
V1                                  ...
1   0.457635  0.687396  0.227141  ...  0.116446  0.342512
221.418938
2   0.534162  1.008391  0.313238  ...  0.201503  0.493064
156.100173
3   0.524689  1.076514  0.182756  ...  0.113243  0.269262
113.891805

[3 rows x 13 columns]

## Sample sizes:
     0
V1
1   58
2   71
3   48
```

- Standardising variables

```
V2    -5.218675e-16
V3     2.810056e-16
V4    -3.813647e-16
V5    -2.408619e-16
V6    -8.028731e-17
V7    -2.810056e-16
V8     1.605746e-16
V9    -6.021549e-16
V10   -4.014366e-17
V11    1.806465e-16
V12    6.021549e-16
V13    7.225858e-16
V14    1.605746e-16
dtype: float64

V2     1.0
V3     1.0
V4     1.0
V5     1.0
V6     1.0
V7     1.0
V8     1.0
V9     1.0
V10    1.0
V11    1.0
V12    1.0
V13    1.0
V14    1.0
dtype: float64
```

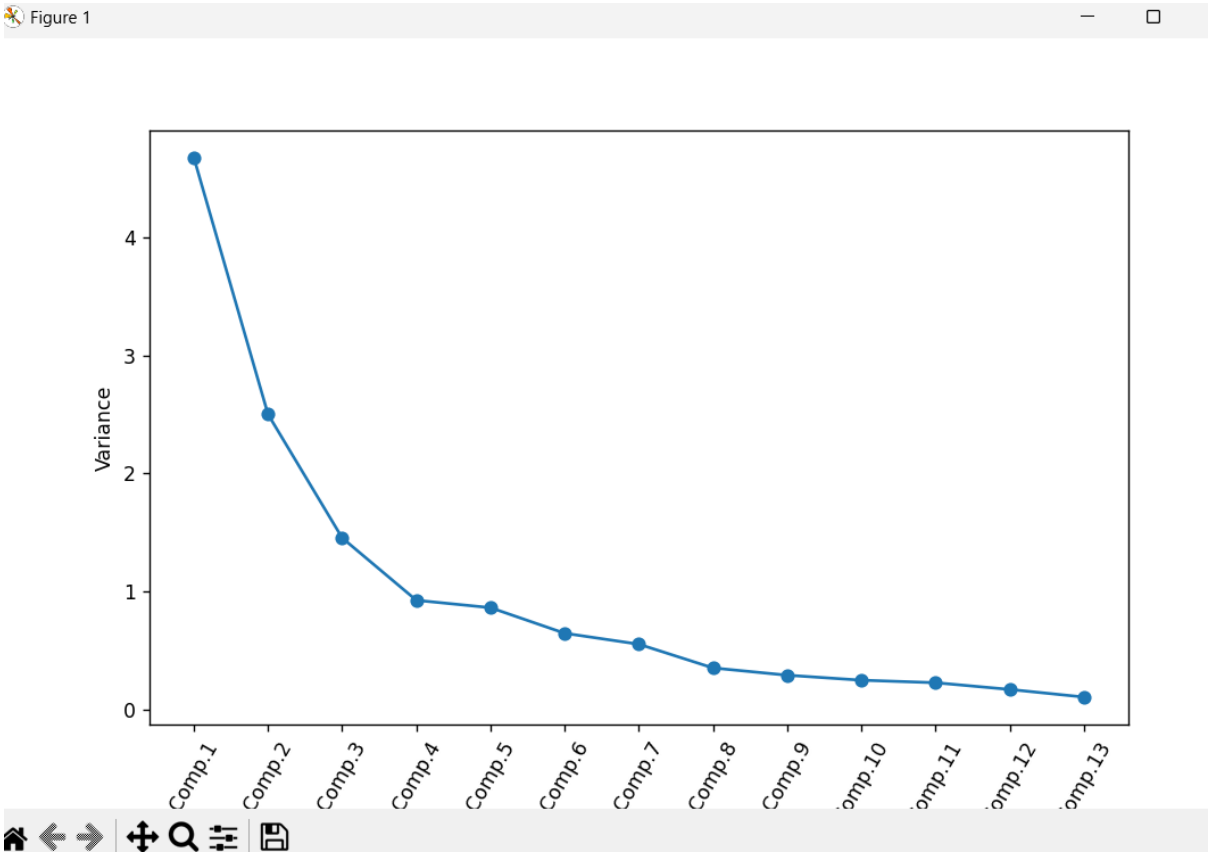
Check the summary of PCA results

Output:

```
Importance of components:
                          sdev                    varprop
cumprop
     Standard deviation Proportion of Variance Cumulative
Proportion
PC1             2.162822                  0.359831
0.359831
PC2             1.581571                  0.192413
0.552244
PC3             1.205541                  0.111795
0.664038
PC4             0.961480                  0.071111
0.735149
PC5             0.928298                  0.066287
0.801437
PC6             0.803024                  0.049604
0.851040
PC7             0.742955                  0.042460
0.893500
PC8             0.592232                  0.026980
0.920480
PC9             0.537755                  0.022245
0.942725
PC10            0.496798                  0.018985
0.961710
PC11            0.474805                  0.017342
0.979052
PC12            0.410337                  0.012952
0.992004
```

```
PC13            0.322412                 0.007996
1.000000
      Standard deviation
PC1              2.162822
PC2              1.581571
PC3              1.205541
PC4              0.961480
PC5              0.928298
PC6              0.803024
PC7              0.742955
PC8              0.592232
PC9              0.537755
PC10             0.496798
PC11             0.474805
PC12             0.410337
PC13             0.322412
Standard deviation    13.0
```

- Check how many principal components to retain



- Calculate the values of the first principal component

Output:

```
[ 0.13788809 -0.24638109 -0.0043183  -0.23737955  0.1350017
0.39586939
  0.42439422 -0.29913568  0.31280321 -0.09328558  0.29956536
0.37720252
  0.28428101]

1.0000000000000002

[ 2.23024297  2.53192196  3.75467731  1.0201307   3.04919938
2.45822831
  2.06160512  2.51844454  2.76797089  3.48916135  1.76638133
2.12870494
  3.46649467  4.31363172  2.30845048  2.16745547  1.90220844
3.54012997
  2.09274066  3.1319081   1.10804505  2.55760384  1.67255267
1.78792909
  1.00222687  1.79246479  1.25516785  2.20313645  2.27398683
2.51223477
  2.68519586  1.64501308  1.90224111  1.42130848  1.92515877
1.39514757
  1.14008674  1.52596172  2.52872196  2.59899338  0.69107085
3.08322733
  0.48029669  2.12234776  1.14107039  2.73816159  2.83615695
2.01759308
  2.7116427   3.23402865  2.87439604  3.51199543  2.2259525
2.15305567
  2.47635157  2.74480414  2.18479692  3.14461992 -0.89347977
-1.51961494
```

```
 -1.81823296  0.05512564  2.09192254 -0.5789596   0.92558177
2.28800128
  0.22876166 -0.80125027  1.99108531 -1.5523202   1.69124851
-0.69605139
  2.58036214  1.86768348 -0.83266108  0.40359327 -1.43101297
1.27464161
  0.4101286   0.81320276  1.07017169 -0.44937791 -2.51731021
0.86981672
  0.82262339 -0.76802261 -0.51110168 -1.07453318 -0.50399535
-1.31124431
 -1.52773342 -1.90072666  0.79056143  0.9989761   2.54738234
-0.53118357
  1.07397322  2.29024085  1.45409066  0.8375519  -0.51305733
-0.12723061
 -0.61536912  0.43497615 -1.73444494 -0.32427811 -1.5888709
0.123098
  1.61791755  1.45726543 -0.23890288 -1.27665922 -0.41499111
-0.45065081
  0.54139419 -0.20498599 -0.0729984  -2.40448838 -0.50815969
0.77987484
  1.36652399 -1.14506231 -0.42827684  1.0247241  -0.05143996
0.07538255
 -1.55993845 -0.43841321 -1.755462   -1.32428406 -2.37655439
-2.92579835
 -2.13716639 -2.35121439 -3.0531239  -3.89923965 -3.92146674
-3.08235716
 -2.35895565 -2.764957   -2.27351064 -2.97458054 -2.36193359
-2.20681631
 -2.61743092 -4.27191366 -3.57327927 -2.80423095 -2.90607992
-2.33247599
 -2.55578663 -1.81375585 -2.76500454 -2.73013413 -3.60242822
-2.89083274
 -3.38308624 -1.06059682 -1.61171861 -3.12911042 -2.23928358
-2.83779448
 -2.59226184 -2.94879996 -3.52184398 -2.41581922 -2.92351427
-2.18547501
 -2.38683089 -3.19522322 -3.67033271 -2.47138831 -3.37288802
-2.60215457
 -2.69214577 -2.39839363 -3.21585159]

[ 2.23024297  2.53192196  3.75467731  1.0201307   3.04919938
2.45822831
  2.06160512  2.51844454  2.76797089  3.48916135  1.76638133
2.12870494
  3.46649467  4.31363172  2.30845048  2.16745547  1.90220844
3.54012997
  2.09274066  3.1319081   1.10804505  2.55760384  1.67255267
1.78792909
  1.00222687  1.79246479  1.25516785  2.20313645  2.27398683
2.51223477
  2.68519586  1.64501308  1.90224111  1.42130848  1.92515877
1.39514757
  1.14008674  1.52596172  2.52872196  2.59899338  0.69107085
3.08322733
  0.48029669  2.12234776  1.14107039  2.73816159  2.83615695
2.01759308
  2.7116427   3.23402865  2.87439604  3.51199543  2.2259525
2.15305567
```

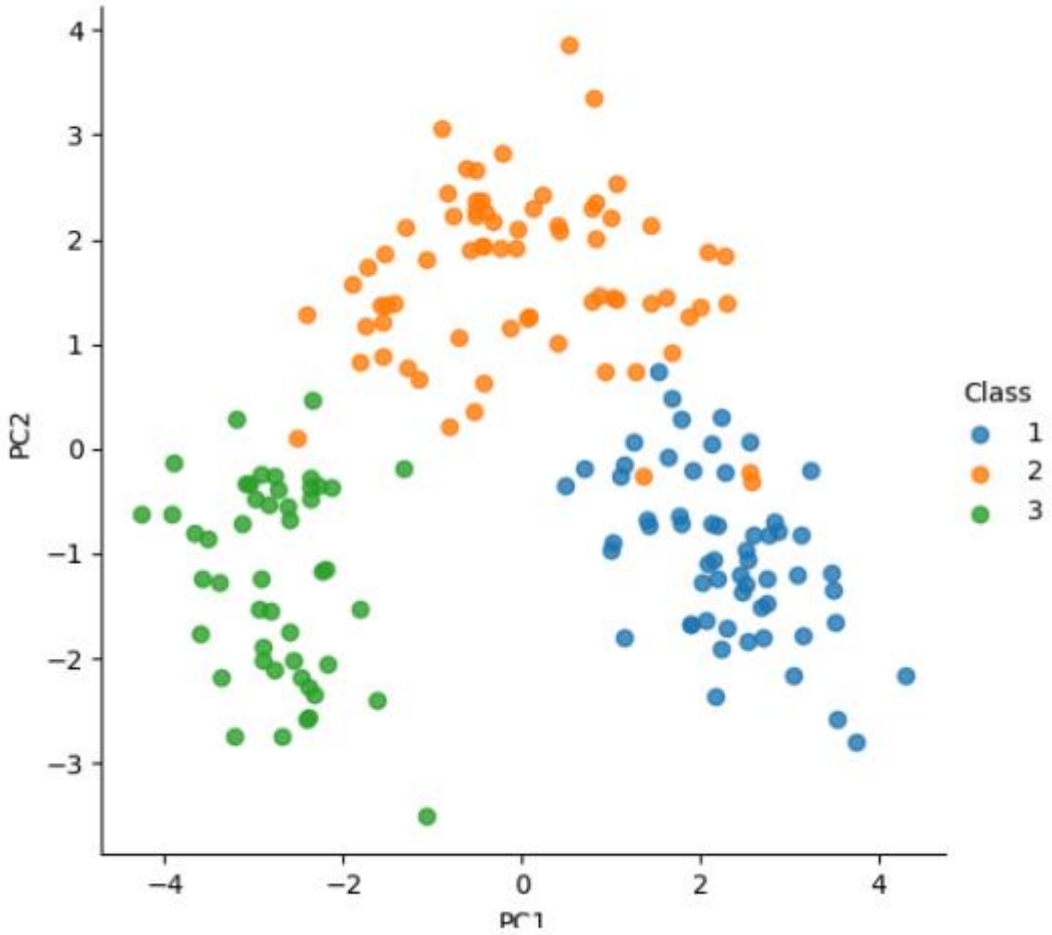
```
  2.47635157  2.74480414  2.18479692  3.14461992 -0.89347977
-1.51961494
 -1.81823296  0.05512564  2.09192254 -0.5789596   0.92558177
2.28800128
  0.22876166 -0.80125027  1.99108531 -1.5523202   1.69124851
-0.69605139
  2.58036214  1.86768348 -0.83266108  0.40359327 -1.43101297
1.27464161
  0.4101286   0.81320276  1.07017169 -0.44937791 -2.51731021
0.86981672
  0.82262339 -0.76802261 -0.51110168 -1.07453318 -0.50399535
-1.31124431
 -1.52773342 -1.90072666  0.79056143  0.9989761   2.54738234
-0.53118357
  1.07397322  2.29024085  1.45409066  0.8375519  -0.51305733
-0.12723061
 -0.61536912  0.43497615 -1.73444494 -0.32427811 -1.5888709
0.123098
  1.61791755  1.45726543 -0.23890288 -1.27665922 -0.41499111
-0.45065081
  0.54139419 -0.20498599 -0.0729984  -2.40448838 -0.50815969
0.77987484
  1.36652399 -1.14506231 -0.42827684  1.0247241  -0.05143996
0.07538255
 -1.55993845 -0.43841321 -1.755462   -1.32428406 -2.37655439
-2.92579835
 -2.13716639 -2.35121439 -3.0531239  -3.89923965 -3.92146674
-3.08235716
 -2.35895565 -2.764957   -2.27351064 -2.97458054 -2.36193359
-2.20681631
 -2.61743092 -4.27191366 -3.57327927 -2.80423095 -2.90607992
-2.33247599
 -2.55578663 -1.81375585 -2.76500454 -2.73013413 -3.60242822
-2.89083274
 -3.38308624 -1.06059682 -1.61171861 -3.12911042 -2.23928358
-2.83779448
 -2.59226184 -2.94879996 -3.52184398 -2.41581922 -2.92351427
-2.18547501
 -2.38683089 -3.19522322 -3.67033271 -2.47138831 -3.37288802
-2.60215457
 -2.69214577 -2.39839363 -3.21585159]
[-0.48583464 -0.22157478 -0.31528188  0.01214349 -0.30028828
-0.07054905
 -0.00173207 -0.02466918 -0.04144561 -0.52801878  0.27405069
0.16544914
 -0.3695384 ]

1.0000000000000001
```

- Obtain the loadings for the second principal component

Output:

```
[-0.48583464 -0.22157478 -0.31528188  0.01214349 -0.30028828
-0.07054905
 -0.00173207 -0.02466918 -0.04144561 -0.52801878  0.27405069
0.16544914
 -0.3695384 ]
1.000000000000001
```

- Visualize scatterplots of the principal components



- Get mean, standard deviations, and sample sizes

Output:

```
## Means:
          V2        V3        V4  ...       V12       V13
V14
V1                                  ...
1    0.920878 -0.290306  0.327654  ...  0.461430  0.768532
1.183115
2   -0.886450 -0.364836 -0.442466  ...  0.434592  0.257511
-0.718452
3    0.198479  0.890440  0.258566  ... -1.200396 -1.309545
-0.366888

[3 rows x 13 columns]

## Standard deviations:
          V2        V3        V4  ...       V12       V13
V14
V1                                  ...
1    0.567419  0.615865  0.828067  ...  0.50964  0.487140
0.705171
2    0.662305  0.903457  1.141944  ...  0.88190  0.701263
0.497145
3    0.650559  0.964490  0.666258  ...  0.49562  0.382960
0.362721

[3 rows x 13 columns]

## Sample sizes:
     0
V1
1   58
2   71
3   48
```

-Scatter plot of LDA components

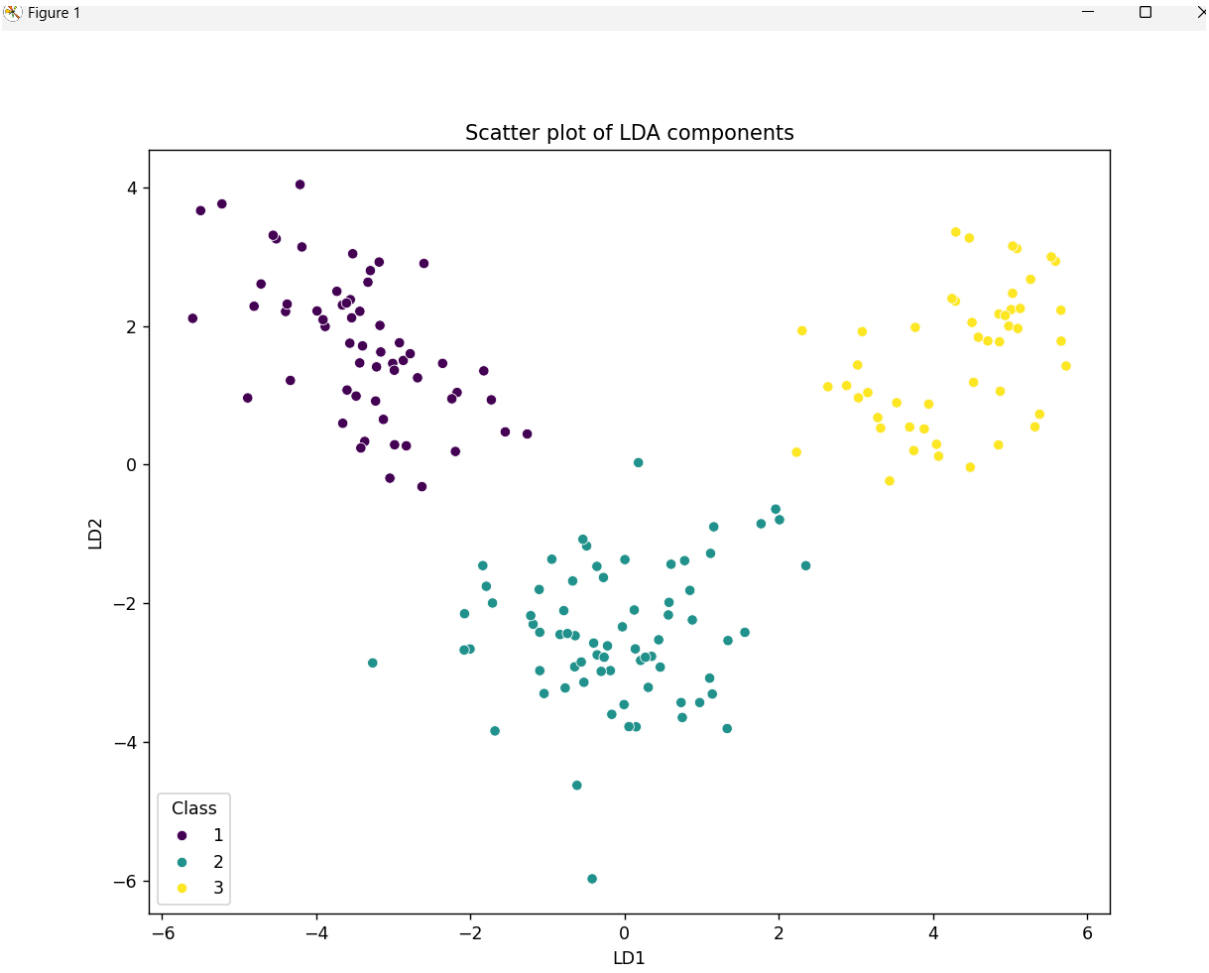


Figure 1
Scatter plot of LDA components
LD2
LD1
Class
1
2
3
4
2
0
−2
−4
−6
−6
−4
−2
0
2
4
6

```
Explained variance ratio: [0.68786128 0.31213872]
Coefficients of the linear discriminants:
[[-0.32852651  0.7031932 ]
 [ 0.19127318  0.33887802]
 [-0.09623441  0.64277973]
 [ 0.51693438 -0.48962779]
 [-0.0427306  -0.00777917]
 [ 0.39565753 -0.02230197]
 [-1.65189378 -0.47313781]
 [-0.19399225 -0.2013789 ]
 [ 0.07095482 -0.17578607]
 [ 0.82422089  0.57771039]
 [-0.18568503 -0.34327374]
 [-0.83747766  0.04017052]
 [-0.82867011  0.90234381]]
Group means:
         V2        V3        V4  ...       V12       V13       V14
0  0.920878 -0.290306  0.327654  ...  0.461430  0.768532  1.183115
1 -0.886450 -0.364836 -0.442466  ...  0.434592  0.257511 -0.718452
2  0.198479  0.890440  0.258566  ... -1.200396 -1.309545 -0.366888

[3 rows x 13 columns]
Group sizes:
   Group Size
1    0.327684
2    0.401130
3    0.271186
```