

# ML\_Assignment\_2\_Task\_2\_SalehAlkhailfa

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## 1 Assignment 2 - Task 2

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### 1.0.1 1. Import Libraries:

```
[269]: import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
import numpy as np
from sklearn.preprocessing import StandardScaler
from sklearn.model_selection import train_test_split
from sklearn.decomposition import PCA
from sklearn.metrics import classification_report
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, roc_auc_score
from sklearn.naive_bayes import GaussianNB
from sklearn.discriminant_analysis import LinearDiscriminantAnalysis, QuadraticDiscriminantAnalysis
from sklearn.linear_model import LogisticRegression, Perceptron
from sklearn.metrics import roc_curve
```

### 1.0.2 2. Import Data:

```
[270]: # col names
columns = ['ID', 'Diagnosis', 'Radius_mean', 'Texture_mean', 'Perimeter_mean', 'Area_mean', 'Smoothness_mean',
```

```

'Compactness_mean', 'Concavity_mean', 'Concave_points_mean', ↵
↳ 'Symmetry_mean', 'Fractal_dimension_mean',
    'Radius_se', 'Texture_se', 'Perimeter_se', 'Area_se', ↵
↳ 'Smoothness_se', 'Compactness_se', 'Concavity_se',
    'Concave_points_se', 'Symmetry_se', 'Fractal_dimension_se', ↵
↳ 'Radius_worst', 'Texture_worst',
    'Perimeter_worst', 'Area_worst', 'Smoothness_worst', ↵
↳ 'Compactness_worst', 'Concavity_worst',
    'Concave_points_worst', 'Symmetry_worst', 'Fractal_dimension_worst']

# load data
data = pd.read_csv('wdbc.data', header=None, names=columns)
data = data.drop(columns=['ID'])
data['Diagnosis'] = data['Diagnosis'].map({'M': 1, 'B': 0})

# Check the dataset we imported
print(data.shape)
data.head()

```

(569, 31)

```
[270]:   Diagnosis  Radius_mean  Texture_mean  Perimeter_mean  Area_mean  \
0          1        17.99       10.38        122.80      1001.0
1          1        20.57       17.77        132.90      1326.0
2          1        19.69       21.25        130.00      1203.0
3          1        11.42       20.38        77.58       386.1
4          1        20.29       14.34        135.10      1297.0

  Smoothness_mean  Compactness_mean  Concavity_mean  Concave_points_mean  \
0        0.11840        0.27760        0.3001        0.14710
1        0.08474        0.07864        0.0869        0.07017
2        0.10960        0.15990        0.1974        0.12790
3        0.14250        0.28390        0.2414        0.10520
4        0.10030        0.13280        0.1980        0.10430

  Symmetry_mean  ...  Radius_worst  Texture_worst  Perimeter_worst  \
0        0.2419  ...        25.38       17.33        184.60
1        0.1812  ...        24.99       23.41        158.80
2        0.2069  ...        23.57       25.53        152.50
3        0.2597  ...        14.91       26.50         98.87
4        0.1809  ...        22.54       16.67        152.20

  Area_worst  Smoothness_worst  Compactness_worst  Concavity_worst  \
0      2019.0        0.1622        0.6656        0.7119
1      1956.0        0.1238        0.1866        0.2416
2      1709.0        0.1444        0.4245        0.4504
3       567.7        0.2098        0.8663        0.6869
```

4	1575.0	0.1374	0.2050	0.4000
	Concave_points_worst	Symmetry_worst	Fractal_dimension_worst	
0	0.2654	0.4601	0.11890	
1	0.1860	0.2750	0.08902	
2	0.2430	0.3613	0.08758	
3	0.2575	0.6638	0.17300	
4	0.1625	0.2364	0.07678	

[5 rows x 31 columns]

```
[271]: # Check for null values
print(data.isnull().sum())
```

Diagnosis	0
Radius_mean	0
Texture_mean	0
Perimeter_mean	0
Area_mean	0
Smoothness_mean	0
Compactness_mean	0
Concavity_mean	0
Concave_points_mean	0
Symmetry_mean	0
Fractal_dimension_mean	0
Radius_se	0
Texture_se	0
Perimeter_se	0
Area_se	0
Smoothness_se	0
Compactness_se	0
Concavity_se	0
Concave_points_se	0
Symmetry_se	0
Fractal_dimension_se	0
Radius_worst	0
Texture_worst	0
Perimeter_worst	0
Area_worst	0
Smoothness_worst	0
Compactness_worst	0
Concavity_worst	0
Concave_points_worst	0
Symmetry_worst	0
Fractal_dimension_worst	0
dtype: int64	

```
[272]: data.describe()
# Check the basic statistics of the dataset
```

	Diagnosis	Radius_mean	Texture_mean	Perimeter_mean	Area_mean	\
count	569.000000	569.000000	569.000000	569.000000	569.000000	
mean	0.372583	14.127292	19.289649	91.969033	654.889104	
std	0.483918	3.524049	4.301036	24.298981	351.914129	
min	0.000000	6.981000	9.710000	43.790000	143.500000	
25%	0.000000	11.700000	16.170000	75.170000	420.300000	
50%	0.000000	13.370000	18.840000	86.240000	551.100000	
75%	1.000000	15.780000	21.800000	104.100000	782.700000	
max	1.000000	28.110000	39.280000	188.500000	2501.000000	
	Smoothness_mean	Compactness_mean	Concavity_mean	Concave_points_mean	\	
count	569.000000	569.000000	569.000000	569.000000		
mean	0.096360	0.104341	0.088799	0.048919		
std	0.014064	0.052813	0.079720	0.038803		
min	0.052630	0.019380	0.000000	0.000000		
25%	0.086370	0.064920	0.029560	0.020310		
50%	0.095870	0.092630	0.061540	0.033500		
75%	0.105300	0.130400	0.130700	0.074000		
max	0.163400	0.345400	0.426800	0.201200		
	Symmetry_mean	...	Radius_worst	Texture_worst	Perimeter_worst	\
count	569.000000	...	569.000000	569.000000	569.000000	
mean	0.181162	...	16.269190	25.677223	107.261213	
std	0.027414	...	4.833242	6.146258	33.602542	
min	0.106000	...	7.930000	12.020000	50.410000	
25%	0.161900	...	13.010000	21.080000	84.110000	
50%	0.179200	...	14.970000	25.410000	97.660000	
75%	0.195700	...	18.790000	29.720000	125.400000	
max	0.304000	...	36.040000	49.540000	251.200000	
	Area_worst	Smoothness_worst	Compactness_worst	Concavity_worst	\	
count	569.000000	569.000000	569.000000	569.000000		
mean	880.583128	0.132369	0.254265	0.272188		
std	569.356993	0.022832	0.157336	0.208624		
min	185.200000	0.071170	0.027290	0.000000		
25%	515.300000	0.116600	0.147200	0.114500		
50%	686.500000	0.131300	0.211900	0.226700		
75%	1084.000000	0.146000	0.339100	0.382900		
max	4254.000000	0.222600	1.058000	1.252000		
	Concave_points_worst	Symmetry_worst	Fractal_dimension_worst			
count	569.000000	569.000000	569.000000			
mean	0.114606	0.290076	0.083946			
std	0.065732	0.061867	0.018061			

min	0.000000	0.156500	0.055040
25%	0.064930	0.250400	0.071460
50%	0.099930	0.282200	0.080040
75%	0.161400	0.317900	0.092080
max	0.291000	0.663800	0.207500

[8 rows x 31 columns]

### 1.0.3 3. Exploratory Data Analysis:

```
[273]: class EDA:
    def __init__(self, data, target_column):
        """
        Initialize EDA class with a dataset and the target variable to explore and understand what the data looks like
        """
        self.data = data
        self.target_column = target_column
        self.X = self.data.drop(columns=[self.target_column])
        self.y = self.data[self.target_column]
        self.scaled_data = None
        self.remaining_columns = self.X.columns

    def dataset_overview(self):
        """
        Display basic info and stats
        """
        print(f"Dataset Shape: {self.data.shape}")
        print(self.data.info())
        print(self.data.describe())
        print(self.data.head())
        print(f"Missing Vals:\n{self.data.isnull().sum()}")
        print(f"Class Dist:\n{self.data[self.target_column].value_counts()}")

        sns.countplot(x=self.target_column, data=self.data)
        plt.title('Class Distribution')
        plt.show()

    def univariate_analysis(self, features=None):
        """
        Plot histograms of features
        """
        if features is None:
            features = self.data.columns

        # Plot the histograms
        self.data[features].hist(bins=30, figsize=(20, 15))
```

```

plt.suptitle('Histograms of Features / Cols')
plt.show()

def boxplot_features(self, features):
    """
    Plot box plots for selected features
    """
    plt.figure(figsize=(12, 8))
    sns.boxplot(data=self.data[features])
    plt.xticks(rotation=90)
    plt.title('Boxplots of Selected Features')
    plt.show()

def bivariate_analysis(self, feature1, feature2):
    """
    Plot a scatter plot for two features
    """
    plt.figure(figsize=(8, 6))
    sns.scatterplot(x=feature1, y=feature2, hue=self.target_column,
                    data=self.data)
    plt.title(f'Scatter Plot of {feature1} vs {feature2}')
    plt.show()

def boxplot_by_target(self, feature):
    """
    Create boxplots to show feature distribution
    """
    plt.figure(figsize=(10, 6))
    sns.boxplot(x=self.target_column, y=feature, data=self.data)
    plt.title(f'Boxplot of {feature} by {self.target_column}')
    plt.show()

def correlation_matrix(self):
    """
    plot a heatmap of the correlation matrix
    """
    plt.figure(figsize=(20, 15))
    corr_matrix = self.data.corr()
    sns.heatmap(corr_matrix, annot=True, cmap='coolwarm', fmt='.2f')
    plt.title('Correlation Matrix')
    plt.show()

def check_multicollinearity(self, threshold=0.75):
    """
    Check for multicollinearity and remove correlated cols based on
    threshold
    """

```

```

# Calc correaltion
corr_matrix = self.data.corr().abs()
upper_tri = corr_matrix.where(np.triu(np.ones(corr_matrix.shape), k=1).
                             astype(bool))
to_drop = [column for column in upper_tri.columns if
any(upper_tri[column] > threshold)]

# Drop the features from X
self.X = self.X.drop(columns=to_drop)
self.remaining_columns = self.X.columns

print(f"Features to drop: {to_drop}")
return to_drop

def pairplot(self, features=None):
    """
    Plot pairwise relationships
    """
    if features is None:
        features = self.data.columns

    # Get selected features
    selected_features = features.tolist() if isinstance(features, pd.Index) else features
    if self.target_column not in selected_features:
        selected_features.append(self.target_column)

    # plot the pair plot and color by taget
    sns.pairplot(self.data[selected_features], hue=self.target_column)
    plt.suptitle('Pair Plot of Selected Features')
    plt.show()

def violin_plot(self, features):
    """
    Create violin plots to show the distribution
    """
    for feature in features:
        plt.figure(figsize=(10, 6))
        sns.violinplot(x=self.target_column, y=feature, data=self.data)
        plt.title(f'Violin Plot of {feature} by {self.target_column}')
        plt.show()

def scale_data(self):
    """
    Scale the dataset features using StandardScaler

```

```

"""
scaler = StandardScaler()
self.scaled_data = pd.DataFrame(scaler.fit_transform(self.X), columns=self.remaining_columns)
print(f"Scaled data sample:\n{self.scaled_data.head()}")


def split_data(self, test_size=0.2, random_state=42):
"""
Split the dataset into training and test sets
"""

if self.scaled_data is None:
    print("> Error: Scale before splitting.")
    return None, None, None

X_train, X_test, y_train, y_test = train_test_split(self.scaled_data, self.y, test_size=test_size, random_state=random_state)
return X_train, X_test, y_train, y_test


def split_data_with_pca(self, n_components, test_size=0.2, random_state=42):
"""
Split the dataset into training and test sets using PCA
"""

if self.scaled_data is None:
    print("> Error: Scale before split.")
    return None, None, None

# Apply PCA to reduce dims
pca = PCA(n_components=n_components)
X_pca = pca.fit_transform(self.scaled_data)

# Split data into train, test, and return
X_train_pca, X_test_pca, y_train, y_test = train_test_split(X_pca, self.y, test_size=test_size, random_state=random_state)
return X_train_pca, X_test_pca, y_train, y_test

```

```

[274]: columns = ['ID', 'Diagnosis', 'Radius_mean', 'Texture_mean', 'Perimeter_mean', 'Area_mean', 'Smoothness_mean', 'Compactness_mean', 'Concavity_mean', 'Concave_points_mean', 'Symmetry_mean', 'Fractal_dimension_mean', 'Radius_se', 'Texture_se', 'Perimeter_se', 'Area_se', 'Smoothness_se', 'Compactness_se', 'Concavity_se', 'Concave_points_se', 'Symmetry_se', 'Fractal_dimension_se', 'Radius_worst', 'Texture_worst', 'Perimeter_worst', 'Area_worst', 'Smoothness_worst', 'Compactness_worst', 'Concavity_worst', 'Concave_points_worst', 'Symmetry_worst', 'Fractal_dimension_worst']

```

```

data = pd.read_csv('wdbc.data', header=None, names=columns)
data = data.drop(columns=['ID'])
data['Diagnosis'] = data['Diagnosis'].map({'M': 1, 'B': 0})

```

[275]: # init eda  
`eda = EDA(data, target_column='Diagnosis')`

[276]: # Overview of dataset. This shows us that there is a slight imbalance, but since we are talking about diagnosis, I will make the assumption that this distribution is a true representation of real-life, and I will actively not rebalance it.  
`eda.dataset_overview()`

Dataset Shape: (569, 31)  
<class 'pandas.core.frame.DataFrame'>  
RangeIndex: 569 entries, 0 to 568  
Data columns (total 31 columns):

#	Column	Non-Null Count	Dtype
0	Diagnosis	569 non-null	int64
1	Radius_mean	569 non-null	float64
2	Texture_mean	569 non-null	float64
3	Perimeter_mean	569 non-null	float64
4	Area_mean	569 non-null	float64
5	Smoothness_mean	569 non-null	float64
6	Compactness_mean	569 non-null	float64
7	Concavity_mean	569 non-null	float64
8	Concave_points_mean	569 non-null	float64
9	Symmetry_mean	569 non-null	float64
10	Fractal_dimension_mean	569 non-null	float64
11	Radius_se	569 non-null	float64
12	Texture_se	569 non-null	float64
13	Perimeter_se	569 non-null	float64
14	Area_se	569 non-null	float64
15	Smoothness_se	569 non-null	float64
16	Compactness_se	569 non-null	float64
17	Concavity_se	569 non-null	float64
18	Concave_points_se	569 non-null	float64
19	Symmetry_se	569 non-null	float64
20	Fractal_dimension_se	569 non-null	float64
21	Radius_worst	569 non-null	float64
22	Texture_worst	569 non-null	float64
23	Perimeter_worst	569 non-null	float64
24	Area_worst	569 non-null	float64
25	Smoothness_worst	569 non-null	float64
26	Compactness_worst	569 non-null	float64
27	Concavity_worst	569 non-null	float64

```

28 Concave_points_worst      569 non-null      float64
29 Symmetry_worst           569 non-null      float64
30 Fractal_dimension_worst  569 non-null      float64
dtypes: float64(30), int64(1)
memory usage: 137.9 KB
None
   Diagnosis    Radius_mean  Texture_mean  Perimeter_mean  Area_mean \
count  569.000000  569.000000  569.000000  569.000000  569.000000
mean   0.372583  14.127292  19.289649  91.969033  654.889104
std    0.483918  3.524049   4.301036  24.298981  351.914129
min   0.000000  6.981000  9.710000  43.790000  143.500000
25%  0.000000  11.700000  16.170000  75.170000  420.300000
50%  0.000000  13.370000  18.840000  86.240000  551.100000
75%  1.000000  15.780000  21.800000  104.100000 782.700000
max   1.000000  28.110000  39.280000  188.500000 2501.000000

   Smoothness_mean  Compactness_mean  Concavity_mean  Concave_points_mean \
count  569.000000          569.000000          569.000000          569.000000
mean   0.096360          0.104341          0.088799          0.048919
std    0.014064          0.052813          0.079720          0.038803
min   0.052630          0.019380          0.000000          0.000000
25%  0.086370          0.064920          0.029560          0.020310
50%  0.095870          0.092630          0.061540          0.033500
75%  0.105300          0.130400          0.130700          0.074000
max   0.163400          0.345400          0.426800          0.201200

   Symmetry_mean ...  Radius_worst  Texture_worst  Perimeter_worst \
count  569.000000 ...  569.000000  569.000000  569.000000
mean   0.181162 ...  16.269190  25.677223  107.261213
std    0.027414 ...  4.833242  6.146258  33.602542
min   0.106000 ...  7.930000  12.020000  50.410000
25%  0.161900 ...  13.010000  21.080000  84.110000
50%  0.179200 ...  14.970000  25.410000  97.660000
75%  0.195700 ...  18.790000  29.720000  125.400000
max   0.304000 ...  36.040000  49.540000  251.200000

   Area_worst  Smoothness_worst  Compactness_worst  Concavity_worst \
count  569.000000  569.000000  569.000000  569.000000
mean   880.583128  0.132369  0.254265  0.272188
std    569.356993  0.022832  0.157336  0.208624
min   185.200000  0.071170  0.027290  0.000000
25%  515.300000  0.116600  0.147200  0.114500
50%  686.500000  0.131300  0.211900  0.226700
75% 1084.000000  0.146000  0.339100  0.382900
max  4254.000000  0.222600  1.058000  1.252000

   Concave_points_worst  Symmetry_worst  Fractal_dimension_worst
count  569.000000  569.000000  569.000000

```

mean	0.114606	0.290076	0.083946
std	0.065732	0.061867	0.018061
min	0.000000	0.156500	0.055040
25%	0.064930	0.250400	0.071460
50%	0.099930	0.282200	0.080040
75%	0.161400	0.317900	0.092080
max	0.291000	0.663800	0.207500

[8 rows x 31 columns]

	Diagnosis	Radius_mean	Texture_mean	Perimeter_mean	Area_mean	\
0	1	17.99	10.38	122.80	1001.0	
1	1	20.57	17.77	132.90	1326.0	
2	1	19.69	21.25	130.00	1203.0	
3	1	11.42	20.38	77.58	386.1	
4	1	20.29	14.34	135.10	1297.0	

	Smoothness_mean	Compactness_mean	Concavity_mean	Concave_points_mean	\
0	0.11840	0.27760	0.3001	0.14710	
1	0.08474	0.07864	0.0869	0.07017	
2	0.10960	0.15990	0.1974	0.12790	
3	0.14250	0.28390	0.2414	0.10520	
4	0.10030	0.13280	0.1980	0.10430	

	Symmetry_mean	...	Radius_worst	Texture_worst	Perimeter_worst	\
0	0.2419	...	25.38	17.33	184.60	
1	0.1812	...	24.99	23.41	158.80	
2	0.2069	...	23.57	25.53	152.50	
3	0.2597	...	14.91	26.50	98.87	
4	0.1809	...	22.54	16.67	152.20	

	Area_worst	Smoothness_worst	Compactness_worst	Concavity_worst	\
0	2019.0	0.1622	0.6656	0.7119	
1	1956.0	0.1238	0.1866	0.2416	
2	1709.0	0.1444	0.4245	0.4504	
3	567.7	0.2098	0.8663	0.6869	
4	1575.0	0.1374	0.2050	0.4000	

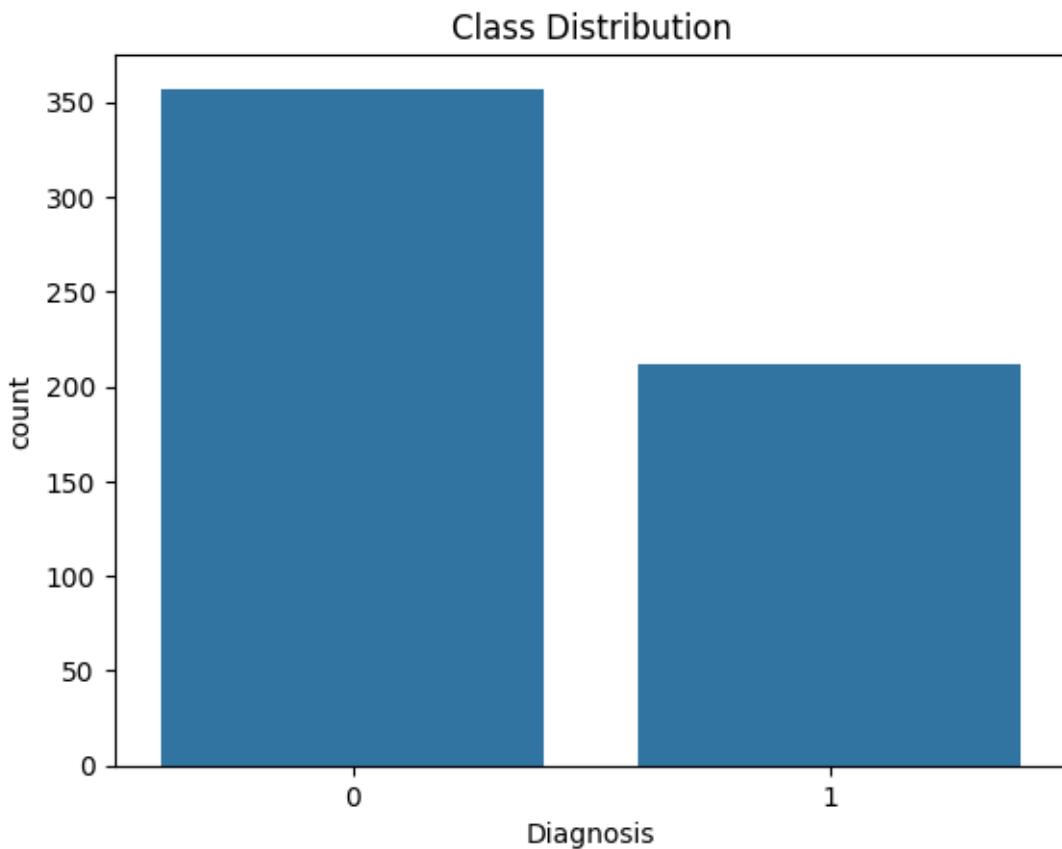
	Concave_points_worst	Symmetry_worst	Fractal_dimension_worst	
0	0.2654	0.4601	0.11890	
1	0.1860	0.2750	0.08902	
2	0.2430	0.3613	0.08758	
3	0.2575	0.6638	0.17300	
4	0.1625	0.2364	0.07678	

[5 rows x 31 columns]

Missing Vals:

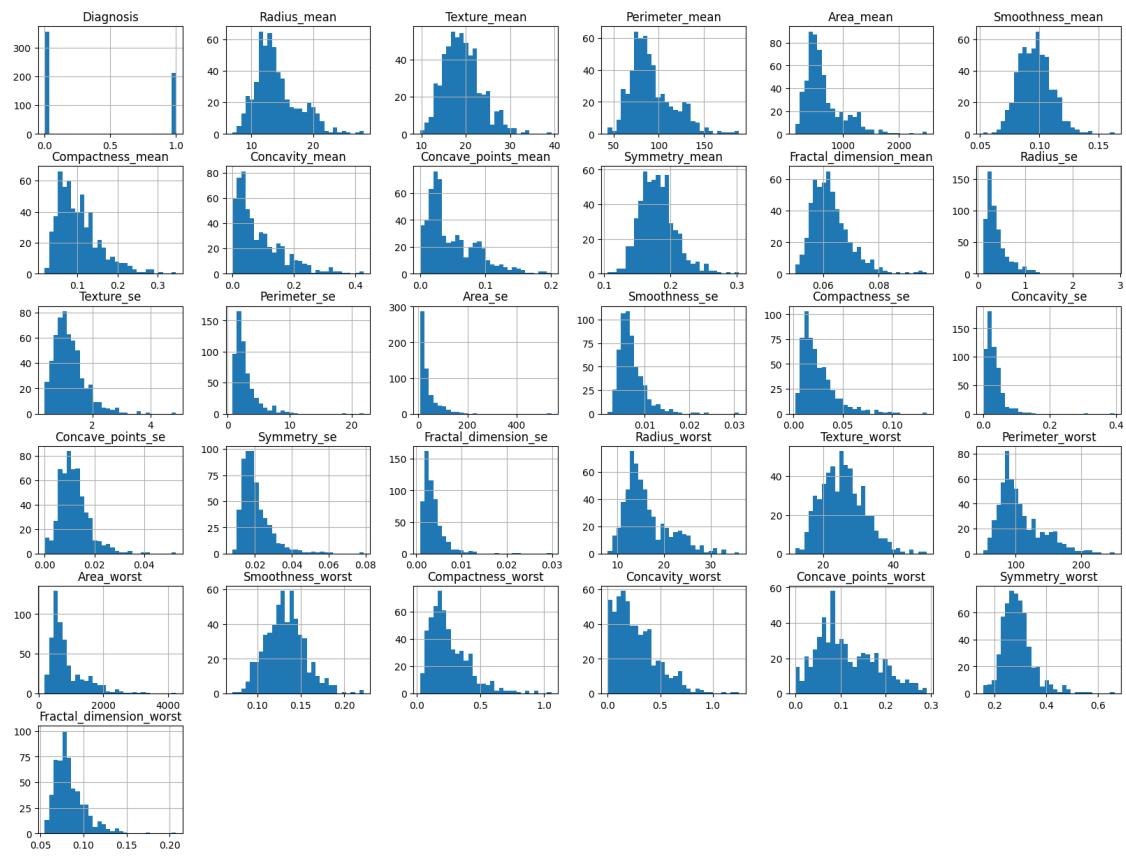
Diagnosis	0
Radius_mean	0

```
Texture_mean          0
Perimeter_mean        0
Area_mean             0
Smoothness_mean       0
Compactness_mean      0
Concavity_mean        0
Concave_points_mean   0
Symmetry_mean         0
Fractal_dimension_mean 0
Radius_se              0
Texture_se              0
Perimeter_se            0
Area_se                0
Smoothness_se            0
Compactness_se           0
Concavity_se             0
Concave_points_se        0
Symmetry_se              0
Fractal_dimension_se     0
Radius_worst             0
Texture_worst            0
Perimeter_worst          0
Area_worst               0
Smoothness_worst          0
Compactness_worst         0
Concavity_worst            0
Concave_points_worst       0
Symmetry_worst             0
Fractal_dimension_worst     0
dtype: int64
Class Dist:
Diagnosis
0    357
1    212
Name: count, dtype: int64
```

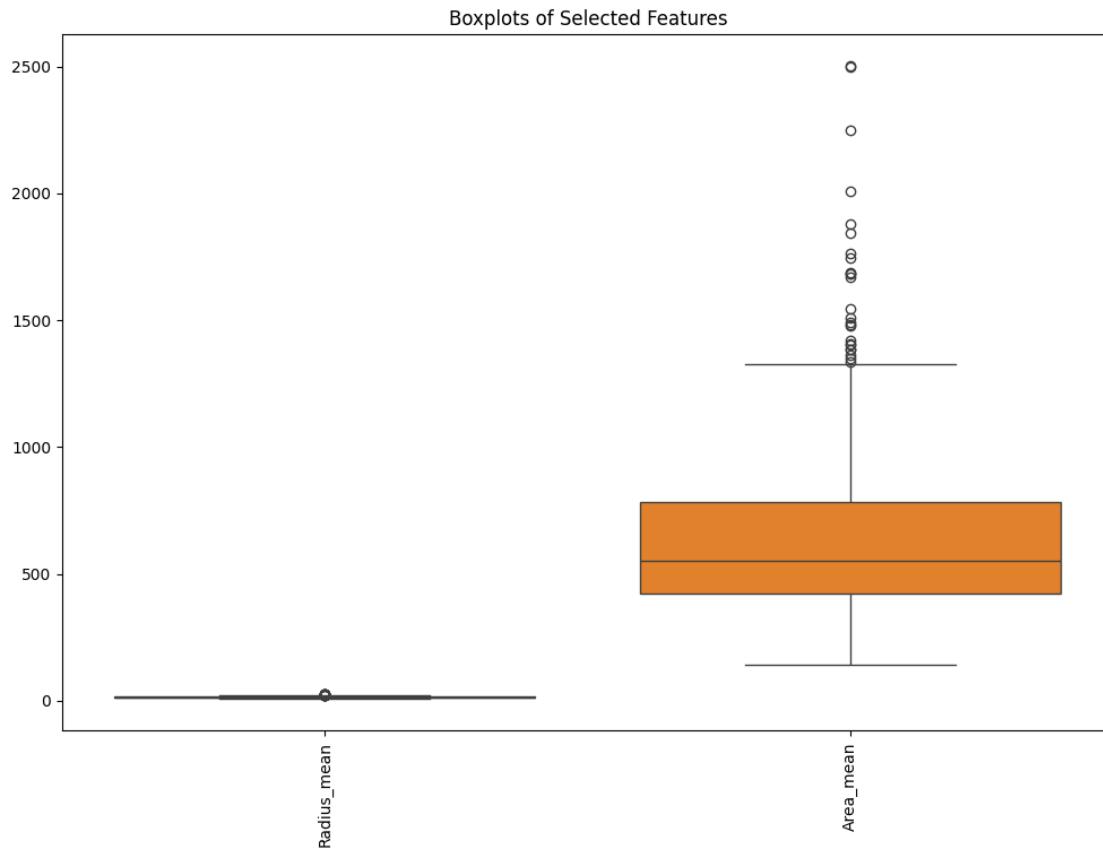


```
[277]: # We see a good distribution of data within the features. We will need to scale them to ensure the models can appropriately converge.  
eda.univariate_analysis()
```

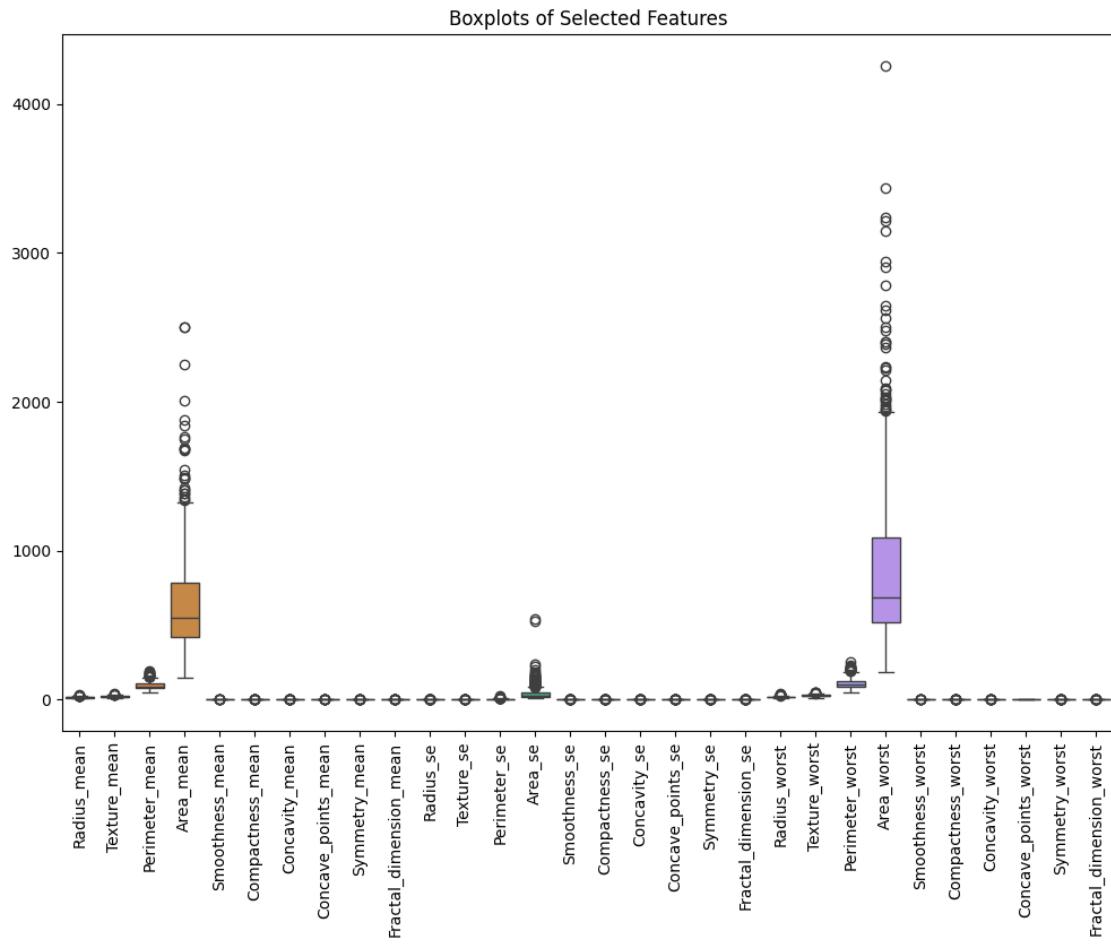
Histograms of Features / Cols



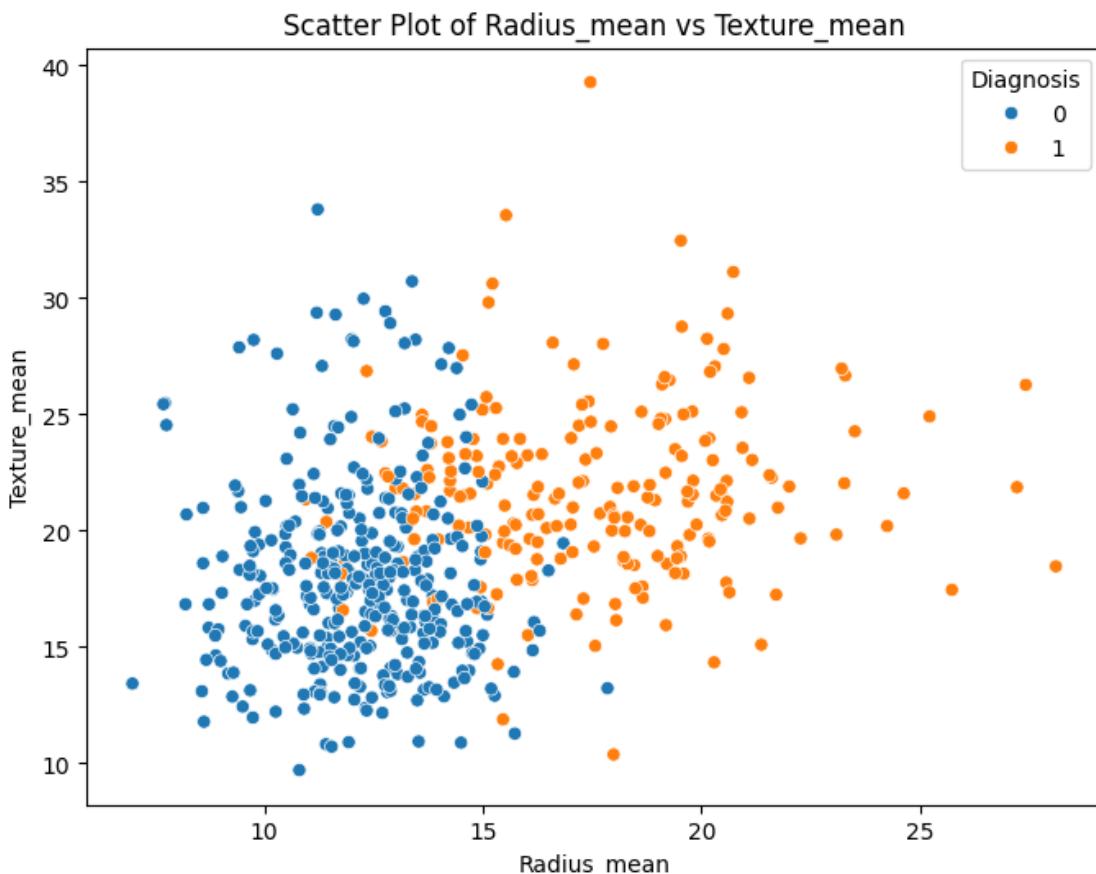
```
[278]: # Boxplots show the difference in distributions of the features  
eda.boxplot_features(['Radius_mean', 'Area_mean'])
```



```
[279]: eda.boxplot_features(['Radius_mean', 'Texture_mean', 'Perimeter_mean',
                           'Area_mean', 'Smoothness_mean',
                           'Compactness_mean', 'Concavity_mean', 'Concave_points_mean',
                           'Symmetry_mean', 'Fractal_dimension_mean',
                           'Radius_se', 'Texture_se', 'Perimeter_se', 'Area_se',
                           'Smoothness_se', 'Compactness_se', 'Concavity_se',
                           'Concave_points_se', 'Symmetry_se', 'Fractal_dimension_se',
                           'Radius_worst', 'Texture_worst',
                           'Perimeter_worst', 'Area_worst', 'Smoothness_worst',
                           'Compactness_worst', 'Concavity_worst',
                           'Concave_points_worst', 'Symmetry_worst', 'Fractal_dimension_worst'])
```

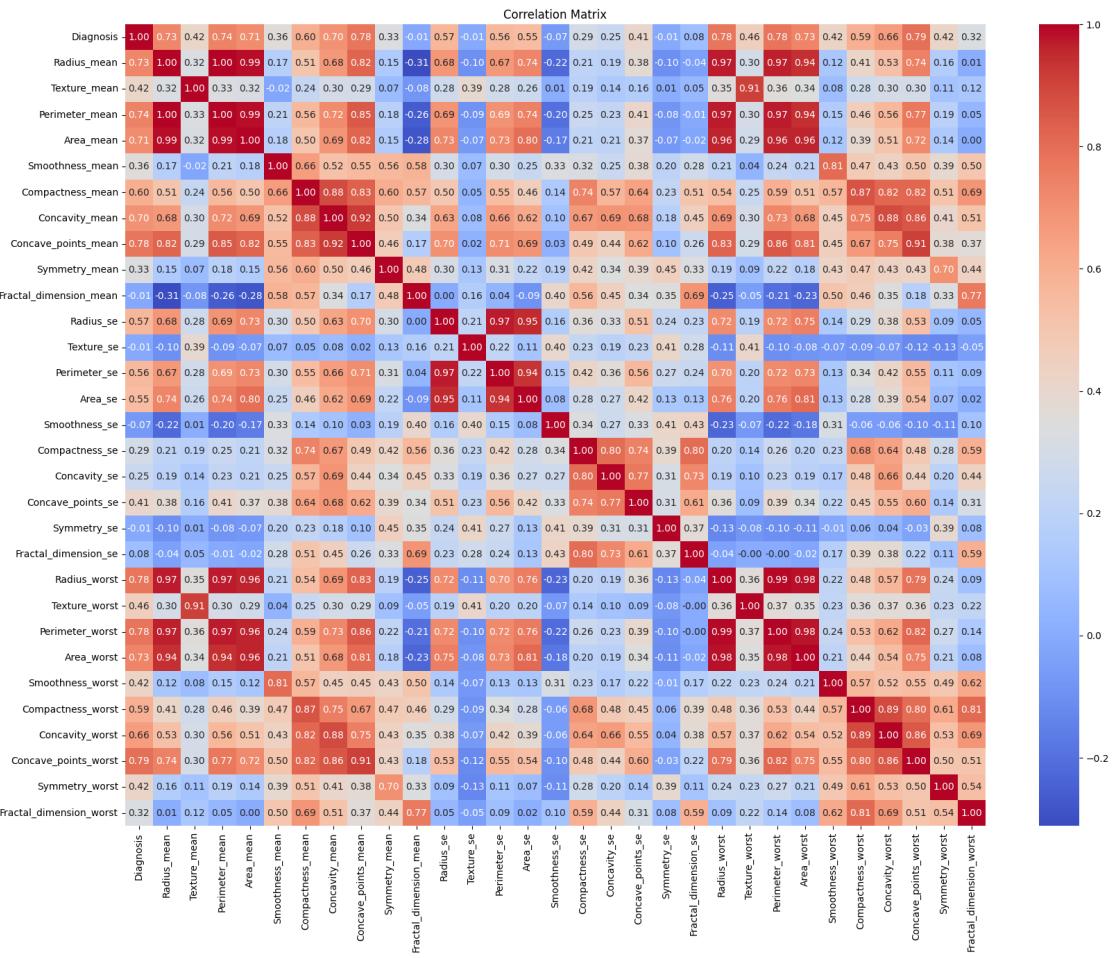


```
[280]: # Shows us good separation between malignant and benign using only two features.
# Can tentatively be linearly separable
eda.bivariate_analysis('Radius_mean', 'Texture_mean')
```



```
[281]: # Some strong correlation across some features
# Most seem to be not correlated
# We will need to address multicollinearity

eda.correlation_matrix()
```



```
[282]: # Create the EDA object
```

```
eda = EDA(data, target_column='Diagnosis')
```

```
# Remove correlated features via threshold
```

```
eda.check_multicollinearity(threshold=0.75)
```

```
Features to drop: ['Perimeter_mean', 'Area_mean', 'Concavity_mean',
'Concave_points_mean', 'Perimeter_se', 'Area_se', 'Concavity_se',
'Concave_points_se', 'Fractal_dimension_se', 'Radius_worst', 'Texture_worst',
'Perimeter_worst', 'Area_worst', 'Smoothness_worst', 'Compactness_worst',
'Concavity_worst', 'Concave_points_worst', 'Fractal_dimension_worst']
```

```
[282]: ['Perimeter_mean',
```

```
'Area_mean',
```

```
'Concavity_mean',
```

```
'Concave_points_mean',
```

```
'Perimeter_se',
```

```
'Area_se',
```

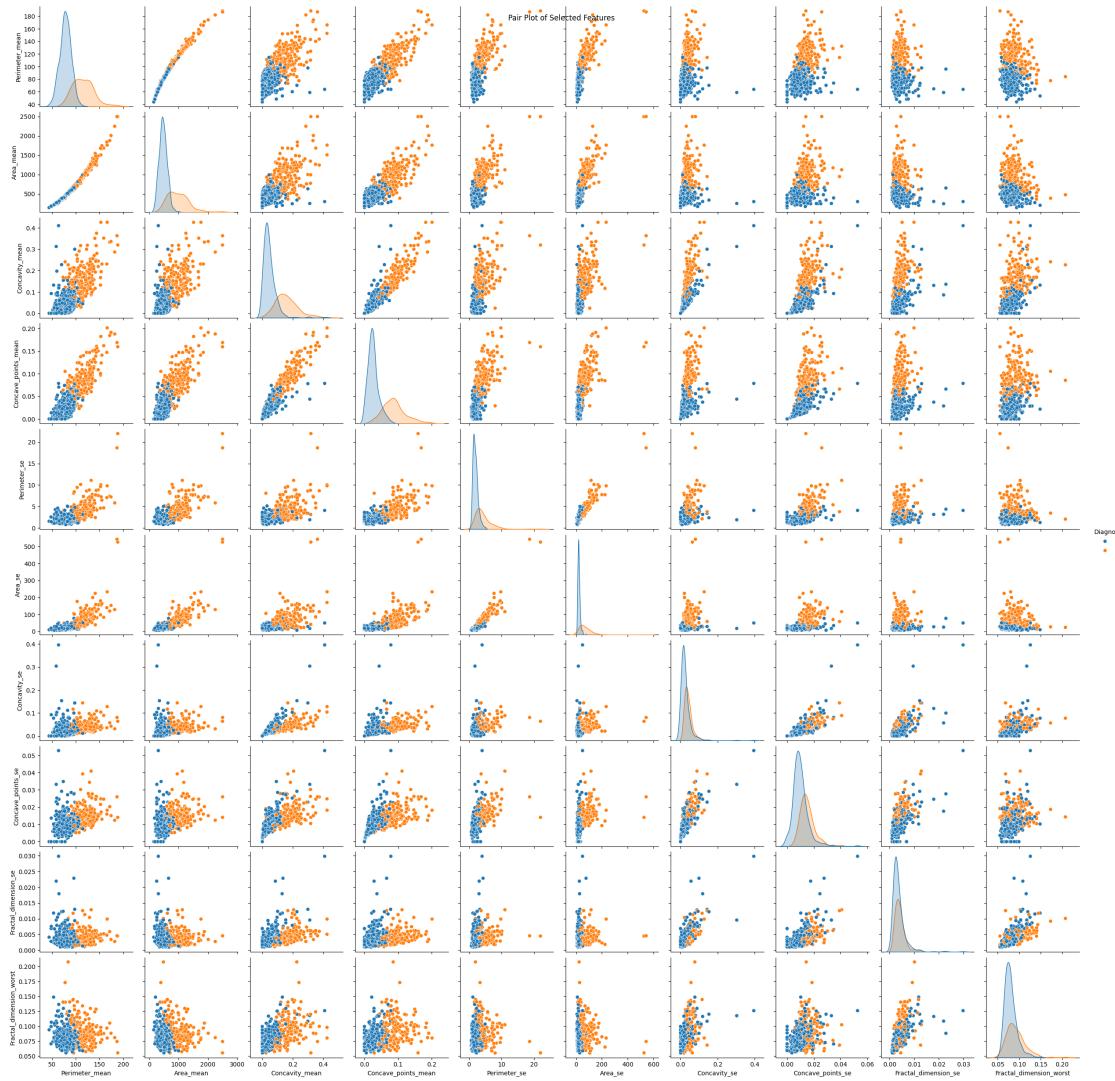
```
'Concavity_se',
'Concave_points_se',
'Fractal_dimension_se',
'Radius_worst',
'Texture_worst',
'Perimeter_worst',
'Area_worst',
'Smoothness_worst',
'Compactness_worst',
'Concavity_worst',
'Concave_points_worst',
'Fractal_dimension_worst']
```

```
[180]: # Check for separation across multiple features
eda.pairplot(['Perimeter_mean',
'Area_mean',
'Concavity_mean',
'Concave_points_mean',
'Perimeter_se',
'Area_se',
'Concavity_se',
'Concave_points_se',
'Fractal_dimension_se',
'Radius_worst',
'Texture_worst',
'Perimeter_worst',
'Area_worst',
'Smoothness_worst',
'Compactness_worst',
'Concavity_worst',
'Concave_points_worst',
'Fractal_dimension_worst'])
```



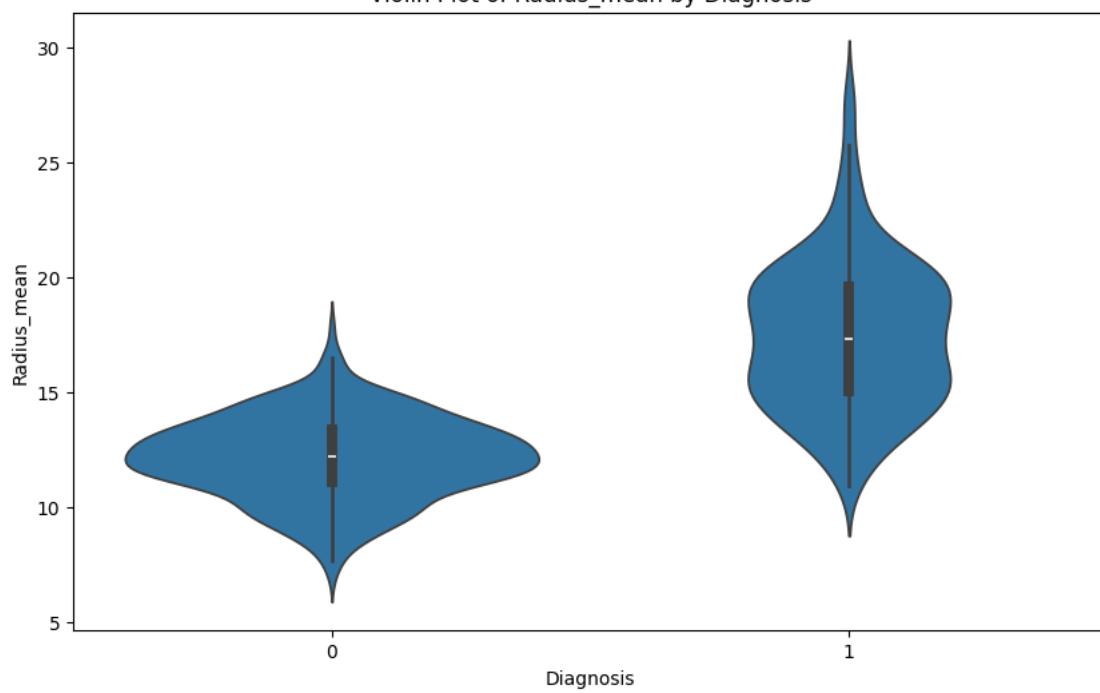
```
[181]: # Check for separation across multiple features
```

```
eda.pairplot(['Perimeter_mean',
 'Area_mean',
 'Concavity_mean',
 'Concave_points_mean',
 'Perimeter_se',
 'Area_se',
 'Concavity_se',
 'Concave_points_se',
 'Fractal_dimension_se',
 'Fractal_dimension_worst'])
```

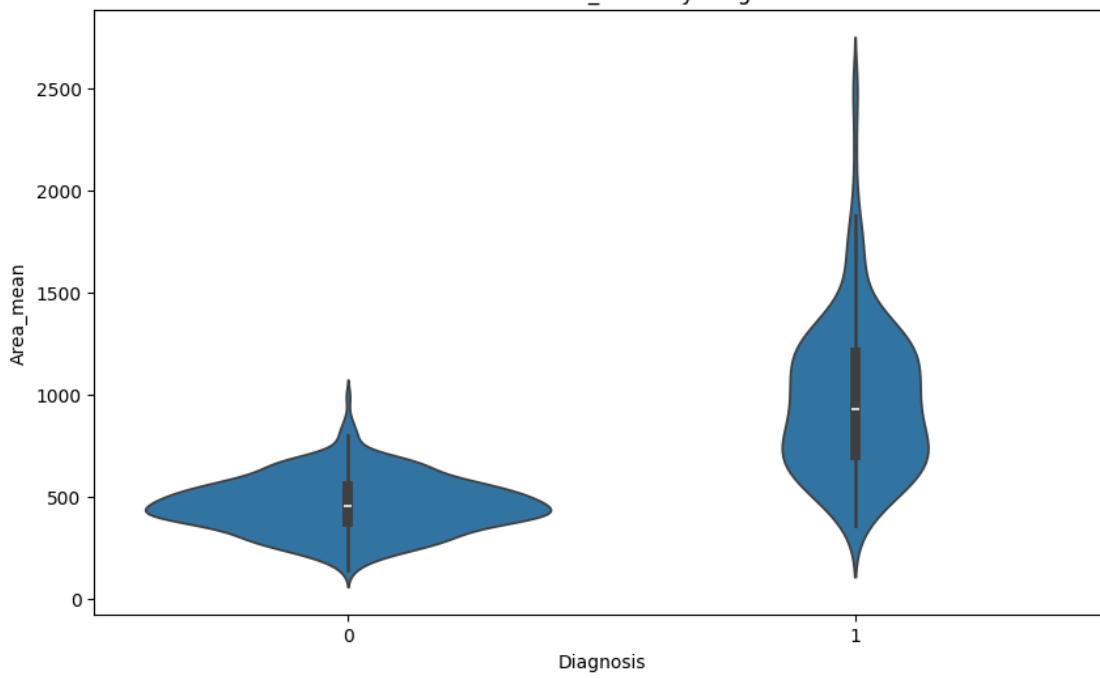


```
[182]: eda.violin_plot(['Radius_mean', 'Area_mean', 'Smoothness_mean',  
                     'Concavity_mean', 'Concave_points_mean', 'Fractal_dimension_se',  
                     'Fractal_dimension_worst'])
```

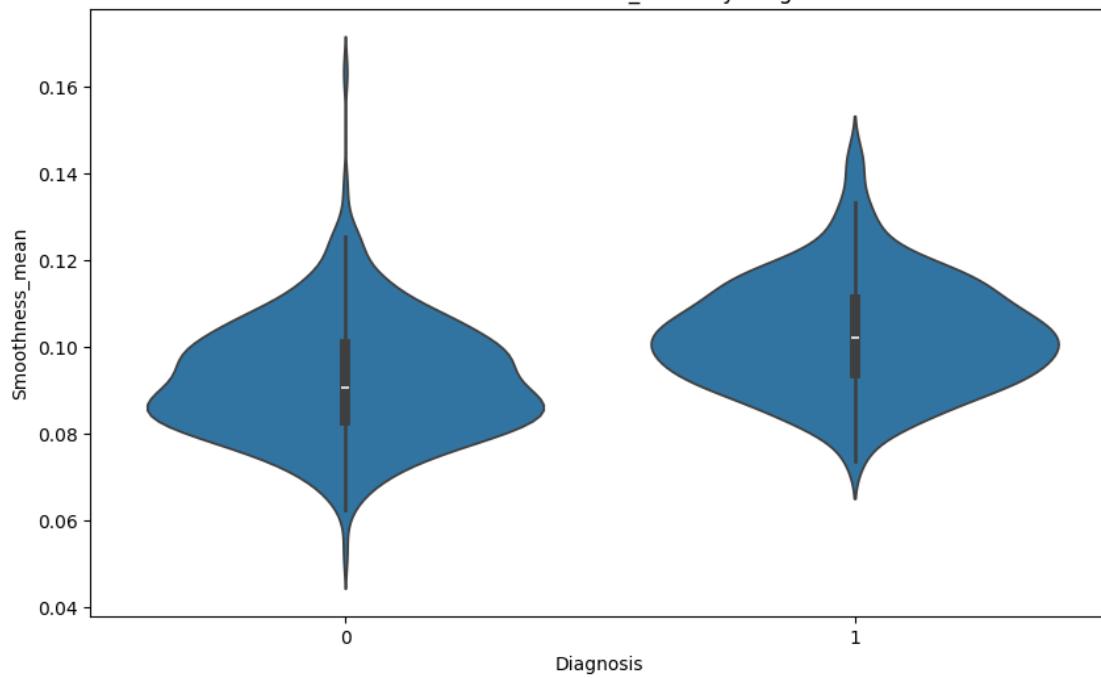
Violin Plot of Radius\_mean by Diagnosis



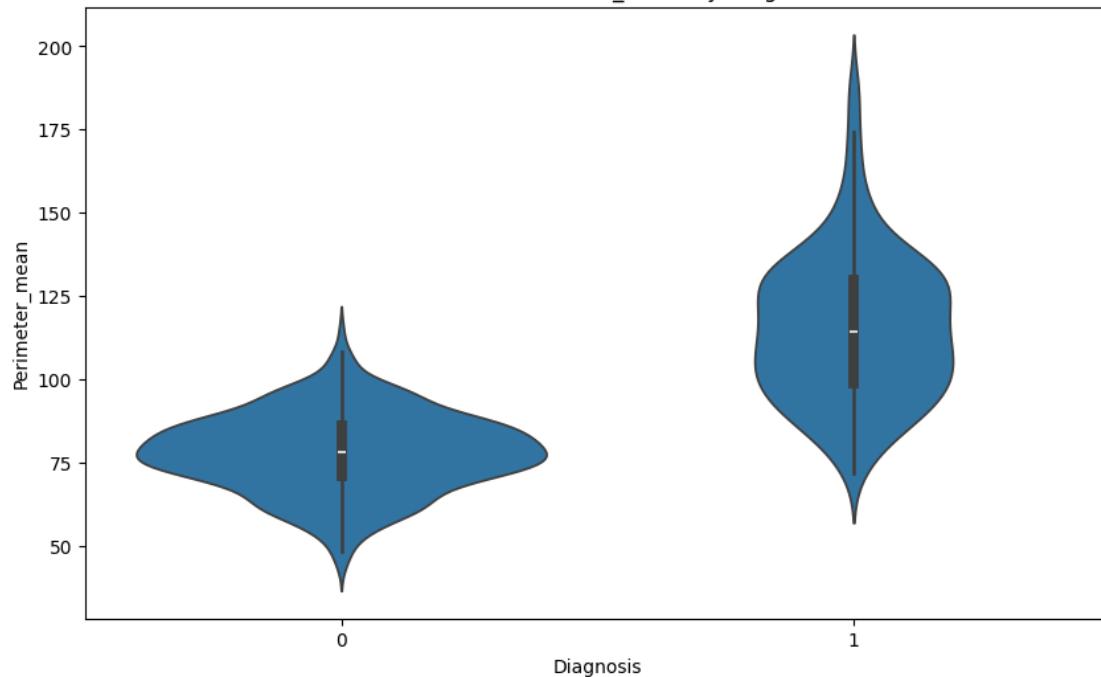
Violin Plot of Area\_mean by Diagnosis



Violin Plot of Smoothness\_mean by Diagnosis



Violin Plot of Perimeter\_mean by Diagnosis



## 1.1 4. Data Preprocessing:

```
[231]: # Scale the data using Standard Scaler  
eda.scale_data()
```

Scaled data sample:

```
   Radius_mean  Texture_mean  Smoothness_mean  Compactness_mean  \\\n0      1.097064     -2.073335       1.568466        3.283515\n1      1.829821     -0.353632      -0.826962       -0.487072\n2      1.579888      0.456187       0.942210        1.052926\n3     -0.768909      0.253732       3.283553        3.402909\n4      1.750297     -1.151816       0.280372        0.539340\n\n   Symmetry_mean  Fractal_dimension_mean  Radius_se  Texture_se  \\\n0          2.217515                  2.255747    2.489734     -0.565265\n1          0.001392                 -0.868652    0.499255     -0.876244\n2          0.939685                 -0.398008    1.228676     -0.780083\n3          2.867383                  4.910919    0.326373     -0.110409\n4         -0.009560                 -0.562450    1.270543     -0.790244\n\n   Smoothness_se  Compactness_se  Symmetry_se  Symmetry_worst\n0      -0.214002       1.316862      1.148757       2.750622\n1      -0.605351      -0.692926     -0.805450      -0.243890\n2      -0.297005       0.814974      0.237036       1.152255\n3       0.689702       2.744280      4.732680       6.046041\n4      1.483067      -0.048520     -0.361092      -0.868353
```

```
[233]: # Split the data into train and test  
# We will use PCA to reduce the features first to 2 components  
X_train, X_test, y_train, y_test = eda.split_data_with_pca(n_components=2,  
test_size=0.2, random_state=42)
```

```
[216]: # Check the dataset after scaling and reduction of dims  
X_train
```

```
[216]: array([[ 9.50238392, -2.99738153,  1.1612891 ],  
           [ 6.53126807,  2.95531415, -1.41438354],  
           [ 0.44491071, -3.58253924,  0.85116851],  
           ...,  
           [-4.98447284,  0.89890951,  0.56255196],  
           [ 0.60404177,  1.14447517, -1.98188377],  
           [-3.31384151,  0.128595 ,  0.28643056]])
```

```
[217]: y_train
```

```
[217]: 68      0  
181      1  
63      0
```

```

248    0
60     0
...
71     0
106    0
270    0
435    1
102    0
Name: Diagnosis, Length: 455, dtype: int64

```

[212]:

## 1.2 5. Gaussian Naive Bayes

```

[229]: class CustomGaussianNaiveBayes:
    # Class for a custom implementation of NB
    def __init__(self):
        self.class_priors = {} # Priors
        self.means = {} # Mean of feats
        self.variances = {} # vars
        self.classes = None # Unique classes

    def fit(self, X, y):
        """
        fit the Gaussian NB model
        """
        # Get labels
        self.classes = np.unique(y)

        # For loop to calc priors, means, and vars
        for c in self.classes:
            # sub set the data
            X_c = X[y == c]

            # Calc prior
            self.class_priors[c] = X_c.shape[0] / X.shape[0]

            # Calc mean
            self.means[c] = np.mean(X_c, axis=0)

            # Calc variance
            self.variances[c] = np.var(X_c, axis=0)

    def _calculate_likelihood(self, X, mean, variance):
        """
        Calculate the likelihood
        """

```

```

# Calc to get the exp
exponent = np.exp(-(
    (X - mean) ** 2) / (2 * variance)
)

# return the results
return (1 / np.sqrt(2 * np.pi * variance)) * exponent

def _calculate_posteriors(self, X):
    """
    Calculate the posterior
    """
    posteriors = []

    # For loop tp calculate the posterior
    for c in self.classes:

        # prior for the class via log
        prior = np.log(self.class_priors[c])

        # Likelihood for the class using sum
        likelihood = np.sum(
            np.log(
                self._calculate_likelihood(X, self.means[c], self.
variances[c])
            ), axis=1)

        # Calculate posterior
        posteriors.append(prior + likelihood)

    # return the posteriors
    return np.array(posteriors).T

def predict(self, X):
    """
    Predict the labels for the input
    """
    # calc post
    posteriors = self._calculate_posteriors(X)

    # Return highest prob class
    return self.classes[np.argmax(posteriors, axis=1)]

def predict_proba(self, X):
    """
    Predict the probabilities for each class
    """

```

```

# Calculate posteriors
posteriors = self._calculate_posteriors(X)

#return probas
return np.exp(posteriors) / np.sum(np.exp(posteriors), axis=1, keepdims=True)

```

[237]: # Initialize and train the Gaussian Naive Bayes model  
gnb = CustomGaussianNaiveBayes()

```

# fit the model
gnb.fit(X_train, y_train)

# Make predictions
y_pred = gnb.predict(X_test)

# Evaluate accuracy
accuracy = np.mean(y_pred == y_test)
print(f"Accuracy of Gaussian Naive Bayes: {accuracy * 100:.1f}%")

```

Accuracy of Gaussian Naive Bayes: 93.0%

[238]: # Calculate Accuracy, Recall, F1, precision  
print(classification\_report(y\_test, y\_pred))

	precision	recall	f1-score	support
0	0.90	1.00	0.95	71
1	1.00	0.81	0.90	43
accuracy			0.93	114
macro avg	0.95	0.91	0.92	114
weighted avg	0.94	0.93	0.93	114

[239]: # Predict the proba for y pred  
y\_pred\_proba = gnb.predict\_proba(X\_test)[:, 1]

# Calculate ROC
fpr, tpr, thresholds = roc\_curve(y\_test, y\_pred\_proba)

# Calculate AUC
auc\_score = roc\_auc\_score(y\_test, y\_pred\_proba)

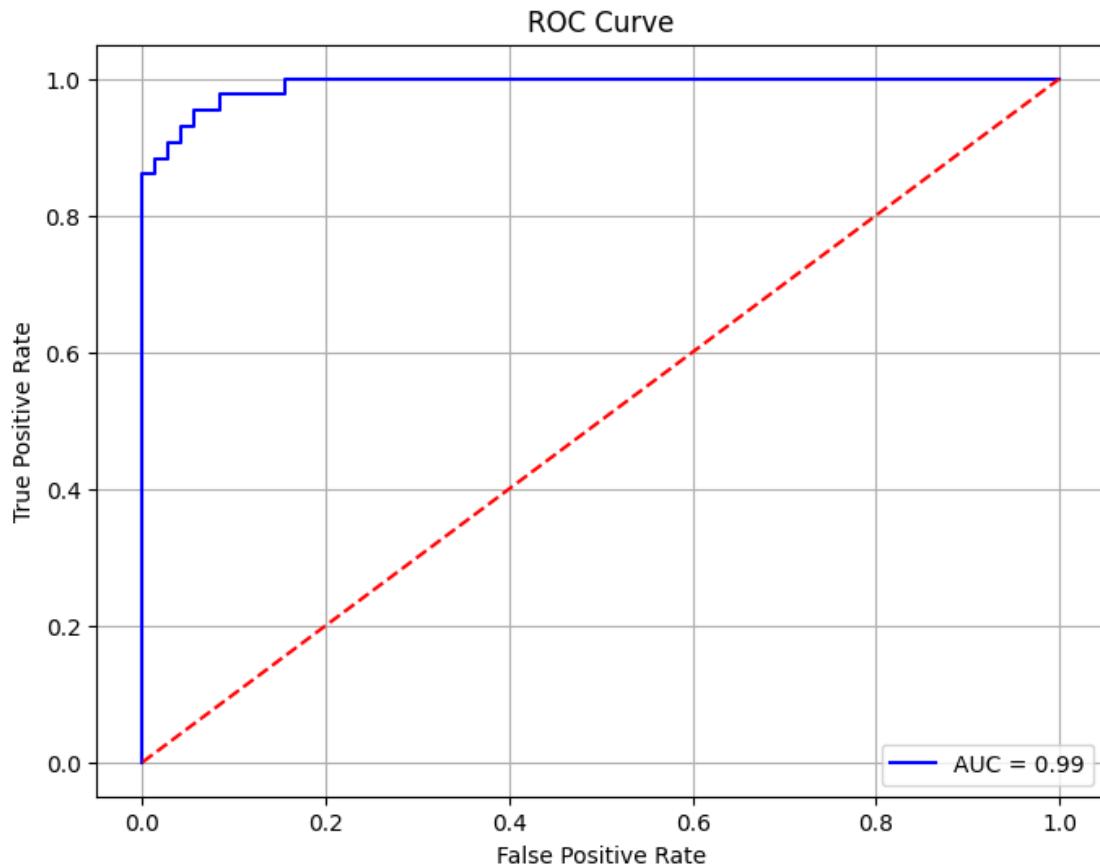
# Plot the results
plt.figure(figsize=(8, 6))
plt.plot(fpr, tpr, color='blue', label=f'AUC = {auc\_score:.2f}')
plt.plot([0, 1], [0, 1], color='red', linestyle='--') # Diagonal line (random guessing)

```

plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('ROC Curve')
plt.legend(loc="lower right")
plt.grid(True)
plt.show()

# Display AUC score
print(f"AUC Score: {auc_score:.2f}")

```



AUC Score: 0.99

### 1.3 6. Gaussian Discriminant Analysis

```
[240]: class CustomGaussianDiscriminantAnalysis:
    def __init__(self, shared_covariance=True):
        """
        init GDA model.
        """

```

```

        self.shared_covariance = shared_covariance
        self.class_priors = {} # Prior probs
        self.means = {} # Means
        self.covariance = None # Covariance matrix
        self.covariances = {} # Covariances per class
        self.classes = None # Unique classes

    def fit(self, X, y):
        """
        Fit GDA model to the training data
        """
        # class labels
        self.classes = np.unique(y)

        # num features
        n_features = X.shape[1]
        total_samples = X.shape[0]

        # account for share cov
        if self.shared_covariance:
            self.covariance = np.zeros((n_features, n_features))

        # loop over classes
        for c in self.classes:
            # Get Subset
            X_c = X[y == c]

            # calc prior
            self.class_priors[c] = X_c.shape[0] / total_samples

            # calc mean
            self.means[c] = np.mean(X_c, axis=0)

            # calc cov
            if self.shared_covariance:
                centered_X = X_c - self.means[c]
                self.covariance += centered_X.T @ centered_X
            else:
                # C-S Cov
                centered_X = X_c - self.means[c]
                self.covariances[c] = (centered_X.T @ centered_X) / X_c.shape[0]

            # Shared Cov
            if self.shared_covariance:
                self.covariance /= total_samples

    def _calculate_gaussian_density(self, X, mean, covariance):

```

```

"""
Calculate the multivariate gaussian probability density
"""

n_features = X.shape[1]
centered_X = X - mean
covariance_inv = np.linalg.inv(covariance)
covariance_det = np.linalg.det(covariance)

exponent = np.sum(centered_X @ covariance_inv * centered_X, axis=1)
density = np.exp(-0.5 * exponent) / np.sqrt((2 * np.pi) ** n_features * covariance_det)

return density

def _calculate_posteriors(self, X):
    """
    Calculate the posterior proba
    """
    posteriors = []

    # Iterate and loop over each class, calc the posterior proba
    for c in self.classes:
        # Calculate prior
        prior = np.log(self.class_priors[c])

        # Calc likelihood
        if self.shared_covariance:
            # shared
            likelihood = np.log(self._calculate_gaussian_density(X, self.means[c], self.covariance))
        else:
            # not shared
            likelihood = np.log(self._calculate_gaussian_density(X, self.means[c], self.covariances[c]))

        # Posterior = Prior + Likelihood (in log space for numerical stability)
        posteriors.append(prior + likelihood)

    return np.array(posteriors).T

def predict(self, X):
    """
    Predict the class labels for input
    """
    # Calc posteriors

```

```

posterior = self._calculate_posterior(X)

# Return the class with the highest posterior
return self.classes[np.argmax(posterior, axis=1)]


def predict_proba(self, X):
    """
    Predict the probabilities for class
    """
    posterior = self._calculate_posterior(X)
    return np.exp(posterior) / np.sum(np.exp(posterior), axis=1, ↴
    keepdims=True)

```

[243]: # init and train model

```

gda = CustomGaussianDiscriminantAnalysis(shared_covariance=True)

# fit the model with training set
gda.fit(X_train, y_train)

# predict
y_pred = gda.predict(X_test)

# Calc accuracy
accuracy = np.mean(y_pred == y_test)
print(f"Accuracy of Gaussian Discriminant Analysis (Shared Covariance):" ↴
    {accuracy * 100:.2f}%"')

```

Accuracy of Gaussian Discriminant Analysis (Shared Covariance): 93.86%

[244]: print(classification\_report(y\_test, y\_pred))

	precision	recall	f1-score	support
0	0.91	1.00	0.95	71
1	1.00	0.84	0.91	43
accuracy			0.94	114
macro avg	0.96	0.92	0.93	114
weighted avg	0.94	0.94	0.94	114

[246]: # Init without shared cov

```

gda_class_specific = CustomGaussianDiscriminantAnalysis(shared_covariance=False)
gda_class_specific.fit(X_train, y_train)

# calc predictions
y_pred_class_specific = gda_class_specific.predict(X_test)

# calc accuracy

```

```

accuracy_class_specific = np.mean(y_pred_class_specific == y_test)
print(f"Accuracy of Gaussian Discriminant Analysis (Class-Specific Covariance): {accuracy_class_specific * 100:.2f}%")

```

Accuracy of Gaussian Discriminant Analysis (Class-Specific Covariance): 94.74%

[248]: `print(classification_report(y_test, y_pred_class_specific))`

	precision	recall	f1-score	support
0	0.93	0.99	0.96	71
1	0.97	0.88	0.93	43
accuracy			0.95	114
macro avg	0.95	0.93	0.94	114
weighted avg	0.95	0.95	0.95	114

## 1.4 7. Logistic Regression

```

[249]: class CustomLogisticRegressionGD:
    def __init__(self, learning_rate=0.01, iterations=1000):
        self.learning_rate = learning_rate
        self.iterations = iterations
        self.theta = None

    def sigmoid(self, z):
        # simple sigmoid calculation
        return 1 / (1 + np.exp(-z))

    def cost_function(self, h, y):
        # calcuate length of y
        m = len(y)
        # return calcualted cost function
        return (-1/m) * np.sum(y * np.log(h) + (1 - y) * np.log(1 - h))

    def fit(self, X, y):
        # Init weights
        m, n = X.shape
        self.theta = np.zeros(n)
        self.cost_history = []

        # iterate of the values
        for i in range(self.iterations):
            # calc the model prediction
            z = np.dot(X, self.theta)

            # calc sigmoid
            h = self.sigmoid(z)

```

```

# calc gradient
gradient = np.dot(X.T, (h - y)) / m
# update weights
self.theta -= self.learning_rate * gradient

# calc cost for monitoring convergence
cost = self.cost_function(h, y)
# update
self.cost_history.append(cost)

return self

def predict_prob(self, X):
    return self.sigmoid(np.dot(X, self.theta))

def predict(self, X):
    return (self.predict_prob(X) >= 0.5).astype(int)

```

```
[250]: # Init and train Reg model using Gradient Descent
log_reg_gd = CustomLogisticRegressionGD(learning_rate=0.01, iterations=10000)
log_reg_gd.fit(X_train, y_train)

# Make prediction
y_pred_train = log_reg_gd.predict(X_train)
y_pred_test = log_reg_gd.predict(X_test)

# Calc accuracy, recall, f1, ROC-AUC of model
accuracy_train = accuracy_score(y_train, y_pred_train)
accuracy_test = accuracy_score(y_test, y_pred_test)
recall_test = recall_score(y_test, y_pred_test)
f1_test = f1_score(y_test, y_pred_test)
roc_auc_test = roc_auc_score(y_test, log_reg_gd.predict_prob(X_test))
```

```
[254]: print("accuracy_test: ", accuracy_test)
```

```
accuracy_test: 0.9473684210526315
```

```
[252]: print(classification_report(y_test, y_pred_test))
```

	precision	recall	f1-score	support
0	0.99	0.93	0.96	71
1	0.89	0.98	0.93	43
accuracy			0.95	114
macro avg	0.94	0.95	0.94	114
weighted avg	0.95	0.95	0.95	114

```
[253]: # Init the LR model and fit
log_reg_gd = CustomLogisticRegressionGD(learning_rate=0.01, iterations=10000)
log_reg_gd.fit(X_train, y_train)

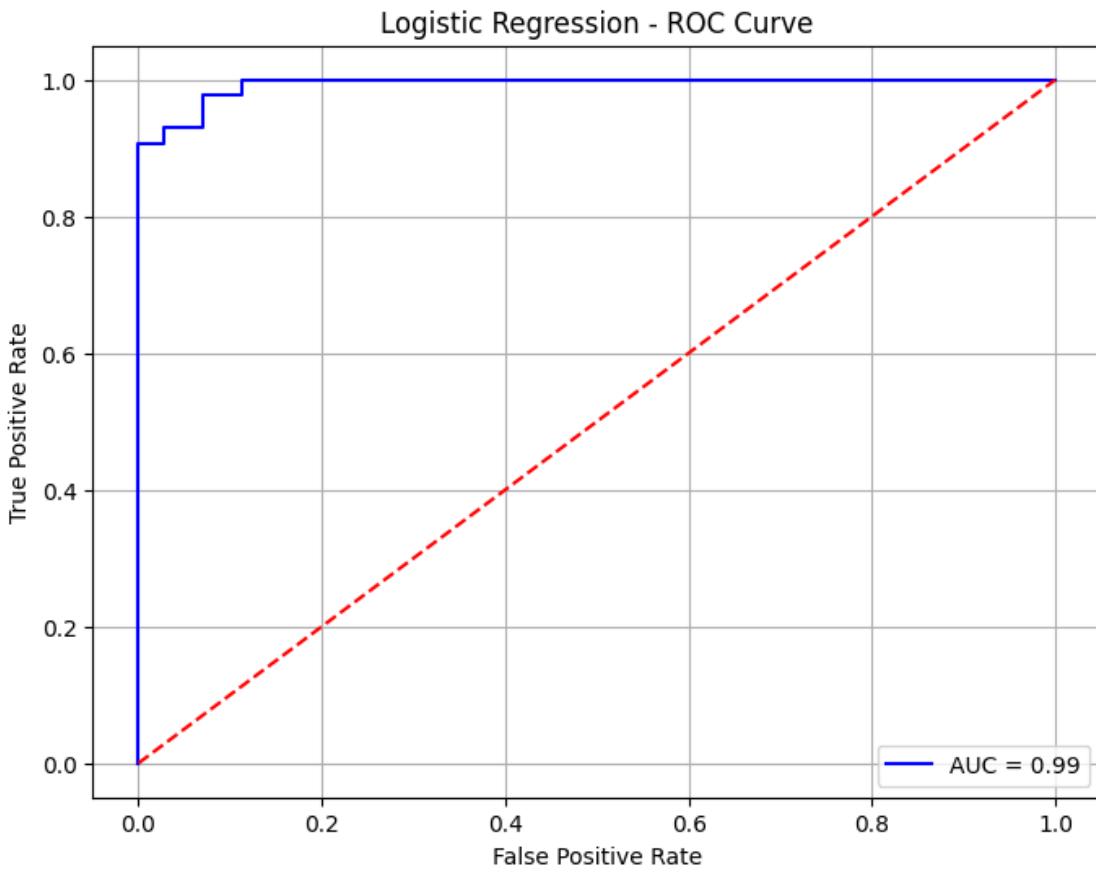
# predict probabilities
y_pred_proba_lr = log_reg_gd.predict_prob(X_test)

# ROC curve
fpr_lr, tpr_lr, thresholds_lr = roc_curve(y_test, y_pred_proba_lr)

# Calc AUC
auc_score_lr = roc_auc_score(y_test, y_pred_proba_lr)

# Plot the ROC curve
plt.figure(figsize=(8, 6))
plt.plot(fpr_lr, tpr_lr, color='blue', label=f'AUC = {auc_score_lr:.2f}')
plt.plot([0, 1], [0, 1], color='red', linestyle='--')
plt.xlabel('False Positive Rate')
plt.ylabel('True Positive Rate')
plt.title('Logistic Regression - ROC Curve')
plt.legend(loc="lower right")
plt.grid(True)
plt.show()

print(f"AUC Score for Logistic Regression: {auc_score_lr:.2f}")
```



AUC Score for Logistic Regression: 0.99

## 1.5 8. Perceptron:

```
[259]: class CustomPerceptronModel:
    def __init__(self, learning_rate=0.01, iterations=1000):
        self.learning_rate = learning_rate
        self.iterations = iterations
        self.theta = None

    def fit(self, X, y):
        # Convert to np array
        y = np.array(y)

        # init weights
        m, n = X.shape
        self.theta = np.zeros(n + 1)

        # add bias
        X = np.c_[np.ones((m, 1)), X]
```

```

# train using the perceptron learning
for _ in range(self.iterations):
    for i in range(m):
        # make pred
        linear_output = np.dot(X[i], self.theta)
        y_pred = 1 if linear_output >= 0 else 0

        # update weights
        self.theta += self.learning_rate * (y[i] - y_pred) * X[i]

def predict(self, X):
    # Add bias
    X = np.c_[np.ones((X.shape[0], 1)), X]
    # get dot
    linear_output = np.dot(X, self.theta)
    # return results
    return (linear_output >= 0).astype(int)

```

```

[261]: # Init and fit Perceptron
perceptron = CustomPerceptronModel(learning_rate=0.01, iterations=2000)
perceptron.fit(X_train, y_train)

# predict
y_pred_train = perceptron.predict(X_train)
y_pred_test = perceptron.predict(X_test)

# evaluate
accuracy_train = accuracy_score(y_train, y_pred_train)
accuracy_test = accuracy_score(y_test, y_pred_test)
recall_test = recall_score(y_test, y_pred_test)
f1_test = f1_score(y_test, y_pred_test)

# Output metrics
results_perceptron = {
    "Training Accuracy": accuracy_train,
    "Test Accuracy": accuracy_test,
    "Test Recall": recall_test,
    "Test F1 Score": f1_test
}

results_perceptron

```

```

[261]: {'Training Accuracy': 0.9318681318681319,
        'Test Accuracy': 0.9473684210526315,
        'Test Recall': np.float64(0.9069767441860465),
        'Test F1 Score': np.float64(0.9285714285714286)}

```

```
[263]: X_vis = X_train[:, :2]

def plot_perceptron_decision_boundary(X, y, model):
    # Plots the separation

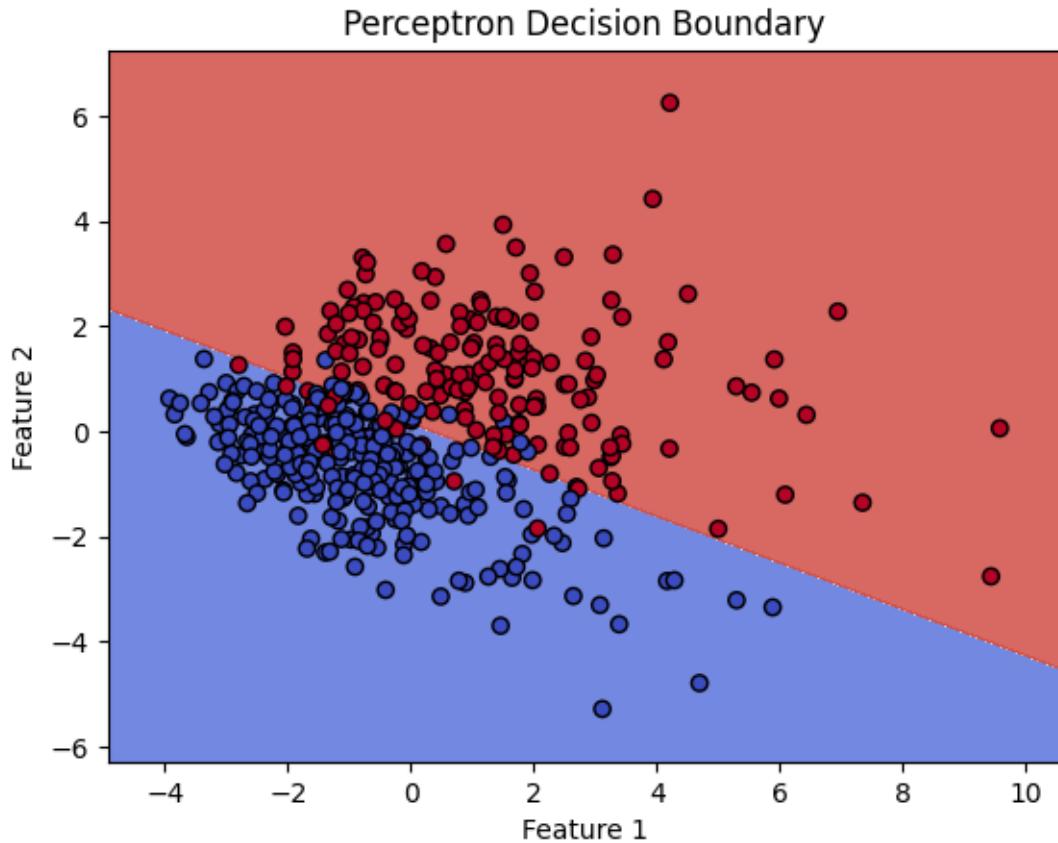
    # get min and max for plot
    x_min, x_max = X[:, 0].min() - 1, X[:, 0].max() + 1
    y_min, y_max = X[:, 1].min() - 1, X[:, 1].max() + 1
    xx, yy = np.meshgrid(np.arange(x_min, x_max, 0.01),
                          np.arange(y_min, y_max, 0.01))

    # pred the output
    Z = model.predict(np.c_[xx.ravel(), yy.ravel()])
    Z = Z.reshape(xx.shape)

    # plot decision boundary
    plt.contourf(xx, yy, Z, alpha=0.8, cmap='coolwarm')

    # generate plot
    plt.scatter(X[:, 0], X[:, 1], c=y, edgecolor='k', marker='o', cmap='coolwarm')
    plt.xlabel('Feature 1')
    plt.ylabel('Feature 2')
    plt.title('Perceptron Decision Boundary')
    plt.show()

# invoke the function to see the boundary
plot_perceptron_decision_boundary(X_vis, y_train, perceptron)
```



## 1.6 9. Comparison Analysis:

```
[266]: def evaluate_model(model, X_train, X_test, y_train, y_test):
    # Function to evaluate model and return metrics

    # fit the model
    model.fit(X_train, y_train)

    # make predictions on testing
    y_pred_test = model.predict(X_test)

    # predict_proba conditional
    if hasattr(model, "predict_proba"):
        y_pred_proba_test = model.predict_proba(X_test)[:, 1]

        # calc roc auc
        roc_auc = roc_auc_score(y_test, y_pred_proba_test)
    else:
        roc_auc = "N/A"
```

```

# calculate acc, pre, rec, f1
accuracy = accuracy_score(y_test, y_pred_test)
precision = precision_score(y_test, y_pred_test)
recall = recall_score(y_test, y_pred_test)
f1 = f1_score(y_test, y_pred_test)

return accuracy, precision, recall, f1, roc_auc

# results
comparison_results = {}

# cusotm models
custom_models = {
    "Custom Gaussian Naive Bayes": CustomGaussianNaiveBayes(),
    "Custom Logistic Regression": CustomLogisticRegressionGD(learning_rate=0.01, iterations=5000),
    "Custom Perceptron": CustomPerceptronModel(learning_rate=0.01, iterations=1000),
    "Custom GDA (Shared Covariance)": CustomGaussianDiscriminantAnalysis(shared_covariance=True),
    "Custom GDA (Class-Specific Covariance)": CustomGaussianDiscriminantAnalysis(shared_covariance=False)
}

# run the custom models
for model_name, model in custom_models.items():
    accuracy, precision, recall, f1, roc_auc = evaluate_model(model, X_train, X_test, y_train, y_test)
    comparison_results[model_name] = {
        'Accuracy': accuracy,
        'Precision': precision,
        'Recall': recall,
        'F1 Score': f1,
        'ROC AUC': roc_auc
    }

# sklearn models
sklearn_models = {
    "Sklearn Gaussian Naive Bayes": GaussianNB(),
    "Sklearn Logistic Regression": LogisticRegression(max_iter=5000),
    "Sklearn Perceptron": Perceptron(max_iter=1000),
    "Sklearn Linear Discriminant Analysis": LinearDiscriminantAnalysis(),
    "Sklearn Quadratic Discriminant Analysis": QuadraticDiscriminantAnalysis()
}

# run models

```

```

for model_name, model in sklearn_models.items():
    accuracy, precision, recall, f1, roc_auc = evaluate_model(model, X_train, X_test, y_train, y_test)
    comparison_results[model_name] = {
        'Accuracy': accuracy,
        'Precision': precision,
        'Recall': recall,
        'F1 Score': f1,
        'ROC AUC': roc_auc
    }

# convert to DF
comparison_df = pd.DataFrame(comparison_results).T

# display
comparison_df

```

[266]:

	Accuracy	Precision	Recall	\
Custom Gaussian Naive Bayes	0.929825	1.0	0.813953	
Custom Logistic Regression	0.947368	0.893617	0.976744	
Custom Perceptron	0.938596	0.891304	0.953488	
Custom GDA (Shared Covariance)	0.938596	1.0	0.837209	
Custom GDA (Class-Specific Covariance)	0.947368	0.974359	0.883721	
Sklearn Gaussian Naive Bayes	0.929825	1.0	0.813953	
Sklearn Logistic Regression	0.95614	0.975	0.906977	
Sklearn Perceptron	0.894737	0.860465	0.860465	
Sklearn Linear Discriminant Analysis	0.938596	1.0	0.837209	
Sklearn Quadratic Discriminant Analysis	0.947368	0.974359	0.883721	
	F1 Score	ROC AUC		
Custom Gaussian Naive Bayes	0.897436	0.991156		
Custom Logistic Regression	0.933333	N/A		
Custom Perceptron	0.921348	N/A		
Custom GDA (Shared Covariance)	0.911392	0.994104		
Custom GDA (Class-Specific Covariance)	0.926829	0.994432		
Sklearn Gaussian Naive Bayes	0.897436	0.991156		
Sklearn Logistic Regression	0.939759	0.993449		
Sklearn Perceptron	0.860465	N/A		
Sklearn Linear Discriminant Analysis	0.911392	0.994104		
Sklearn Quadratic Discriminant Analysis	0.926829	0.994432		

### 1.6.1 Compare Custom VS API

- Custom vs Sklearn LR:
  - Sklearn LR show that it mildly outperforms the custom version in terms of accuracy 95.6% and precision 97.5%
  - The custom model has higher recall 97.7%, showing it catches more positive cases but at the cost of reduced precision vs the API.

- Custom vs Sklearn GDA (Class-Specific):
  - Both models show nearly identical performance with accuracy = 94.7%, precision = 97.4% and recall = 88.4% showing that the custom implementation closely follows API
  - This shows that the mathematical implementation in the custom model is accurate and consistent with the API
- Custom vs Sklearn Perceptron:
  - The API Perceptron performs worse with accuracy of 89.5% compared to the custom Perceptron with an accuracy 93.9%
  - The custom Perceptron achieves a higher recall as well with a value of 95.3%, which may indicate better sensitivity to positive cases vs API
- Custom vs Sklearn Gaussian Naive Bayes:
  - Both custom and API perform very closely about 92.98% and recall about 81.4%, showing that our Gaussian assumption holds well, and the custom model correctly contains the necessary calculations one would expect relative to API.
- Custom vs Sklearn GDA (Shared-Covariance):
  - Both models perform very similarly with accuracy around 93.9%, showing that the shared covariance assumptions are equally well handled by both implementations.
  - This shows that the shared covariance calculation is correct in the custom model relative to the API

### 1.6.2 Strengths and Weaknesses:

- Logistic Regression:
  - Strengths: Performs well on linearly separable data, provides probabilistic interpretation. Easily interpretable as a user.
  - Weaknesses: Struggles with non-linearly separable data, and custom implementation may suffer from slower convergence compared to Sklearn's highly optimized solver. I have used SKleans implementation in the past, and its very well optimized.
- Gaussian Naive Bayes:
  - Strengths: Simple and fast, works well with small datasets and when the independence assumption holds. Interpretable by users.
  - Weaknesses: The independence assumption may not hold for all features, leading to suboptimal performance. Custom implementation will take longer to converge than SKleans implementation.
- Gaussian Discriminant Analysis (GDA):
  - Strengths: Handles Gaussian distributed data well. This is for both shared and class-specific covariance since versions work effectively.
  - Weaknesses: Can perform poorly if the data deviates significantly from the Gaussian assumption
- Perceptron:
  - Strengths: Simple and efficient when data is linearly separable. Mostly interpretable, but becomes less so with multilayer perceptron if we grew the model.
  - Weaknesses: Struggles with non-linearly separable data, and doesn't provide probabilistic outputs.

### 1.6.3 Discussion of Linear Separability

- Separability: Linear separability can be visually checked by plotting the data in 2D. Purposefully used PCA to be able to see this better. I provided an image of this for the perceptron specifically.
- Perceptron Convergence: The Perceptron algorithm will converge if the data is linearly separable as we showed above. If the model does not converge or suffers from poor performance it tells us the data is not linearly separable
- Logistic Regression: Poor performance on Logistic Regression may indicate non-linear separability. This is because it relies on a linear decision boundary.
- Sklearn Perceptron Lower Acc: The lower accuracy of Sklearn Perceptron compared to other models suggests that the dataset may not be perfectly linearly separable. This is usually because the Perceptron assumes a linear boundary