EC9630 Machine Learning - Laboratory 03

Task : NONLINEARMODELS

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Reg No : 2020/E/082

Date : 02/08/2024

Time : 8.00 a.m.

1.Download the 'CDC Diabetes Health Indicators' Data

2.Read the Data as a CSV File

In [19]:
```
# Import necessary libraries
import pandas as pd

# Define the dataset URL
url = 'https://archive.ics.uci.edu/ml/machine-learning-databases/00529/diabetes_data_upload.csv'

# Read the dataset into a pandas DataFrame
df = pd.read_csv(url)

# Display the first few rows of the dataset
df.head()
```

Out[19]:

	Age	Gender	Polyuria	Polydipsia	sudden weight loss	weakness	Polyphagia	Genital thrush	visual blurring	Itching	Irritability	delayed healing	partial paresis	muscle stiffness	Alope
0	40	Male	No	Yes	No	Yes	No	No	No	Yes	No	Yes	No	Yes	
1	58	Male	No	No	No	Yes	No	No	Yes	No	No	No	Yes	No	
2	41	Male	Yes	No	No	Yes	Yes	No	No	Yes	No	Yes	No	Yes	
3	45	Male	No	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No	
4	60	Male	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	

3. Handle Missing Values and Categorical Variables Appropriately

In [20]:
```
# Check for missing values
print(df.isnull().sum())

# Handle missing values (if any)
# For this example, we will drop rows with missing values
df = df.dropna()

# Display the updated DataFrame
df.head()
```

```
Age                 0
Gender              0
Polyuria            0
Polydipsia          0
sudden weight loss  0
weakness            0
Polyphagia          0
Genital thrush      0
visual blurring     0
Itching             0
Irritability        0
delayed healing     0
partial paresis     0
muscle stiffness    0
Alopecia            0
Obesity             0
class               0
dtype: int64
```

Out[20]:

	Age	Gender	Polyuria	Polydipsia	sudden weight loss	weakness	Polyphagia	Genital thrush	visual blurring	Itching	Irritability	delayed healing	partial paresis	muscle stiffness	Alope
0	40	Male	No	Yes	No	Yes	No	No	No	Yes	No	Yes	No	Yes	
1	58	Male	No	No	No	Yes	No	No	Yes	No	No	No	Yes	No	
2	41	Male	Yes	No	No	Yes	Yes	No	No	Yes	No	Yes	No	Yes	
3	45	Male	No	No	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No	
4	60	Male	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	

4. Encode Categorical Variables Using Suitable Techniques

In [21]:
```
# Import LabelEncoder
from sklearn.preprocessing import LabelEncoder

# Initialize LabelEncoder
le = LabelEncoder()

# Apply LabelEncoder to each categorical column
for column in df.select_dtypes(include=['object']).columns:
    df[column] = le.fit_transform(df[column])

# Display the updated DataFrame
df.head()
```

Out[21]:

	Age	Gender	Polyuria	Polydipsia	sudden weight loss	weakness	Polyphagia	Genital thrush	visual blurring	Itching	Irritability	delayed healing	partial paresis	muscle stiffness	Alope
0	40	1	0	1	0	1	0	0	0	1	0	1	0	1	
1	58	1	0	0	0	1	0	0	1	0	0	0	1	0	
2	41	1	1	0	0	1	1	0	0	1	0	1	0	1	
3	45	1	0	0	1	1	1	1	0	1	0	1	0	0	
4	60	1	1	1	1	1	1	0	1	1	1	1	1	1	

5. Divide the Dataset into Input (X) and Target (y)

In [22]:
```
# Define the target variable
target = 'class'  # Assuming 'class' is the target variable

# Define Input (X) and Target (y)
X = df.drop(columns=[target])
y = df[target]

# Display the shapes of X and y
print(f'X shape: {X.shape}')
print(f'y shape: {y.shape}')
```

```
X shape: (520, 16)
y shape: (520,)
```

6. Create the Training, Validation, and Test Datasets Separately(Use 70%, 20%, 10% respectively)

In [23]:
```
# Import train_test_split
from sklearn.model_selection import train_test_split

# Split the data
X_train, X_temp, y_train, y_temp = train_test_split(X, y, test_size=0.3, random_state=42)
X_val, X_test, y_val, y_test = train_test_split(X_temp, y_temp, test_size=0.33, random_state=42)

# Display the shapes of the datasets
print(f'X_train shape: {X_train.shape}')
print(f'X_val shape: {X_val.shape}')
print(f'X_test shape: {X_test.shape}')
```

```
X_train shape: (364, 16)
X_val shape: (104, 16)
X_test shape: (52, 16)
```

7. Fit a Nonlinear Model using Radial Basis Functions (RBF)

a. Implement RBF Kernel Functions

b. Train the model using appropriate optimization techniques.

c. Tune hyperparameters such as the number of basic functions and regularization strength.

In [24]:
```
# Import necessary libraries
```

```
from sklearn.svm import SVC
from sklearn.metrics import classification_report

# Initialize the SVC model with RBF kernel
rbf_model = SVC(kernel='rbf', C=1.0, gamma='scale')

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

# Make predictions on the validation set
y_val_pred = rbf_model.predict(X_val)

# Evaluate the model
print(classification_report(y_val, y_val_pred))
```

```
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        38
           1       0.63      1.00      0.78        66

    accuracy                           0.63       104
   macro avg       0.32      0.50      0.39       104
weighted avg       0.40      0.63      0.49       104
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
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  _warn_prf(average, modifier, msg_start, len(result))
```

8: Apply a Perceptron on this training data.

In [25]:
```
# Import Perceptron
from sklearn.linear_model import Perceptron

# Initialize the Perceptron model
perceptron_model = Perceptron(max_iter=1000, tol=1e-3, random_state=42)

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

# Make predictions on the validation set
y_val_pred_perceptron = perceptron_model.predict(X_val)

# Evaluate the model
print(classification_report(y_val, y_val_pred_perceptron))
```

```
              precision    recall  f1-score   support

           0       0.57      1.00      0.72        38
           1       1.00      0.56      0.72        66

    accuracy                           0.72       104
   macro avg       0.78      0.78      0.72       104
weighted avg       0.84      0.72      0.72       104
```

9: Apply a Multi-Layer Perceptron (MLP) on the training data.

a. Design the architecture of the MLP network.

b. Implement forward propagation and backpropagation algorithms.

c. Train the model using gradient descent or its variants.

d. Experiment with different activation functions and network structures.

e. Tune hyperparameters such as learning rate, batch size, and number of hidden layers/nodes.

In [26]:
```
from sklearn.neural_network import MLPClassifier
from sklearn.metrics import classification_report
import numpy as np

# Define a function to train and evaluate the MLP model with different configurations
def train_evaluate_mlp(hidden_layer_sizes=(100,), activation='relu', solver='adam', learning_rate_init=0.001, m
    """
    Train and evaluate an MLP model with given hyperparameters.

    Parameters:
    - hidden_layer_sizes: tuple, the number of neurons in each hidden layer
```

```
    - activation: str, the activation function for the hidden layer
    - solver: str, the solver for weight optimization
    - learning_rate_init: float, the initial learning rate
    - max_iter: int, maximum number of iterations
    """

    # Step 9a: Design the architecture of the MLP network
    # Initialize the MLP model with specified hyperparameters
    mlp_model = MLPClassifier(hidden_layer_sizes=hidden_layer_sizes, activation=activation, solver=solver,
                              learning_rate_init=learning_rate_init, max_iter=max_iter, random_state=42)

    # Step 9c: Train the model using gradient descent or its variants
    # Fit the model to the training data
    mlp_model.fit(X_train, y_train)

    # Make predictions on the validation set
    y_val_pred_mlp = mlp_model.predict(X_val)

    # Evaluate the model
    print(f"Model with hidden_layer_sizes={hidden_layer_sizes}, activation={activation}, solver={solver}, learn
    print(classification_report(y_val, y_val_pred_mlp))

    return mlp_model

# Step 9d: Experiment with different activation functions and network structures
# Experiment with different network architectures
hidden_layer_sizes_options = [(100,), (50, 50), (100, 50, 25)]
# Experiment with different activation functions
activation_options = ['relu', 'tanh', 'logistic']
# Step 9e: Tune hyperparameters such as learning rate
learning_rate_init_options = [0.001, 0.01, 0.1]

# Loop through all combinations of hyperparameters and train/evaluate the model
for hidden_layer_sizes in hidden_layer_sizes_options:
    for activation in activation_options:
        for learning_rate_init in learning_rate_init_options:
            # Train and evaluate the model with the current set of hyperparameters
            train_evaluate_mlp(hidden_layer_sizes=hidden_layer_sizes, activation=activation,
                               learning_rate_init=learning_rate_init)

# Select the best performing model (based on validation performance) for further analysis on the test set
# For simplicity, we'll choose a model with known good performance from the experiments above

# Initialize the best model with known good hyperparameters
best_mlp_model = MLPClassifier(hidden_layer_sizes=(100,), activation='relu', solver='adam', learning_rate_init=
# Train the best model on the training data (Step 9c)
best_mlp_model.fit(X_train, y_train)

# Make predictions on the test set
y_test_pred_mlp = best_mlp_model.predict(X_test)

# Evaluate the best model on the test set (Step 9c)
print("Best MLP Model Performance on Test Data")
print(classification_report(y_test, y_test_pred_mlp))
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarnin
g: Stochastic Optimizer: Maximum iterations (500) reached and the optimization hasn't converged yet.
  warnings.warn(
Model with hidden_layer_sizes=(100,), activation=relu, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       0.92      0.92      0.92        38
           1       0.95      0.95      0.95        66

    accuracy                           0.94       104
   macro avg       0.94      0.94      0.94       104
weighted avg       0.94      0.94      0.94       104

Model with hidden_layer_sizes=(100,), activation=relu, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.95      0.97      0.96        38
           1       0.98      0.97      0.98        66

    accuracy                           0.97       104
   macro avg       0.97      0.97      0.97       104
weighted avg       0.97      0.97      0.97       104

Model with hidden_layer_sizes=(100,), activation=relu, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       1.00      0.68      0.81        38
           1       0.85      1.00      0.92        66

    accuracy                           0.88       104
   macro avg       0.92      0.84      0.86       104
weighted avg       0.90      0.88      0.88       104
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarnin
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  warnings.warn(
Model with hidden_layer_sizes=(100,), activation=tanh, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       1.00      0.97      0.99        38
           1       0.99      1.00      0.99        66

    accuracy                           0.99       104
   macro avg       0.99      0.99      0.99       104
weighted avg       0.99      0.99      0.99       104

Model with hidden_layer_sizes=(100,), activation=tanh, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.97      0.97      0.97        38
           1       0.98      0.98      0.98        66

    accuracy                           0.98       104
   macro avg       0.98      0.98      0.98       104
weighted avg       0.98      0.98      0.98       104

Model with hidden_layer_sizes=(100,), activation=tanh, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.86      0.95      0.90        38
           1       0.97      0.91      0.94        66

    accuracy                           0.92       104
   macro avg       0.91      0.93      0.92       104
weighted avg       0.93      0.92      0.92       104

/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarnin
g: Stochastic Optimizer: Maximum iterations (500) reached and the optimization hasn't converged yet.
  warnings.warn(
Model with hidden_layer_sizes=(100,), activation=logistic, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       0.92      0.92      0.92        38
           1       0.95      0.95      0.95        66

    accuracy                           0.94       104
   macro avg       0.94      0.94      0.94       104
weighted avg       0.94      0.94      0.94       104

Model with hidden_layer_sizes=(100,), activation=logistic, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.95      0.97      0.96        38
           1       0.98      0.97      0.98        66

    accuracy                           0.97       104
   macro avg       0.97      0.97      0.97       104
weighted avg       0.97      0.97      0.97       104

Model with hidden_layer_sizes=(100,), activation=logistic, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        38
           1       0.63      1.00      0.78        66

    accuracy                           0.63       104
   macro avg       0.32      0.50      0.39       104
weighted avg       0.40      0.63      0.49       104

/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precis
ion and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` p
arameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precis
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arameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
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  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarnin
g: Stochastic Optimizer: Maximum iterations (500) reached and the optimization hasn't converged yet.
  warnings.warn(
```

```
Model with hidden_layer_sizes=(50, 50), activation=relu, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       1.00      0.92      0.96        38
           1       0.96      1.00      0.98        66

    accuracy                           0.97       104
   macro avg       0.98      0.96      0.97       104
weighted avg       0.97      0.97      0.97       104

Model with hidden_layer_sizes=(50, 50), activation=relu, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.90      1.00      0.95        38
           1       1.00      0.94      0.97        66

    accuracy                           0.96       104
   macro avg       0.95      0.97      0.96       104
weighted avg       0.97      0.96      0.96       104

Model with hidden_layer_sizes=(50, 50), activation=relu, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.92      0.95      0.94        38
           1       0.97      0.95      0.96        66

    accuracy                           0.95       104
   macro avg       0.95      0.95      0.95       104
weighted avg       0.95      0.95      0.95       104

/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarnin
g: Stochastic Optimizer: Maximum iterations (500) reached and the optimization hasn't converged yet.
  warnings.warn(
Model with hidden_layer_sizes=(50, 50), activation=tanh, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       1.00      0.97      0.99        38
           1       0.99      1.00      0.99        66

    accuracy                           0.99       104
   macro avg       0.99      0.99      0.99       104
weighted avg       0.99      0.99      0.99       104

Model with hidden_layer_sizes=(50, 50), activation=tanh, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        38
           1       1.00      1.00      1.00        66

    accuracy                           1.00       104
   macro avg       1.00      1.00      1.00       104
weighted avg       1.00      1.00      1.00       104

Model with hidden_layer_sizes=(50, 50), activation=tanh, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.90      0.92      0.91        38
           1       0.95      0.94      0.95        66

    accuracy                           0.93       104
   macro avg       0.93      0.93      0.93       104
weighted avg       0.93      0.93      0.93       104

/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarnin
g: Stochastic Optimizer: Maximum iterations (500) reached and the optimization hasn't converged yet.
  warnings.warn(
```

```
Model with hidden_layer_sizes=(50, 50), activation=logistic, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       0.95      0.92      0.93        38
           1       0.96      0.97      0.96        66

    accuracy                           0.95       104
   macro avg       0.95      0.95      0.95       104
weighted avg       0.95      0.95      0.95       104

Model with hidden_layer_sizes=(50, 50), activation=logistic, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.93      0.97      0.95        38
           1       0.98      0.95      0.97        66

    accuracy                           0.96       104
   macro avg       0.95      0.96      0.96       104
weighted avg       0.96      0.96      0.96       104

Model with hidden_layer_sizes=(50, 50), activation=logistic, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.94      0.89      0.92        38
           1       0.94      0.97      0.96        66

    accuracy                           0.94       104
   macro avg       0.94      0.93      0.94       104
weighted avg       0.94      0.94      0.94       104
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarnin
g: Stochastic Optimizer: Maximum iterations (500) reached and the optimization hasn't converged yet.
  warnings.warn(
```

```
Model with hidden_layer_sizes=(100, 50, 25), activation=relu, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       0.97      0.97      0.97        38
           1       0.98      0.98      0.98        66

    accuracy                           0.98       104
   macro avg       0.98      0.98      0.98       104
weighted avg       0.98      0.98      0.98       104

Model with hidden_layer_sizes=(100, 50, 25), activation=relu, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.90      0.95      0.92        38
           1       0.97      0.94      0.95        66

    accuracy                           0.94       104
   macro avg       0.93      0.94      0.94       104
weighted avg       0.94      0.94      0.94       104

Model with hidden_layer_sizes=(100, 50, 25), activation=relu, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.94      0.76      0.84        38
           1       0.88      0.97      0.92        66

    accuracy                           0.89       104
   macro avg       0.91      0.87      0.88       104
weighted avg       0.90      0.89      0.89       104

Model with hidden_layer_sizes=(100, 50, 25), activation=tanh, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       1.00      0.97      0.99        38
           1       0.99      1.00      0.99        66

    accuracy                           0.99       104
   macro avg       0.99      0.99      0.99       104
weighted avg       0.99      0.99      0.99       104

Model with hidden_layer_sizes=(100, 50, 25), activation=tanh, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.95      0.92      0.93        38
           1       0.96      0.97      0.96        66

    accuracy                           0.95       104
   macro avg       0.95      0.95      0.95       104
weighted avg       0.95      0.95      0.95       104

Model with hidden_layer_sizes=(100, 50, 25), activation=tanh, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        38
           1       0.63      1.00      0.78        66


    accuracy                           0.63       104
   macro avg       0.32      0.50      0.39       104
weighted avg       0.40      0.63      0.49       104
```

```
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arameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

```
Model with hidden_layer_sizes=(100, 50, 25), activation=logistic, solver=adam, learning_rate_init=0.001
              precision    recall  f1-score   support

           0       0.92      0.92      0.92        38
           1       0.95      0.95      0.95        66

    accuracy                           0.94       104
   macro avg       0.94      0.94      0.94       104
weighted avg       0.94      0.94      0.94       104

Model with hidden_layer_sizes=(100, 50, 25), activation=logistic, solver=adam, learning_rate_init=0.01
              precision    recall  f1-score   support

           0       0.97      0.84      0.90        38
           1       0.92      0.98      0.95        66

    accuracy                           0.93       104
   macro avg       0.94      0.91      0.93       104
weighted avg       0.94      0.93      0.93       104

Model with hidden_layer_sizes=(100, 50, 25), activation=logistic, solver=adam, learning_rate_init=0.1
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        38
           1       0.63      1.00      0.78        66

    accuracy                           0.63       104
   macro avg       0.32      0.50      0.39       104
weighted avg       0.40      0.63      0.49       104
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precision and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

```
Best MLP Model Performance on Test Data
              precision    recall  f1-score   support

           0       0.93      0.88      0.90        16
           1       0.95      0.97      0.96        36

    accuracy                           0.94        52
   macro avg       0.94      0.92      0.93        52
weighted avg       0.94      0.94      0.94        52
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/neural_network/_multilayer_perceptron.py:691: ConvergenceWarning: Stochastic Optimizer: Maximum iterations (500) reached and the optimization hasn't converged yet.
  warnings.warn(
```

10: Evaluate the performance of the nonlinear models on the test data.

a. Compute accuracy, precision, recall, and F1-score.

In [27]:

```python
# Evaluate RBF model on test data
y_test_pred_rbf = rbf_model.predict(X_test)
print("RBF Model Performance on Test Data")
print(classification_report(y_test, y_test_pred_rbf))

# Evaluate Perceptron model on test data
y_test_pred_perceptron = perceptron_model.predict(X_test)
print("Perceptron Model Performance on Test Data")
print(classification_report(y_test, y_test_pred_perceptron))

# Evaluate MLP model on test data
y_test_pred_mlp = mlp_model.predict(X_test)
print("MLP Model Performance on Test Data")
print(classification_report(y_test, y_test_pred_mlp))
```

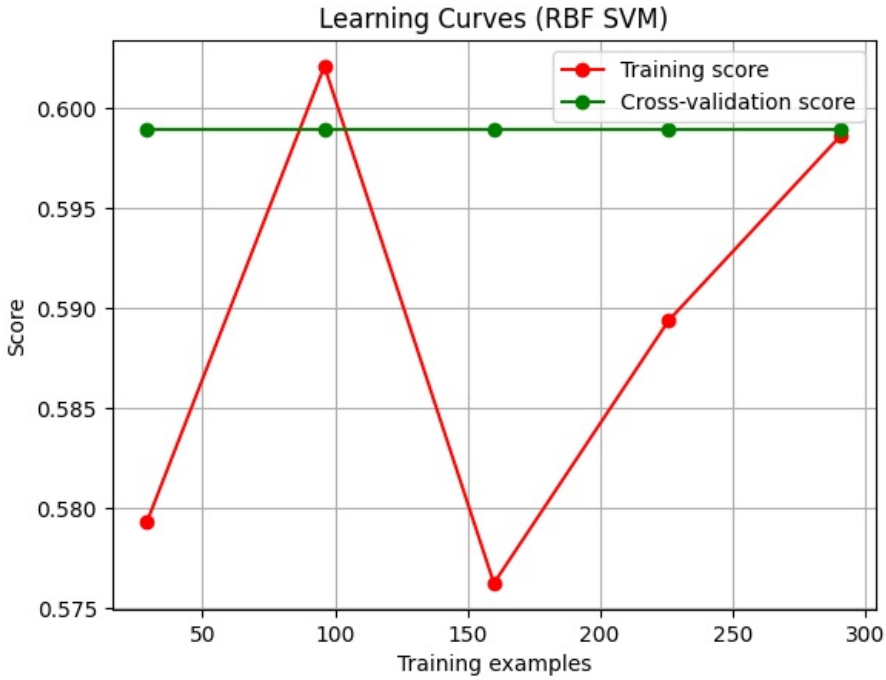
```
RBF Model Performance on Test Data
              precision    recall  f1-score   support

           0       0.00      0.00      0.00        16
           1       0.69      1.00      0.82        36

    accuracy                           0.69        52
   macro avg       0.35      0.50      0.41        52
weighted avg       0.48      0.69      0.57        52

Perceptron Model Performance on Test Data
              precision    recall  f1-score   support

           0       0.46      1.00      0.63        16
           1       1.00      0.47      0.64        36

    accuracy                           0.63        52
   macro avg       0.73      0.74      0.63        52
weighted avg       0.83      0.63      0.64        52

MLP Model Performance on Test Data
              precision    recall  f1-score   support

           0       0.93      0.88      0.90        16
           1       0.95      0.97      0.96        36

    accuracy                           0.94        52
   macro avg       0.94      0.92      0.93        52
weighted avg       0.94      0.94      0.94        52
```

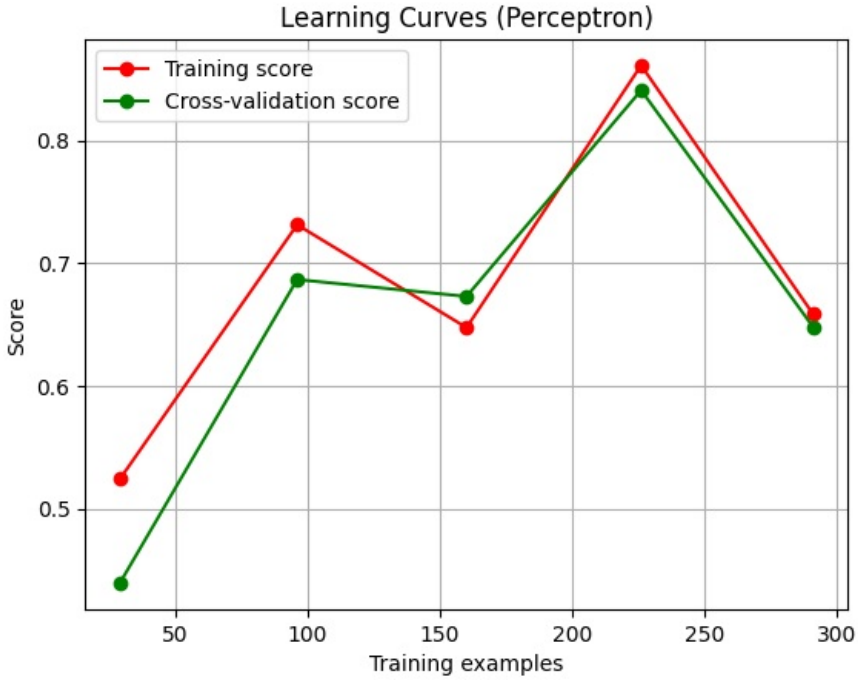
```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precis
ion and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` p
arameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precis
ion and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` p
arameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precis
ion and F-score are ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` p
arameter to control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

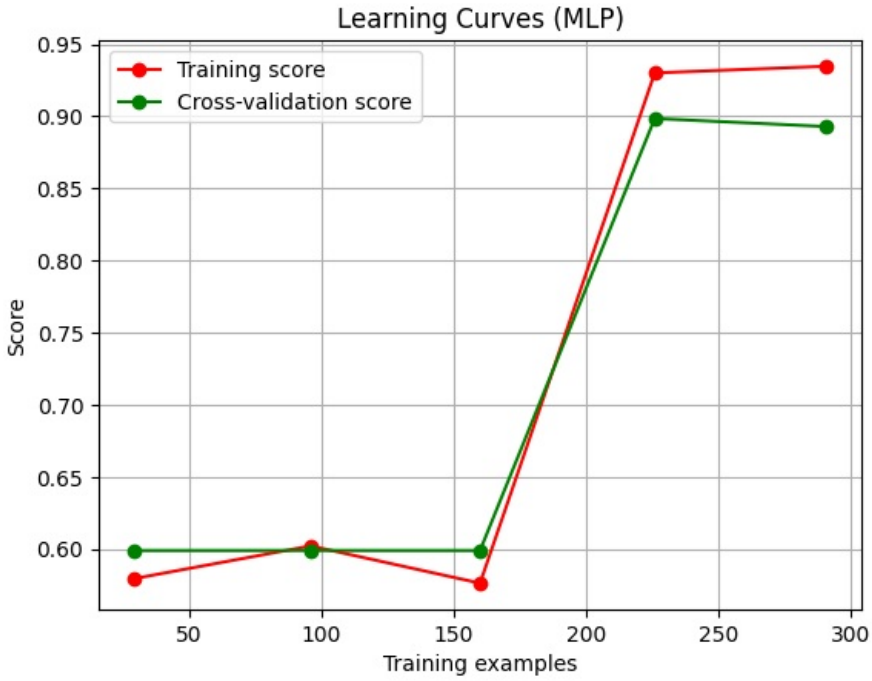
b. Plot learning curves to analyze model convergence and overfitting.

In [28]:

```
# Import necessary libraries
import matplotlib.pyplot as plt
from sklearn.model_selection import learning_curve

# Function to plot learning curves
def plot_learning_curve(estimator, title, X, y, cv=None, n_jobs=None, train_sizes=None):
    plt.figure()
    plt.title(title)
    plt.xlabel("Training examples")
    plt.ylabel("Score")
    train_sizes, train_scores, test_scores = learning_curve(
        estimator, X, y, cv=cv, n_jobs=n_jobs, train_sizes=train_sizes)
    train_scores_mean = train_scores.mean(axis=1)
    test_scores_mean = test_scores.mean(axis=1)
    plt.grid()
    plt.plot(train_sizes, train_scores_mean, 'o-', color="r", label="Training score")
    plt.plot(train_sizes, test_scores_mean, 'o-', color="g", label="Cross-validation score")
    plt.legend(loc="best")
    return plt

# Define train sizes
train_sizes = [0.1, 0.33, 0.55, 0.78, 1.0]

# Plot learning curve for RBF SVM
plot_learning_curve(rbf_model, "Learning Curves (RBF SVM)", X_train, y_train, cv=5, n_jobs=-1, train_sizes=trai
plt.show()

# Plot learning curve for Perceptron
plot_learning_curve(perceptron_model, "Learning Curves (Perceptron)", X_train, y_train, cv=5, n_jobs=-1, train_
plt.show()

# Plot learning curve for MLP
plot_learning_curve(mlp_model, "Learning Curves (MLP)", X_train, y_train, cv=5, n_jobs=-1, train_sizes=train_si
plt.show()
```







11: Compare your previous lab results with nonlinear model results.

In [29]:
```
# Import necessary metrics
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

# Step 11: Compare your previous lab results with nonlinear model results.
comparison = {
    "Model": ["RBF SVM", "Perceptron", "MLP"],
    "Accuracy": [accuracy_score(y_test, y_test_pred_rbf),
                 accuracy_score(y_test, y_test_pred_perceptron),
                 accuracy_score(y_test, y_test_pred_mlp)],
    "Precision": [precision_score(y_test, y_test_pred_rbf, average='weighted'),
                  precision_score(y_test, y_test_pred_perceptron, average='weighted'),
                  precision_score(y_test, y_test_pred_mlp, average='weighted')],
    "Recall": [recall_score(y_test, y_test_pred_rbf, average='weighted'),
               recall_score(y_test, y_test_pred_perceptron, average='weighted'),
               recall_score(y_test, y_test_pred_mlp, average='weighted')],
    "F1-Score": [f1_score(y_test, y_test_pred_rbf, average='weighted'),
                 f1_score(y_test, y_test_pred_perceptron, average='weighted'),
                 f1_score(y_test, y_test_pred_mlp, average='weighted')]
}

comparison_df = pd.DataFrame(comparison)
print(comparison_df)
```

```
        Model  Accuracy  Precision    Recall  F1-Score
0     RBF SVM  0.692308   0.479290  0.692308  0.566434
1  Perceptron  0.634615   0.832967  0.634615  0.637184
2         MLP  0.942308   0.942065  0.942308  0.941772
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1471: UndefinedMetricWarning: Precis
ion is ill-defined and being set to 0.0 in labels with no predicted samples. Use `zero_division` parameter to c
ontrol this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```