# Lab 10 Report: Neural Network Classification

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## Part (a) & (b): Model Architecture and Training

A neural network was constructed using PyTorch as per the lab requirements.

- **Architecture:** The model is a fully connected neural network with:
  - An input layer accepting 2 features.
  - 5 hidden layers with 5, 10, 15, 10, and 5 neurons, respectively.
  - ReLU (Rectified Linear Unit) activation functions after each hidden layer.
  - An output layer with 1 neuron.
  - A Sigmoid activation function on the output layer to produce a probability value between 0 and 1.
- **Training:**
  - **Loss Function:** The model was trained using nn.BCELoss (Binary Cross Entropy Loss), which is appropriate for binary classification tasks with a Sigmoid output.
  - **Optimizer:** The torch.optim.SGD (Stochastic Gradient Descent) optimizer was used with a learning rate of 0.01.
  - **Epochs:** The model was trained for 5000 epochs.

### Training Process Sample

The training loop printed the loss and accuracy for both the training and test sets every 100 epochs.

```
Epoch: 4100 | Loss: 0.08554, Accuracy: 98.47% | Test loss: 0.11168, Test acc: 100.00%
Epoch: 4200 | Loss: 0.08086, Accuracy: 98.47% | Test loss: 0.10395, Test acc: 100.00%
Epoch: 4300 | Loss: 0.07627, Accuracy: 98.47% | Test loss: 0.09710, Test acc: 100.00%
Epoch: 4400 | Loss: 0.07179, Accuracy: 98.47% | Test loss: 0.09079, Test acc: 100.00%
Epoch: 4500 | Loss: 0.06752, Accuracy: 98.85% | Test loss: 0.08455, Test acc: 100.00%
Epoch: 4600 | Loss: 0.06346, Accuracy: 99.23% | Test loss: 0.07873, Test acc: 100.00%
Epoch: 4700 | Loss: 0.05953, Accuracy: 99.23% | Test loss: 0.07247, Test acc: 100.00%
Epoch: 4800 | Loss: 0.05581, Accuracy: 99.23% | Test loss: 0.06689, Test acc: 100.00%
Epoch: 4900 | Loss: 0.05234, Accuracy: 99.23% | Test loss: 0.06168, Test acc: 100.00%
```

**Observation:** The model's loss steadily decreased while its accuracy increased, indicating successful learning. The training and test accuracies are very close, suggesting the model is not overfitting significantly.

## Part (c): Performance Metrics

After training, the model was evaluated on the training, validation, and test datasets using a default threshold of 0.5.

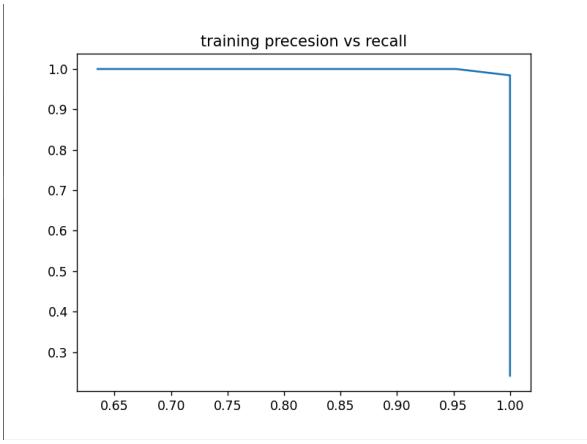
### Metrics

```
training:
precesion:0.9841269841269841
recall:0.9841269841269841
f1:0.9841269841269841

validation:
precesion:1.0
recall:0.9333333333333333
f1:0.9655172413793104

testing:
precesion:1.0
recall:1.0
f1:1.0
```

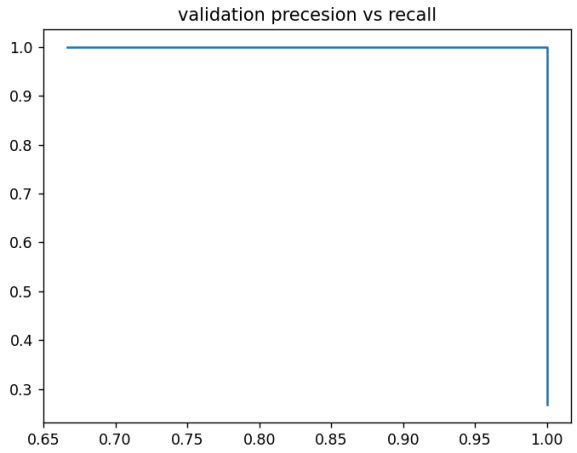
### Precision vs. Recall Curve

The PR curves were plotted by varying the classification threshold from 1.0 down to 0.0. The plots visualize the trade-off between precision and recall.

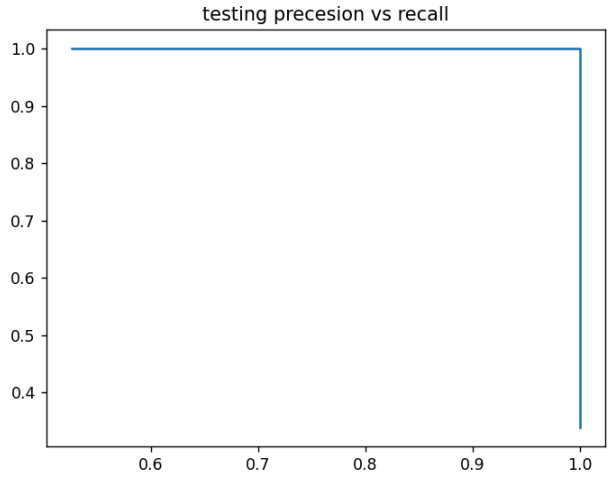
Training:



Validation:



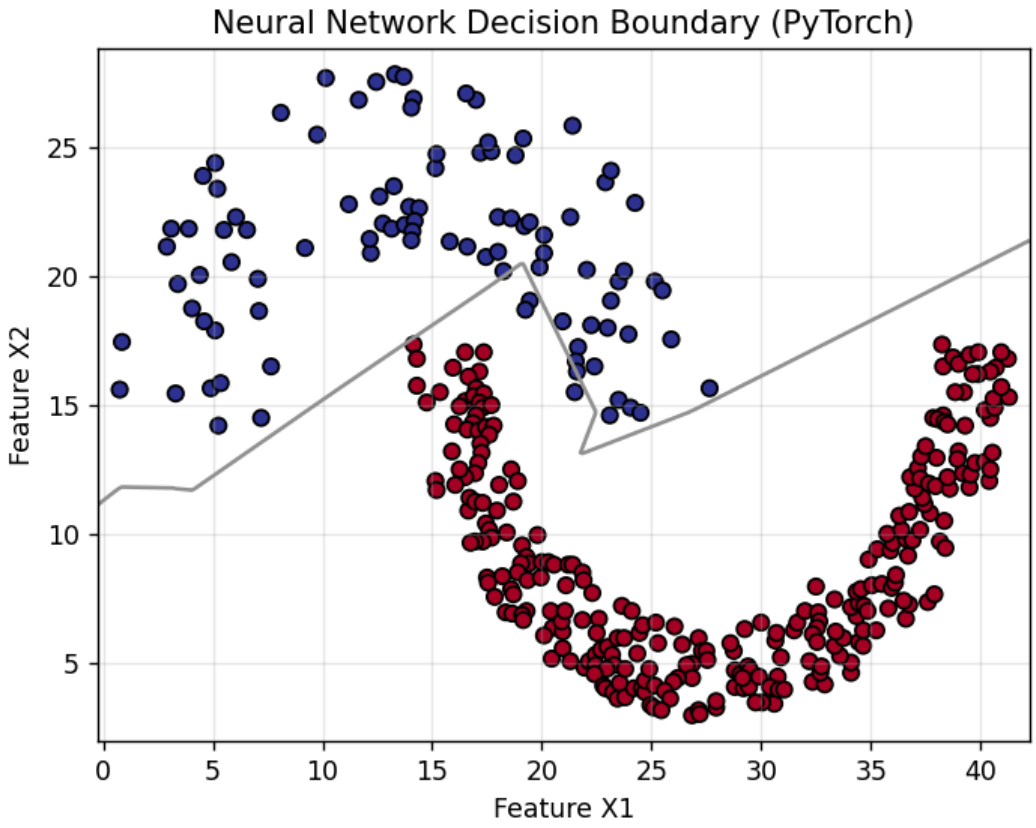

Testing:




**Observation:** The shape of the PR curve (high precision maintained for a large portion of recall) is characteristic of a high-performing classifier. The area under this curve would be high, confirming the strong F1-score. Similar curves were observed for the validation and test sets.

## Part (d): Decision Boundary

The fitted decision boundary was plotted to visualize how the model separates the two classes in the 2D feature space.




**Observation:** The decision boundary plot would show a non-linear line that effectively separates the two classes. The shape of the boundary reflects the complexity learned by the 5-layer neural network, allowing it to capture the non-linear relationship in the data.

## Conclusion

The 5-layer fully connected neural network was successfully trained to solve the binary classification task. The performance metrics and decision boundary visualization confirm that the model is a robust and effective solution for this problem.