Multi-Layer Perceptron from scratch (Implementation)

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In [ ]:
```
import pandas as pd
import numpy as np
import seaborn as sn
import matplotlib.pyplot as plt
from sklearn.model_selection import KFold
from sklearn.metrics import accuracy_score,confusion_matrix
```

Part 1: SPECT Dataset

In [ ]:
```
!wget 'https://archive.ics.uci.edu/ml/machine-learning-databases/spect/SPECT.train'
```

```
--2022-08-30 04:59:26--  https://archive.ics.uci.edu/ml/machine-learning-databases/spect/SPECT.train (http
s://archive.ics.uci.edu/ml/machine-learning-databases/spect/SPECT.train)
Resolving archive.ics.uci.edu (archive.ics.uci.edu)... 128.195.10.252
Connecting to archive.ics.uci.edu (archive.ics.uci.edu)|128.195.10.252|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 3758 (3.7K) [application/x-httpd-php]
Saving to: ‘SPECT.train’

SPECT.train         100%[===================>]   3.67K  --.-KB/s    in 0s

2022-08-30 04:59:27 (72.5 MB/s) - ‘SPECT.train’ saved [3758/3758]
```

In [ ]:
```
features = ['F'+str(i) for i in range(1,23)]
df=pd.read_csv('SPECT.train',header=None, names=['class']+features)
df = df.reindex(columns=features +['class'])
df = df.sample(frac=1,random_state=16).reset_index(drop=True)
df
```

Out[18]:

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	...	F14	F15	F16	F17	F18	F19	F20	F21	F22	class
0	0	0	1	0	0	0	0	1	0	0	...	0	0	0	0	0	0	0	0	1	1
1	0	0	0	1	0	0	1	0	1	0	...	1	0	0	0	0	0	0	1	0	1
2	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	1	0	...	1	0	0	0	0	0	0	0	0	0
4	0	0	0	1	0	0	0	0	1	0	...	1	0	1	0	0	0	1	0	1	1
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
75	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	1
76	1	0	0	0	1	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0	0	0	...	0	0	0	0	0	0	0	0	0	0

80 rows × 23 columns

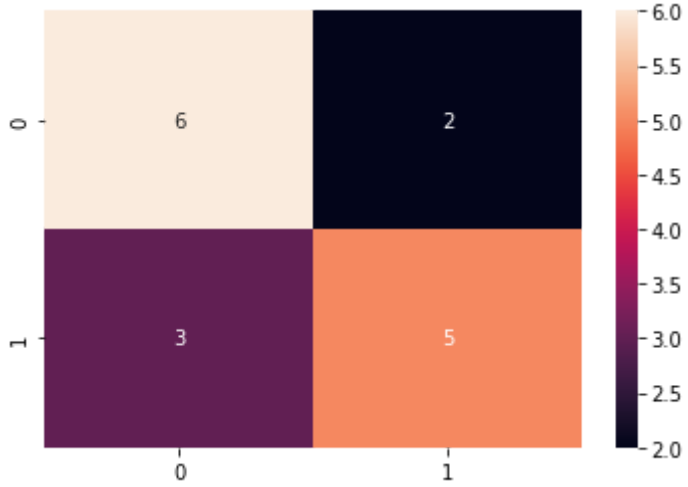
In [ ]:
```
def initialize(num_features,dim1,dim2,dim3,output):
  w1 = np.random.rand(num_features,dim1)
  b1 = np.random.rand(1,dim1)
  w2 = np.random.rand(dim1,dim2)
  b2 = np.random.rand(1,dim2)
  w3 = np.random.rand(dim2,dim3)
  b3 = np.random.rand(1,dim3)
  w4 = np.random.rand(dim3,output)
  b4 = np.random.rand(1,output)
  return w1,b1,w2,b2,w3,b3,w4,b4
```

In [ ]:
```
def predict(data,w1,b1,w2,b2,w3,b3,w4,b4):
  hop1 = np.matmul(data, w1) + b1
  hop2 = np.matmul(hop1, w2) + b2
  hop3 = np.matmul(hop2, w3) + b3
  hop4 = np.matmul(hop3, w4) + b4
  output = 1 / (1 + np.exp(- hop4))

  return hop1, hop2, hop3, hop4, output
```

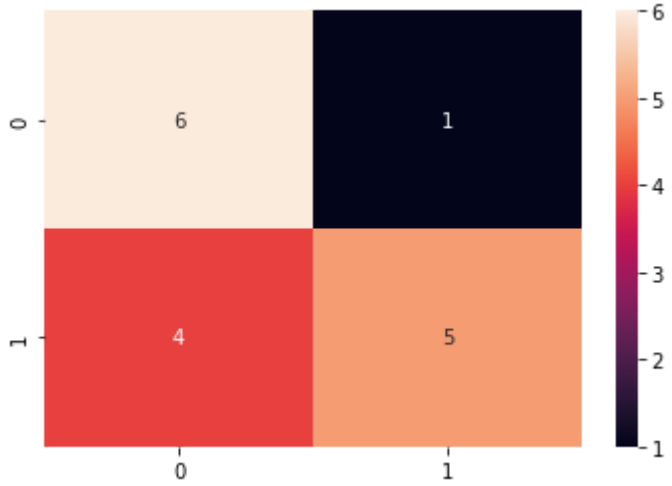
In [ ]:
```
def train_perceptron(data,w1,b1,w2,b2,w3,b3,w4,b4,lr):
  x = data[:,:-1]
  actual = data[:,-1:]

  iterations = 200
  for i in range(iterations):
    hop1, hop2, hop3, hop4, output = predict(x,w1,b1,w2,b2,w3,b3,w4,b4)

    w1 = w1 - lr * np.clip(x.T @ (output-actual) @ w4.T @ w3.T @ w2.T,-10,10)
    b1 = b1 - lr * np.clip(np.sum((output-actual) @ w4.T @ w3.T @ w2.T, axis = 0),-10,10)
    w2 = w2 - lr * np.clip(hop1.T @ (output-actual) @ w4.T @ w3.T,-10,10)
    b2 = b2 - lr * np.clip(np.sum((output-actual) @ w4.T @ w3.T, axis = 0),-10,10)
    w3 = w3 - lr * np.clip(hop2.T @ (output-actual) @ w4.T,-10,10)
    b3 = b3 - lr * np.clip(np.sum((output-actual) @ w4.T, axis = 0),-10,10)
    w4 = w4 - lr * np.clip(hop3.T @ (output-actual),-10,10)
    b4 = b4 - lr * np.clip(np.sum((output-actual), axis = 0),-10,10)

  return w1,b1,w2,b2,w3,b3,w4,b4
```

In [ ]:
```
def evaluate_perceptron(data,w1,b1,w2,b2,w3,b3,w4,b4):
  x = data[:,:-1]
  y = data[:,-1:]

  _, _, _, _, y_pred3 = predict(x,w1,b1,w2,b2,w3,b3,w4,b4)
  for i in range(len(y_pred3)):
    if y_pred3[i] < 0.5:
      y_pred3[i] = 0
    else:
      y_pred3[i] = 1
  accuracy = accuracy_score(y,y_pred3)
  cm = confusion_matrix(y,y_pred3)
  sn.heatmap(cm,annot=True)
  plt.show()
  return accuracy
```

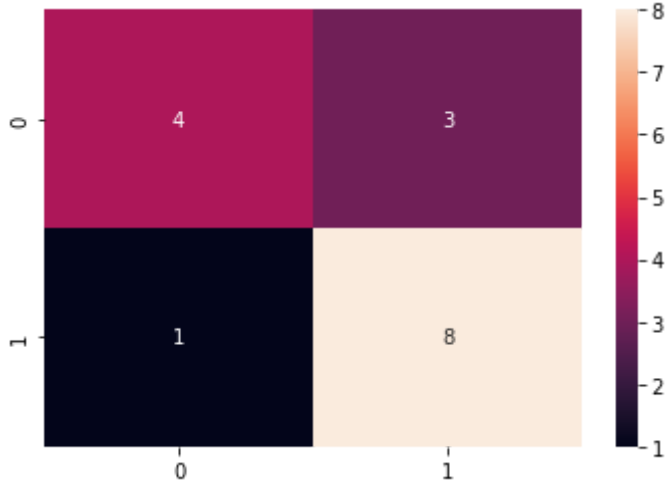
In [ ]:
```
k=5
lr = 0.01
df_numpy = df.values
kf = KFold(n_splits=k)
accuracies = []
fold = 0

for train_idx, test_idx in kf.split(df):
  fold+=1
  train = df_numpy[train_idx]
  test = df_numpy[test_idx]

  w1,b1,w2,b2,w3,b3,w4,b4 = initialize(22,16,8,4,1)
  w1,b1,w2,b2,w3,b3,w4,b4 = train_perceptron(train,w1,b1,w2,b2,w3,b3,w4,b4,lr)
  accuracy = evaluate_perceptron(test,w1,b1,w2,b2,w3,b3,w4,b4)
  print('Fold',fold,'accuracy:',accuracy)
  accuracies.append(accuracy)

print('Mean accuracy:',np.mean(accuracies))
```



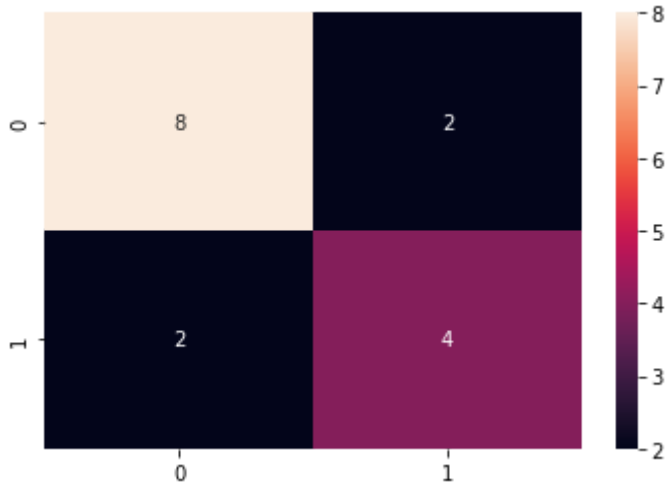

```
Fold 1 accuracy: 0.6875
```



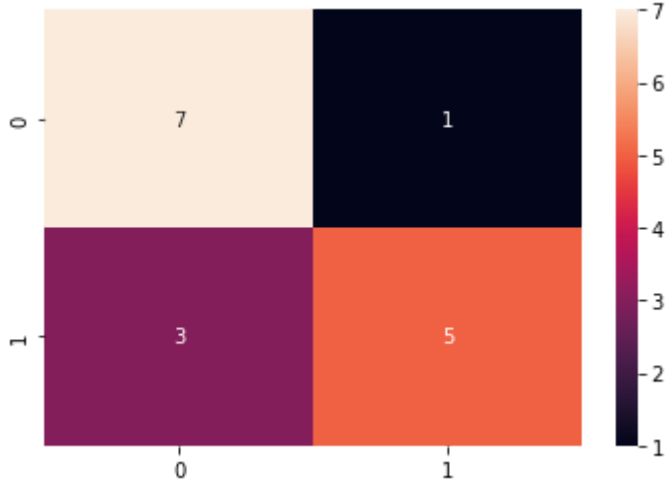
Fold 2 accuracy: 0.6875



Fold 3 accuracy: 0.75

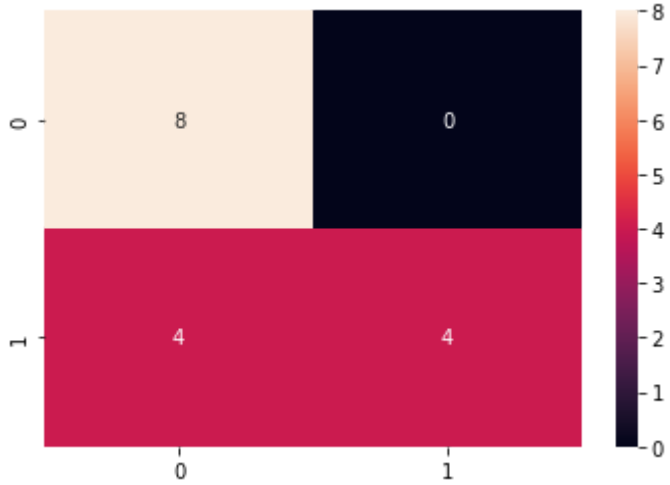



```
Fold 4 accuracy: 0.75
```

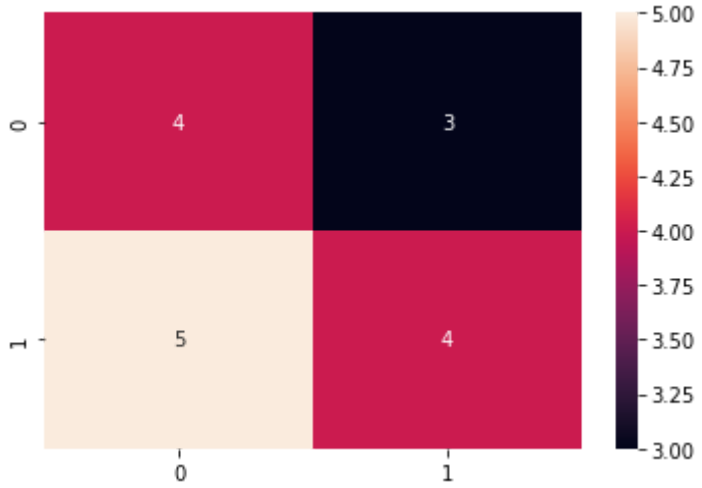



```
Fold 5 accuracy: 0.75
Mean accuracy: 0.725
```

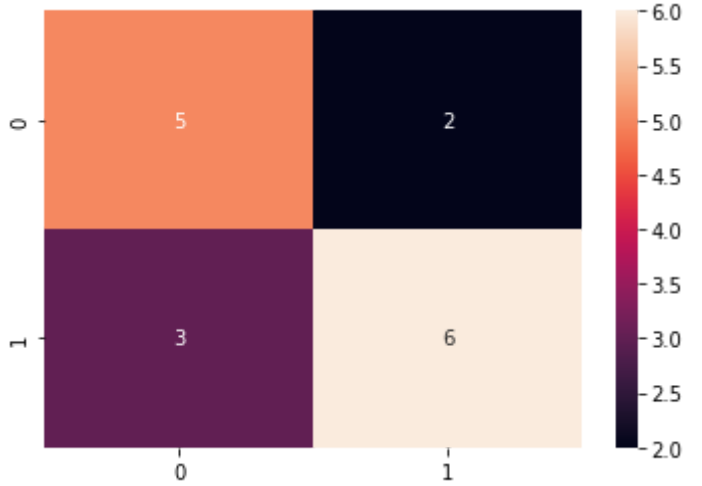
In [ ]:
```
k=5
lr = 0.001
df_numpy = df.values
kf = KFold(n_splits=k)
accuracies = []
fold = 0

for train_idx, test_idx in kf.split(df):
  fold+=1
  train = df_numpy[train_idx]
  test = df_numpy[test_idx]

  w1,b1,w2,b2,w3,b3,w4,b4 = initialize(22,16,8,4,1)
  w1,b1,w2,b2,w3,b3,w4,b4 = train_perceptron(train,w1,b1,w2,b2,w3,b3,w4,b4,lr)
  accuracy = evaluate_perceptron(test,w1,b1,w2,b2,w3,b3,w4,b4)
  print('Fold',fold,'accuracy:',accuracy)
  accuracies.append(accuracy)

print('Mean accuracy:',np.mean(accuracies))
```



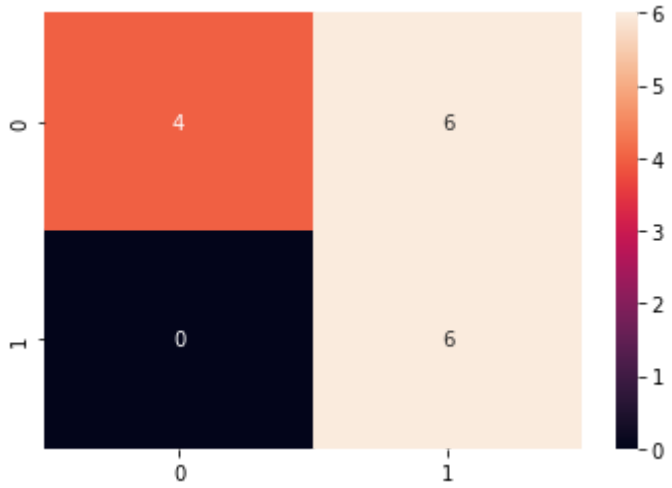

```
Fold 1 accuracy: 0.75
```



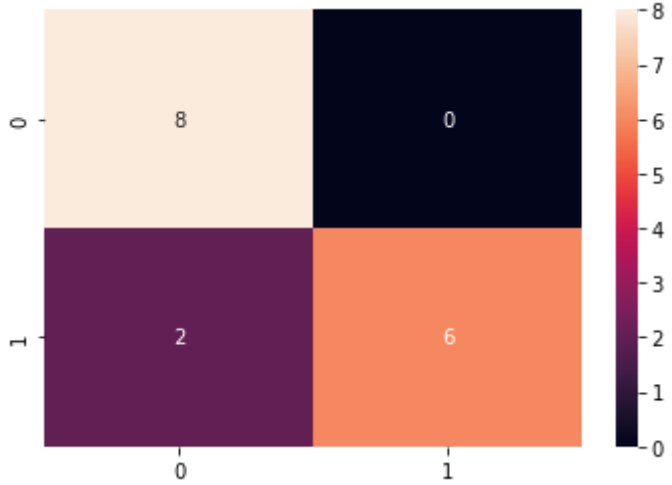

```
Fold 2 accuracy: 0.5
```




```
Fold 3 accuracy: 0.6875
```

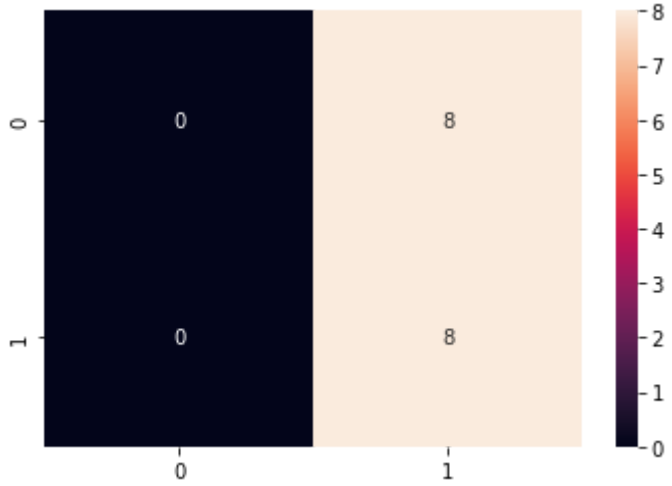



```
Fold 4 accuracy: 0.625
```

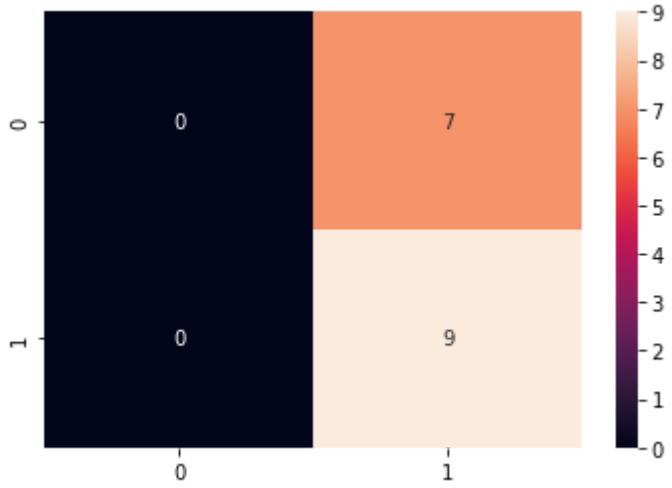



```
Fold 5 accuracy: 0.875
Mean accuracy: 0.6875
```

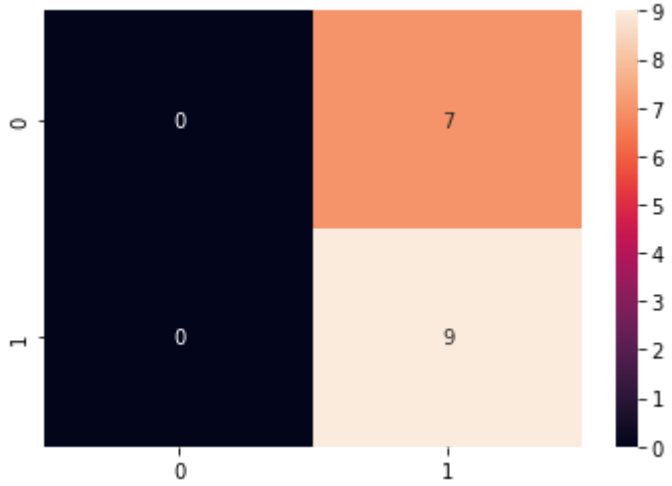
In [ ]:
```
k=5
lr = 0.0001
df_numpy = df.values
kf = KFold(n_splits=k)
accuracies = []
fold = 0

for train_idx, test_idx in kf.split(df):
  fold+=1
  train = df_numpy[train_idx]
  test = df_numpy[test_idx]

  w1,b1,w2,b2,w3,b3,w4,b4 = initialize(22,16,8,4,1)
  w1,b1,w2,b2,w3,b3,w4,b4 = train_perceptron(train,w1,b1,w2,b2,w3,b3,w4,b4,lr)
  accuracy = evaluate_perceptron(test,w1,b1,w2,b2,w3,b3,w4,b4)
  print('Fold',fold,'accuracy:',accuracy)
  accuracies.append(accuracy)

print('Mean accuracy:',np.mean(accuracies))
```



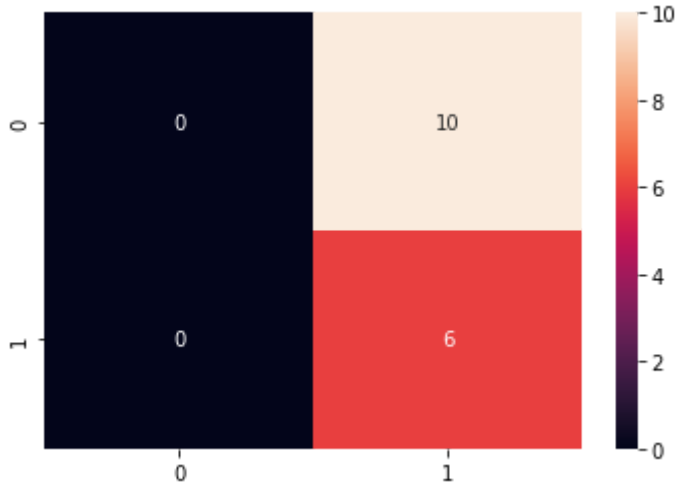
```
Fold 1 accuracy: 0.5
```



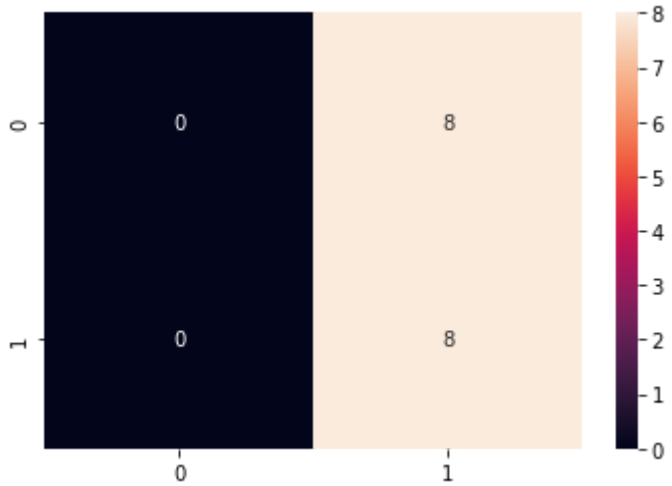

```
Fold 2 accuracy: 0.5625
```



```
Fold 3 accuracy: 0.5625
```




```
Fold 4 accuracy: 0.375
```




```
Fold 5 accuracy: 0.5
Mean accuracy: 0.5
```

Part 2: IRIS dataset

In [ ]:
```
from sklearn.datasets import load_iris
```

In [ ]:
```
#Load Iris dataset
iris = load_iris()
df = pd.DataFrame(data= np.c_[iris['data'], iris['target']], columns= ['sepal_length','sepal_width','petal_l
df = df.sample(frac = 1,random_state=12).reset_index(drop=True)
df
```

Out[8]:

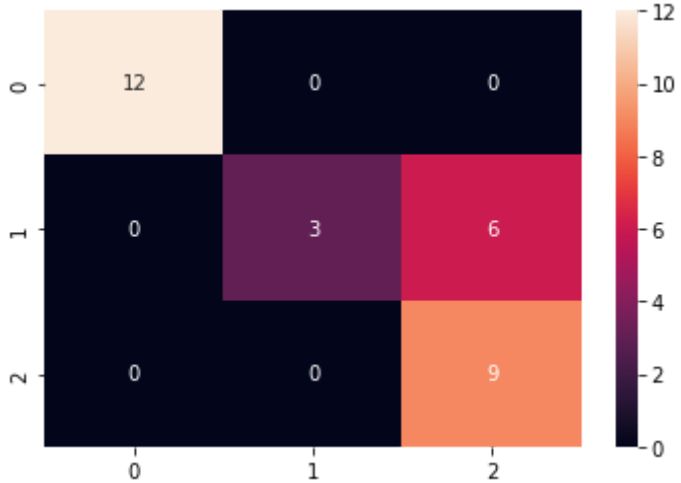
	sepal_length	sepal_width	petal_length	petal_width	class
0	5.0	3.5	1.3	0.3	0.0
1	6.3	2.5	5.0	1.9	2.0
2	4.4	3.0	1.3	0.2	0.0
3	5.7	2.8	4.1	1.3	1.0
4	6.8	3.2	5.9	2.3	2.0
...	...	...	...	...	...
145	6.8	2.8	4.8	1.4	1.0
146	4.6	3.1	1.5	0.2	0.0
147	7.4	2.8	6.1	1.9	2.0
148	6.1	2.6	5.6	1.4	2.0
149	6.6	3.0	4.4	1.4	1.0

150 rows × 5 columns

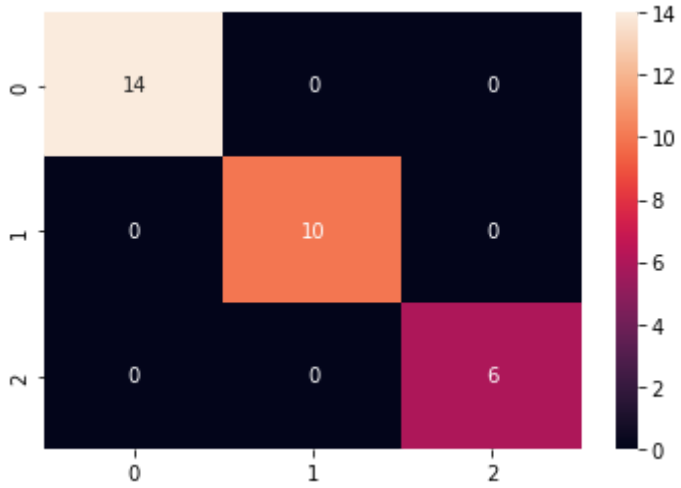
In [ ]:
```
def evaluate_perceptron_2(data,w1,b1,w2,b2,w3,b3,w4,b4):
  x = data[:,:-1]
  y = data[:,-1:]
  pred = []

  h1, h2, h3, h4, y_pred3 = predict(x,w1,b1,w2,b2,w3,b3,w4,b4)

  for i in range(len(y_pred3)):
    pred.append(y_pred3[i].argmax(axis=0))
  cm = confusion_matrix(y,pred)
  accuracy = np.sum(np.diag(cm))/np.sum(cm)
  sn.heatmap(cm,annot=True)
  plt.show()
  return accuracy
```

In [ ]:
```
def train_perceptron_2(data,w1,b1,w2,b2,w3,b3,w4,b4,lr,iterations = 2000):
  x = data[:,:-1]
  y_new = data[:,-1:]

  actual = []
  for i in range(len(y_new)):
    if y_new[i]==0:
      actual.append([1,0,0])
    elif y_new[i]==1:
      actual.append([0,1,0)
    elif y_new[i]==2]:
      actual.append([0,0,1])

  for i in range(iterations):
    hop1, hop2, hop3, hop4, output = predict(x,w1,b1,w2,b2,w3,b3,w4,b4)
    w1 = w1 - lr * np.clip(x.T @ (output-actual) @ w4.T @ w3.T @ w2.T,-1,1)
    b1 = b1 - lr * np.clip(np.sum((output-actual) @ w4.T @ w3.T @ w2.T, axis = 0),-1,1)
    w2 = w2 - lr * np.clip(hop1.T @ (output-actual) @ w4.T @ w3.T,-1,1)
    b2 = b2 - lr * np.clip(np.sum((output-actual) @ w4.T @ w3.T, axis = 0),-1,1)
    w3 = w3 - lr * np.clip(hop2.T @ (output-actual) @ w4.T,-1,1)
    b3 = b3 - lr * np.clip(np.sum((output-actual) @ w4.T, axis = 0),-1,1)
    w4 = w4 - lr * np.clip(hop3.T @ (output-actual),-1,1)
    b4 = b4 - lr * np.clip(np.sum((output-actual), axis = 0),-1,1)

  return w1,b1,w2,b2,w3,b3,w4,b4
```

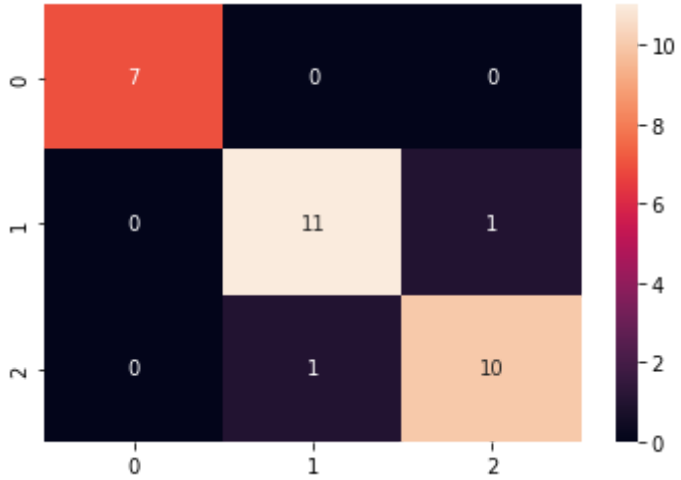
In [ ]:
```
k=5
lr = 0.01
df_numpy = df.values
kf = KFold(n_splits=k)
accuracies = []
fold = 0

for train_idx, test_idx in kf.split(df):
  fold+=1
  train = df_numpy[train_idx]
  test = df_numpy[test_idx]

  w1,b1,w2,b2,w3,b3,w4,b4 = initialize(4,3,3,3,3)
  w1,b1,w2,b2,w3,b3,w4,b4 = train_perceptron_2(train,w1,b1,w2,b2,w3,b3,w4,b4,lr)

  accuracy = evaluate_perceptron_2(test,w1,b1,w2,b2,w3,b3,w4,b4)
  print('Fold',fold,'accuracy:',accuracy)
  accuracies.append(accuracy)

print('Mean accuracy:',np.mean(accuracies))
```



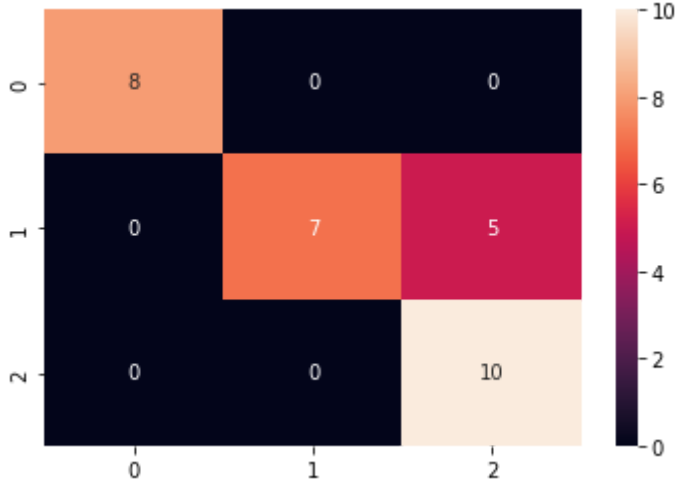

```
Fold 1 accuracy: 0.8
```



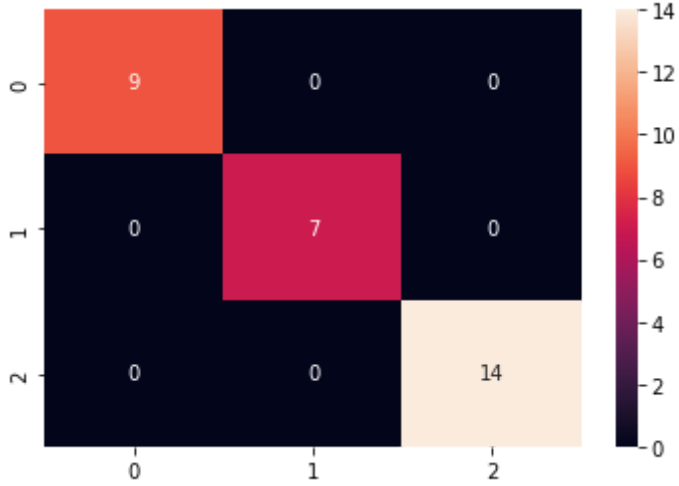

```
Fold 2 accuracy: 1.0
```




```
Fold 3 accuracy: 0.9333333333333333
```

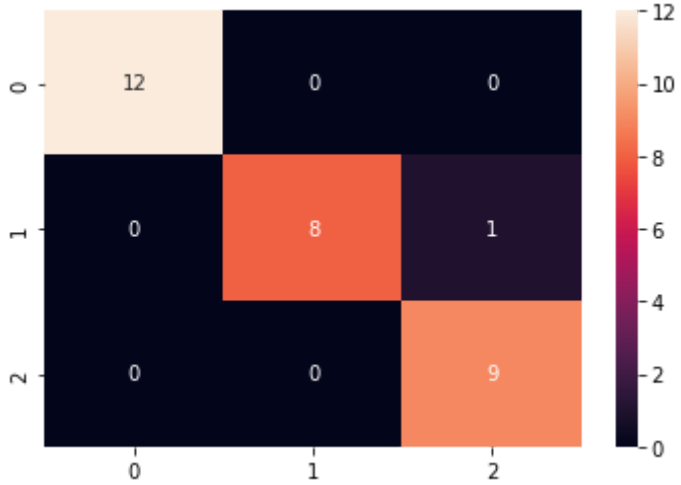



```
Fold 4 accuracy: 0.8333333333333334
```

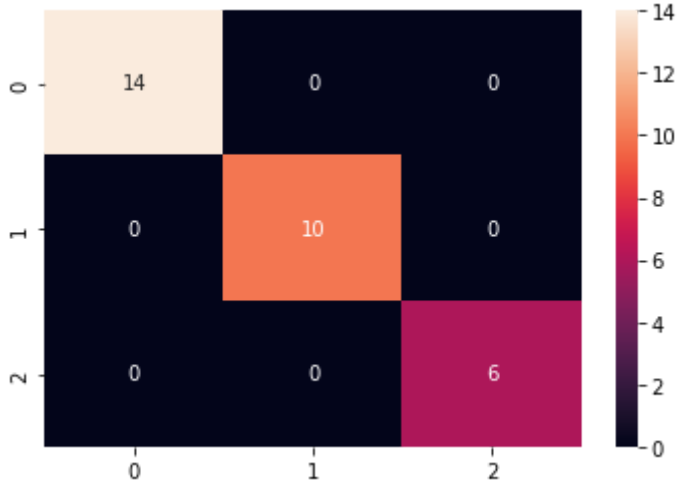



```
Fold 5 accuracy: 1.0
Mean accuracy: 0.9133333333333333
```

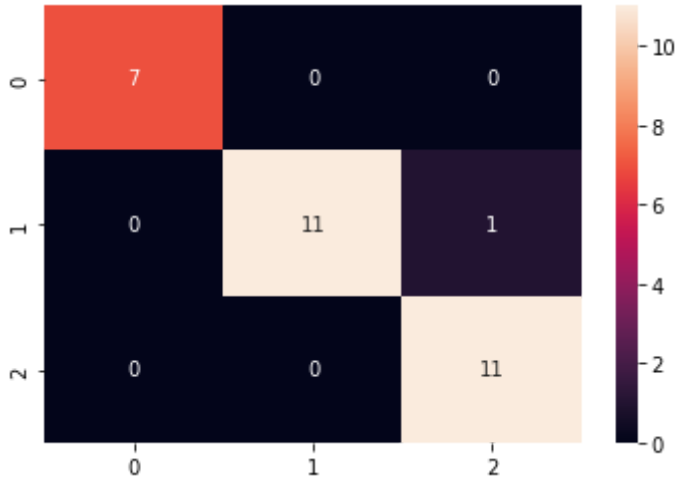
In [ ]:
```
k=5
lr = 0.001
df_numpy = df.values
kf = KFold(n_splits=k)
accuracies = []
fold = 0

for train_idx, test_idx in kf.split(df):
  fold+=1
  train = df_numpy[train_idx]
  test = df_numpy[test_idx]

  w1,b1,w2,b2,w3,b3,w4,b4 = initialize(4,3,3,3,3)
  w1,b1,w2,b2,w3,b3,w4,b4 = train_perceptron_2(train,w1,b1,w2,b2,w3,b3,w4,b4,lr)

  accuracy = evaluate_perceptron_2(test,w1,b1,w2,b2,w3,b3,w4,b4)
  print('Fold',fold,'accuracy:',accuracy)
  accuracies.append(accuracy)

print('Mean accuracy:',np.mean(accuracies))
```



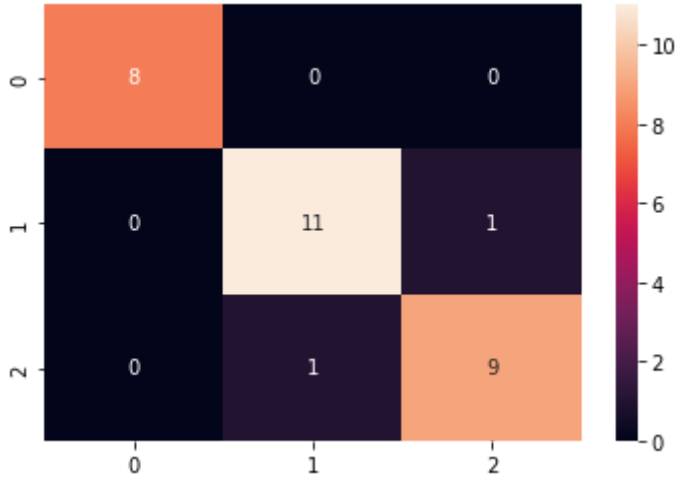

```
Fold 1 accuracy: 0.9666666666666667
```



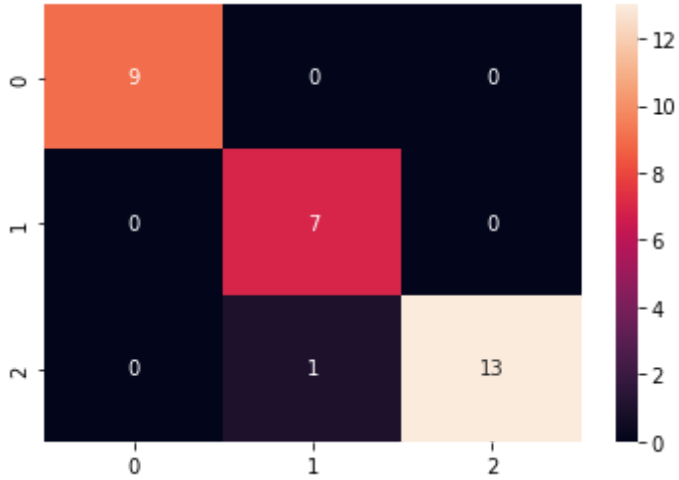

```
Fold 2 accuracy: 1.0
```




```
Fold 3 accuracy: 0.9666666666666667
```

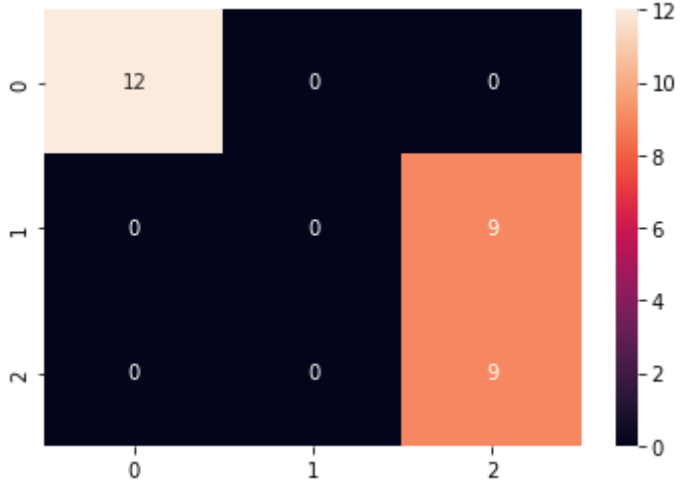



```
Fold 4 accuracy: 0.9333333333333333
```

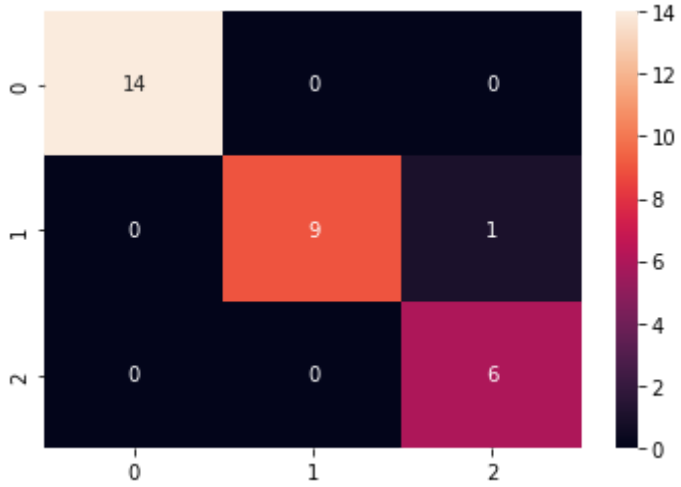



```
Fold 5 accuracy: 0.9666666666666667
Mean accuracy: 0.9666666666666668
```

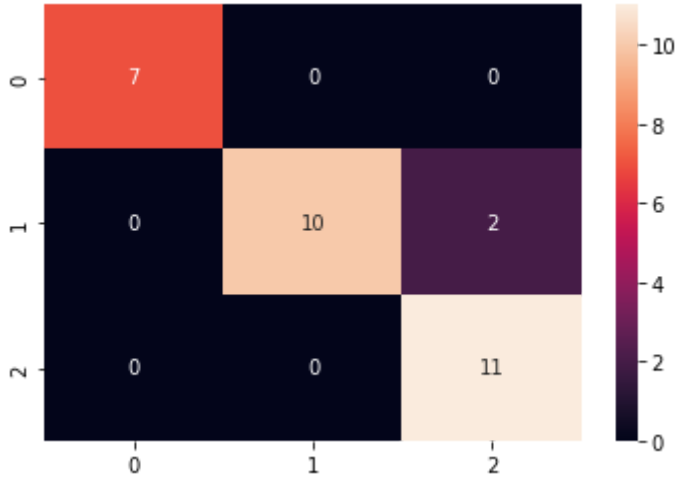
In [ ]:
```
k=5
lr = 0.0001
df_numpy = df.values
kf = KFold(n_splits=k)
accuracies = []
fold = 0

for train_idx, test_idx in kf.split(df):
  fold+=1
  train = df_numpy[train_idx]
  test = df_numpy[test_idx]

  w1,b1,w2,b2,w3,b3,w4,b4 = initialize(4,4,4,3,3)
  w1,b1,w2,b2,w3,b3,w4,b4 = train_perceptron_2(train,w1,b1,w2,b2,w3,b3,w4,b4,lr,7000)

  accuracy = evaluate_perceptron_2(test,w1,b1,w2,b2,w3,b3,w4,b4)
  print('Fold',fold,'accuracy:',accuracy)
  accuracies.append(accuracy)

print('Mean accuracy:',np.mean(accuracies))
```



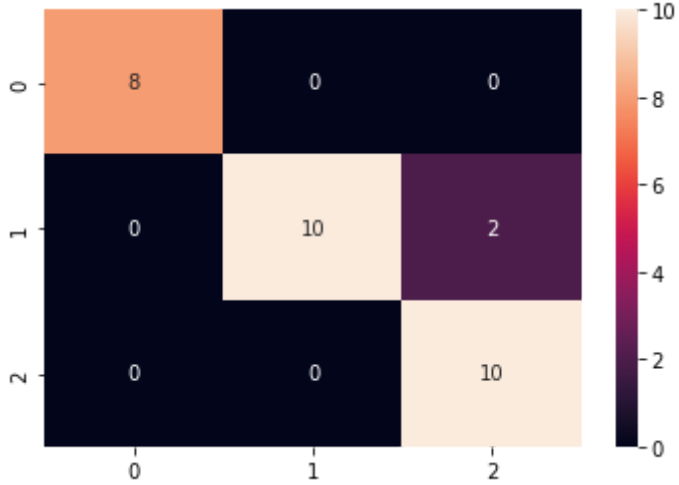
```
Fold 1 accuracy: 0.7
```



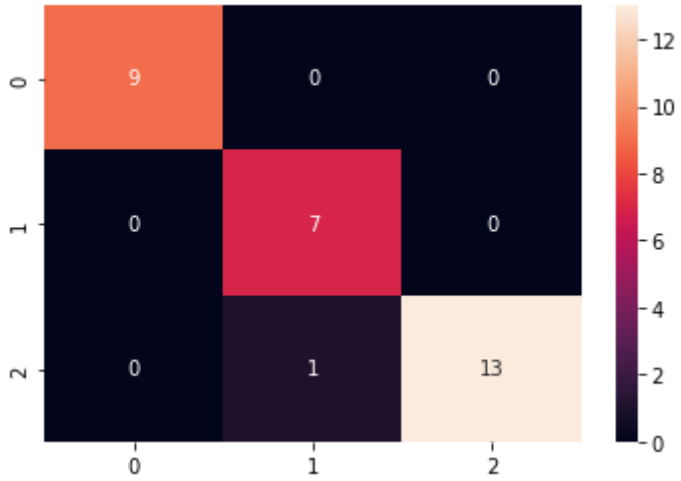

```
Fold 2 accuracy: 0.9666666666666667
```




```
Fold 3 accuracy: 0.9333333333333333
```




```
Fold 4 accuracy: 0.9333333333333333
```




```
Fold 5 accuracy: 0.9666666666666667
Mean accuracy: 0.9
```

Analysis of learning rate:

As the learning rate decreases, the speed of convergence decreases due to which the accuracy decreases. Also the number of datapoints is less the accuracy decreases as learning rate decreases.

In [ ]: