Neural Networks - intro

Part 1 - XOR

1. Using the XOR dataset below, train (400 epochs) a neural network (NN) using 2, 3, 4, and 5 hidden layers (where each layer has only 2 neurons). For each n layers, store the resulting accuracy along with n. Plot the results to find what the optimal number of layers is.
2. Repeat the above with 3 neurons in each Hidden layers. How do these results compare to the 2 neuron layers?
3. Repeat the above with 4 neurons in each Hidden layers. How do these results compare to the 2 and 3 neuron layers?
4. Using the most optimal configuraion (n-layers, k-neurons per layer), compare how `tanh` , `sigmoid` , `softplus` and `relu` effect the loss after 400 epochs. Try other Activation functions as well ([https://keras.io/activations/ (https://keras.io/activations/)](https://keras.io/activations/))
5. Again with the most optimal setup, try other optimizers (instead of `SGD`) and report on the loss score. ([https://keras.io/optimizers/ (https://keras.io/optimizers/)](https://keras.io/optimizers/))

In [106]:
```
!pip3 install tensorflow keras
```

```
Requirement already satisfied: tensorflow in c:\users\michael\anaconda3\insta
llationmain\lib\site-packages (2.16.1)
Requirement already satisfied: keras in c:\users\michael\anaconda3\installati
onmain\lib\site-packages (3.0.4)
Requirement already satisfied: tensorflow-intel==2.16.1 in c:\users\michael\a
naconda3\installationmain\lib\site-packages (from tensorflow) (2.16.1)
Requirement already satisfied: astunparse>=1.6.0 in c:\users\michael\anaconda
3\installationmain\lib\site-packages (from tensorflow-intel==2.16.1->tensorfl
ow) (1.6.3)
Requirement already satisfied: h5py>=3.10.0 in c:\users\michael\anaconda3\ins
tallationmain\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow)
(3.10.0)
Requirement already satisfied: setuptools in c:\users\michael\anaconda3\insta
llationmain\lib\site-packages (from tensorflow-intel==2.16.1->tensorflow) (6
3.4.1)
Requirement already satisfied: ml-dtypes~=0.3.1 in c:\users\michael\anaconda3
\installationmain\lib\site-packages (from tensorflow-intel==2.16.1->tensorflo
w) (0.3.2)
Requirement already satisfied: flatbuffers>=23.5.26 in c:\users\michael\anaco
```

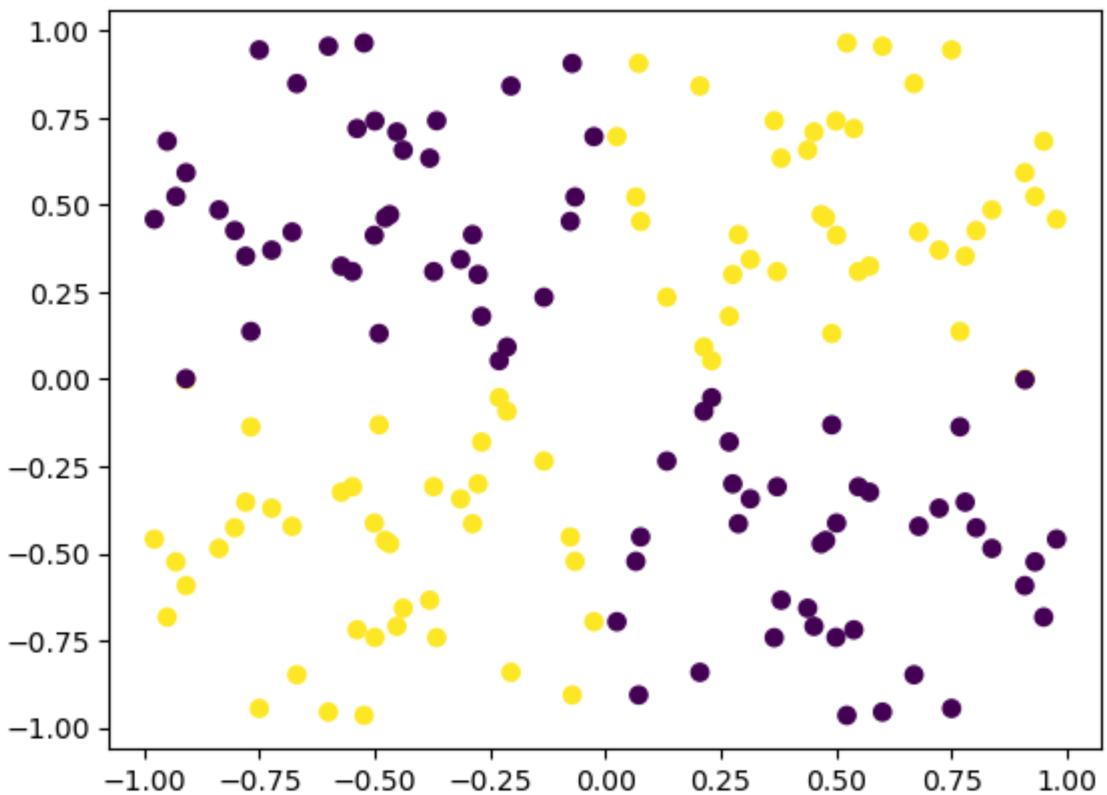
In [107]:
```
from keras.models import Sequential
from keras.layers import Dense
from keras.optimizers import SGD  #Stochastic Gradient Descent

import numpy as np
# fix random seed for reproducibility
np.random.seed(7)

import matplotlib.pyplot as plt
%matplotlib inline
```

In [108]:
```
n = 40
xx = np.random.random((n,1))
yy = np.random.random((n,1))
```

In [109]:
```
X = np.array([np.array([xx,-xx,-xx,xx]),np.array([yy,-yy,yy,-yy])]).reshape(2,
y = np.array([np.ones([2*n]),np.zeros([2*n])]).reshape(4*n)
```

In [110]:
```
plt.scatter(*zip(*X), c=y)
```

Out[110]:
```
<matplotlib.collections.PathCollection at 0x1d29d917580>
```



In [111]:
```python
model = Sequential()

model.add(Dense(2, input_dim=2, activation='tanh'))  #sigmoid, relu
# model.add(Dense(2, activation='tanh'))
model.add(Dense(1, activation='sigmoid'))
# model.add(Dense(1,input_dim=2, activation='sigmoid'))


sgd = SGD(learning_rate=0.1)
model.compile(loss='binary_crossentropy', optimizer='sgd')

model.fit(X, y, batch_size=2, epochs=400) #160/4 = 40 per epoch
print(model.predict(X).reshape(4*n))

# evaluate the model
scores = model.evaluate(X, y)
```

```
Epoch 1/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 442us/step - loss: 0.7230
Epoch 2/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 417us/step - loss: 0.7241
Epoch 3/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 404us/step - loss: 0.7257
Epoch 4/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 404us/step - loss: 0.7000
Epoch 5/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 417us/step - loss: 0.7026
Epoch 6/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 417us/step - loss: 0.6962
Epoch 7/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 417us/step - loss: 0.7031
Epoch 8/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 404us/step - loss: 0.7032
Epoch 9/400
80/80 ━━━━━━━━━━━━━━━━━━━━ 0s 417us/step - loss: 0.6823
Epoch 10/400
```

In [112]:
```
print(model.predict(X).reshape(4*n))
```

```
5/5 ━━━━━━━━━━━━━━━━━━━━ 0s 499us/step
[0.8233326  0.7851529  0.92263514 0.8653396  0.6256814  0.93323207
 0.95154804 0.11636674 0.9513515  0.9139756  0.9199855  0.844564
 0.90962416 0.7090833  0.9445333  0.09083924 0.94833153 0.9073454
 0.8142549  0.2806965  0.8368649  0.91753924 0.9400358  0.92531407
 0.89312786 0.94804853 0.72254866 0.9285857  0.9330403  0.9536838
 0.33493754 0.85678095 0.9528151  0.95386803 0.8186072  0.8675493
 0.37036923 0.9530742  0.922545   0.9532871  0.83192205 0.77845234
 0.92731005 0.8588438  0.62358665 0.9369862  0.95046943 0.11587252
 0.9501259  0.91939145 0.9156539  0.83788073 0.91525567 0.7172676
 0.9468526  0.09070256 0.94649094 0.91319966 0.8077284  0.27745664
 0.8461813  0.913296   0.93709344 0.9212473  0.88769716 0.9497851
 0.7323817  0.9329294  0.9368886  0.954027   0.3328948  0.8497143
 0.95204973 0.95392585 0.8278697  0.8612857  0.37502685 0.953715
 0.91829675 0.95382434 0.5702121  0.04884041 0.0516821  0.05236302
 0.03698845 0.04138882 0.08631167 0.06769861 0.73226404 0.04205319
 0.05150391 0.04276443 0.06191263 0.439576   0.24132797 0.08968262
 0.8872395  0.04630749 0.03670062 0.21251893 0.03553687 0.03504034
 0.9000991  0.10976804 0.03611169 0.8357028  0.03619096 0.03471535
```

In [113]:
```
scores = model.evaluate(X, y)
scores, model.metrics_names
```

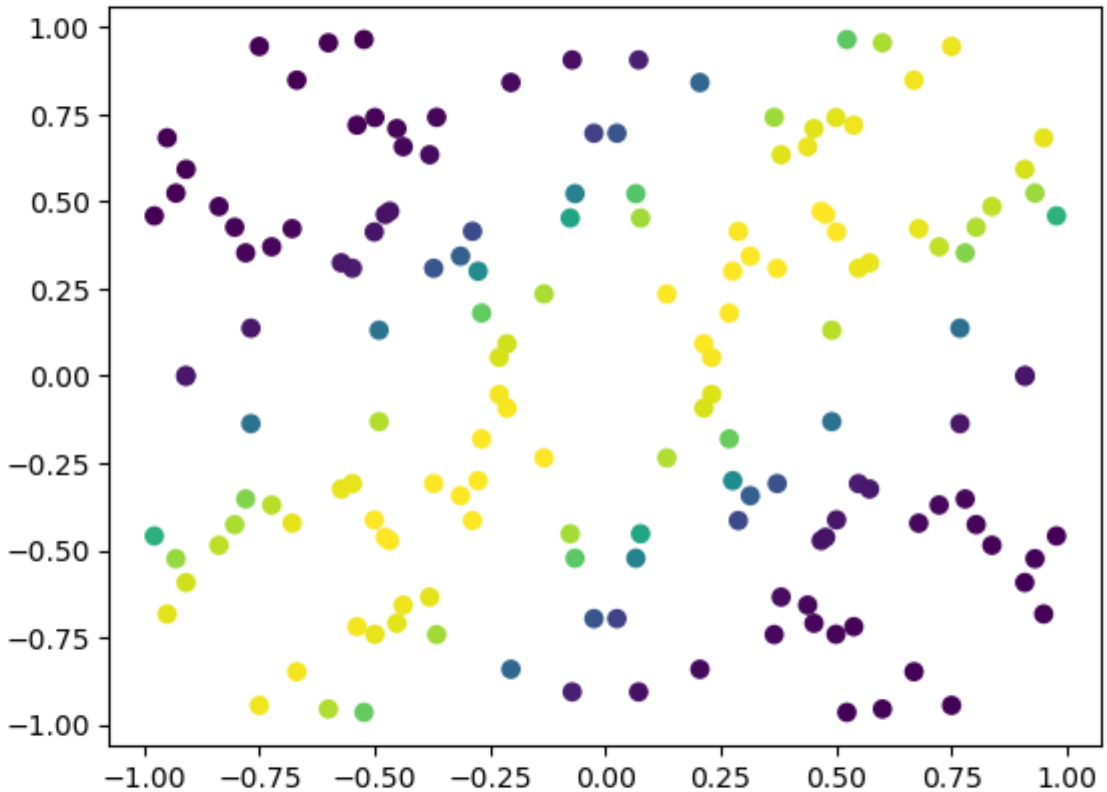
```
5/5 ━━━━━━━━━━━━━━━━━━━━ 0s 749us/step - loss: 0.3153
```

Out[113]:
```
(0.3172093629837036, ['loss'])
```

In [114]:
```
plt.scatter(*zip(*X), c=model.predict(X))
```

```
5/5 ━━━━━━━━━━━━━━━━━━━━ 0s 748us/step
```

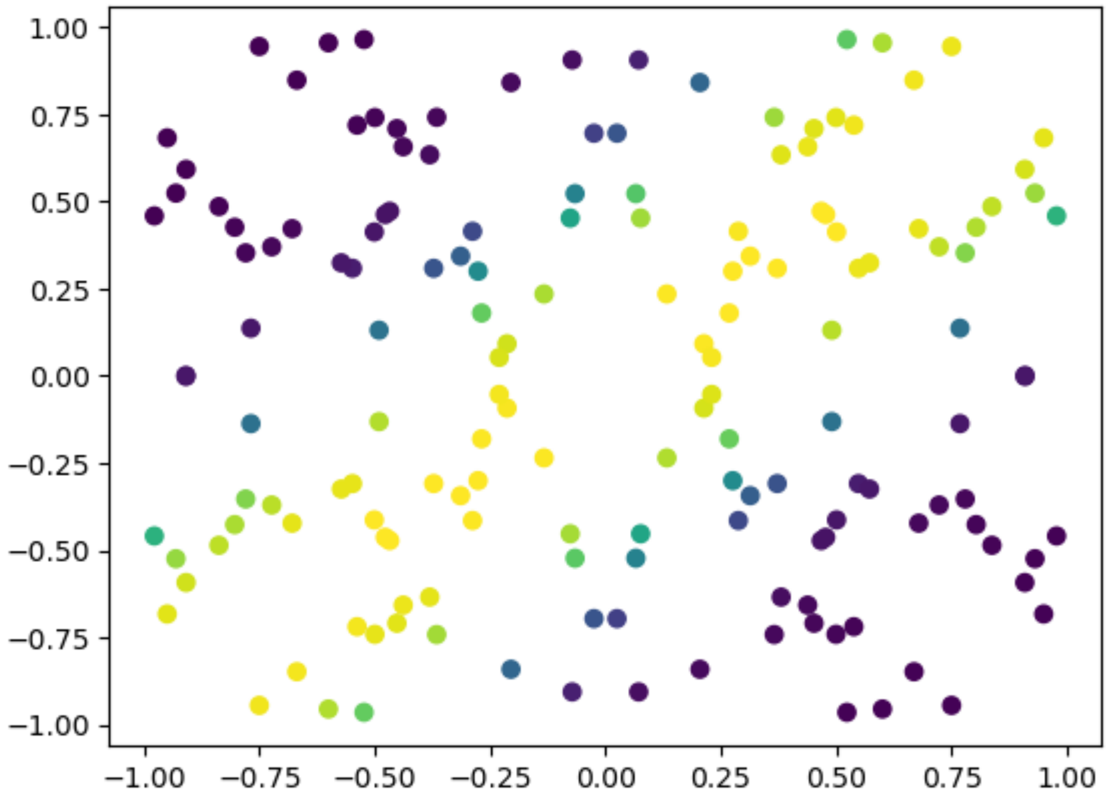
Out[114]:
```
<matplotlib.collections.PathCollection at 0x1d2ad96fb80>
```



In [115]:
```
plt.scatter(*zip(*X), c=model.predict(X))
```

```
5/5 ━━━━━━━━━━━━━━━━━━━━ 0s 750us/step
```

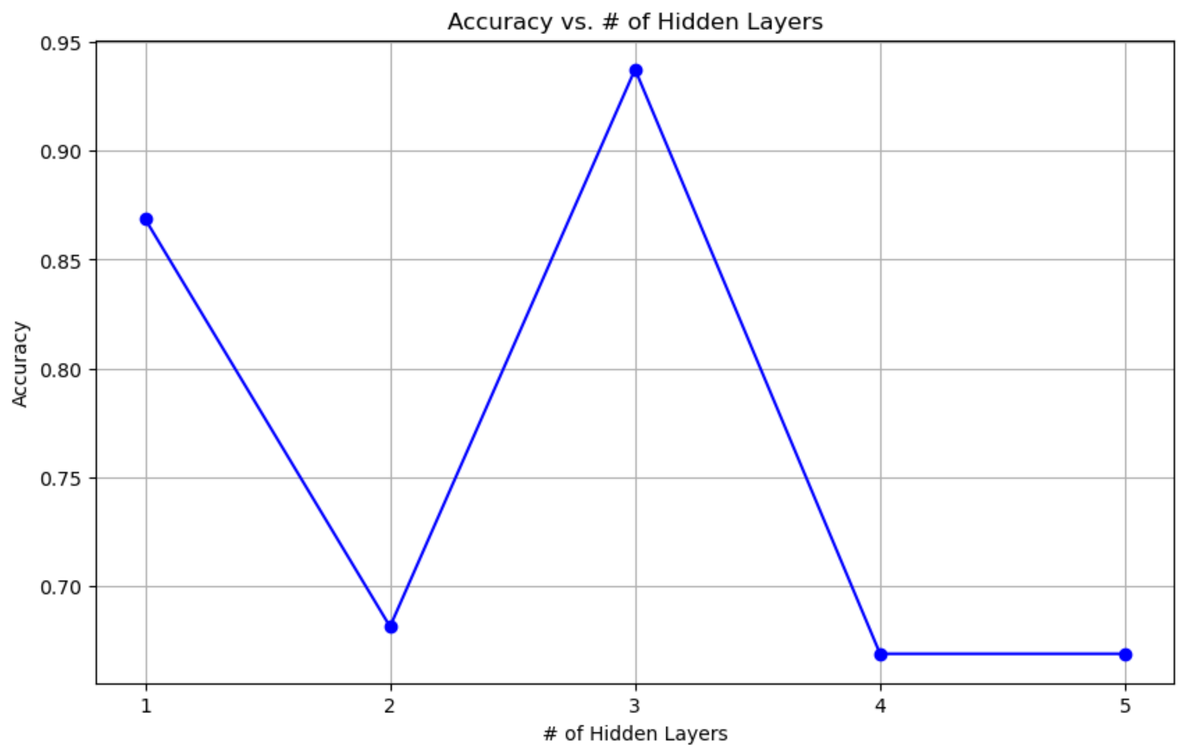
Out[115]:
```
<matplotlib.collections.PathCollection at 0x1d2afcbaf40>
```



In [116]:
```
#Part 1 - Question #1
from keras.models import Sequential
from keras.layers import Dense
from keras.optimizers import SGD

#Define loop
num_layers = [1,2,3,4,5]
scores_1 = []
for num_layer in num_layers:
    model = Sequential([
        Dense(2, input_dim=2, activation='tanh')
    ])
    if num_layer >= 1:
        model.add(Dense(2, activation='tanh'))
    if num_layer >= 2:
        model.add(Dense(2, activation='tanh'))
    if num_layer >= 3:
        model.add(Dense(2, activation='tanh'))
    if num_layer >= 4:
        model.add(Dense(2, activation='tanh'))
    if num_layer == 5:
        model.add(Dense(2, activation='tanh'))
    model.add(Dense(1, activation='sigmoid'))

    #Define the model
    sgd = SGD(learning_rate=0.1)
    model.compile(loss='binary_crossentropy', optimizer=sgd, metrics=['accurac
    model.fit(X, y, batch_size=1, epochs=400)

    #Model evaluation
    score_1 = model.evaluate(X, y)[1]
    scores_1.append(score_1)

#Print accuracy scores
print(f"Accuracy scores: {scores_1}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 433us/step - accuracy: 0.4953 - loss: 0.7003
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 427us/step - accuracy: 0.7357 - loss: 0.6128
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 439us/step - accuracy: 0.7318 - loss: 0.5245
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 445us/step - accuracy: 0.8248 - loss: 0.4594
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 445us/step - accuracy: 0.8627 - loss: 0.3963
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 427us/step - accuracy: 0.7778 - loss: 0.4619
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 424us/step - accuracy: 0.7743 - loss: 0.4589
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 420us/step - accuracy: 0.8522 - loss: 0.3384
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 424us/step - accuracy: 0.8548 - loss: 0.3756
Epoch 10/400
```

In [122]:
```
#Plot the results
plt.figure(figsize=(10, 6))
plt.plot(num_layers, scores_1, marker='o', linestyle='-', color='b')
plt.title('Accuracy vs. # of Hidden Layers')
plt.xlabel('# of Hidden Layers')
plt.ylabel('Accuracy')
plt.xticks(num_layers)
plt.grid(True)
plt.show()
```



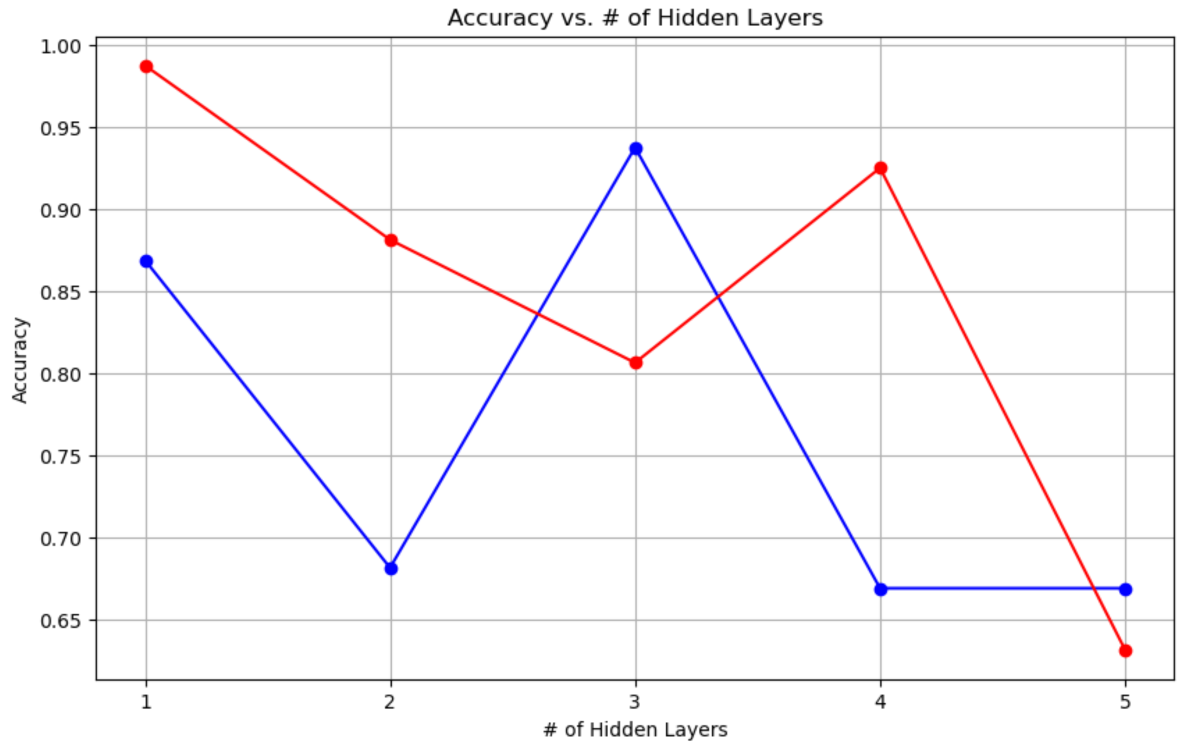
In [123]:
```
print("""The optimal number of hidden layers for the first model would be 3, a
```

```
The optimal number of hidden layers for the first model would be 3, as that l
ayer has the highest corresponding accuracy score @ 0.9375.
```

In [124]:
```
#Part 1 - Question #2

#Define Loop
num_layers = [1,2,3,4,5]
scores_2 = []
for num_layer in num_layers:
    model = Sequential([
        Dense(2, input_dim=2, activation='tanh')
    ])
    if num_layer >= 1:
        model.add(Dense(3, activation='tanh'))
    if num_layer >= 2:
        model.add(Dense(3, activation='tanh'))
    if num_layer >= 3:
        model.add(Dense(3, activation='tanh'))
    if num_layer >= 4:
        model.add(Dense(3, activation='tanh'))
    if num_layer == 5:
        model.add(Dense(3, activation='tanh'))
    model.add(Dense(1, activation='sigmoid'))

    #Define the model
    sgd = SGD(learning_rate=0.1)
    model.compile(loss='binary_crossentropy', optimizer=sgd, metrics=['accurac
    model.fit(X, y, batch_size=1, epochs=400)

    #Model evaluation
    score_2 = model.evaluate(X, y)[1]
    scores_2.append(score_2)

#Print accuracy scores
print(f"Accuracy scores: {scores_2}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.5447 - loss: 0.6999
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.6468 - loss: 0.6367
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 450us/step - accuracy: 0.8898 - loss: 0.4988
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 432us/step - accuracy: 0.9292 - loss: 0.3328
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 445us/step - accuracy: 0.8591 - loss: 0.3477
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 440us/step - accuracy: 0.9223 - loss: 0.2142
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 445us/step - accuracy: 0.8594 - loss: 0.2791
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 464us/step - accuracy: 0.8826 - loss: 0.2278
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.9482 - loss: 0.1494
Epoch 10/400
```

In [129]:
```
#Plot the results
plt.figure(figsize=(10, 6))
plt.plot(num_layers, scores_1, marker='o', linestyle='-', color='b')
plt.plot(num_layers, scores_2, marker='o', linestyle='-', color='r', label='Mo
plt.title('Accuracy vs. # of Hidden Layers')
plt.xlabel('# of Hidden Layers')
plt.ylabel('Accuracy')
plt.xticks(num_layers)
plt.grid(True)
plt.show()
```



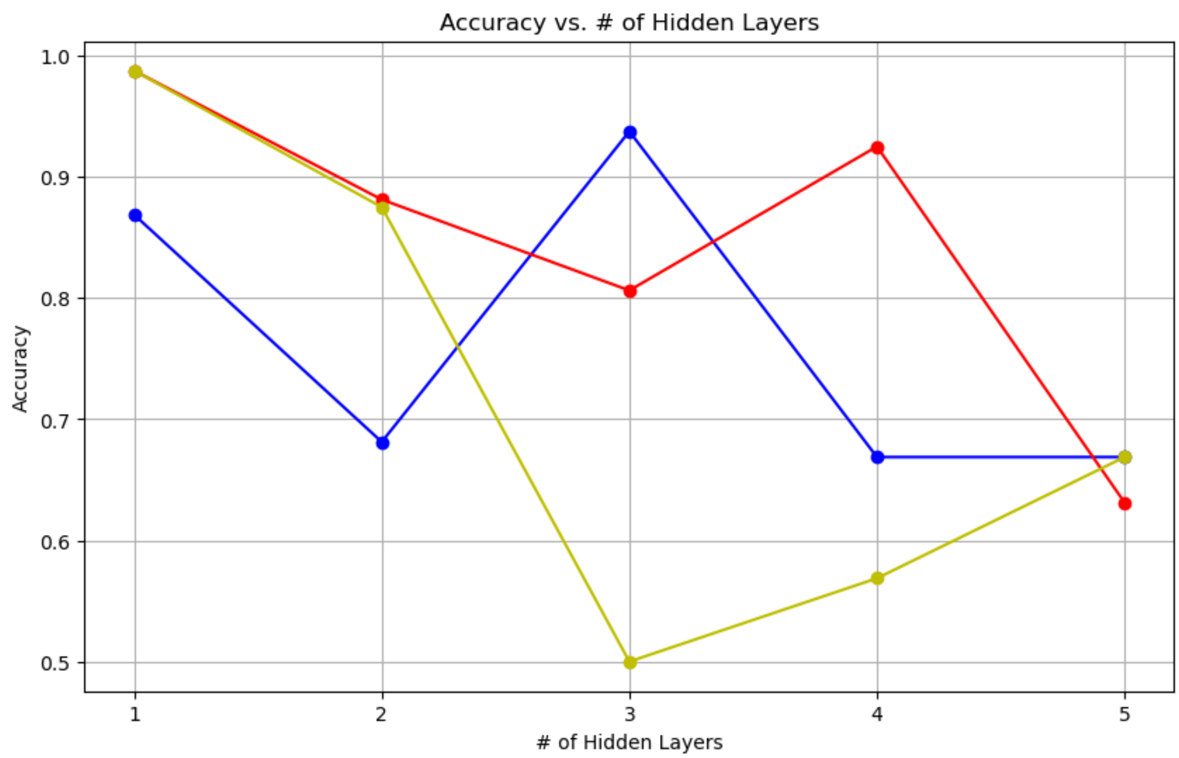
In [126]:
```
print("""The optimal number of hidden layers for the second model would be 1,
```

```
The optimal number of hidden layers for the second model would be 1, as that
has the highest accuracy score @ 0.987500011920929.
```

In [127]:
```
#Part 1 - Question #3

#Define loop
num_layers = [1,2,3,4,5]
scores_3 = []
for num_layer in num_layers:
    model = Sequential([
        Dense(2, input_dim=2, activation='tanh')
    ])
    if num_layer >= 1:
        model.add(Dense(4, activation='tanh'))
    if num_layer >= 2:
        model.add(Dense(4, activation='tanh'))
    if num_layer >= 3:
        model.add(Dense(4, activation='tanh'))
    if num_layer >= 4:
        model.add(Dense(4, activation='tanh'))
    if num_layer == 5:
        model.add(Dense(4, activation='tanh'))
    model.add(Dense(1, activation='sigmoid'))

    #Define the model
    sgd = SGD(learning_rate=0.1)
    model.compile(loss='binary_crossentropy', optimizer=sgd, metrics=['accurac
    model.fit(X, y, batch_size=1, epochs=400)

    #Model evaluation
    score_3 = model.evaluate(X, y)[1]
    scores_3.append(score_3)

#Print accuracy scores
print(f"Accuracy scores: {scores_3}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 433us/step - accuracy: 0.5401 - loss: 0.7105
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 414us/step - accuracy: 0.5699 - loss: 0.6746
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 427us/step - accuracy: 0.7400 - loss: 0.5962
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 439us/step - accuracy: 0.7825 - loss: 0.4598
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 439us/step - accuracy: 0.9100 - loss: 0.3361
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 470us/step - accuracy: 0.9279 - loss: 0.2639
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 420us/step - accuracy: 0.9083 - loss: 0.1998
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 433us/step - accuracy: 0.9262 - loss: 0.1916
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 427us/step - accuracy: 0.9278 - loss: 0.1936
Epoch 10/400
```

In [130]:
```
#Plot the results
plt.figure(figsize=(10, 6))
plt.plot(num_layers, scores_1, marker='o', linestyle='-', color='b', label='Mo
plt.plot(num_layers, scores_2, marker='o', linestyle='-', color='r', label='Mo
plt.plot(num_layers, scores_3, marker='o', linestyle='-', color='y', label='Mo
plt.title('Accuracy vs. # of Hidden Layers')
plt.xlabel('# of Hidden Layers')
plt.ylabel('Accuracy')
plt.xticks(num_layers)
plt.grid(True)
```



In [132]:
```
print("""The optimal number of hidden layers for the third model would be 1, a
```

```
The optimal number of hidden layers for the third model would be 1, as that h
as the highest accuracy score @ 0.987500011920929.
```

In [133]:

```
#Part 1 - Question #4

###SOFTPLUS Activation###

from keras.models import Sequential
from keras.layers import Dense
from keras.optimizers import SGD

#Define optimal parameters
num_layers = 1
neurons_per_hidden_layer = 4

#Define the model + compile + fit
model = Sequential()
model.add(Dense(neurons_per_hidden_layer, input_dim=2, activation='softplus'))
model.add(Dense(neurons_per_hidden_layer, activation='softplus'))
model.add(Dense(1, activation='sigmoid'))
sgd = SGD(learning_rate=0.1)
model.compile(loss='binary_crossentropy', optimizer=sgd, metrics=['accuracy'])
model.fit(X, y, batch_size=1, epochs=400)

#Model evaluation
loss, accuracy = model.evaluate(X, y)

#Print model metrics
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.4205 - loss: 0.7391
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 445us/step - accuracy: 0.5769 - loss: 0.6903
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.5215 - loss: 0.7001
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 439us/step - accuracy: 0.5911 - loss: 0.6808
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 436us/step - accuracy: 0.5765 - loss: 0.6735
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 421us/step - accuracy: 0.6048 - loss: 0.6428
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 427us/step - accuracy: 0.5329 - loss: 0.6416
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 427us/step - accuracy: 0.5998 - loss: 0.6137
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.7444 - loss: 0.5105
Epoch 10/400
```

In [134]:

```
print("""Using the softplus activation function, we are able to observe a mode
```

```
Using the softplus activation function, we are able to observe a model with a
fairly minimal loss function @ 0.017431840300559998
```

In [135]:
```
#Part 1 - Question #4

###RELU Activation###

from keras.models import Sequential
from keras.layers import Dense
from keras.optimizers import SGD

#Define optimal parameters
num_layers = 1
neurons_per_hidden_layer = 4

#Define the model + compile + fit
model = Sequential()
model.add(Dense(neurons_per_hidden_layer, input_dim=2, activation='relu'))
model.add(Dense(neurons_per_hidden_layer, activation='relu'))
model.add(Dense(1, activation='sigmoid'))
sgd = SGD(learning_rate=0.1)
model.compile(loss='binary_crossentropy', optimizer=sgd, metrics=['accuracy'])
model.fit(X, y, batch_size=1, epochs=400)

#Model evaluation
loss, accuracy = model.evaluate(X, y)

#Print model metrics
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 508us/step - accuracy: 0.5743 - loss: 0.6561
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 470us/step - accuracy: 0.8218 - loss: 0.4361
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 470us/step - accuracy: 0.9133 - loss: 0.2649
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.8752 - loss: 0.3281
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 464us/step - accuracy: 0.9079 - loss: 0.2200
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 464us/step - accuracy: 0.9018 - loss: 0.1827
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.9145 - loss: 0.2693
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 457us/step - accuracy: 0.9051 - loss: 0.2070
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 450us/step - accuracy: 0.9630 - loss: 0.1313
Epoch 10/400
```

In [136]:
```
print("""Utilization of the relu activation function resulted in a model with
```

```
Utilization of the relu activation function resulted in a model with minimal
loss function @ 0.28042155504226685. This value is higher compared to the mod
el containing the softplus activation function (0.017431840300559998).
```

In [137]:
```
#Part 1 - Question #4

###TANH Activation###

from keras.models import Sequential
from keras.layers import Dense
from keras.optimizers import SGD

#Define optimal parameters
num_layers = 1
neurons_per_hidden_layer = 4

#Define the model + compile + fit
model = Sequential()
model.add(Dense(neurons_per_hidden_layer, input_dim=2, activation='tanh'))
model.add(Dense(neurons_per_hidden_layer, activation='tanh'))
model.add(Dense(1, activation='sigmoid'))
sgd = SGD(learning_rate=0.1)
model.compile(loss='binary_crossentropy', optimizer=sgd, metrics=['accuracy'])
model.fit(X, y, batch_size=1, epochs=400)

#Model evaluation
loss, accuracy = model.evaluate(X, y)

#Print model metrics
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.4554 - loss: 0.7009
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.7473 - loss: 0.5622
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.8356 - loss: 0.3730
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 464us/step - accuracy: 0.9062 - loss: 0.2941
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 477us/step - accuracy: 0.9051 - loss: 0.2467
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.8905 - loss: 0.2636
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.9339 - loss: 0.1526
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 455us/step - accuracy: 0.9147 - loss: 0.2007
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 443us/step - accuracy: 0.8697 - loss: 0.2340
Epoch 10/400
```

In [139]:
```
print("""This particular model utilized the tanh activation function. The loss
```

```
This particular model utilized the tanh activation function. The loss functio
n for this particular model is 0.06121869012713432. This value is lower whenc
compared to relu activation, but higher when compared to softplus activation
```

In [140]:
```
#Part 1 - Question #4

###SIGMOID Activation###

from keras.models import Sequential
from keras.layers import Dense
from keras.optimizers import SGD

#Define optimal parameters
num_layers = 1
neurons_per_hidden_layer = 4

#Define the model + compile + fit
model = Sequential()
model.add(Dense(neurons_per_hidden_layer, input_dim=2, activation='sigmoid'))
model.add(Dense(neurons_per_hidden_layer, activation='sigmoid'))
model.add(Dense(1, activation='sigmoid'))
sgd = SGD(learning_rate=0.1)
model.compile(loss='binary_crossentropy', optimizer=sgd, metrics=['accuracy'])
model.fit(X, y, batch_size=1, epochs=400)

#Model evaluation
loss, accuracy = model.evaluate(X, y)

#Print model metrics
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 514us/step - accuracy: 0.5095 - loss: 0.7087
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.5255 - loss: 0.7056
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.4597 - loss: 0.7189
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.5484 - loss: 0.6934
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.5391 - loss: 0.6919
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.5181 - loss: 0.7046
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 452us/step - accuracy: 0.5177 - loss: 0.7050
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.5762 - loss: 0.6963
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 464us/step - accuracy: 0.4839 - loss: 0.7097
Epoch 10/400
```

In [141]:
```
print("""The utilization of the sigmoid activation function resulted in a mode
```

```
The utilization of the sigmoid activation function resulted in a model with m
ininmal loss function @ 0.03711051121354103. Overall, with regards to the los
s function, it seems that softplus activation had the lowest loss value @ 0.0
17431840300559998, followed by sigmoid activation @ 0.03711051121354103, foll
owed by tanh activation @ 0.06121869012713432, and finally followed by relu a
ctivation @ 0.28042155504226685. For question #5, I will utilize softplus act
ivation.
```

In [142]:

```
#Part 1 - Question #5
#I utilized the Adam optimizer for this model + softplus activation

from keras.models import Sequential
from keras.layers import Dense
from keras.optimizers import Adam

#Define optimal parameters
num_layers = 1
neurons_per_hidden_layer = 4

#Define the model + compile + fit
model = Sequential()
model.add(Dense(neurons_per_hidden_layer, input_dim=2, activation='softplus'))
model.add(Dense(neurons_per_hidden_layer, activation='softplus'))
model.add(Dense(1, activation='sigmoid'))
adam = Adam(learning_rate=0.1)
model.compile(loss='binary_crossentropy', optimizer=adam, metrics=['accuracy']
model.fit(X, y, batch_size=1, epochs=400)

#Model evaluation
loss, accuracy = model.evaluate(X, y)

#Print model metrics
print(f"Final loss: {loss}")
print(f"Final accuracy: {accuracy}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 1s 521us/step - accuracy: 0.5007 - loss: 0.7567
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 493us/step - accuracy: 0.4475 - loss: 0.7229
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 523us/step - accuracy: 0.5346 - loss: 0.6828
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 505us/step - accuracy: 0.7317 - loss: 0.5943
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 501us/step - accuracy: 0.7149 - loss: 0.5625
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 492us/step - accuracy: 0.7644 - loss: 0.5169
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 491us/step - accuracy: 0.6783 - loss: 0.5648
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 508us/step - accuracy: 0.6911 - loss: 0.5472
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 489us/step - accuracy: 0.7725 - loss: 0.4635
Epoch 10/400
```

In [145]:

```
print("""This particular model, which utilized the Adam optimizer + softplus a
```

```
This particular model, which utilized the Adam optimizer + softplus activatio
n, has a loss function of 7.971192836761475. The loss value actually increase
d with the utilization of the Adam optimizer.
```

In [143]:
```
#Part 1 - Question #5
#I utliized the Adagrad optimizer for this model + softplus activation

from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
from tensorflow.keras.optimizers import Adagrad

#Define optimal parameters
num_layers = 1
neurons_per_hidden_layer = 4

#Define the model + compile + fit
model = Sequential()
model.add(Dense(neurons_per_hidden_layer, input_dim=2, activation='softplus'))
model.add(Dense(neurons_per_hidden_layer, activation='softplus'))
model.add(Dense(1, activation='sigmoid'))
adagrad = Adagrad(learning_rate=0.1)
model.compile(loss='binary_crossentropy', optimizer=adagrad, metrics=['accurac
model.fit(X, y, batch_size=1, epochs=400)

#Model evaluation
loss, accuracy = model.evaluate(X, y)

#Print model metrics
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 496us/step - accuracy: 0.4576 - loss: 0.7254
Epoch 2/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 514us/step - accuracy: 0.5713 - loss: 0.6893
Epoch 3/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 464us/step - accuracy: 0.5675 - loss: 0.6826
Epoch 4/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 458us/step - accuracy: 0.6516 - loss: 0.6650
Epoch 5/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 455us/step - accuracy: 0.6165 - loss: 0.6187
Epoch 6/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 468us/step - accuracy: 0.8832 - loss: 0.5355
Epoch 7/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 464us/step - accuracy: 0.8474 - loss: 0.4725
Epoch 8/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 470us/step - accuracy: 0.8590 - loss: 0.3895
Epoch 9/400
160/160 ━━━━━━━━━━━━━━━━━━━━ 0s 477us/step - accuracy: 0.8897 - loss: 0.3205
Epoch 10/400
```

In [147]:
```
print("""Utilization of the Adagrad optimzer + softplus activation brought dow
```

```
Utilization of the Adagrad optimzer + softplus activation brought down the lo
ss function to 0.0366697758436203, which is an improvement over the previous
loss function associated with the Adam optimizer model (Adam optimizer - loss
value @ 7.971192836761475)
```

Part 2 - BYOD (Bring your own Dataset)

Using your own dataset, experiment and find the best Neural Network configuration. You may use any resource to improve results, just reference it.

While you may use any dataset, I'd prefer you didn't use the diabetes dataset used in the lesson.

https://stackoverflow.com/questions/34673164/how-to-train-and-tune-an-artificial-multilayer-perceptron-neural-network-using-k (https://stackoverflow.com/questions/34673164/how-to-train-and-tune-an-artificial-multilayer-perceptron-neural-network-using-k)

https://keras.io/ (https://keras.io/)

In [148]:
```
import numpy as np
import pandas as pd
import pandas as pd
from sklearn import preprocessing
from sklearn.preprocessing import OneHotEncoder

stars = pd.read_csv('C:\\Users\\Michael\\Desktop\\MLData\\stars.csv')
stars.head()
```

Out[148]:

	Temperature	L	R	A_M	Color	Spectral_Class	Type
0	3068	0.002400	0.1700	16.12	Red	M	0
1	3042	0.000500	0.1542	16.60	Red	M	0
2	2600	0.000300	0.1020	18.70	Red	M	0
3	2800	0.000200	0.1600	16.65	Red	M	0
4	1939	0.000138	0.1030	20.06	Red	M	0

In [149]:
```
stars_Color = stars['Color'].unique()
stars_Color
```

Out[149]:
```
array(['Red', 'Blue White', 'White', 'Yellowish White', 'Blue white',
       'Pale yellow orange', 'Blue', 'Blue-white', 'Whitish',
       'yellow-white', 'Orange', 'White-Yellow', 'white', 'yellowish',
       'Yellowish', 'Orange-Red', 'Blue-White'], dtype=object)
```

In [150]:
```
stars_Spectral_Class = stars['Spectral_Class'].unique()
stars_Spectral_Class
```

Out[150]:
```
array(['M', 'B', 'A', 'F', 'O', 'K', 'G'], dtype=object)
```

In [151]:
```
stars_Type = stars['Type'].unique()
stars_Type
```

Out[151]:
```
array([0, 1, 2, 3, 4, 5], dtype=int64)
```

In [152]:
```
#Define columns/variables to transform
cvariables = ['Color', 'Spectral_Class']

#Use OneHotEncoder to transform the categorical categories that are a part of
OH = OneHotEncoder(handle_unknown="ignore", sparse=False)
OHcategory = OH.fit_transform(stars[cvariables])

#Create dataframe that contain the transformed categorical values & concatenat
Tcategories = OH.get_feature_names_out(cvariables)
StarsTcategories = pd.DataFrame(OHcategory, columns=Tcategories)
Tstars = pd.concat([stars.drop(cvariables, axis=1), StarsTcategories], axis=1)
Tstars
```

Out[152]:

	Temperature	L	R	A_M	Type	Color_Blue	Color_Blue White	Color_Blue white
0	3068	0.002400	0.1700	16.12	0	0.0	0.0	0.0
1	3042	0.000500	0.1542	16.60	0	0.0	0.0	0.0
2	2600	0.000300	0.1020	18.70	0	0.0	0.0	0.0
3	2800	0.000200	0.1600	16.65	0	0.0	0.0	0.0
4	1939	0.000138	0.1030	20.06	0	0.0	0.0	0.0
...	...	...	...	...	...	...	...	...
235	38940	374830.000000	1356.0000	-9.93	5	1.0	0.0	0.0
236	30839	834042.000000	1194.0000	-10.63	5	1.0	0.0	0.0
237	8829	537493.000000	1423.0000	-10.73	5	0.0	0.0	0.0
238	9235	404940.000000	1112.0000	-11.23	5	0.0	0.0	0.0
239	37882	294903.000000	1783.0000	-7.80	5	1.0	0.0	0.0

240 rows × 29 columns

In [153]:
```
from tensorflow.keras.utils import to_categorical

#Define X and Y
X = Tstars.drop('Type', axis=1)
Y = Tstars['Type']

#Encode Y using tensorflow.keras.utils
Y_stars = to_categorical(Y, num_classes=6)
Y_stars
```

Out[153]:
```
array([[1., 0., 0., 0., 0., 0.],
       [1., 0., 0., 0., 0., 0.],
       [1., 0., 0., 0., 0., 0.],
       ...,
       [0., 0., 0., 0., 0., 1.],
       [0., 0., 0., 0., 0., 1.],
       [0., 0., 0., 0., 0., 1.]])
```

In [154]:
```
from keras.models import Sequential
from keras.layers import Dense
from sklearn.model_selection import train_test_split

#Model 1/Attempt 1

#Split data into train/test sets
Xtrain, Xtest, Ytrain, Ytest = train_test_split(X, Y_stars, test_size=0.2)

#Define model + compiles + fit
model = Sequential()
model.add(Dense(16, input_dim=28, activation='tanh'))
model.add(Dense(16, activation='tanh'))
model.add(Dense(6, activation='softmax'))
adam = Adam(learning_rate=0.1)
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['acc
model.fit(Xtrain, Ytrain, epochs=1000, batch_size=10)

#Model evaluation
loss, accuracy = model.evaluate(Xtest, Ytest)

#Print evaluation
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/1000

C:\Users\Michael\anaconda3\InstallationMain\lib\site-packages\keras\src\layer
s\core\dense.py:85: UserWarning: Do not pass an `input_shape`/`input_dim` arg
ument to a layer. When using Sequential models, prefer using an `Input(shap
e)` object as the first layer in the model instead.
  super().__init__(activity_regularizer=activity_regularizer, **kwargs)

20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 682us/step - accuracy: 0.0936 - loss: 1.8849
Epoch 2/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 578us/step - accuracy: 0.2124 - loss: 1.6484
Epoch 3/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 577us/step - accuracy: 0.3114 - loss: 1.4693
Epoch 4/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 578us/step - accuracy: 0.3512 - loss: 1.3754
Epoch 5/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.3048 - loss: 1.3997
Epoch 6/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 578us/step - accuracy: 0.3907 - loss: 1.2859
Epoch 7/1000
```

In [157]:
```
print("""This particular model had an accuracy of roughly 25%, with a loss of
```

```
This particular model had an accuracy of roughly 25%, with a loss of 1.301504
135131836. I utilized the Adam optimizer for this model and utilized softmax
for the activation function associated with the output layer (in order to acc
omodate multi-class classification). The hidden neuron layers were associated
with the Tanh activation function.
```

In [158]:
```
from keras.models import Sequential
from keras.layers import Dense

#Model 1/Attempt 2

#Split data into train/test sets
Xtrain, Xtest, Ytrain, Ytest = train_test_split(X, Y_stars, test_size=0.2)

#Define model + compiles + fit
model = Sequential()
model.add(Dense(16, input_dim=28, activation='relu'))
model.add(Dense(16, activation='relu'))
model.add(Dense(16, activation='relu'))
model.add(Dense(6, activation='softmax'))
adam = Adam(learning_rate=0.1)
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['acc
model.fit(Xtrain, Ytrain, epochs=1000, batch_size=10)

#Model evaluation
loss, accuracy = model.evaluate(Xtest, Ytest)

#Print evaluation
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 1s 735us/step - accuracy: 0.1857 - loss: 5748.5591
Epoch 2/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.1861 - loss: 2939.8323
Epoch 3/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.1711 - loss: 2223.9612
Epoch 4/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 682us/step - accuracy: 0.0975 - loss: 636.8438
Epoch 5/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.2966 - loss: 224.9568
Epoch 6/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.3234 - loss: 83.2017
Epoch 7/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.4250 - loss: 69.0094
Epoch 8/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 683us/step - accuracy: 0.3872 - loss: 38.7431
Epoch 9/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.3788 - loss: 31.8035
Epoch 10/1000
```

In [159]:
```
print("""For this model, I went ahead and added an additional hidden layer, co
```

```
For this model, I went ahead and added an additional hidden layer, consisting
of 16 hidden neurons. Additionally, I changed the activation function from ta
nh to relu. This model had an accuracy of approximately 75% and a loss of 0.4
815387427806854
```

In [167]:
```
from keras.models import Sequential
from keras.layers import Dense

#Model 3/Attempt 3

#Split data into train/test sets
Xtrain, Xtest, Ytrain, Ytest = train_test_split(X, Y_stars, test_size=0.2)

#Define model + compiles + fit
model = Sequential()
model.add(Dense(16, input_dim=28, activation='softplus'))
model.add(Dense(16, activation='softplus'))
model.add(Dense(6, activation='softmax'))
adam = Adam(learning_rate=0.1)
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['acc
model.fit(Xtrain, Ytrain, epochs=1000, batch_size=10)

#Model evaluation
loss, accuracy = model.evaluate(Xtest, Ytest)

#Print evaluation
print(f"Loss: {loss}")
print(f"Accuracy: {accuracy}")
```

```
Epoch 1/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 1s 787us/step - accuracy: 0.1243 - loss: 15051.542
0
Epoch 2/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 682us/step - accuracy: 0.1542 - loss: 7096.4336
Epoch 3/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.3142 - loss: 2590.5034
Epoch 4/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 840us/step - accuracy: 0.2521 - loss: 1574.9565
Epoch 5/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 577us/step - accuracy: 0.2626 - loss: 1939.1041
Epoch 6/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.2871 - loss: 2434.8018
Epoch 7/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.3499 - loss: 964.7509
Epoch 8/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.3409 - loss: 608.4494
Epoch 9/1000
20/20 ━━━━━━━━━━━━━━━━━━━━ 0s 630us/step - accuracy: 0.5073 - loss: 895.4412
```

In [168]:
```
print("""For this model, I actually trimmed the number hidden neuron layers to
```

```
For this model, I actually trimmed the number hidden neuron layers to just on
e (consisting of 16 neurons) + I changed the activation function to softplus
to see what kind of impact it had on accuracy and loss. Overall, I am pretty
pleased with how this model turned out. The accuracy of the model is 95.83% a
nd the loss function is @ 0.1138666570186615.
```

In [78]:
```
print("""Overall, I would say that the third model is the strongest of the thr
```

```
Overall, I would say that the third model is the strongest of the three field
ed in terms of accuracy and loss.
```