Node Classification using Graph Convolutional Networks

This node classification task uses CORA dataset from https://linqs.soe.ucsc.edu/data
The dataset consists of **2708** nodes which correspond to scientific publications.
The nodes are classified into **7** categories indicating the topics of each document.
The edges indicate whether a document is cited by the other or vice versa.
Each node has **1433** features which is described by a 0/1-valued vector, indicating the bag-of-words from the dictionary.

This is an undirected graph problem

In [ ]:
```
#importing dependencies

import numpy as np
import os
import networkx as nx
from keras.utils import to_categorical
from sklearn.preprocessing import LabelEncoder
from sklearn.utils import shuffle
from sklearn.metrics import classification_report

from spektral.layers import GraphConv

from tensorflow.keras.models import Model
from tensorflow.keras.layers import Input, Dropout, Dense
from tensorflow.keras import Sequential
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import TensorBoard, EarlyStopping
import tensorflow as tf
from tensorflow.keras.regularizers import l2

from collections import Counter
from sklearn.manifold import TSNE
import matplotlib.pyplot as plt
```

Data Loading and Preprocessing

We are going to use the edges connecting the (from file **cora.cites**).
The nodes are loaded from file **cora.content**.

In [ ]:
```
#Loading the data

all_data = []
all_edges = []

for root,dirs,files in os.walk('./cora'):
    for file in files:
        if '.content' in file:
            with open(os.path.join(root,file),'r') as f:
                all_data.extend(f.read().splitlines())
        elif 'cites' in file:
            with open(os.path.join(root,file),'r') as f:
                all_edges.extend(f.read().splitlines())


#Shuffle the data because the raw data is ordered based on the label
random_state = 77
all_data = shuffle(all_data,random_state=random_state)
```

In **cora.content** file:
The **first** element indicates the **node name**

The **second** until the last second elements indicate the **node features**
The **last** element indicates the **label of that particular node**

In **cora.cites** file:
Each line indicates the tuple of connected nodes

Parsing the data

In [ ]:
```
#parse the data
labels = []
nodes = []
X = []

for i,data in enumerate(all_data):
    elements = data.split('\t')
    labels.append(elements[-1])
    X.append(elements[1:-1])
    nodes.append(elements[0])

X = np.array(X,dtype=int)
N = X.shape[0] #the number of nodes
F = X.shape[1] #the size of node features
print('X shape: ', X.shape)


#parse the edge
edge_list=[]
for edge in all_edges:
    e = edge.split('\t')
    edge_list.append((e[0],e[1]))

print('\nNumber of nodes (N): ', N)
print('\nNumber of features (F) of each node: ', F)
print('\nCategories: ', set(labels))

num_classes = len(set(labels))
print('\nNumber of classes: ', num_classes)
```

```
X shape:  (2708, 1433)

Number of nodes (N):  2708

Number of features (F) of each node:  1433

Categories:  {'Reinforcement_Learning', 'Neural_Networks', 'Rule_Learning', 'Probabilistic_Methods', 'Genetic
_Algorithms', 'Case_Based', 'Theory'}

Number of classes:  7
```

Select examples for training, validation, and test then set the mask

In [ ]:
```
def limit_data(labels,limit=20,val_num=500,test_num=1000):
    '''
    Get the index of train, validation, and test data
    '''
    label_counter = dict((l, 0) for l in labels)
    train_idx = []

    for i in range(len(labels)):
        label = labels[i]
        if label_counter[label]<limit:
            #add the example to the training data
            train_idx.append(i)
            label_counter[label]+=1

        #exit the loop once we found 20 examples for each class
        if all(count == limit for count in label_counter.values()):
            break
```

```
    #get the indices that do not go to traning data
    rest_idx = [x for x in range(len(labels)) if x not in train_idx]
    #get the first val_num
    val_idx = rest_idx[:val_num]
    test_idx = rest_idx[val_num:(val_num+test_num)]
    return train_idx, val_idx,test_idx


train_idx,val_idx,test_idx = limit_data(labels)
```

In [ ]:
```
#set the mask
train_mask = np.zeros((N,),dtype=bool)
train_mask[train_idx] = True

val_mask = np.zeros((N,),dtype=bool)
val_mask[val_idx] = True

test_mask = np.zeros((N,),dtype=bool)
test_mask[test_idx] = True
```

Show Data Distribution

In [ ]:
```
print("All Data Distribution: \n{}".format(Counter(labels)))
```

```
All Data Distribution:
Counter({'Neural_Networks': 818, 'Probabilistic_Methods': 426, 'Genetic_Algorithms': 418, 'Theory': 351, 'Cas
e_Based': 298, 'Reinforcement_Learning': 217, 'Rule_Learning': 180})
```

In [ ]:
```
print("Training Data Distribution: \n{}".format(Counter([labels[i] for i in train_idx])))
```

```
Training Data Distribution:
Counter({'Reinforcement_Learning': 20, 'Probabilistic_Methods': 20, 'Neural_Networks': 20, 'Case_Based': 20,
'Theory': 20, 'Genetic_Algorithms': 20, 'Rule_Learning': 20})
```

In [ ]:
```
print("Validation Data Distribution: \n{}".format(Counter([labels[i] for i in val_idx])))
```

```
Validation Data Distribution:
Counter({'Neural_Networks': 172, 'Genetic_Algorithms': 78, 'Probabilistic_Methods': 72, 'Theory': 63, 'Case_B
ased': 58, 'Reinforcement_Learning': 35, 'Rule_Learning': 22})
```

Convert the labels to one hot encoding

In [ ]:
```
def encode_label(labels):
    label_encoder = LabelEncoder()
    labels = label_encoder.fit_transform(labels)
    labels = to_categorical(labels)
    return labels, label_encoder.classes_

labels_encoded, classes = encode_label(labels)
```

Build a graph on NetworkX using the obtained nodes and edges list

In [ ]:
```
#build the graph
G = nx.Graph()
G.add_nodes_from(nodes)
G.add_edges_from(edge_list)

#obtain the adjacency matrix (A)
A = nx.adjacency_matrix(G)
print('Graph info: ', nx.info(G))
print('Adjacency matrix:')
print(A)
```

```
Graph info:  Name:
Type: Graph
Number of nodes: 2708
Number of edges: 5278
Average degree:   3.8981
Adjacency matrix:
  (0, 79)       1
  (0, 1537)     1
  (0, 2149)     1
  (0, 2160)     1
  (0, 2675)     1
  (0, 2692)     1
  (1, 108)      1
  (1, 486)      1
  (1, 1987)     1
  (1, 2126)     1
  (1, 2133)     1
  (2, 2526)     1
  (2, 2677)     1
  (3, 202)      1
  (3, 352)      1
  (3, 1522)     1
  (3, 2487)     1
  (4, 285)      1
  (4, 1806)     1
  (5, 34)       1
  (5, 317)      1
  (5, 394)      1
  (5, 714)      1
  (5, 2679)     1
  (6, 13)       1
  :     :
  (2698, 715)   1
  (2699, 1258)  1
  (2699, 1656)  1
  (2699, 2632)  1
  (2700, 419)   1
  (2700, 1078)  1
  (2700, 2526)  1
  (2701, 714)   1
  (2701, 2539)  1
  (2701, 2634)  1
  (2701, 2679)  1
  (2702, 644)   1
  (2702, 937)   1
  (2702, 1932)  1
  (2703, 1692)  1
  (2703, 1811)  1
  (2704, 294)   1
  (2705, 1839)  1
  (2706, 643)   1
  (2706, 1421)  1
  (2706, 1630)  1
  (2707, 1348)  1
  (2707, 1431)  1
  (2707, 1939)  1
  (2707, 2380)  1
```

Building and Training Graph Convolutional Networks

In [ ]:
```
# Parameters
channels = 16           # Number of channels in the first layer
dropout = 0.5           # Dropout rate for the features
l2_reg = 5e-4           # L2 regularization rate
learning_rate = 1e-2    # Learning rate
epochs = 400            # Number of training epochs
es_patience = 200        # Patience for early stopping

# Preprocessing operations
A = GraphConv.preprocess(A).astype('f4')
```

```
# Model definition
X_in = Input(shape=(F, ))
fltr_in = Input((N, ), sparse=True)

dropout_1 = Dropout(dropout)(X_in)
graph_conv_1 = GraphConv(channels,
                         activation='relu',
                         kernel_regularizer=l2(l2_reg),
                         use_bias=False)([dropout_1, fltr_in])

dropout_2 = Dropout(dropout)(graph_conv_1)
graph_conv_2 = GraphConv(num_classes,
                         activation='softmax',
                         use_bias=False)([dropout_2, fltr_in])

# Build model
model = Model(inputs=[X_in, fltr_in], outputs=graph_conv_2)
optimizer = Adam(lr=learning_rate)
model.compile(optimizer=optimizer,
              loss='categorical_crossentropy',
              weighted_metrics=['acc'])
model.summary()

tbCallBack_GCN = tf.keras.callbacks.TensorBoard(
    log_dir='./Tensorboard_GCN_cora',
)
callback_GCN = [tbCallBack_GCN]
```

```
Model: "model"
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_1 (InputLayer)            [(None, 1433)]       0
__________________________________________________________________________________________________
dropout (Dropout)               (None, 1433)         0           input_1[0][0]
__________________________________________________________________________________________________
input_2 (InputLayer)            [(None, 2708)]       0
__________________________________________________________________________________________________
graph_conv (GraphConv)          (None, 16)           22928       dropout[0][0]
                                                                 input_2[0][0]
__________________________________________________________________________________________________
dropout_1 (Dropout)             (None, 16)           0           graph_conv[0][0]
__________________________________________________________________________________________________
graph_conv_1 (GraphConv)        (None, 7)            112         dropout_1[0][0]
                                                                 input_2[0][0]
==================================================================================================
Total params: 23,040
Trainable params: 23,040
Non-trainable params: 0
__________________________________________________________________________________________________
```

In [ ]:
```
# Train model
validation_data = ([X, A], labels_encoded, val_mask)
model.fit([X, A],
          labels_encoded,
          sample_weight=train_mask,
          epochs=epochs,
          batch_size=N,
          validation_data=validation_data,
          shuffle=False,
          callbacks=[
              EarlyStopping(patience=es_patience,  restore_best_weights=True),
              tbCallBack_GCN
          ])
```

```
Epoch 1/400
1/1 [==============================] - 0s 317ms/step - loss: 0.1165 - acc: 0.1857 - val_loss: 0.3666 - val_ac
c: 0.3600
Epoch 2/400
1/1 [==============================] - ETA: 0s - loss: 0.1092 - acc: 0.3429WARNING:tensorflow:Method (on_trai
n_batch_end) is slow compared to the batch update (0.153413). Check your callbacks.
1/1 [==============================] - 0s 157ms/step - loss: 0.1092 - acc: 0.3429 - val_loss: 0.3552 - val_ac
c: 0.4420
Epoch 3/400
1/1 [==============================] - 0s 167ms/step - loss: 0.1021 - acc: 0.5500 - val_loss: 0.3435 - val_ac
c: 0.4700
Epoch 4/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0956 - acc: 0.6000 - val_loss: 0.3327 - val_ac
c: 0.4720
Epoch 5/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0906 - acc: 0.6071 - val_loss: 0.3228 - val_ac
c: 0.4820
Epoch 6/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0862 - acc: 0.6357 - val_loss: 0.3129 - val_ac
c: 0.4960
Epoch 7/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0832 - acc: 0.7000 - val_loss: 0.3033 - val_ac
c: 0.5100
Epoch 8/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0785 - acc: 0.7143 - val_loss: 0.2943 - val_ac
c: 0.5480
Epoch 9/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0767 - acc: 0.7214 - val_loss: 0.2860 - val_ac
c: 0.6080
Epoch 10/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0746 - acc: 0.7786 - val_loss: 0.2788 - val_ac
c: 0.6380
Epoch 11/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0712 - acc: 0.8071 - val_loss: 0.2716 - val_ac
c: 0.6700
Epoch 12/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0692 - acc: 0.8429 - val_loss: 0.2649 - val_ac
c: 0.6960
Epoch 13/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0663 - acc: 0.8786 - val_loss: 0.2582 - val_ac
c: 0.7160
Epoch 14/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0645 - acc: 0.8714 - val_loss: 0.2515 - val_ac
c: 0.7320
Epoch 15/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0641 - acc: 0.8571 - val_loss: 0.2447 - val_ac
c: 0.7420
Epoch 16/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0636 - acc: 0.9143 - val_loss: 0.2381 - val_ac
c: 0.7480
Epoch 17/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0623 - acc: 0.8714 - val_loss: 0.2319 - val_ac
c: 0.7540
Epoch 18/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0614 - acc: 0.8857 - val_loss: 0.2264 - val_ac
c: 0.7640
Epoch 19/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0631 - acc: 0.8857 - val_loss: 0.2220 - val_ac
c: 0.7720
Epoch 20/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0580 - acc: 0.9500 - val_loss: 0.2182 - val_ac
c: 0.7800
Epoch 21/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0594 - acc: 0.8714 - val_loss: 0.2147 - val_ac
c: 0.7740
Epoch 22/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0561 - acc: 0.9000 - val_loss: 0.2116 - val_ac
c: 0.7700
Epoch 23/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0568 - acc: 0.8857 - val_loss: 0.2086 - val_ac
c: 0.7740
```

```
Epoch 24/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0583 - acc: 0.8643 - val_loss: 0.2060 - val_ac
c: 0.7800
Epoch 25/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0517 - acc: 0.9429 - val_loss: 0.2033 - val_ac
c: 0.7880
Epoch 26/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0509 - acc: 0.9429 - val_loss: 0.2005 - val_ac
c: 0.7900
Epoch 27/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0510 - acc: 0.9429 - val_loss: 0.1975 - val_ac
c: 0.7900
Epoch 28/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0517 - acc: 0.9286 - val_loss: 0.1949 - val_ac
c: 0.7900
Epoch 29/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0521 - acc: 0.9214 - val_loss: 0.1924 - val_ac
c: 0.7880
Epoch 30/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0481 - acc: 0.9357 - val_loss: 0.1908 - val_ac
c: 0.7900
Epoch 31/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0479 - acc: 0.9429 - val_loss: 0.1896 - val_ac
c: 0.7900
Epoch 32/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0497 - acc: 0.8714 - val_loss: 0.1880 - val_ac
c: 0.7820
Epoch 33/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0492 - acc: 0.9286 - val_loss: 0.1864 - val_ac
c: 0.7800
Epoch 34/400
1/1 [==============================] - 0s 147ms/step - loss: 0.0492 - acc: 0.9143 - val_loss: 0.1849 - val_ac
c: 0.7800
Epoch 35/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0485 - acc: 0.9357 - val_loss: 0.1830 - val_ac
c: 0.7840
Epoch 36/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0465 - acc: 0.9643 - val_loss: 0.1808 - val_ac
c: 0.7880
Epoch 37/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0461 - acc: 0.9357 - val_loss: 0.1783 - val_ac
c: 0.7860
Epoch 38/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0439 - acc: 0.9500 - val_loss: 0.1764 - val_ac
c: 0.7900
Epoch 39/400
1/1 [==============================] - 0s 147ms/step - loss: 0.0436 - acc: 0.9500 - val_loss: 0.1754 - val_ac
c: 0.7860
Epoch 40/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0428 - acc: 0.8857 - val_loss: 0.1747 - val_ac
c: 0.7860
Epoch 41/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0430 - acc: 0.9500 - val_loss: 0.1739 - val_ac
c: 0.7840
Epoch 42/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0406 - acc: 0.9286 - val_loss: 0.1729 - val_ac
c: 0.7820
Epoch 43/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0416 - acc: 0.9429 - val_loss: 0.1725 - val_ac
c: 0.7760
Epoch 44/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0436 - acc: 0.9357 - val_loss: 0.1718 - val_ac
c: 0.7780
Epoch 45/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0404 - acc: 0.9571 - val_loss: 0.1712 - val_ac
c: 0.7760
Epoch 46/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0411 - acc: 0.9214 - val_loss: 0.1709 - val_ac
c: 0.7760
Epoch 47/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0421 - acc: 0.9429 - val_loss: 0.1702 - val_ac
```

```
c: 0.7820
Epoch 48/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0404 - acc: 0.9714 - val_loss: 0.1695 - val_ac
c: 0.7820
Epoch 49/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0389 - acc: 0.9571 - val_loss: 0.1680 - val_ac
c: 0.7840
Epoch 50/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0381 - acc: 0.9571 - val_loss: 0.1667 - val_ac
c: 0.7880
Epoch 51/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0423 - acc: 0.9214 - val_loss: 0.1655 - val_ac
c: 0.7900
Epoch 52/400
1/1 [==============================] - 0s 212ms/step - loss: 0.0384 - acc: 0.9714 - val_loss: 0.1643 - val_ac
c: 0.7840
Epoch 53/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0381 - acc: 0.9571 - val_loss: 0.1630 - val_ac
c: 0.7760
Epoch 54/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0407 - acc: 0.9000 - val_loss: 0.1612 - val_ac
c: 0.7860
Epoch 55/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0376 - acc: 0.9643 - val_loss: 0.1601 - val_ac
c: 0.7820
Epoch 56/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0347 - acc: 0.9857 - val_loss: 0.1591 - val_ac
c: 0.7840
Epoch 57/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0365 - acc: 0.9429 - val_loss: 0.1590 - val_ac
c: 0.7860
Epoch 58/400
1/1 [==============================] - 0s 147ms/step - loss: 0.0391 - acc: 0.9214 - val_loss: 0.1589 - val_ac
c: 0.7880
Epoch 59/400
1/1 [==============================] - 0s 197ms/step - loss: 0.0367 - acc: 0.9500 - val_loss: 0.1587 - val_ac
c: 0.7920
Epoch 60/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0372 - acc: 0.9714 - val_loss: 0.1582 - val_ac
c: 0.7960
Epoch 61/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0378 - acc: 0.9357 - val_loss: 0.1584 - val_ac
c: 0.7960
Epoch 62/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0367 - acc: 0.9643 - val_loss: 0.1583 - val_ac
c: 0.7960
Epoch 63/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0351 - acc: 0.9714 - val_loss: 0.1583 - val_ac
c: 0.7940
Epoch 64/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0365 - acc: 0.9286 - val_loss: 0.1587 - val_ac
c: 0.7980
Epoch 65/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0342 - acc: 0.9643 - val_loss: 0.1591 - val_ac
c: 0.7940
Epoch 66/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0352 - acc: 0.9643 - val_loss: 0.1589 - val_ac
c: 0.7880
Epoch 67/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0344 - acc: 0.9286 - val_loss: 0.1585 - val_ac
c: 0.7880
Epoch 68/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0348 - acc: 0.9643 - val_loss: 0.1575 - val_ac
c: 0.7940
Epoch 69/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0349 - acc: 0.9571 - val_loss: 0.1562 - val_ac
c: 0.7900
Epoch 70/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0338 - acc: 0.9571 - val_loss: 0.1558 - val_ac
c: 0.7920
Epoch 71/400
```

```
1/1 [==============================] - 0s 154ms/step - loss: 0.0364 - acc: 0.9786 - val_loss: 0.1558 - val_ac
c: 0.7880
Epoch 72/400
1/1 [==============================] - 0s 147ms/step - loss: 0.0335 - acc: 0.9714 - val_loss: 0.1554 - val_ac
c: 0.7920
Epoch 73/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0358 - acc: 0.9714 - val_loss: 0.1550 - val_ac
c: 0.7920
Epoch 74/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0364 - acc: 0.9357 - val_loss: 0.1531 - val_ac
c: 0.7880
Epoch 75/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0339 - acc: 0.9643 - val_loss: 0.1521 - val_ac
c: 0.7980
Epoch 76/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0324 - acc: 0.9571 - val_loss: 0.1516 - val_ac
c: 0.8020
Epoch 77/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0321 - acc: 0.9714 - val_loss: 0.1515 - val_ac
c: 0.8040
Epoch 78/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0346 - acc: 0.9286 - val_loss: 0.1526 - val_ac
c: 0.8040
Epoch 79/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0305 - acc: 0.9929 - val_loss: 0.1530 - val_ac
c: 0.7960
Epoch 80/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0323 - acc: 0.9429 - val_loss: 0.1529 - val_ac
c: 0.7900
Epoch 81/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0327 - acc: 0.9429 - val_loss: 0.1521 - val_ac
c: 0.7880
Epoch 82/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0316 - acc: 0.9714 - val_loss: 0.1517 - val_ac
c: 0.7880
Epoch 83/400
1/1 [==============================] - 0s 147ms/step - loss: 0.0339 - acc: 0.9429 - val_loss: 0.1505 - val_ac
c: 0.7940
Epoch 84/400
1/1 [==============================] - 0s 147ms/step - loss: 0.0310 - acc: 0.9571 - val_loss: 0.1491 - val_ac
c: 0.7960
Epoch 85/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0310 - acc: 0.9714 - val_loss: 0.1486 - val_ac
c: 0.7940
Epoch 86/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0318 - acc: 0.9714 - val_loss: 0.1484 - val_ac
c: 0.7920
Epoch 87/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0309 - acc: 0.9714 - val_loss: 0.1494 - val_ac
c: 0.7880
Epoch 88/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0307 - acc: 0.9643 - val_loss: 0.1501 - val_ac
c: 0.7800
Epoch 89/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0331 - acc: 0.9429 - val_loss: 0.1513 - val_ac
c: 0.7760
Epoch 90/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0310 - acc: 0.9857 - val_loss: 0.1517 - val_ac
c: 0.7760
Epoch 91/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0305 - acc: 0.9857 - val_loss: 0.1518 - val_ac
c: 0.7760
Epoch 92/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0312 - acc: 0.9571 - val_loss: 0.1518 - val_ac
c: 0.7760
Epoch 93/400
1/1 [==============================] - 0s 146ms/step - loss: 0.0303 - acc: 0.9643 - val_loss: 0.1513 - val_ac
c: 0.7740
Epoch 94/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0325 - acc: 0.9429 - val_loss: 0.1509 - val_ac
c: 0.7820
```

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Epoch 95/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0295 - acc: 0.9857 - val_loss: 0.1506 - val_ac
c: 0.7820
Epoch 96/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0300 - acc: 0.9786 - val_loss: 0.1507 - val_ac
c: 0.7800
Epoch 97/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0298 - acc: 0.9714 - val_loss: 0.1499 - val_ac
c: 0.7800
Epoch 98/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0312 - acc: 0.9643 - val_loss: 0.1491 - val_ac
c: 0.7780
Epoch 99/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0305 - acc: 0.9500 - val_loss: 0.1487 - val_ac
c: 0.7780
Epoch 100/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0308 - acc: 0.9571 - val_loss: 0.1483 - val_ac
c: 0.7800
Epoch 101/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0307 - acc: 0.9643 - val_loss: 0.1484 - val_ac
c: 0.7760
Epoch 102/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0308 - acc: 0.9571 - val_loss: 0.1485 - val_ac
c: 0.7820
Epoch 103/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0279 - acc: 0.9929 - val_loss: 0.1486 - val_ac
c: 0.7760
Epoch 104/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0315 - acc: 0.9643 - val_loss: 0.1489 - val_ac
c: 0.7700
Epoch 105/400
1/1 [==============================] - 0s 146ms/step - loss: 0.0309 - acc: 0.9500 - val_loss: 0.1493 - val_ac
c: 0.7760
Epoch 106/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0288 - acc: 0.9643 - val_loss: 0.1501 - val_ac
c: 0.7780
Epoch 107/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0301 - acc: 0.9643 - val_loss: 0.1500 - val_ac
c: 0.7760
Epoch 108/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0280 - acc: 0.9571 - val_loss: 0.1482 - val_ac
c: 0.7800
Epoch 109/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0310 - acc: 0.9571 - val_loss: 0.1464 - val_ac
c: 0.7840
Epoch 110/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0304 - acc: 0.9357 - val_loss: 0.1442 - val_ac
c: 0.7860
Epoch 111/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0283 - acc: 0.9571 - val_loss: 0.1428 - val_ac
c: 0.7920
Epoch 112/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0287 - acc: 0.9357 - val_loss: 0.1434 - val_ac
c: 0.7920
Epoch 113/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0283 - acc: 0.9643 - val_loss: 0.1447 - val_ac
c: 0.7840
Epoch 114/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0287 - acc: 0.9286 - val_loss: 0.1472 - val_ac
c: 0.7760
Epoch 115/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0284 - acc: 0.9714 - val_loss: 0.1502 - val_ac
c: 0.7680
Epoch 116/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0301 - acc: 0.9500 - val_loss: 0.1525 - val_ac
c: 0.7700
Epoch 117/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0271 - acc: 0.9857 - val_loss: 0.1543 - val_ac
c: 0.7640
Epoch 118/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0285 - acc: 0.9714 - val_loss: 0.1545 - val_ac
```

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c: 0.7660
Epoch 119/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0308 - acc: 0.9429 - val_loss: 0.1542 - val_ac
c: 0.7680
Epoch 120/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0278 - acc: 0.9857 - val_loss: 0.1520 - val_ac
c: 0.7660
Epoch 121/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0284 - acc: 0.9786 - val_loss: 0.1487 - val_ac
c: 0.7720
Epoch 122/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0291 - acc: 0.9500 - val_loss: 0.1452 - val_ac
c: 0.7720
Epoch 123/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0245 - acc: 1.0000 - val_loss: 0.1426 - val_ac
c: 0.7740
Epoch 124/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0277 - acc: 0.9500 - val_loss: 0.1420 - val_ac
c: 0.7860
Epoch 125/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0273 - acc: 0.9643 - val_loss: 0.1428 - val_ac
c: 0.7840
Epoch 126/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0282 - acc: 0.9571 - val_loss: 0.1442 - val_ac
c: 0.7740
Epoch 127/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0271 - acc: 0.9786 - val_loss: 0.1454 - val_ac
c: 0.7760
Epoch 128/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0261 - acc: 0.9571 - val_loss: 0.1459 - val_ac
c: 0.7740
Epoch 129/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0260 - acc: 0.9786 - val_loss: 0.1464 - val_ac
c: 0.7740
Epoch 130/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0274 - acc: 0.9929 - val_loss: 0.1467 - val_ac
c: 0.7760
Epoch 131/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0252 - acc: 0.9929 - val_loss: 0.1447 - val_ac
c: 0.7760
Epoch 132/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0271 - acc: 0.9643 - val_loss: 0.1428 - val_ac
c: 0.7820
Epoch 133/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0244 - acc: 0.9786 - val_loss: 0.1407 - val_ac
c: 0.7860
Epoch 134/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0251 - acc: 0.9714 - val_loss: 0.1392 - val_ac
c: 0.7900
Epoch 135/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0262 - acc: 0.9714 - val_loss: 0.1385 - val_ac
c: 0.7920
Epoch 136/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0279 - acc: 0.9571 - val_loss: 0.1381 - val_ac
c: 0.8000
Epoch 137/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0261 - acc: 0.9571 - val_loss: 0.1388 - val_ac
c: 0.7920
Epoch 138/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0258 - acc: 0.9500 - val_loss: 0.1399 - val_ac
c: 0.7880
Epoch 139/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0263 - acc: 0.9429 - val_loss: 0.1420 - val_ac
c: 0.7700
Epoch 140/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0261 - acc: 0.9643 - val_loss: 0.1439 - val_ac
c: 0.7720
Epoch 141/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0277 - acc: 0.9357 - val_loss: 0.1467 - val_ac
c: 0.7700
Epoch 142/400
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1/1 [==============================] - 0s 150ms/step - loss: 0.0271 - acc: 0.9571 - val_loss: 0.1481 - val_ac
c: 0.7640
Epoch 143/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0252 - acc: 0.9643 - val_loss: 0.1485 - val_ac
c: 0.7700
Epoch 144/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0252 - acc: 0.9571 - val_loss: 0.1482 - val_ac
c: 0.7700
Epoch 145/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0259 - acc: 0.9571 - val_loss: 0.1465 - val_ac
c: 0.7740
Epoch 146/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0258 - acc: 0.9643 - val_loss: 0.1458 - val_ac
c: 0.7800
Epoch 147/400
1/1 [==============================] - 0s 149ms/step - loss: 0.0262 - acc: 0.9857 - val_loss: 0.1448 - val_ac
c: 0.7800
Epoch 148/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0283 - acc: 0.9643 - val_loss: 0.1435 - val_ac
c: 0.7900
Epoch 149/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0252 - acc: 0.9929 - val_loss: 0.1416 - val_ac
c: 0.7980
Epoch 150/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0254 - acc: 0.9786 - val_loss: 0.1412 - val_ac
c: 0.7920
Epoch 151/400
1/1 [==============================] - 0s 148ms/step - loss: 0.0246 - acc: 0.9857 - val_loss: 0.1412 - val_ac
c: 0.7860
Epoch 152/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0263 - acc: 0.9643 - val_loss: 0.1420 - val_ac
c: 0.7800
Epoch 153/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0271 - acc: 0.9571 - val_loss: 0.1446 - val_ac
c: 0.7700
Epoch 154/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0260 - acc: 0.9714 - val_loss: 0.1464 - val_ac
c: 0.7700
Epoch 155/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0238 - acc: 0.9786 - val_loss: 0.1469 - val_ac
c: 0.7680
Epoch 156/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0240 - acc: 0.9857 - val_loss: 0.1460 - val_ac
c: 0.7640
Epoch 157/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0256 - acc: 0.9643 - val_loss: 0.1438 - val_ac
c: 0.7660
Epoch 158/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0249 - acc: 0.9714 - val_loss: 0.1407 - val_ac
c: 0.7740
Epoch 159/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0264 - acc: 0.9786 - val_loss: 0.1394 - val_ac
c: 0.7760
Epoch 160/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0257 - acc: 0.9571 - val_loss: 0.1383 - val_ac
c: 0.7920
Epoch 161/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0238 - acc: 0.9643 - val_loss: 0.1378 - val_ac
c: 0.8000
Epoch 162/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0262 - acc: 0.9500 - val_loss: 0.1382 - val_ac
c: 0.8020
Epoch 163/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0243 - acc: 0.9643 - val_loss: 0.1400 - val_ac
c: 0.7940
Epoch 164/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0278 - acc: 0.9643 - val_loss: 0.1413 - val_ac
c: 0.7900
Epoch 165/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0247 - acc: 0.9929 - val_loss: 0.1424 - val_ac
c: 0.7860
```

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Epoch 166/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0252 - acc: 0.9929 - val_loss: 0.1421 - val_ac
c: 0.7920
Epoch 167/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0245 - acc: 0.9714 - val_loss: 0.1422 - val_ac
c: 0.7960
Epoch 168/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0235 - acc: 0.9857 - val_loss: 0.1426 - val_ac
c: 0.7900
Epoch 169/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0271 - acc: 0.9786 - val_loss: 0.1424 - val_ac
c: 0.7840
Epoch 170/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0266 - acc: 0.9714 - val_loss: 0.1419 - val_ac
c: 0.7820
Epoch 171/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0232 - acc: 0.9714 - val_loss: 0.1409 - val_ac
c: 0.7820
Epoch 172/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0250 - acc: 0.9643 - val_loss: 0.1399 - val_ac
c: 0.7860
Epoch 173/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0246 - acc: 0.9571 - val_loss: 0.1406 - val_ac
c: 0.7860
Epoch 174/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0237 - acc: 0.9786 - val_loss: 0.1418 - val_ac
c: 0.7880
Epoch 175/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0246 - acc: 0.9714 - val_loss: 0.1445 - val_ac
c: 0.7800
Epoch 176/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0221 - acc: 0.9857 - val_loss: 0.1465 - val_ac
c: 0.7740
Epoch 177/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0247 - acc: 0.9714 - val_loss: 0.1456 - val_ac
c: 0.7820
Epoch 178/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0227 - acc: 1.0000 - val_loss: 0.1441 - val_ac
c: 0.7780
Epoch 179/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0259 - acc: 0.9500 - val_loss: 0.1420 - val_ac
c: 0.7820
Epoch 180/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0243 - acc: 0.9714 - val_loss: 0.1396 - val_ac
c: 0.7840
Epoch 181/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0246 - acc: 0.9714 - val_loss: 0.1376 - val_ac
c: 0.7900
Epoch 182/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0248 - acc: 0.9714 - val_loss: 0.1365 - val_ac
c: 0.7880
Epoch 183/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0219 - acc: 0.9929 - val_loss: 0.1360 - val_ac
c: 0.7960
Epoch 184/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0232 - acc: 0.9643 - val_loss: 0.1352 - val_ac
c: 0.7980
Epoch 185/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0243 - acc: 0.9786 - val_loss: 0.1360 - val_ac
c: 0.7960
Epoch 186/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0262 - acc: 0.9571 - val_loss: 0.1370 - val_ac
c: 0.7900
Epoch 187/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0249 - acc: 0.9500 - val_loss: 0.1397 - val_ac
c: 0.7920
Epoch 188/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0246 - acc: 0.9571 - val_loss: 0.1421 - val_ac
c: 0.7800
Epoch 189/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0235 - acc: 0.9857 - val_loss: 0.1439 - val_ac
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c: 0.7760
Epoch 190/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0235 - acc: 0.9643 - val_loss: 0.1440 - val_ac
c: 0.7840
Epoch 191/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0251 - acc: 0.9643 - val_loss: 0.1422 - val_ac
c: 0.7920
Epoch 192/400
1/1 [==============================] - 0s 213ms/step - loss: 0.0234 - acc: 0.9571 - val_loss: 0.1414 - val_ac
c: 0.7900
Epoch 193/400
1/1 [==============================] - 0s 224ms/step - loss: 0.0238 - acc: 0.9643 - val_loss: 0.1416 - val_ac
c: 0.7840
Epoch 194/400
1/1 [==============================] - 0s 247ms/step - loss: 0.0219 - acc: 0.9786 - val_loss: 0.1423 - val_ac
c: 0.7860
Epoch 195/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0239 - acc: 0.9857 - val_loss: 0.1422 - val_ac
c: 0.7840
Epoch 196/400
1/1 [==============================] - 0s 219ms/step - loss: 0.0251 - acc: 0.9643 - val_loss: 0.1416 - val_ac
c: 0.7800
Epoch 197/400
1/1 [==============================] - 0s 208ms/step - loss: 0.0246 - acc: 0.9857 - val_loss: 0.1408 - val_ac
c: 0.7840
Epoch 198/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0245 - acc: 0.9643 - val_loss: 0.1401 - val_ac
c: 0.7880
Epoch 199/400
1/1 [==============================] - 0s 205ms/step - loss: 0.0230 - acc: 0.9643 - val_loss: 0.1381 - val_ac
c: 0.7920
Epoch 200/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0233 - acc: 0.9857 - val_loss: 0.1359 - val_ac
c: 0.7880
Epoch 201/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0235 - acc: 0.9857 - val_loss: 0.1336 - val_ac
c: 0.7920
Epoch 202/400
1/1 [==============================] - 0s 280ms/step - loss: 0.0221 - acc: 0.9857 - val_loss: 0.1328 - val_ac
c: 0.7940
Epoch 203/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0208 - acc: 0.9929 - val_loss: 0.1327 - val_ac
c: 0.8000
Epoch 204/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0219 - acc: 0.9857 - val_loss: 0.1341 - val_ac
c: 0.8000
Epoch 205/400
1/1 [==============================] - 0s 199ms/step - loss: 0.0218 - acc: 0.9714 - val_loss: 0.1344 - val_ac
c: 0.7900
Epoch 206/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0228 - acc: 0.9571 - val_loss: 0.1355 - val_ac
c: 0.7880
Epoch 207/400
1/1 [==============================] - 0s 208ms/step - loss: 0.0234 - acc: 0.9643 - val_loss: 0.1362 - val_ac
c: 0.7880
Epoch 208/400
1/1 [==============================] - 0s 274ms/step - loss: 0.0225 - acc: 0.9929 - val_loss: 0.1367 - val_ac
c: 0.7860
Epoch 209/400
1/1 [==============================] - 0s 218ms/step - loss: 0.0230 - acc: 0.9643 - val_loss: 0.1378 - val_ac
c: 0.7820
Epoch 210/400
1/1 [==============================] - 0s 220ms/step - loss: 0.0215 - acc: 0.9929 - val_loss: 0.1387 - val_ac
c: 0.7840
Epoch 211/400
1/1 [==============================] - 0s 204ms/step - loss: 0.0219 - acc: 0.9714 - val_loss: 0.1405 - val_ac
c: 0.7840
Epoch 212/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0219 - acc: 0.9786 - val_loss: 0.1410 - val_ac
c: 0.7860
Epoch 213/400
```

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1/1 [==============================] - 0s 187ms/step - loss: 0.0225 - acc: 0.9857 - val_loss: 0.1415 - val_ac
c: 0.7820
Epoch 214/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0219 - acc: 0.9643 - val_loss: 0.1416 - val_ac
c: 0.7800
Epoch 215/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0213 - acc: 0.9714 - val_loss: 0.1403 - val_ac
c: 0.7760
Epoch 216/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0211 - acc: 0.9571 - val_loss: 0.1406 - val_ac
c: 0.7720
Epoch 217/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0254 - acc: 0.9500 - val_loss: 0.1405 - val_ac
c: 0.7700
Epoch 218/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0219 - acc: 0.9786 - val_loss: 0.1400 - val_ac
c: 0.7720
Epoch 219/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0203 - acc: 1.0000 - val_loss: 0.1413 - val_ac
c: 0.7760
Epoch 220/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0212 - acc: 0.9714 - val_loss: 0.1445 - val_ac
c: 0.7640
Epoch 221/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0223 - acc: 0.9857 - val_loss: 0.1468 - val_ac
c: 0.7600
Epoch 222/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0229 - acc: 0.9643 - val_loss: 0.1462 - val_ac
c: 0.7620
Epoch 223/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0230 - acc: 0.9571 - val_loss: 0.1448 - val_ac
c: 0.7640
Epoch 224/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0190 - acc: 0.9929 - val_loss: 0.1429 - val_ac
c: 0.7640
Epoch 225/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0216 - acc: 0.9857 - val_loss: 0.1399 - val_ac
c: 0.7720
Epoch 226/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0226 - acc: 0.9857 - val_loss: 0.1367 - val_ac
c: 0.7740
Epoch 227/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0210 - acc: 0.9857 - val_loss: 0.1347 - val_ac
c: 0.7740
Epoch 228/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0202 - acc: 0.9857 - val_loss: 0.1337 - val_ac
c: 0.7720
Epoch 229/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0212 - acc: 0.9857 - val_loss: 0.1329 - val_ac
c: 0.7760
Epoch 230/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0217 - acc: 0.9929 - val_loss: 0.1340 - val_ac
c: 0.7760
Epoch 231/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0220 - acc: 0.9786 - val_loss: 0.1353 - val_ac
c: 0.7760
Epoch 232/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0217 - acc: 0.9786 - val_loss: 0.1374 - val_ac
c: 0.7800
Epoch 233/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0228 - acc: 0.9429 - val_loss: 0.1403 - val_ac
c: 0.7720
Epoch 234/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0203 - acc: 0.9786 - val_loss: 0.1424 - val_ac
c: 0.7760
Epoch 235/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0210 - acc: 0.9929 - val_loss: 0.1447 - val_ac
c: 0.7780
Epoch 236/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0208 - acc: 0.9857 - val_loss: 0.1426 - val_ac
c: 0.7780
```

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Epoch 237/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0200 - acc: 0.9929 - val_loss: 0.1410 - val_ac
c: 0.7760
Epoch 238/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0217 - acc: 0.9571 - val_loss: 0.1390 - val_ac
c: 0.7760
Epoch 239/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0209 - acc: 0.9786 - val_loss: 0.1381 - val_ac
c: 0.7740
Epoch 240/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0212 - acc: 0.9857 - val_loss: 0.1376 - val_ac
c: 0.7760
Epoch 241/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0212 - acc: 0.9571 - val_loss: 0.1357 - val_ac
c: 0.7720
Epoch 242/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0200 - acc: 0.9786 - val_loss: 0.1331 - val_ac
c: 0.7740
Epoch 243/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0211 - acc: 0.9929 - val_loss: 0.1331 - val_ac
c: 0.7700
Epoch 244/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0211 - acc: 0.9714 - val_loss: 0.1355 - val_ac
c: 0.7720
Epoch 245/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0213 - acc: 0.9786 - val_loss: 0.1375 - val_ac
c: 0.7760
Epoch 246/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0188 - acc: 0.9786 - val_loss: 0.1389 - val_ac
c: 0.7800
Epoch 247/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0207 - acc: 0.9929 - val_loss: 0.1389 - val_ac
c: 0.7760
Epoch 248/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0216 - acc: 0.9857 - val_loss: 0.1390 - val_ac
c: 0.7780
Epoch 249/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0233 - acc: 0.9643 - val_loss: 0.1383 - val_ac
c: 0.7820
Epoch 250/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0207 - acc: 0.9714 - val_loss: 0.1373 - val_ac
c: 0.7860
Epoch 251/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0203 - acc: 0.9857 - val_loss: 0.1357 - val_ac
c: 0.7800
Epoch 252/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0241 - acc: 0.9357 - val_loss: 0.1360 - val_ac
c: 0.7740
Epoch 253/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0215 - acc: 0.9714 - val_loss: 0.1379 - val_ac
c: 0.7640
Epoch 254/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0194 - acc: 0.9857 - val_loss: 0.1409 - val_ac
c: 0.7660
Epoch 255/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0212 - acc: 0.9714 - val_loss: 0.1420 - val_ac
c: 0.7660
Epoch 256/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0207 - acc: 0.9786 - val_loss: 0.1405 - val_ac
c: 0.7700
Epoch 257/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0208 - acc: 0.9929 - val_loss: 0.1390 - val_ac
c: 0.7700
Epoch 258/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0225 - acc: 0.9643 - val_loss: 0.1374 - val_ac
c: 0.7740
Epoch 259/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0221 - acc: 0.9714 - val_loss: 0.1398 - val_ac
c: 0.7700
Epoch 260/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0206 - acc: 0.9643 - val_loss: 0.1428 - val_ac
```

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c: 0.7700
Epoch 261/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0232 - acc: 0.9643 - val_loss: 0.1431 - val_ac
c: 0.7700
Epoch 262/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0218 - acc: 0.9714 - val_loss: 0.1413 - val_ac
c: 0.7720
Epoch 263/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0212 - acc: 0.9857 - val_loss: 0.1415 - val_ac
c: 0.7700
Epoch 264/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0204 - acc: 0.9857 - val_loss: 0.1416 - val_ac
c: 0.7640
Epoch 265/400
1/1 [==============================] - 0s 150ms/step - loss: 0.0227 - acc: 0.9643 - val_loss: 0.1414 - val_ac
c: 0.7640
Epoch 266/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0203 - acc: 0.9857 - val_loss: 0.1412 - val_ac
c: 0.7560
Epoch 267/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0236 - acc: 0.9571 - val_loss: 0.1411 - val_ac
c: 0.7460
Epoch 268/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0227 - acc: 0.9571 - val_loss: 0.1404 - val_ac
c: 0.7540
Epoch 269/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0205 - acc: 0.9857 - val_loss: 0.1382 - val_ac
c: 0.7640
Epoch 270/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0220 - acc: 0.9786 - val_loss: 0.1364 - val_ac
c: 0.7640
Epoch 271/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0211 - acc: 0.9857 - val_loss: 0.1356 - val_ac
c: 0.7780
Epoch 272/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0191 - acc: 0.9786 - val_loss: 0.1343 - val_ac
c: 0.7880
Epoch 273/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0193 - acc: 1.0000 - val_loss: 0.1335 - val_ac
c: 0.7940
Epoch 274/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0211 - acc: 0.9857 - val_loss: 0.1329 - val_ac
c: 0.7940
Epoch 275/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0237 - acc: 0.9714 - val_loss: 0.1332 - val_ac
c: 0.7840
Epoch 276/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0210 - acc: 0.9714 - val_loss: 0.1366 - val_ac
c: 0.7680
Epoch 277/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0212 - acc: 0.9786 - val_loss: 0.1402 - val_ac
c: 0.7640
Epoch 278/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0229 - acc: 0.9500 - val_loss: 0.1410 - val_ac
c: 0.7700
Epoch 279/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0213 - acc: 0.9857 - val_loss: 0.1404 - val_ac
c: 0.7740
Epoch 280/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0200 - acc: 0.9929 - val_loss: 0.1400 - val_ac
c: 0.7780
Epoch 281/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0199 - acc: 1.0000 - val_loss: 0.1388 - val_ac
c: 0.7840
Epoch 282/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0211 - acc: 0.9643 - val_loss: 0.1379 - val_ac
c: 0.7840
Epoch 283/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0221 - acc: 0.9571 - val_loss: 0.1373 - val_ac
c: 0.7880
Epoch 284/400
```

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1/1 [==============================] - 0s 161ms/step - loss: 0.0227 - acc: 0.9643 - val_loss: 0.1374 - val_ac
c: 0.7820
Epoch 285/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0181 - acc: 0.9786 - val_loss: 0.1387 - val_ac
c: 0.7740
Epoch 286/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0208 - acc: 0.9786 - val_loss: 0.1387 - val_ac
c: 0.7680
Epoch 287/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0199 - acc: 0.9857 - val_loss: 0.1384 - val_ac
c: 0.7640
Epoch 288/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0207 - acc: 0.9786 - val_loss: 0.1374 - val_ac
c: 0.7740
Epoch 289/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0211 - acc: 0.9786 - val_loss: 0.1384 - val_ac
c: 0.7740
Epoch 290/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0211 - acc: 0.9643 - val_loss: 0.1405 - val_ac
c: 0.7720
Epoch 291/400
1/1 [==============================] - 0s 195ms/step - loss: 0.0213 - acc: 0.9714 - val_loss: 0.1438 - val_ac
c: 0.7720
Epoch 292/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0203 - acc: 0.9786 - val_loss: 0.1465 - val_ac
c: 0.7700
Epoch 293/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0199 - acc: 0.9714 - val_loss: 0.1478 - val_ac
c: 0.7700
Epoch 294/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0216 - acc: 0.9786 - val_loss: 0.1456 - val_ac
c: 0.7740
Epoch 295/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0202 - acc: 0.9714 - val_loss: 0.1427 - val_ac
c: 0.7720
Epoch 296/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0201 - acc: 0.9786 - val_loss: 0.1396 - val_ac
c: 0.7720
Epoch 297/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0216 - acc: 0.9571 - val_loss: 0.1382 - val_ac
c: 0.7680
Epoch 298/400
1/1 [==============================] - 0s 151ms/step - loss: 0.0191 - acc: 0.9786 - val_loss: 0.1380 - val_ac
c: 0.7700
Epoch 299/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0196 - acc: 0.9857 - val_loss: 0.1373 - val_ac
c: 0.7680
Epoch 300/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0216 - acc: 0.9500 - val_loss: 0.1372 - val_ac
c: 0.7740
Epoch 301/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0210 - acc: 0.9857 - val_loss: 0.1397 - val_ac
c: 0.7640
Epoch 302/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0210 - acc: 0.9714 - val_loss: 0.1433 - val_ac
c: 0.7660
Epoch 303/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0181 - acc: 0.9857 - val_loss: 0.1475 - val_ac
c: 0.7720
Epoch 304/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0200 - acc: 0.9786 - val_loss: 0.1473 - val_ac
c: 0.7640
Epoch 305/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0185 - acc: 0.9857 - val_loss: 0.1430 - val_ac
c: 0.7700
Epoch 306/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0197 - acc: 1.0000 - val_loss: 0.1388 - val_ac
c: 0.7820
Epoch 307/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0204 - acc: 0.9714 - val_loss: 0.1342 - val_ac
c: 0.7800
```

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Epoch 308/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0193 - acc: 0.9929 - val_loss: 0.1317 - val_ac
c: 0.7780
Epoch 309/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0222 - acc: 0.9714 - val_loss: 0.1301 - val_ac
c: 0.7800
Epoch 310/400
1/1 [==============================] - 0s 205ms/step - loss: 0.0186 - acc: 1.0000 - val_loss: 0.1301 - val_ac
c: 0.7760
Epoch 311/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0211 - acc: 0.9714 - val_loss: 0.1312 - val_ac
c: 0.7720
Epoch 312/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0203 - acc: 0.9857 - val_loss: 0.1333 - val_ac
c: 0.7680
Epoch 313/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0195 - acc: 0.9857 - val_loss: 0.1371 - val_ac
c: 0.7660
Epoch 314/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0206 - acc: 0.9786 - val_loss: 0.1388 - val_ac
c: 0.7780
Epoch 315/400
1/1 [==============================] - 0s 189ms/step - loss: 0.0181 - acc: 1.0000 - val_loss: 0.1412 - val_ac
c: 0.7680
Epoch 316/400
1/1 [==============================] - 0s 219ms/step - loss: 0.0215 - acc: 0.9571 - val_loss: 0.1433 - val_ac
c: 0.7680
Epoch 317/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0202 - acc: 0.9643 - val_loss: 0.1410 - val_ac
c: 0.7760
Epoch 318/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0204 - acc: 0.9786 - val_loss: 0.1394 - val_ac
c: 0.7820
Epoch 319/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0192 - acc: 0.9929 - val_loss: 0.1385 - val_ac
c: 0.7860
Epoch 320/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0196 - acc: 0.9786 - val_loss: 0.1365 - val_ac
c: 0.7900
Epoch 321/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0183 - acc: 0.9786 - val_loss: 0.1341 - val_ac
c: 0.7880
Epoch 322/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0183 - acc: 0.9786 - val_loss: 0.1323 - val_ac
c: 0.7900
Epoch 323/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0201 - acc: 0.9643 - val_loss: 0.1318 - val_ac
c: 0.7920
Epoch 324/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0206 - acc: 0.9643 - val_loss: 0.1300 - val_ac
c: 0.7940
Epoch 325/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0188 - acc: 0.9786 - val_loss: 0.1301 - val_ac
c: 0.7880
Epoch 326/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0195 - acc: 0.9714 - val_loss: 0.1314 - val_ac
c: 0.7820
Epoch 327/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0199 - acc: 0.9643 - val_loss: 0.1361 - val_ac
c: 0.7660
Epoch 328/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0183 - acc: 0.9786 - val_loss: 0.1434 - val_ac
c: 0.7600
Epoch 329/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0212 - acc: 0.9643 - val_loss: 0.1464 - val_ac
c: 0.7480
Epoch 330/400
1/1 [==============================] - 0s 152ms/step - loss: 0.0191 - acc: 0.9929 - val_loss: 0.1479 - val_ac
c: 0.7560
Epoch 331/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0206 - acc: 0.9643 - val_loss: 0.1461 - val_ac
```

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c: 0.7620
Epoch 332/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0218 - acc: 0.9429 - val_loss: 0.1444 - val_ac
c: 0.7700
Epoch 333/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0178 - acc: 1.0000 - val_loss: 0.1440 - val_ac
c: 0.7740
Epoch 334/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0211 - acc: 0.9500 - val_loss: 0.1376 - val_ac
c: 0.7680
Epoch 335/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0191 - acc: 0.9857 - val_loss: 0.1324 - val_ac
c: 0.7820
Epoch 336/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0202 - acc: 0.9643 - val_loss: 0.1315 - val_ac
c: 0.7760
Epoch 337/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0190 - acc: 0.9857 - val_loss: 0.1338 - val_ac
c: 0.7800
Epoch 338/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0216 - acc: 0.9429 - val_loss: 0.1367 - val_ac
c: 0.7680
Epoch 339/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0189 - acc: 0.9857 - val_loss: 0.1388 - val_ac
c: 0.7640
Epoch 340/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0192 - acc: 0.9857 - val_loss: 0.1400 - val_ac
c: 0.7660
Epoch 341/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0184 - acc: 0.9929 - val_loss: 0.1421 - val_ac
c: 0.7700
Epoch 342/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0172 - acc: 0.9929 - val_loss: 0.1448 - val_ac
c: 0.7740
Epoch 343/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0207 - acc: 0.9714 - val_loss: 0.1445 - val_ac
c: 0.7780
Epoch 344/400
1/1 [==============================] - 0s 154ms/step - loss: 0.0197 - acc: 0.9786 - val_loss: 0.1418 - val_ac
c: 0.7800
Epoch 345/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0182 - acc: 0.9929 - val_loss: 0.1397 - val_ac
c: 0.7820
Epoch 346/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0173 - acc: 0.9929 - val_loss: 0.1367 - val_ac
c: 0.7800
Epoch 347/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0192 - acc: 0.9786 - val_loss: 0.1341 - val_ac
c: 0.7760
Epoch 348/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0204 - acc: 0.9786 - val_loss: 0.1334 - val_ac
c: 0.7720
Epoch 349/400
1/1 [==============================] - 0s 235ms/step - loss: 0.0193 - acc: 0.9714 - val_loss: 0.1336 - val_ac
c: 0.7740
Epoch 350/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0198 - acc: 0.9786 - val_loss: 0.1341 - val_ac
c: 0.7820
Epoch 351/400
1/1 [==============================] - 0s 200ms/step - loss: 0.0200 - acc: 0.9429 - val_loss: 0.1361 - val_ac
c: 0.7760
Epoch 352/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0170 - acc: 0.9857 - val_loss: 0.1376 - val_ac
c: 0.7740
Epoch 353/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0173 - acc: 1.0000 - val_loss: 0.1394 - val_ac
c: 0.7800
Epoch 354/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0202 - acc: 0.9500 - val_loss: 0.1394 - val_ac
c: 0.7740
Epoch 355/400
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1/1 [==============================] - 0s 164ms/step - loss: 0.0192 - acc: 0.9714 - val_loss: 0.1394 - val_ac
c: 0.7700
Epoch 356/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0190 - acc: 0.9643 - val_loss: 0.1403 - val_ac
c: 0.7780
Epoch 357/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0181 - acc: 0.9929 - val_loss: 0.1417 - val_ac
c: 0.7680
Epoch 358/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0203 - acc: 0.9571 - val_loss: 0.1415 - val_ac
c: 0.7620
Epoch 359/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0196 - acc: 0.9857 - val_loss: 0.1404 - val_ac
c: 0.7640
Epoch 360/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0181 - acc: 0.9929 - val_loss: 0.1388 - val_ac
c: 0.7680
Epoch 361/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0191 - acc: 0.9857 - val_loss: 0.1375 - val_ac
c: 0.7720
Epoch 362/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0182 - acc: 0.9857 - val_loss: 0.1378 - val_ac
c: 0.7760
Epoch 363/400
1/1 [==============================] - 0s 195ms/step - loss: 0.0182 - acc: 0.9857 - val_loss: 0.1390 - val_ac
c: 0.7800
Epoch 364/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0186 - acc: 0.9714 - val_loss: 0.1407 - val_ac
c: 0.7760
Epoch 365/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0180 - acc: 0.9786 - val_loss: 0.1405 - val_ac
c: 0.7800
Epoch 366/400
1/1 [==============================] - 0s 208ms/step - loss: 0.0194 - acc: 0.9786 - val_loss: 0.1380 - val_ac
c: 0.7840
Epoch 367/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0195 - acc: 0.9714 - val_loss: 0.1363 - val_ac
c: 0.7860
Epoch 368/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0186 - acc: 0.9929 - val_loss: 0.1323 - val_ac
c: 0.7820
Epoch 369/400
1/1 [==============================] - 0s 202ms/step - loss: 0.0186 - acc: 0.9786 - val_loss: 0.1312 - val_ac
c: 0.7840
Epoch 370/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0184 - acc: 0.9786 - val_loss: 0.1317 - val_ac
c: 0.7860
Epoch 371/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0187 - acc: 0.9714 - val_loss: 0.1332 - val_ac
c: 0.7840
Epoch 372/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0194 - acc: 0.9643 - val_loss: 0.1339 - val_ac
c: 0.7880
Epoch 373/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0193 - acc: 0.9857 - val_loss: 0.1350 - val_ac
c: 0.7840
Epoch 374/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0181 - acc: 0.9643 - val_loss: 0.1376 - val_ac
c: 0.7820
Epoch 375/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0171 - acc: 0.9786 - val_loss: 0.1397 - val_ac
c: 0.7760
Epoch 376/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0195 - acc: 0.9643 - val_loss: 0.1396 - val_ac
c: 0.7780
Epoch 377/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0187 - acc: 0.9714 - val_loss: 0.1383 - val_ac
c: 0.7800
Epoch 378/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0183 - acc: 0.9857 - val_loss: 0.1369 - val_ac
c: 0.7800
```

```
Epoch 379/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0174 - acc: 0.9857 - val_loss: 0.1366 - val_ac
c: 0.7780
Epoch 380/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0186 - acc: 0.9929 - val_loss: 0.1375 - val_ac
c: 0.7740
Epoch 381/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0176 - acc: 0.9929 - val_loss: 0.1372 - val_ac
c: 0.7680
Epoch 382/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0183 - acc: 0.9786 - val_loss: 0.1365 - val_ac
c: 0.7680
Epoch 383/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0181 - acc: 0.9857 - val_loss: 0.1349 - val_ac
c: 0.7720
Epoch 384/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0181 - acc: 0.9929 - val_loss: 0.1340 - val_ac
c: 0.7780
Epoch 385/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0182 - acc: 0.9857 - val_loss: 0.1349 - val_ac
c: 0.7720
Epoch 386/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0176 - acc: 0.9857 - val_loss: 0.1362 - val_ac
c: 0.7720
Epoch 387/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0175 - acc: 0.9786 - val_loss: 0.1370 - val_ac
c: 0.7660
Epoch 388/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0190 - acc: 0.9643 - val_loss: 0.1351 - val_ac
c: 0.7660
Epoch 389/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0179 - acc: 0.9929 - val_loss: 0.1327 - val_ac
c: 0.7660
Epoch 390/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0169 - acc: 0.9857 - val_loss: 0.1319 - val_ac
c: 0.7660
Epoch 391/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0172 - acc: 0.9857 - val_loss: 0.1313 - val_ac
c: 0.7680
Epoch 392/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0190 - acc: 0.9643 - val_loss: 0.1316 - val_ac
c: 0.7700
Epoch 393/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0177 - acc: 0.9929 - val_loss: 0.1329 - val_ac
c: 0.7720
Epoch 394/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0193 - acc: 0.9857 - val_loss: 0.1353 - val_ac
c: 0.7660
Epoch 395/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0175 - acc: 0.9786 - val_loss: 0.1392 - val_ac
c: 0.7780
Epoch 396/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0194 - acc: 0.9571 - val_loss: 0.1405 - val_ac
c: 0.7780
Epoch 397/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0179 - acc: 0.9714 - val_loss: 0.1415 - val_ac
c: 0.7780
Epoch 398/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0199 - acc: 0.9571 - val_loss: 0.1414 - val_ac
c: 0.7660
Epoch 399/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0184 - acc: 0.9857 - val_loss: 0.1383 - val_ac
c: 0.7600
Epoch 400/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0182 - acc: 0.9857 - val_loss: 0.1345 - val_ac
c: 0.7700
```

Out[ ]:
```
<tensorflow.python.keras.callbacks.History at 0x1cac77c8988>
```

In [ ]:
```
# Evaluate model
X_te = X[test_mask]
```

```
A_te = A[test_mask,:][:,test_mask]
y_te = labels_encoded[test_mask]

y_pred = model.predict([X_te, A_te], batch_size=N)
report = classification_report(np.argmax(y_te,axis=1), np.argmax(y_pred,axis=1), target_names=classes)
print('GCN Classification Report: \n {}'.format(report))
```

```
GCN Classification Report:
                        precision    recall  f1-score   support

            Case_Based       0.74      0.71      0.72       114
    Genetic_Algorithms       0.85      0.88      0.87       156
       Neural_Networks       0.75      0.72      0.73       290
 Probabilistic_Methods       0.82      0.62      0.71       172
Reinforcement_Learning       0.68      0.78      0.73        85
         Rule_Learning       0.51      0.82      0.62        60
                Theory       0.56      0.57      0.57       123

              accuracy                           0.72      1000
             macro avg       0.70      0.73      0.71      1000
          weighted avg       0.73      0.72      0.72      1000
```

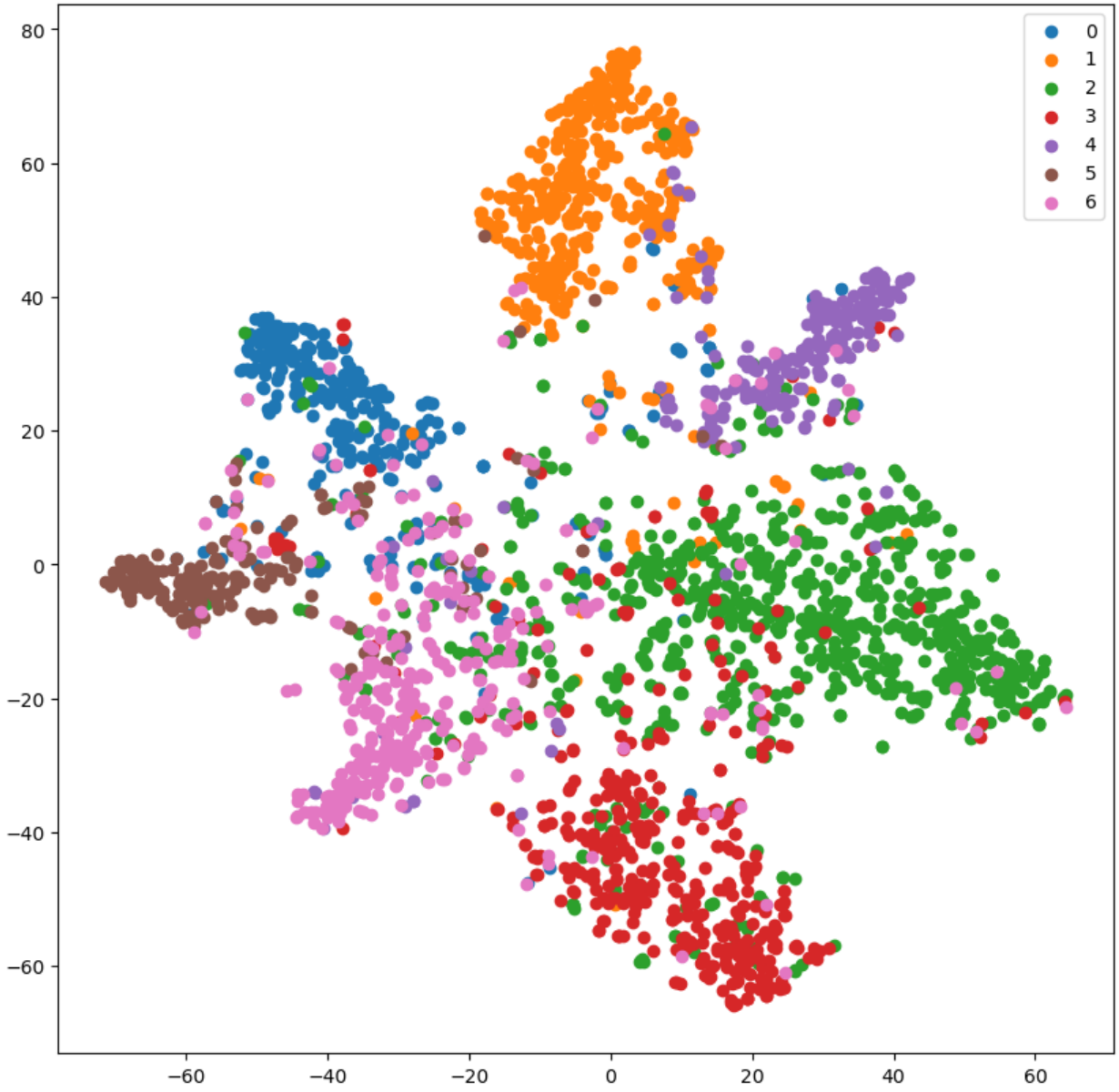
Get hidden layer representation for GCN

In [ ]:
```
layer_outputs = [layer.output for layer in model.layers]
activation_model = Model(inputs=model.input, outputs=layer_outputs)
activations = activation_model.predict([X,A],batch_size=N)

#Get t-SNE Representation
#get the hidden layer representation after the first GCN layer
x_tsne = TSNE(n_components=2).fit_transform(activations[3])
```

In [ ]:
```
def plot_tSNE(labels_encoded,x_tsne):
    color_map = np.argmax(labels_encoded, axis=1)
    plt.figure(figsize=(10,10))
    for cl in range(num_classes):
        indices = np.where(color_map==cl)
        indices = indices[0]
        plt.scatter(x_tsne[indices,0], x_tsne[indices, 1], label=cl)
    plt.legend()
    plt.show()

plot_tSNE(labels_encoded,x_tsne)
```



Comparison to Fully-Connected Neural Networks

Building and Training FNN

In [ ]:
```
es_patience = 200
optimizer = Adam(lr=1e-2)
l2_reg = 5e-4
epochs = 400

#Compare with FNN
#Construct the model
model_fnn = Sequential()
model_fnn.add(Dense(
                    128,
                    input_dim=X.shape[1],
                    activation=tf.nn.relu,
                    kernel_regularizer=tf.keras.regularizers.l2(l2_reg))
              )
model_fnn.add(Dropout(0.5))
model_fnn.add(Dense(256, activation=tf.nn.relu))
model_fnn.add(Dropout(0.5))
model_fnn.add(Dense(num_classes, activation=tf.keras.activations.softmax))
```

```
model_fnn.compile(optimizer=optimizer,
              loss='categorical_crossentropy',
              weighted_metrics=['acc'])


#define TensorBoard
tbCallBack_FNN = TensorBoard(
    log_dir='./Tensorboard_FNN_cora',
)

#Train model
validation_data_fnn = (X, labels_encoded, val_mask)
model_fnn.fit(
                X,labels_encoded,
                sample_weight=train_mask,
                epochs=epochs,
                batch_size=N,
                validation_data=validation_data_fnn,
                shuffle=False,
                callbacks=[
                  EarlyStopping(patience=es_patience,  restore_best_weights=True),
                  tbCallBack_FNN
          ])
```

```
Epoch 1/400
1/1 [==============================] - 0s 295ms/step - loss: 0.2194 - acc: 0.1000 - val_loss: 0.4332 - val_ac
c: 0.3020
Epoch 2/400
1/1 [==============================] - ETA: 0s - loss: 0.1749 - acc: 0.3571WARNING:tensorflow:Method (on_trai
n_batch_end) is slow compared to the batch update (0.149612). Check your callbacks.
1/1 [==============================] - 0s 177ms/step - loss: 0.1749 - acc: 0.3571 - val_loss: 0.3953 - val_ac
c: 0.4300
Epoch 3/400
1/1 [==============================] - 0s 193ms/step - loss: 0.1417 - acc: 0.5357 - val_loss: 0.3626 - val_ac
c: 0.5300
Epoch 4/400
1/1 [==============================] - 0s 171ms/step - loss: 0.1126 - acc: 0.6643 - val_loss: 0.3317 - val_ac
c: 0.5460
Epoch 5/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0875 - acc: 0.8214 - val_loss: 0.3026 - val_ac
c: 0.5500
Epoch 6/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0668 - acc: 0.9000 - val_loss: 0.2765 - val_ac
c: 0.5600
Epoch 7/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0503 - acc: 0.9429 - val_loss: 0.2610 - val_ac
c: 0.5620
Epoch 8/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0459 - acc: 0.9429 - val_loss: 0.2561 - val_ac
c: 0.5820
Epoch 9/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0410 - acc: 0.9929 - val_loss: 0.2629 - val_ac
c: 0.5900
Epoch 10/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0412 - acc: 0.9929 - val_loss: 0.2810 - val_ac
c: 0.5800
Epoch 11/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0424 - acc: 0.9857 - val_loss: 0.3046 - val_ac
c: 0.5600
Epoch 12/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0423 - acc: 0.9857 - val_loss: 0.3253 - val_ac
c: 0.5660
Epoch 13/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0404 - acc: 0.9929 - val_loss: 0.3475 - val_ac
c: 0.5600
Epoch 14/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0388 - acc: 0.9857 - val_loss: 0.3576 - val_ac
c: 0.5660
Epoch 15/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0358 - acc: 0.9929 - val_loss: 0.3682 - val_ac
c: 0.5660
Epoch 16/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0333 - acc: 0.9929 - val_loss: 0.3698 - val_ac
c: 0.5800
Epoch 17/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0310 - acc: 0.9857 - val_loss: 0.3705 - val_ac
c: 0.5840
Epoch 18/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0274 - acc: 1.0000 - val_loss: 0.3771 - val_ac
c: 0.5760
Epoch 19/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0277 - acc: 0.9857 - val_loss: 0.3936 - val_ac
c: 0.5660
Epoch 20/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0294 - acc: 0.9714 - val_loss: 0.4007 - val_ac
c: 0.5440
Epoch 21/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0256 - acc: 0.9643 - val_loss: 0.4114 - val_ac
c: 0.5380
Epoch 22/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0242 - acc: 0.9714 - val_loss: 0.4263 - val_ac
c: 0.5180
Epoch 23/400
1/1 [==============================] - 0s 189ms/step - loss: 0.0235 - acc: 0.9643 - val_loss: 0.4224 - val_ac
c: 0.5120
```

```
Epoch 24/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0227 - acc: 0.9929 - val_loss: 0.4091 - val_ac
c: 0.5120
Epoch 25/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0190 - acc: 0.9929 - val_loss: 0.3987 - val_ac
c: 0.4940
Epoch 26/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0207 - acc: 0.9857 - val_loss: 0.3921 - val_ac
c: 0.4820
Epoch 27/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0215 - acc: 0.9714 - val_loss: 0.3759 - val_ac
c: 0.4940
Epoch 28/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0205 - acc: 0.9786 - val_loss: 0.3540 - val_ac
c: 0.5060
Epoch 29/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0207 - acc: 0.9857 - val_loss: 0.3450 - val_ac
c: 0.5040
Epoch 30/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0216 - acc: 0.9714 - val_loss: 0.3413 - val_ac
c: 0.5060
Epoch 31/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0204 - acc: 0.9857 - val_loss: 0.3411 - val_ac
c: 0.4980
Epoch 32/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0200 - acc: 1.0000 - val_loss: 0.3410 - val_ac
c: 0.4980
Epoch 33/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0228 - acc: 0.9857 - val_loss: 0.3313 - val_ac
c: 0.5080
Epoch 34/400
1/1 [==============================] - 0s 202ms/step - loss: 0.0210 - acc: 0.9929 - val_loss: 0.3237 - val_ac
c: 0.5160
Epoch 35/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0219 - acc: 0.9786 - val_loss: 0.3191 - val_ac
c: 0.5180
Epoch 36/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0220 - acc: 0.9929 - val_loss: 0.3201 - val_ac
c: 0.5240
Epoch 37/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0203 - acc: 1.0000 - val_loss: 0.3209 - val_ac
c: 0.5260
Epoch 38/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0233 - acc: 0.9714 - val_loss: 0.3185 - val_ac
c: 0.5240
Epoch 39/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0210 - acc: 1.0000 - val_loss: 0.3181 - val_ac
c: 0.5220
Epoch 40/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0210 - acc: 0.9929 - val_loss: 0.3200 - val_ac
c: 0.5200
Epoch 41/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0203 - acc: 1.0000 - val_loss: 0.3248 - val_ac
c: 0.5180
Epoch 42/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0206 - acc: 0.9929 - val_loss: 0.3333 - val_ac
c: 0.5160
Epoch 43/400
1/1 [==============================] - 0s 189ms/step - loss: 0.0211 - acc: 0.9929 - val_loss: 0.3318 - val_ac
c: 0.5180
Epoch 44/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0200 - acc: 0.9929 - val_loss: 0.3299 - val_ac
c: 0.5280
Epoch 45/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0193 - acc: 0.9929 - val_loss: 0.3266 - val_ac
c: 0.5440
Epoch 46/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0200 - acc: 0.9857 - val_loss: 0.3235 - val_ac
c: 0.5540
Epoch 47/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0191 - acc: 0.9929 - val_loss: 0.3200 - val_ac
```

```
c: 0.5720
Epoch 48/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0196 - acc: 0.9857 - val_loss: 0.3199 - val_ac
c: 0.5780
Epoch 49/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0191 - acc: 0.9857 - val_loss: 0.3214 - val_ac
c: 0.5720
Epoch 50/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0184 - acc: 0.9929 - val_loss: 0.3259 - val_ac
c: 0.5560
Epoch 51/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0170 - acc: 1.0000 - val_loss: 0.3347 - val_ac
c: 0.5420
Epoch 52/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0171 - acc: 0.9929 - val_loss: 0.3447 - val_ac
c: 0.5300
Epoch 53/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0162 - acc: 1.0000 - val_loss: 0.3510 - val_ac
c: 0.5160
Epoch 54/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0169 - acc: 0.9857 - val_loss: 0.3551 - val_ac
c: 0.5280
Epoch 55/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0166 - acc: 0.9857 - val_loss: 0.3524 - val_ac
c: 0.5320
Epoch 56/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0181 - acc: 0.9714 - val_loss: 0.3460 - val_ac
c: 0.5340
Epoch 57/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0163 - acc: 0.9857 - val_loss: 0.3477 - val_ac
c: 0.5260
Epoch 58/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0194 - acc: 0.9643 - val_loss: 0.3555 - val_ac
c: 0.5200
Epoch 59/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0168 - acc: 0.9857 - val_loss: 0.3581 - val_ac
c: 0.5180
Epoch 60/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0165 - acc: 0.9929 - val_loss: 0.3625 - val_ac
c: 0.5100
Epoch 61/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0171 - acc: 0.9857 - val_loss: 0.3650 - val_ac
c: 0.5140
Epoch 62/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0178 - acc: 0.9857 - val_loss: 0.3650 - val_ac
c: 0.5040
Epoch 63/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0174 - acc: 0.9786 - val_loss: 0.3682 - val_ac
c: 0.5060
Epoch 64/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0204 - acc: 0.9643 - val_loss: 0.3859 - val_ac
c: 0.4900
Epoch 65/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0183 - acc: 0.9929 - val_loss: 0.4134 - val_ac
c: 0.4660
Epoch 66/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0214 - acc: 0.9786 - val_loss: 0.4259 - val_ac
c: 0.4740
Epoch 67/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0233 - acc: 0.9714 - val_loss: 0.4025 - val_ac
c: 0.4920
Epoch 68/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0200 - acc: 0.9929 - val_loss: 0.3871 - val_ac
c: 0.5020
Epoch 69/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0222 - acc: 0.9786 - val_loss: 0.3729 - val_ac
c: 0.5020
Epoch 70/400
1/1 [==============================] - 0s 246ms/step - loss: 0.0217 - acc: 0.9929 - val_loss: 0.3641 - val_ac
c: 0.5180
Epoch 71/400
```

```
1/1 [==============================] - 0s 171ms/step - loss: 0.0219 - acc: 0.9857 - val_loss: 0.3614 - val_ac
c: 0.5220
Epoch 72/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0236 - acc: 0.9857 - val_loss: 0.3590 - val_ac
c: 0.5260
Epoch 73/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0217 - acc: 1.0000 - val_loss: 0.3594 - val_ac
c: 0.5340
Epoch 74/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0248 - acc: 0.9714 - val_loss: 0.3677 - val_ac
c: 0.5300
Epoch 75/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0252 - acc: 0.9643 - val_loss: 0.3879 - val_ac
c: 0.5140
Epoch 76/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0229 - acc: 1.0000 - val_loss: 0.4053 - val_ac
c: 0.5160
Epoch 77/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0245 - acc: 0.9786 - val_loss: 0.4160 - val_ac
c: 0.5060
Epoch 78/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0236 - acc: 0.9929 - val_loss: 0.4216 - val_ac
c: 0.5020
Epoch 79/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0263 - acc: 0.9786 - val_loss: 0.4215 - val_ac
c: 0.5020
Epoch 80/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0256 - acc: 0.9786 - val_loss: 0.4076 - val_ac
c: 0.4980
Epoch 81/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0230 - acc: 1.0000 - val_loss: 0.4066 - val_ac
c: 0.4920
Epoch 82/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0256 - acc: 0.9786 - val_loss: 0.4002 - val_ac
c: 0.4880
Epoch 83/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0276 - acc: 0.9571 - val_loss: 0.3964 - val_ac
c: 0.4840
Epoch 84/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0262 - acc: 0.9857 - val_loss: 0.3938 - val_ac
c: 0.4960
Epoch 85/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0248 - acc: 0.9857 - val_loss: 0.3803 - val_ac
c: 0.5140
Epoch 86/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0277 - acc: 0.9714 - val_loss: 0.3690 - val_ac
c: 0.5240
Epoch 87/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0260 - acc: 0.9786 - val_loss: 0.3723 - val_ac
c: 0.5220
Epoch 88/400
1/1 [==============================] - 0s 213ms/step - loss: 0.0266 - acc: 0.9714 - val_loss: 0.3823 - val_ac
c: 0.5200
Epoch 89/400
1/1 [==============================] - 0s 247ms/step - loss: 0.0259 - acc: 0.9929 - val_loss: 0.3929 - val_ac
c: 0.5220
Epoch 90/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0251 - acc: 1.0000 - val_loss: 0.4017 - val_ac
c: 0.5320
Epoch 91/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0294 - acc: 0.9643 - val_loss: 0.3957 - val_ac
c: 0.5320
Epoch 92/400
1/1 [==============================] - 0s 204ms/step - loss: 0.0290 - acc: 0.9714 - val_loss: 0.3809 - val_ac
c: 0.5340
Epoch 93/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0281 - acc: 0.9786 - val_loss: 0.3708 - val_ac
c: 0.5120
Epoch 94/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0280 - acc: 0.9786 - val_loss: 0.3732 - val_ac
c: 0.5200
```

```
Epoch 95/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0280 - acc: 0.9786 - val_loss: 0.3835 - val_ac
c: 0.5020
Epoch 96/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0282 - acc: 0.9857 - val_loss: 0.3951 - val_ac
c: 0.4840
Epoch 97/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0331 - acc: 0.9571 - val_loss: 0.3863 - val_ac
c: 0.4940
Epoch 98/400
1/1 [==============================] - 0s 205ms/step - loss: 0.0269 - acc: 1.0000 - val_loss: 0.3914 - val_ac
c: 0.4940
Epoch 99/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0289 - acc: 0.9929 - val_loss: 0.4000 - val_ac
c: 0.5020
Epoch 100/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0302 - acc: 0.9786 - val_loss: 0.3962 - val_ac
c: 0.5060
Epoch 101/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0281 - acc: 0.9857 - val_loss: 0.3857 - val_ac
c: 0.5140
Epoch 102/400
1/1 [==============================] - 0s 195ms/step - loss: 0.0304 - acc: 0.9786 - val_loss: 0.3884 - val_ac
c: 0.5200
Epoch 103/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0281 - acc: 1.0000 - val_loss: 0.3942 - val_ac
c: 0.5220
Epoch 104/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0332 - acc: 0.9571 - val_loss: 0.3950 - val_ac
c: 0.5200
Epoch 105/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0309 - acc: 0.9857 - val_loss: 0.4063 - val_ac
c: 0.5120
Epoch 106/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0288 - acc: 0.9929 - val_loss: 0.4131 - val_ac
c: 0.5080
Epoch 107/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0316 - acc: 0.9643 - val_loss: 0.4179 - val_ac
c: 0.4900
Epoch 108/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0314 - acc: 0.9786 - val_loss: 0.4128 - val_ac
c: 0.4820
Epoch 109/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0279 - acc: 1.0000 - val_loss: 0.4139 - val_ac
c: 0.4880
Epoch 110/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0333 - acc: 0.9643 - val_loss: 0.4181 - val_ac
c: 0.4920
Epoch 111/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0320 - acc: 0.9714 - val_loss: 0.4136 - val_ac
c: 0.5040
Epoch 112/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0319 - acc: 0.9929 - val_loss: 0.4083 - val_ac
c: 0.5000
Epoch 113/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0334 - acc: 0.9786 - val_loss: 0.4005 - val_ac
c: 0.5000
Epoch 114/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0323 - acc: 0.9714 - val_loss: 0.3961 - val_ac
c: 0.5080
Epoch 115/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0318 - acc: 0.9786 - val_loss: 0.3979 - val_ac
c: 0.5200
Epoch 116/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0312 - acc: 0.9857 - val_loss: 0.4019 - val_ac
c: 0.5300
Epoch 117/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0314 - acc: 0.9857 - val_loss: 0.4112 - val_ac
c: 0.5060
Epoch 118/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0306 - acc: 0.9786 - val_loss: 0.4230 - val_ac
```

```
c: 0.4940
Epoch 119/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0319 - acc: 0.9857 - val_loss: 0.4258 - val_ac
c: 0.4860
Epoch 120/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0311 - acc: 0.9929 - val_loss: 0.4225 - val_ac
c: 0.4840
Epoch 121/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0317 - acc: 0.9857 - val_loss: 0.4206 - val_ac
c: 0.4800
Epoch 122/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0310 - acc: 0.9929 - val_loss: 0.4174 - val_ac
c: 0.4860
Epoch 123/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0327 - acc: 0.9786 - val_loss: 0.4155 - val_ac
c: 0.4800
Epoch 124/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0335 - acc: 0.9571 - val_loss: 0.4060 - val_ac
c: 0.5000
Epoch 125/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0339 - acc: 0.9500 - val_loss: 0.3895 - val_ac
c: 0.5080
Epoch 126/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0333 - acc: 0.9786 - val_loss: 0.3811 - val_ac
c: 0.5180
Epoch 127/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0311 - acc: 0.9857 - val_loss: 0.3781 - val_ac
c: 0.5360
Epoch 128/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0327 - acc: 0.9643 - val_loss: 0.3773 - val_ac
c: 0.5440
Epoch 129/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0318 - acc: 0.9857 - val_loss: 0.3764 - val_ac
c: 0.5460
Epoch 130/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0326 - acc: 0.9857 - val_loss: 0.3771 - val_ac
c: 0.5440
Epoch 131/400
1/1 [==============================] - 0s 305ms/step - loss: 0.0335 - acc: 0.9786 - val_loss: 0.3816 - val_ac
c: 0.5440
Epoch 132/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0318 - acc: 0.9857 - val_loss: 0.3885 - val_ac
c: 0.5500
Epoch 133/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0320 - acc: 0.9929 - val_loss: 0.3982 - val_ac
c: 0.5620
Epoch 134/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0333 - acc: 0.9643 - val_loss: 0.4050 - val_ac
c: 0.5540
Epoch 135/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0344 - acc: 0.9786 - val_loss: 0.4130 - val_ac
c: 0.5480
Epoch 136/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0309 - acc: 1.0000 - val_loss: 0.4201 - val_ac
c: 0.5400
Epoch 137/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0329 - acc: 0.9857 - val_loss: 0.4317 - val_ac
c: 0.5340
Epoch 138/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0353 - acc: 0.9786 - val_loss: 0.4472 - val_ac
c: 0.5140
Epoch 139/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0331 - acc: 0.9786 - val_loss: 0.4734 - val_ac
c: 0.4980
Epoch 140/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0315 - acc: 0.9786 - val_loss: 0.4907 - val_ac
c: 0.4780
Epoch 141/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0337 - acc: 0.9714 - val_loss: 0.5007 - val_ac
c: 0.4620
Epoch 142/400
```

```
1/1 [==============================] - 0s 169ms/step - loss: 0.0298 - acc: 0.9929 - val_loss: 0.5028 - val_ac
c: 0.4560
Epoch 143/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0326 - acc: 0.9714 - val_loss: 0.4854 - val_ac
c: 0.4740
Epoch 144/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0299 - acc: 0.9857 - val_loss: 0.4639 - val_ac
c: 0.4860
Epoch 145/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0327 - acc: 0.9643 - val_loss: 0.4432 - val_ac
c: 0.5060
Epoch 146/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0301 - acc: 0.9786 - val_loss: 0.4251 - val_ac
c: 0.5120
Epoch 147/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0299 - acc: 0.9929 - val_loss: 0.4064 - val_ac
c: 0.5160
Epoch 148/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0300 - acc: 0.9857 - val_loss: 0.3998 - val_ac
c: 0.5180
Epoch 149/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0352 - acc: 0.9714 - val_loss: 0.3921 - val_ac
c: 0.5240
Epoch 150/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0352 - acc: 0.9500 - val_loss: 0.3903 - val_ac
c: 0.5260
Epoch 151/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0310 - acc: 0.9643 - val_loss: 0.3877 - val_ac
c: 0.5340
Epoch 152/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0315 - acc: 0.9643 - val_loss: 0.3852 - val_ac
c: 0.5380
Epoch 153/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0310 - acc: 0.9857 - val_loss: 0.3847 - val_ac
c: 0.5440
Epoch 154/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0301 - acc: 0.9929 - val_loss: 0.3850 - val_ac
c: 0.5540
Epoch 155/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0337 - acc: 0.9714 - val_loss: 0.3874 - val_ac
c: 0.5440
Epoch 156/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0342 - acc: 0.9786 - val_loss: 0.3939 - val_ac
c: 0.5520
Epoch 157/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0343 - acc: 0.9714 - val_loss: 0.4069 - val_ac
c: 0.5340
Epoch 158/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0328 - acc: 0.9857 - val_loss: 0.4233 - val_ac
c: 0.5280
Epoch 159/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0382 - acc: 0.9500 - val_loss: 0.4253 - val_ac
c: 0.5200
Epoch 160/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0342 - acc: 0.9786 - val_loss: 0.4221 - val_ac
c: 0.5100
Epoch 161/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0333 - acc: 0.9786 - val_loss: 0.4192 - val_ac
c: 0.5080
Epoch 162/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0346 - acc: 0.9786 - val_loss: 0.4157 - val_ac
c: 0.5060
Epoch 163/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0376 - acc: 0.9429 - val_loss: 0.4141 - val_ac
c: 0.4960
Epoch 164/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0354 - acc: 0.9786 - val_loss: 0.4125 - val_ac
c: 0.5160
Epoch 165/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0375 - acc: 0.9714 - val_loss: 0.4071 - val_ac
c: 0.5240
```

```
Epoch 166/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0341 - acc: 0.9857 - val_loss: 0.4032 - val_ac
c: 0.5340
Epoch 167/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0350 - acc: 0.9786 - val_loss: 0.4084 - val_ac
c: 0.5280
Epoch 168/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0359 - acc: 0.9857 - val_loss: 0.4179 - val_ac
c: 0.5320
Epoch 169/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0364 - acc: 0.9786 - val_loss: 0.4292 - val_ac
c: 0.5180
Epoch 170/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0361 - acc: 0.9714 - val_loss: 0.4383 - val_ac
c: 0.5060
Epoch 171/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0350 - acc: 0.9786 - val_loss: 0.4468 - val_ac
c: 0.5120
Epoch 172/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0357 - acc: 0.9857 - val_loss: 0.4508 - val_ac
c: 0.5020
Epoch 173/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0388 - acc: 0.9714 - val_loss: 0.4443 - val_ac
c: 0.5060
Epoch 174/400
1/1 [==============================] - 0s 215ms/step - loss: 0.0401 - acc: 0.9643 - val_loss: 0.4284 - val_ac
c: 0.5180
Epoch 175/400
1/1 [==============================] - 0s 203ms/step - loss: 0.0353 - acc: 0.9643 - val_loss: 0.4231 - val_ac
c: 0.5160
Epoch 176/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0377 - acc: 0.9857 - val_loss: 0.4260 - val_ac
c: 0.5300
Epoch 177/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0358 - acc: 0.9857 - val_loss: 0.4292 - val_ac
c: 0.5420
Epoch 178/400
1/1 [==============================] - 0s 302ms/step - loss: 0.0386 - acc: 0.9571 - val_loss: 0.4211 - val_ac
c: 0.5500
Epoch 179/400
1/1 [==============================] - 0s 343ms/step - loss: 0.0354 - acc: 0.9857 - val_loss: 0.4087 - val_ac
c: 0.5740
Epoch 180/400
1/1 [==============================] - 0s 204ms/step - loss: 0.0370 - acc: 0.9714 - val_loss: 0.3997 - val_ac
c: 0.5880
Epoch 181/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0368 - acc: 0.9643 - val_loss: 0.3957 - val_ac
c: 0.5840
Epoch 182/400
1/1 [==============================] - 0s 204ms/step - loss: 0.0358 - acc: 0.9857 - val_loss: 0.3916 - val_ac
c: 0.5680
Epoch 183/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0387 - acc: 0.9714 - val_loss: 0.3953 - val_ac
c: 0.5520
Epoch 184/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0380 - acc: 0.9786 - val_loss: 0.4068 - val_ac
c: 0.5360
Epoch 185/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0413 - acc: 0.9714 - val_loss: 0.4237 - val_ac
c: 0.5320
Epoch 186/400
1/1 [==============================] - 0s 189ms/step - loss: 0.0354 - acc: 0.9929 - val_loss: 0.4368 - val_ac
c: 0.5220
Epoch 187/400
1/1 [==============================] - 0s 239ms/step - loss: 0.0363 - acc: 0.9786 - val_loss: 0.4416 - val_ac
c: 0.5200
Epoch 188/400
1/1 [==============================] - 0s 231ms/step - loss: 0.0382 - acc: 0.9786 - val_loss: 0.4462 - val_ac
c: 0.5160
Epoch 189/400
1/1 [==============================] - 0s 205ms/step - loss: 0.0364 - acc: 0.9857 - val_loss: 0.4504 - val_ac
```

```
c: 0.4940
Epoch 190/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0375 - acc: 0.9786 - val_loss: 0.4448 - val_ac
c: 0.4940
Epoch 191/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0377 - acc: 0.9786 - val_loss: 0.4346 - val_ac
c: 0.5100
Epoch 192/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0382 - acc: 0.9714 - val_loss: 0.4156 - val_ac
c: 0.5340
Epoch 193/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0367 - acc: 0.9714 - val_loss: 0.4048 - val_ac
c: 0.5420
Epoch 194/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0398 - acc: 0.9643 - val_loss: 0.3999 - val_ac
c: 0.5420
Epoch 195/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0409 - acc: 0.9786 - val_loss: 0.4003 - val_ac
c: 0.5360
Epoch 196/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0391 - acc: 0.9571 - val_loss: 0.3992 - val_ac
c: 0.5320
Epoch 197/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0373 - acc: 0.9786 - val_loss: 0.3948 - val_ac
c: 0.5460
Epoch 198/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0363 - acc: 0.9857 - val_loss: 0.3924 - val_ac
c: 0.5480
Epoch 199/400
1/1 [==============================] - 0s 197ms/step - loss: 0.0393 - acc: 0.9714 - val_loss: 0.3879 - val_ac
c: 0.5440
Epoch 200/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0363 - acc: 0.9786 - val_loss: 0.3863 - val_ac
c: 0.5480
Epoch 201/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0359 - acc: 0.9786 - val_loss: 0.3932 - val_ac
c: 0.5320
Epoch 202/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0397 - acc: 0.9500 - val_loss: 0.4021 - val_ac
c: 0.5200
Epoch 203/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0422 - acc: 0.9500 - val_loss: 0.4078 - val_ac
c: 0.5140
Epoch 204/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0358 - acc: 0.9786 - val_loss: 0.4076 - val_ac
c: 0.5200
Epoch 205/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0406 - acc: 0.9714 - val_loss: 0.4034 - val_ac
c: 0.5220
Epoch 206/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0357 - acc: 0.9929 - val_loss: 0.3997 - val_ac
c: 0.5260
Epoch 207/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0364 - acc: 0.9929 - val_loss: 0.3976 - val_ac
c: 0.5260
Epoch 208/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0417 - acc: 0.9643 - val_loss: 0.4044 - val_ac
c: 0.5280
```

Out[ ]: <tensorflow.python.keras.callbacks.History at 0x1cad57705c8>

In [ ]:
```
# Evaluate model
y_pred = model_fnn.predict(X_te)
report = classification_report(np.argmax(y_te,axis=1), np.argmax(y_pred,axis=1), target_names=classes)
print('FCNN Classification Report: \n {}'.format(report))
```

```
FCNN Classification Report:
                        precision    recall  f1-score   support

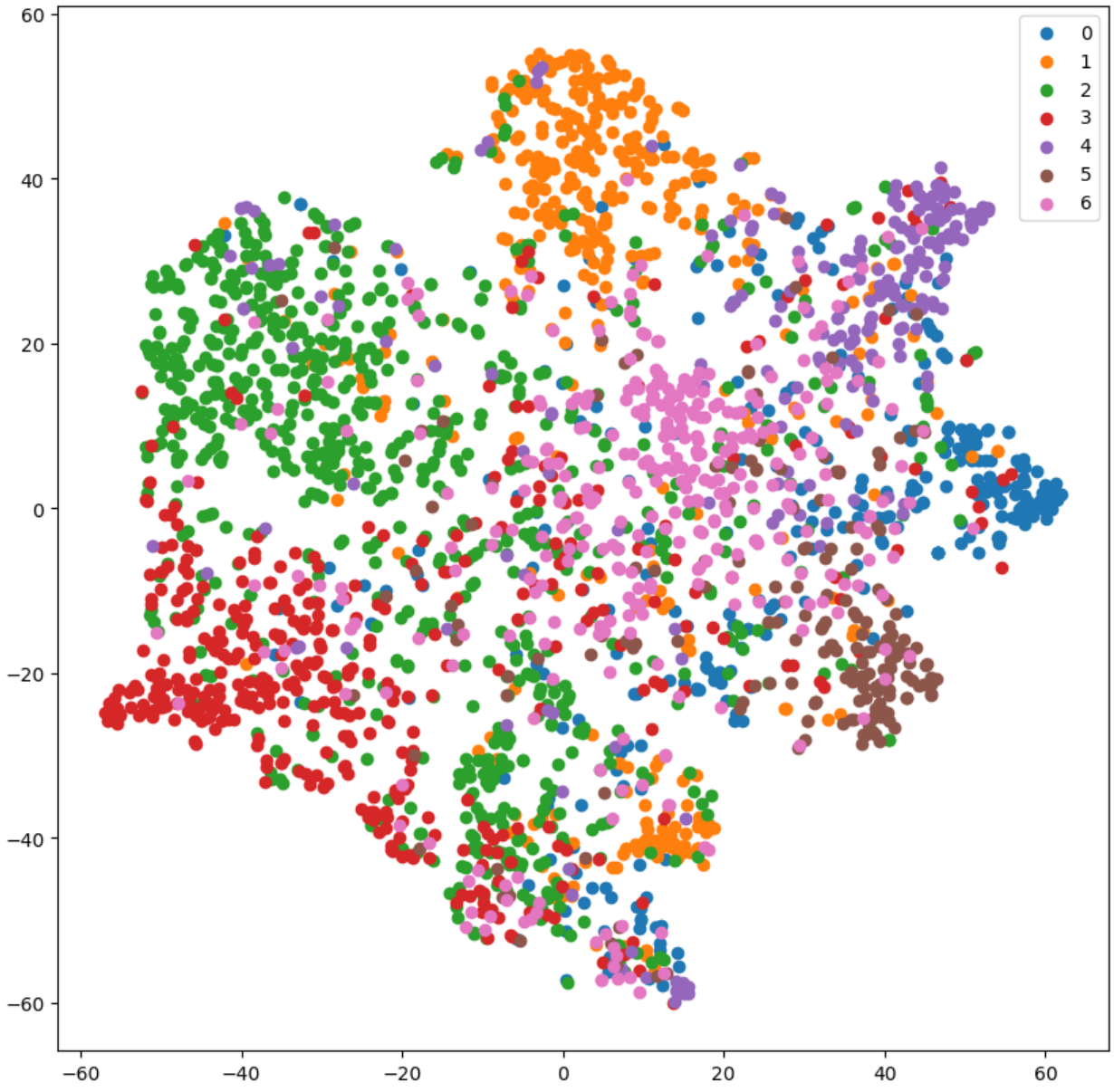
           Case_Based       0.54      0.54      0.54       114
  Genetic_Algorithms        0.62      0.79      0.70       156
      Neural_Networks       0.70      0.56      0.62       290
Probabilistic_Methods       0.71      0.52      0.60       172
Reinforcement_Learning      0.44      0.45      0.44        85
        Rule_Learning       0.38      0.75      0.50        60
               Theory       0.43      0.42      0.42       123

             accuracy                           0.57      1000
            macro avg       0.54      0.58      0.55      1000
         weighted avg       0.59      0.57      0.57      1000
```

Get hidden layer representation for FNN

In [ ]:
```
layer_outputs = [layer.output for layer in model_fnn.layers]
activation_model = Model(inputs=model_fnn.input, outputs=layer_outputs)
activations = activation_model.predict([X])
```

In [ ]:
```
x_tsne = TSNE(n_components=2).fit_transform(activations[3])
plot_tSNE(labels_encoded,x_tsne)
```



In [ ]:
```
### END OF NOTEBOOK ###
```