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', 'Case_Based', 'Genetic_Algorithms', 'Theory', 'Probabilistic_Method
s', 'Rule_Learning', 'Neural_Networks'}

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))
```

```
Graph info:  Name:
Type: Graph
Number of nodes: 2708
Number of edges: 5278
Average degree:   3.8981
```

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 443ms/step - loss: 0.1167 - acc: 0.1143 - val_loss: 0.3666 - val_ac
c: 0.2420
Epoch 2/400
1/1 [==============================] - ETA: 0s - loss: 0.1095 - acc: 0.3214WARNING:tensorflow:Method (on_trai
n_batch_end) is slow compared to the batch update (0.216931). Check your callbacks.
1/1 [==============================] - 0s 195ms/step - loss: 0.1095 - acc: 0.3214 - val_loss: 0.3569 - val_ac
c: 0.4760
Epoch 3/400
1/1 [==============================] - 0s 190ms/step - loss: 0.1028 - acc: 0.5714 - val_loss: 0.3482 - val_ac
c: 0.5740
Epoch 4/400
1/1 [==============================] - 0s 271ms/step - loss: 0.0977 - acc: 0.7000 - val_loss: 0.3402 - val_ac
c: 0.5620
Epoch 5/400
1/1 [==============================] - 0s 280ms/step - loss: 0.0919 - acc: 0.6857 - val_loss: 0.3322 - val_ac
c: 0.5620
Epoch 6/400
1/1 [==============================] - 0s 251ms/step - loss: 0.0869 - acc: 0.7500 - val_loss: 0.3238 - val_ac
c: 0.5900
Epoch 7/400
1/1 [==============================] - 0s 275ms/step - loss: 0.0832 - acc: 0.7571 - val_loss: 0.3144 - val_ac
c: 0.6200
Epoch 8/400
1/1 [==============================] - 0s 256ms/step - loss: 0.0818 - acc: 0.7357 - val_loss: 0.3048 - val_ac
c: 0.6580
Epoch 9/400
1/1 [==============================] - 0s 252ms/step - loss: 0.0805 - acc: 0.7571 - val_loss: 0.2950 - val_ac
c: 0.6880
Epoch 10/400
1/1 [==============================] - 0s 267ms/step - loss: 0.0753 - acc: 0.8643 - val_loss: 0.2857 - val_ac
c: 0.7160
Epoch 11/400
1/1 [==============================] - 0s 249ms/step - loss: 0.0734 - acc: 0.8000 - val_loss: 0.2777 - val_ac
c: 0.7280
Epoch 12/400
1/1 [==============================] - 0s 297ms/step - loss: 0.0721 - acc: 0.8786 - val_loss: 0.2703 - val_ac
c: 0.7340
Epoch 13/400
1/1 [==============================] - 0s 290ms/step - loss: 0.0699 - acc: 0.8286 - val_loss: 0.2633 - val_ac
c: 0.7460
Epoch 14/400
1/1 [==============================] - 0s 250ms/step - loss: 0.0648 - acc: 0.9143 - val_loss: 0.2570 - val_ac
c: 0.7580
Epoch 15/400
1/1 [==============================] - 0s 232ms/step - loss: 0.0658 - acc: 0.8857 - val_loss: 0.2513 - val_ac
c: 0.7560
Epoch 16/400
1/1 [==============================] - 0s 238ms/step - loss: 0.0642 - acc: 0.9071 - val_loss: 0.2460 - val_ac
c: 0.7620
Epoch 17/400
1/1 [==============================] - 0s 225ms/step - loss: 0.0613 - acc: 0.9071 - val_loss: 0.2408 - val_ac
c: 0.7600
Epoch 18/400
1/1 [==============================] - 0s 329ms/step - loss: 0.0607 - acc: 0.9000 - val_loss: 0.2359 - val_ac
c: 0.7640
Epoch 19/400
1/1 [==============================] - 0s 304ms/step - loss: 0.0603 - acc: 0.9000 - val_loss: 0.2306 - val_ac
c: 0.7600
Epoch 20/400
1/1 [==============================] - 0s 288ms/step - loss: 0.0577 - acc: 0.9357 - val_loss: 0.2255 - val_ac
c: 0.7660
Epoch 21/400
1/1 [==============================] - 0s 254ms/step - loss: 0.0580 - acc: 0.9000 - val_loss: 0.2203 - val_ac
c: 0.7680
Epoch 22/400
1/1 [==============================] - 0s 252ms/step - loss: 0.0553 - acc: 0.9357 - val_loss: 0.2159 - val_ac
c: 0.7680
Epoch 23/400
1/1 [==============================] - 0s 246ms/step - loss: 0.0528 - acc: 0.9357 - val_loss: 0.2120 - val_ac
c: 0.7740
```

```
Epoch 24/400
1/1 [==============================] - 0s 273ms/step - loss: 0.0547 - acc: 0.8929 - val_loss: 0.2085 - val_ac
c: 0.7720
Epoch 25/400
1/1 [==============================] - 0s 311ms/step - loss: 0.0530 - acc: 0.9429 - val_loss: 0.2051 - val_ac
c: 0.7720
Epoch 26/400
1/1 [==============================] - 0s 312ms/step - loss: 0.0512 - acc: 0.9714 - val_loss: 0.2021 - val_ac
c: 0.7760
Epoch 27/400
1/1 [==============================] - 0s 232ms/step - loss: 0.0511 - acc: 0.9286 - val_loss: 0.1994 - val_ac
c: 0.7740
Epoch 28/400
1/1 [==============================] - 0s 248ms/step - loss: 0.0503 - acc: 0.9214 - val_loss: 0.1968 - val_ac
c: 0.7700
Epoch 29/400
1/1 [==============================] - 0s 242ms/step - loss: 0.0514 - acc: 0.9286 - val_loss: 0.1950 - val_ac
c: 0.7700
Epoch 30/400
1/1 [==============================] - 0s 222ms/step - loss: 0.0509 - acc: 0.9286 - val_loss: 0.1934 - val_ac
c: 0.7720
Epoch 31/400
1/1 [==============================] - 0s 235ms/step - loss: 0.0487 - acc: 0.9429 - val_loss: 0.1918 - val_ac
c: 0.7700
Epoch 32/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0475 - acc: 0.9214 - val_loss: 0.1903 - val_ac
c: 0.7700
Epoch 33/400
1/1 [==============================] - 0s 209ms/step - loss: 0.0472 - acc: 0.9500 - val_loss: 0.1882 - val_ac
c: 0.7700
Epoch 34/400
1/1 [==============================] - 0s 199ms/step - loss: 0.0462 - acc: 0.9643 - val_loss: 0.1864 - val_ac
c: 0.7700
Epoch 35/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0452 - acc: 0.9571 - val_loss: 0.1847 - val_ac
c: 0.7760
Epoch 36/400
1/1 [==============================] - 0s 243ms/step - loss: 0.0456 - acc: 0.9143 - val_loss: 0.1833 - val_ac
c: 0.7800
Epoch 37/400
1/1 [==============================] - 0s 221ms/step - loss: 0.0439 - acc: 0.9357 - val_loss: 0.1817 - val_ac
c: 0.7820
Epoch 38/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0452 - acc: 0.9143 - val_loss: 0.1806 - val_ac
c: 0.7760
Epoch 39/400
1/1 [==============================] - 0s 218ms/step - loss: 0.0454 - acc: 0.9214 - val_loss: 0.1794 - val_ac
c: 0.7760
Epoch 40/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0408 - acc: 0.9643 - val_loss: 0.1787 - val_ac
c: 0.7720
Epoch 41/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0406 - acc: 0.9714 - val_loss: 0.1785 - val_ac
c: 0.7660
Epoch 42/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0448 - acc: 0.9429 - val_loss: 0.1776 - val_ac
c: 0.7700
Epoch 43/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0439 - acc: 0.9000 - val_loss: 0.1772 - val_ac
c: 0.7720
Epoch 44/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0447 - acc: 0.9286 - val_loss: 0.1763 - val_ac
c: 0.7740
Epoch 45/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0425 - acc: 0.9714 - val_loss: 0.1754 - val_ac
c: 0.7800
Epoch 46/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0408 - acc: 0.9429 - val_loss: 0.1730 - val_ac
c: 0.7840
Epoch 47/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0398 - acc: 0.9500 - val_loss: 0.1705 - val_ac
```

```
c: 0.7880
Epoch 48/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0400 - acc: 0.9571 - val_loss: 0.1682 - val_ac
c: 0.7880
Epoch 49/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0412 - acc: 0.9214 - val_loss: 0.1665 - val_ac
c: 0.7900
Epoch 50/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0382 - acc: 0.9571 - val_loss: 0.1652 - val_ac
c: 0.7860
Epoch 51/400
1/1 [==============================] - 0s 221ms/step - loss: 0.0388 - acc: 0.9714 - val_loss: 0.1648 - val_ac
c: 0.7900
Epoch 52/400
1/1 [==============================] - 0s 238ms/step - loss: 0.0404 - acc: 0.9357 - val_loss: 0.1656 - val_ac
c: 0.7860
Epoch 53/400
1/1 [==============================] - 0s 197ms/step - loss: 0.0393 - acc: 0.9357 - val_loss: 0.1673 - val_ac
c: 0.7840
Epoch 54/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0381 - acc: 0.9643 - val_loss: 0.1690 - val_ac
c: 0.7820
Epoch 55/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0368 - acc: 0.9571 - val_loss: 0.1708 - val_ac
c: 0.7740
Epoch 56/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0361 - acc: 0.9500 - val_loss: 0.1712 - val_ac
c: 0.7720
Epoch 57/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0379 - acc: 0.9286 - val_loss: 0.1710 - val_ac
c: 0.7760
Epoch 58/400
1/1 [==============================] - 0s 202ms/step - loss: 0.0380 - acc: 0.9500 - val_loss: 0.1704 - val_ac
c: 0.7740
Epoch 59/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0377 - acc: 0.9429 - val_loss: 0.1691 - val_ac
c: 0.7780
Epoch 60/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0367 - acc: 0.9429 - val_loss: 0.1669 - val_ac
c: 0.7820
Epoch 61/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0374 - acc: 0.9429 - val_loss: 0.1654 - val_ac
c: 0.7800
Epoch 62/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0350 - acc: 0.9786 - val_loss: 0.1632 - val_ac
c: 0.7820
Epoch 63/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0363 - acc: 0.9500 - val_loss: 0.1606 - val_ac
c: 0.7840
Epoch 64/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0363 - acc: 0.9643 - val_loss: 0.1588 - val_ac
c: 0.7800
Epoch 65/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0346 - acc: 0.9643 - val_loss: 0.1580 - val_ac
c: 0.7800
Epoch 66/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0361 - acc: 0.9286 - val_loss: 0.1585 - val_ac
c: 0.7820
Epoch 67/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0384 - acc: 0.9143 - val_loss: 0.1599 - val_ac
c: 0.7820
Epoch 68/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0343 - acc: 0.9643 - val_loss: 0.1616 - val_ac
c: 0.7760
Epoch 69/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0355 - acc: 0.9714 - val_loss: 0.1623 - val_ac
c: 0.7800
Epoch 70/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0343 - acc: 0.9500 - val_loss: 0.1627 - val_ac
c: 0.7800
Epoch 71/400
```

```
1/1 [==============================] - 0s 182ms/step - loss: 0.0320 - acc: 0.9714 - val_loss: 0.1632 - val_ac
c: 0.7800
Epoch 72/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0356 - acc: 0.9643 - val_loss: 0.1616 - val_ac
c: 0.7760
Epoch 73/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0346 - acc: 0.9571 - val_loss: 0.1611 - val_ac
c: 0.7800
Epoch 74/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0352 - acc: 0.9571 - val_loss: 0.1589 - val_ac
c: 0.7720
Epoch 75/400
1/1 [==============================] - 0s 210ms/step - loss: 0.0314 - acc: 0.9643 - val_loss: 0.1570 - val_ac
c: 0.7780
Epoch 76/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0318 - acc: 0.9857 - val_loss: 0.1551 - val_ac
c: 0.7800
Epoch 77/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0327 - acc: 0.9500 - val_loss: 0.1533 - val_ac
c: 0.7820
Epoch 78/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0334 - acc: 0.9500 - val_loss: 0.1523 - val_ac
c: 0.7840
Epoch 79/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0349 - acc: 0.9571 - val_loss: 0.1519 - val_ac
c: 0.7820
Epoch 80/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0338 - acc: 0.9786 - val_loss: 0.1521 - val_ac
c: 0.7820
Epoch 81/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0344 - acc: 0.9643 - val_loss: 0.1537 - val_ac
c: 0.7800
Epoch 82/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0336 - acc: 0.9857 - val_loss: 0.1549 - val_ac
c: 0.7800
Epoch 83/400
1/1 [==============================] - 0s 202ms/step - loss: 0.0341 - acc: 0.9643 - val_loss: 0.1561 - val_ac
c: 0.7740
Epoch 84/400
1/1 [==============================] - 0s 197ms/step - loss: 0.0328 - acc: 0.9643 - val_loss: 0.1572 - val_ac
c: 0.7700
Epoch 85/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0336 - acc: 0.9571 - val_loss: 0.1580 - val_ac
c: 0.7720
Epoch 86/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0297 - acc: 0.9714 - val_loss: 0.1578 - val_ac
c: 0.7680
Epoch 87/400
1/1 [==============================] - 0s 207ms/step - loss: 0.0307 - acc: 0.9786 - val_loss: 0.1568 - val_ac
c: 0.7700
Epoch 88/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0318 - acc: 0.9429 - val_loss: 0.1549 - val_ac
c: 0.7740
Epoch 89/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0303 - acc: 0.9714 - val_loss: 0.1534 - val_ac
c: 0.7840
Epoch 90/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0293 - acc: 0.9643 - val_loss: 0.1515 - val_ac
c: 0.7840
Epoch 91/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0315 - acc: 0.9643 - val_loss: 0.1494 - val_ac
c: 0.7880
Epoch 92/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0308 - acc: 0.9571 - val_loss: 0.1485 - val_ac
c: 0.7900
Epoch 93/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0303 - acc: 0.9857 - val_loss: 0.1481 - val_ac
c: 0.7900
Epoch 94/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0304 - acc: 0.9714 - val_loss: 0.1496 - val_ac
c: 0.7780
```

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Epoch 95/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0299 - acc: 0.9500 - val_loss: 0.1517 - val_ac
c: 0.7760
Epoch 96/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0315 - acc: 0.9714 - val_loss: 0.1540 - val_ac
c: 0.7680
Epoch 97/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0304 - acc: 0.9643 - val_loss: 0.1544 - val_ac
c: 0.7680
Epoch 98/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0301 - acc: 0.9571 - val_loss: 0.1536 - val_ac
c: 0.7740
Epoch 99/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0285 - acc: 0.9786 - val_loss: 0.1527 - val_ac
c: 0.7780
Epoch 100/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0309 - acc: 0.9500 - val_loss: 0.1528 - val_ac
c: 0.7760
Epoch 101/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0316 - acc: 0.9571 - val_loss: 0.1534 - val_ac
c: 0.7760
Epoch 102/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0315 - acc: 0.9643 - val_loss: 0.1537 - val_ac
c: 0.7760
Epoch 103/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0308 - acc: 0.9500 - val_loss: 0.1539 - val_ac
c: 0.7740
Epoch 104/400
1/1 [==============================] - 0s 207ms/step - loss: 0.0285 - acc: 0.9714 - val_loss: 0.1522 - val_ac
c: 0.7740
Epoch 105/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0311 - acc: 0.9643 - val_loss: 0.1517 - val_ac
c: 0.7680
Epoch 106/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0280 - acc: 0.9929 - val_loss: 0.1506 - val_ac
c: 0.7740
Epoch 107/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0286 - acc: 0.9857 - val_loss: 0.1502 - val_ac
c: 0.7700
Epoch 108/400
1/1 [==============================] - 0s 215ms/step - loss: 0.0266 - acc: 0.9857 - val_loss: 0.1519 - val_ac
c: 0.7740
Epoch 109/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0284 - acc: 0.9643 - val_loss: 0.1532 - val_ac
c: 0.7660
Epoch 110/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0277 - acc: 0.9786 - val_loss: 0.1538 - val_ac
c: 0.7620
Epoch 111/400
1/1 [==============================] - 0s 200ms/step - loss: 0.0323 - acc: 0.9143 - val_loss: 0.1554 - val_ac
c: 0.7620
Epoch 112/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0283 - acc: 0.9571 - val_loss: 0.1567 - val_ac
c: 0.7660
Epoch 113/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0267 - acc: 0.9786 - val_loss: 0.1574 - val_ac
c: 0.7680
Epoch 114/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0295 - acc: 0.9500 - val_loss: 0.1567 - val_ac
c: 0.7640
Epoch 115/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0291 - acc: 0.9857 - val_loss: 0.1548 - val_ac
c: 0.7680
Epoch 116/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0302 - acc: 0.9429 - val_loss: 0.1517 - val_ac
c: 0.7600
Epoch 117/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0302 - acc: 0.9643 - val_loss: 0.1474 - val_ac
c: 0.7680
Epoch 118/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0290 - acc: 0.9857 - val_loss: 0.1438 - val_ac
```

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c: 0.7820
Epoch 119/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0291 - acc: 0.9571 - val_loss: 0.1425 - val_ac
c: 0.7880
Epoch 120/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0269 - acc: 0.9714 - val_loss: 0.1425 - val_ac
c: 0.7960
Epoch 121/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0263 - acc: 0.9929 - val_loss: 0.1444 - val_ac
c: 0.7860
Epoch 122/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0286 - acc: 0.9714 - val_loss: 0.1473 - val_ac
c: 0.7820
Epoch 123/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0286 - acc: 0.9857 - val_loss: 0.1514 - val_ac
c: 0.7760
Epoch 124/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0273 - acc: 0.9857 - val_loss: 0.1550 - val_ac
c: 0.7760
Epoch 125/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0283 - acc: 0.9429 - val_loss: 0.1565 - val_ac
c: 0.7700
Epoch 126/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0280 - acc: 0.9929 - val_loss: 0.1560 - val_ac
c: 0.7780
Epoch 127/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0268 - acc: 0.9857 - val_loss: 0.1545 - val_ac
c: 0.7740
Epoch 128/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0281 - acc: 0.9571 - val_loss: 0.1524 - val_ac
c: 0.7820
Epoch 129/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0273 - acc: 0.9643 - val_loss: 0.1507 - val_ac
c: 0.7820
Epoch 130/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0264 - acc: 0.9786 - val_loss: 0.1501 - val_ac
c: 0.7780
Epoch 131/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0271 - acc: 0.9500 - val_loss: 0.1498 - val_ac
c: 0.7740
Epoch 132/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0275 - acc: 0.9643 - val_loss: 0.1473 - val_ac
c: 0.7700
Epoch 133/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0272 - acc: 0.9714 - val_loss: 0.1445 - val_ac
c: 0.7820
Epoch 134/400
1/1 [==============================] - 0s 224ms/step - loss: 0.0285 - acc: 0.9429 - val_loss: 0.1422 - val_ac
c: 0.7920
Epoch 135/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0310 - acc: 0.9643 - val_loss: 0.1409 - val_ac
c: 0.8000
Epoch 136/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0252 - acc: 0.9857 - val_loss: 0.1412 - val_ac
c: 0.7980
Epoch 137/400
1/1 [==============================] - 0s 212ms/step - loss: 0.0274 - acc: 0.9571 - val_loss: 0.1423 - val_ac
c: 0.7900
Epoch 138/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0269 - acc: 0.9429 - val_loss: 0.1434 - val_ac
c: 0.7900
Epoch 139/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0275 - acc: 0.9571 - val_loss: 0.1471 - val_ac
c: 0.7880
Epoch 140/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0245 - acc: 0.9929 - val_loss: 0.1519 - val_ac
c: 0.7740
Epoch 141/400
1/1 [==============================] - 0s 223ms/step - loss: 0.0258 - acc: 0.9714 - val_loss: 0.1575 - val_ac
c: 0.7620
Epoch 142/400
```

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1/1 [==============================] - 0s 163ms/step - loss: 0.0259 - acc: 0.9857 - val_loss: 0.1593 - val_ac
c: 0.7540
Epoch 143/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0254 - acc: 0.9786 - val_loss: 0.1590 - val_ac
c: 0.7440
Epoch 144/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0270 - acc: 0.9429 - val_loss: 0.1550 - val_ac
c: 0.7500
Epoch 145/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0266 - acc: 0.9500 - val_loss: 0.1483 - val_ac
c: 0.7580
Epoch 146/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0263 - acc: 1.0000 - val_loss: 0.1432 - val_ac
c: 0.7740
Epoch 147/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0280 - acc: 0.9429 - val_loss: 0.1404 - val_ac
c: 0.7880
Epoch 148/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0266 - acc: 0.9714 - val_loss: 0.1402 - val_ac
c: 0.7900
Epoch 149/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0252 - acc: 0.9929 - val_loss: 0.1418 - val_ac
c: 0.7820
Epoch 150/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0244 - acc: 0.9857 - val_loss: 0.1443 - val_ac
c: 0.7800
Epoch 151/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0257 - acc: 0.9857 - val_loss: 0.1477 - val_ac
c: 0.7740
Epoch 152/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0261 - acc: 0.9714 - val_loss: 0.1505 - val_ac
c: 0.7640
Epoch 153/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0264 - acc: 0.9500 - val_loss: 0.1516 - val_ac
c: 0.7600
Epoch 154/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0277 - acc: 0.9571 - val_loss: 0.1513 - val_ac
c: 0.7640
Epoch 155/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0246 - acc: 0.9929 - val_loss: 0.1506 - val_ac
c: 0.7660
Epoch 156/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0256 - acc: 0.9500 - val_loss: 0.1492 - val_ac
c: 0.7640
Epoch 157/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0251 - acc: 0.9714 - val_loss: 0.1478 - val_ac
c: 0.7680
Epoch 158/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0257 - acc: 0.9643 - val_loss: 0.1452 - val_ac
c: 0.7740
Epoch 159/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0250 - acc: 0.9857 - val_loss: 0.1436 - val_ac
c: 0.7840
Epoch 160/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0244 - acc: 0.9857 - val_loss: 0.1419 - val_ac
c: 0.7800
Epoch 161/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0235 - acc: 0.9786 - val_loss: 0.1425 - val_ac
c: 0.7800
Epoch 162/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0250 - acc: 0.9571 - val_loss: 0.1425 - val_ac
c: 0.7800
Epoch 163/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0248 - acc: 0.9643 - val_loss: 0.1434 - val_ac
c: 0.7820
Epoch 164/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0257 - acc: 0.9714 - val_loss: 0.1435 - val_ac
c: 0.7760
Epoch 165/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0251 - acc: 0.9857 - val_loss: 0.1455 - val_ac
c: 0.7760
```

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Epoch 166/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0249 - acc: 0.9643 - val_loss: 0.1478 - val_ac
c: 0.7620
Epoch 167/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0266 - acc: 0.9500 - val_loss: 0.1500 - val_ac
c: 0.7660
Epoch 168/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0241 - acc: 0.9643 - val_loss: 0.1491 - val_ac
c: 0.7660
Epoch 169/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0263 - acc: 0.9357 - val_loss: 0.1453 - val_ac
c: 0.7780
Epoch 170/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0268 - acc: 0.9500 - val_loss: 0.1435 - val_ac
c: 0.7800
Epoch 171/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0247 - acc: 0.9714 - val_loss: 0.1421 - val_ac
c: 0.7840
Epoch 172/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0242 - acc: 0.9643 - val_loss: 0.1413 - val_ac
c: 0.7860
Epoch 173/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0234 - acc: 0.9786 - val_loss: 0.1411 - val_ac
c: 0.7840
Epoch 174/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0248 - acc: 0.9857 - val_loss: 0.1414 - val_ac
c: 0.7800
Epoch 175/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0246 - acc: 0.9857 - val_loss: 0.1406 - val_ac
c: 0.7840
Epoch 176/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0259 - acc: 0.9643 - val_loss: 0.1415 - val_ac
c: 0.7840
Epoch 177/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0236 - acc: 0.9643 - val_loss: 0.1408 - val_ac
c: 0.7820
Epoch 178/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0230 - acc: 0.9857 - val_loss: 0.1398 - val_ac
c: 0.7820
Epoch 179/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0247 - acc: 0.9643 - val_loss: 0.1389 - val_ac
c: 0.7820
Epoch 180/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0248 - acc: 0.9571 - val_loss: 0.1388 - val_ac
c: 0.7760
Epoch 181/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0252 - acc: 0.9714 - val_loss: 0.1407 - val_ac
c: 0.7760
Epoch 182/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0218 - acc: 0.9929 - val_loss: 0.1433 - val_ac
c: 0.7720
Epoch 183/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0242 - acc: 0.9643 - val_loss: 0.1462 - val_ac
c: 0.7740
Epoch 184/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0250 - acc: 0.9500 - val_loss: 0.1481 - val_ac
c: 0.7680
Epoch 185/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0241 - acc: 0.9643 - val_loss: 0.1460 - val_ac
c: 0.7760
Epoch 186/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0216 - acc: 0.9786 - val_loss: 0.1432 - val_ac
c: 0.7820
Epoch 187/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0236 - acc: 0.9786 - val_loss: 0.1384 - val_ac
c: 0.7800
Epoch 188/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0235 - acc: 0.9786 - val_loss: 0.1348 - val_ac
c: 0.7800
Epoch 189/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0219 - acc: 0.9714 - val_loss: 0.1332 - val_ac
```

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c: 0.7700
Epoch 190/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0234 - acc: 0.9643 - val_loss: 0.1341 - val_ac
c: 0.7680
Epoch 191/400
1/1 [==============================] - 0s 189ms/step - loss: 0.0233 - acc: 0.9786 - val_loss: 0.1350 - val_ac
c: 0.7660
Epoch 192/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0246 - acc: 0.9857 - val_loss: 0.1377 - val_ac
c: 0.7660
Epoch 193/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0233 - acc: 0.9643 - val_loss: 0.1417 - val_ac
c: 0.7660
Epoch 194/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0216 - acc: 0.9857 - val_loss: 0.1446 - val_ac
c: 0.7600
Epoch 195/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0226 - acc: 0.9643 - val_loss: 0.1467 - val_ac
c: 0.7600
Epoch 196/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0218 - acc: 0.9786 - val_loss: 0.1483 - val_ac
c: 0.7620
Epoch 197/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0228 - acc: 0.9643 - val_loss: 0.1482 - val_ac
c: 0.7640
Epoch 198/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0236 - acc: 0.9571 - val_loss: 0.1500 - val_ac
c: 0.7640
Epoch 199/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0226 - acc: 0.9429 - val_loss: 0.1500 - val_ac
c: 0.7560
Epoch 200/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0236 - acc: 0.9857 - val_loss: 0.1474 - val_ac
c: 0.7600
Epoch 201/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0256 - acc: 0.9500 - val_loss: 0.1442 - val_ac
c: 0.7720
Epoch 202/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0243 - acc: 0.9857 - val_loss: 0.1412 - val_ac
c: 0.7820
Epoch 203/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0209 - acc: 0.9786 - val_loss: 0.1391 - val_ac
c: 0.7860
Epoch 204/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0240 - acc: 0.9500 - val_loss: 0.1392 - val_ac
c: 0.7920
Epoch 205/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0238 - acc: 0.9786 - val_loss: 0.1398 - val_ac
c: 0.7840
Epoch 206/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0237 - acc: 0.9500 - val_loss: 0.1410 - val_ac
c: 0.7820
Epoch 207/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0220 - acc: 0.9857 - val_loss: 0.1418 - val_ac
c: 0.7840
Epoch 208/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0231 - acc: 0.9786 - val_loss: 0.1438 - val_ac
c: 0.7780
Epoch 209/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0213 - acc: 0.9786 - val_loss: 0.1462 - val_ac
c: 0.7680
Epoch 210/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0224 - acc: 0.9714 - val_loss: 0.1482 - val_ac
c: 0.7640
Epoch 211/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0237 - acc: 0.9643 - val_loss: 0.1468 - val_ac
c: 0.7640
Epoch 212/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0239 - acc: 0.9857 - val_loss: 0.1442 - val_ac
c: 0.7740
Epoch 213/400
```

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1/1 [==============================] - 0s 165ms/step - loss: 0.0230 - acc: 0.9571 - val_loss: 0.1418 - val_ac
c: 0.7720
Epoch 214/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0229 - acc: 0.9857 - val_loss: 0.1401 - val_ac
c: 0.7720
Epoch 215/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0218 - acc: 0.9714 - val_loss: 0.1391 - val_ac
c: 0.7720
Epoch 216/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0228 - acc: 0.9786 - val_loss: 0.1393 - val_ac
c: 0.7700
Epoch 217/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0239 - acc: 0.9714 - val_loss: 0.1388 - val_ac
c: 0.7700
Epoch 218/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0233 - acc: 0.9571 - val_loss: 0.1397 - val_ac
c: 0.7760
Epoch 219/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0221 - acc: 0.9643 - val_loss: 0.1433 - val_ac
c: 0.7680
Epoch 220/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0222 - acc: 0.9857 - val_loss: 0.1483 - val_ac
c: 0.7680
Epoch 221/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0238 - acc: 0.9714 - val_loss: 0.1495 - val_ac
c: 0.7620
Epoch 222/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0211 - acc: 0.9786 - val_loss: 0.1473 - val_ac
c: 0.7600
Epoch 223/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0209 - acc: 0.9857 - val_loss: 0.1439 - val_ac
c: 0.7720
Epoch 224/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0225 - acc: 0.9857 - val_loss: 0.1405 - val_ac
c: 0.7780
Epoch 225/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0196 - acc: 0.9786 - val_loss: 0.1399 - val_ac
c: 0.7760
Epoch 226/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0213 - acc: 0.9714 - val_loss: 0.1404 - val_ac
c: 0.7740
Epoch 227/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0207 - acc: 0.9714 - val_loss: 0.1417 - val_ac
c: 0.7700
Epoch 228/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0210 - acc: 0.9929 - val_loss: 0.1430 - val_ac
c: 0.7760
Epoch 229/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0217 - acc: 0.9786 - val_loss: 0.1450 - val_ac
c: 0.7720
Epoch 230/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0206 - acc: 0.9857 - val_loss: 0.1477 - val_ac
c: 0.7600
Epoch 231/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0200 - acc: 0.9786 - val_loss: 0.1511 - val_ac
c: 0.7540
Epoch 232/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0225 - acc: 0.9643 - val_loss: 0.1498 - val_ac
c: 0.7520
Epoch 233/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0219 - acc: 0.9643 - val_loss: 0.1446 - val_ac
c: 0.7600
Epoch 234/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0205 - acc: 0.9714 - val_loss: 0.1385 - val_ac
c: 0.7800
Epoch 235/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0212 - acc: 0.9857 - val_loss: 0.1350 - val_ac
c: 0.7820
Epoch 236/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0224 - acc: 0.9786 - val_loss: 0.1327 - val_ac
c: 0.7940
```

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Epoch 237/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0210 - acc: 0.9786 - val_loss: 0.1312 - val_ac
c: 0.7920
Epoch 238/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0204 - acc: 0.9786 - val_loss: 0.1311 - val_ac
c: 0.7900
Epoch 239/400
1/1 [==============================] - 0s 156ms/step - loss: 0.0216 - acc: 0.9643 - val_loss: 0.1325 - val_ac
c: 0.7840
Epoch 240/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0203 - acc: 0.9786 - val_loss: 0.1368 - val_ac
c: 0.7760
Epoch 241/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0212 - acc: 0.9643 - val_loss: 0.1416 - val_ac
c: 0.7660
Epoch 242/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0227 - acc: 0.9714 - val_loss: 0.1473 - val_ac
c: 0.7540
Epoch 243/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0231 - acc: 0.9714 - val_loss: 0.1478 - val_ac
c: 0.7500
Epoch 244/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0204 - acc: 0.9857 - val_loss: 0.1466 - val_ac
c: 0.7560
Epoch 245/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0216 - acc: 0.9714 - val_loss: 0.1448 - val_ac
c: 0.7600
Epoch 246/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0216 - acc: 0.9786 - val_loss: 0.1419 - val_ac
c: 0.7720
Epoch 247/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0199 - acc: 0.9786 - val_loss: 0.1395 - val_ac
c: 0.7820
Epoch 248/400
1/1 [==============================] - 0s 226ms/step - loss: 0.0222 - acc: 0.9857 - val_loss: 0.1379 - val_ac
c: 0.7820
Epoch 249/400
1/1 [==============================] - 0s 189ms/step - loss: 0.0217 - acc: 0.9714 - val_loss: 0.1360 - val_ac
c: 0.7800
Epoch 250/400
1/1 [==============================] - 0s 237ms/step - loss: 0.0212 - acc: 0.9714 - val_loss: 0.1353 - val_ac
c: 0.7760
Epoch 251/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0209 - acc: 0.9714 - val_loss: 0.1366 - val_ac
c: 0.7760
Epoch 252/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0216 - acc: 0.9929 - val_loss: 0.1418 - val_ac
c: 0.7700
Epoch 253/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0196 - acc: 0.9786 - val_loss: 0.1475 - val_ac
c: 0.7620
Epoch 254/400
1/1 [==============================] - 0s 214ms/step - loss: 0.0222 - acc: 0.9714 - val_loss: 0.1504 - val_ac
c: 0.7580
Epoch 255/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0203 - acc: 0.9929 - val_loss: 0.1508 - val_ac
c: 0.7700
Epoch 256/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0219 - acc: 0.9857 - val_loss: 0.1491 - val_ac
c: 0.7700
Epoch 257/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0218 - acc: 0.9643 - val_loss: 0.1468 - val_ac
c: 0.7600
Epoch 258/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0212 - acc: 0.9857 - val_loss: 0.1440 - val_ac
c: 0.7680
Epoch 259/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0209 - acc: 0.9786 - val_loss: 0.1399 - val_ac
c: 0.7760
Epoch 260/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0205 - acc: 0.9929 - val_loss: 0.1387 - val_ac
```

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c: 0.7760
Epoch 261/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0193 - acc: 0.9929 - val_loss: 0.1392 - val_ac
c: 0.7640
Epoch 262/400
1/1 [==============================] - 0s 153ms/step - loss: 0.0227 - acc: 0.9571 - val_loss: 0.1386 - val_ac
c: 0.7600
Epoch 263/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0207 - acc: 0.9643 - val_loss: 0.1385 - val_ac
c: 0.7580
Epoch 264/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0204 - acc: 0.9857 - val_loss: 0.1370 - val_ac
c: 0.7620
Epoch 265/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0196 - acc: 0.9857 - val_loss: 0.1355 - val_ac
c: 0.7620
Epoch 266/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0206 - acc: 0.9714 - val_loss: 0.1353 - val_ac
c: 0.7660
Epoch 267/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0212 - acc: 0.9857 - val_loss: 0.1367 - val_ac
c: 0.7660
Epoch 268/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0196 - acc: 0.9714 - val_loss: 0.1385 - val_ac
c: 0.7740
Epoch 269/400
1/1 [==============================] - 0s 274ms/step - loss: 0.0202 - acc: 0.9786 - val_loss: 0.1400 - val_ac
c: 0.7760
Epoch 270/400
1/1 [==============================] - 0s 200ms/step - loss: 0.0203 - acc: 0.9786 - val_loss: 0.1420 - val_ac
c: 0.7740
Epoch 271/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0218 - acc: 0.9929 - val_loss: 0.1429 - val_ac
c: 0.7780
Epoch 272/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0222 - acc: 0.9714 - val_loss: 0.1412 - val_ac
c: 0.7680
Epoch 273/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0229 - acc: 0.9571 - val_loss: 0.1399 - val_ac
c: 0.7620
Epoch 274/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0206 - acc: 0.9857 - val_loss: 0.1389 - val_ac
c: 0.7620
Epoch 275/400
1/1 [==============================] - 0s 295ms/step - loss: 0.0221 - acc: 0.9643 - val_loss: 0.1410 - val_ac
c: 0.7600
Epoch 276/400
1/1 [==============================] - 0s 210ms/step - loss: 0.0198 - acc: 0.9929 - val_loss: 0.1418 - val_ac
c: 0.7600
Epoch 277/400
1/1 [==============================] - 0s 224ms/step - loss: 0.0190 - acc: 0.9857 - val_loss: 0.1446 - val_ac
c: 0.7640
Epoch 278/400
1/1 [==============================] - 0s 219ms/step - loss: 0.0201 - acc: 0.9786 - val_loss: 0.1463 - val_ac
c: 0.7720
Epoch 279/400
1/1 [==============================] - 0s 426ms/step - loss: 0.0199 - acc: 0.9714 - val_loss: 0.1477 - val_ac
c: 0.7740
Epoch 280/400
1/1 [==============================] - 0s 205ms/step - loss: 0.0195 - acc: 0.9857 - val_loss: 0.1462 - val_ac
c: 0.7760
Epoch 281/400
1/1 [==============================] - 0s 275ms/step - loss: 0.0205 - acc: 0.9857 - val_loss: 0.1437 - val_ac
c: 0.7780
Epoch 282/400
1/1 [==============================] - 0s 212ms/step - loss: 0.0218 - acc: 0.9571 - val_loss: 0.1411 - val_ac
c: 0.7760
Epoch 283/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0214 - acc: 0.9857 - val_loss: 0.1387 - val_ac
c: 0.7800
Epoch 284/400
```

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1/1 [==============================] - 0s 222ms/step - loss: 0.0200 - acc: 0.9857 - val_loss: 0.1368 - val_ac
c: 0.7780
Epoch 285/400
1/1 [==============================] - 0s 225ms/step - loss: 0.0194 - acc: 0.9857 - val_loss: 0.1348 - val_ac
c: 0.7860
Epoch 286/400
1/1 [==============================] - 0s 206ms/step - loss: 0.0193 - acc: 0.9857 - val_loss: 0.1345 - val_ac
c: 0.7880
Epoch 287/400
1/1 [==============================] - 0s 226ms/step - loss: 0.0219 - acc: 0.9643 - val_loss: 0.1373 - val_ac
c: 0.7800
Epoch 288/400
1/1 [==============================] - 0s 223ms/step - loss: 0.0225 - acc: 0.9500 - val_loss: 0.1392 - val_ac
c: 0.7840
Epoch 289/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0187 - acc: 0.9714 - val_loss: 0.1401 - val_ac
c: 0.7800
Epoch 290/400
1/1 [==============================] - 0s 461ms/step - loss: 0.0205 - acc: 0.9714 - val_loss: 0.1406 - val_ac
c: 0.7900
Epoch 291/400
1/1 [==============================] - 0s 279ms/step - loss: 0.0192 - acc: 1.0000 - val_loss: 0.1406 - val_ac
c: 0.7940
Epoch 292/400
1/1 [==============================] - 0s 274ms/step - loss: 0.0196 - acc: 0.9857 - val_loss: 0.1400 - val_ac
c: 0.7880
Epoch 293/400
1/1 [==============================] - 0s 237ms/step - loss: 0.0204 - acc: 0.9643 - val_loss: 0.1385 - val_ac
c: 0.7880
Epoch 294/400
1/1 [==============================] - 0s 221ms/step - loss: 0.0206 - acc: 0.9786 - val_loss: 0.1377 - val_ac
c: 0.7800
Epoch 295/400
1/1 [==============================] - 0s 210ms/step - loss: 0.0187 - acc: 0.9857 - val_loss: 0.1372 - val_ac
c: 0.7720
Epoch 296/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0203 - acc: 0.9643 - val_loss: 0.1382 - val_ac
c: 0.7680
Epoch 297/400
1/1 [==============================] - 0s 224ms/step - loss: 0.0175 - acc: 0.9857 - val_loss: 0.1392 - val_ac
c: 0.7660
Epoch 298/400
1/1 [==============================] - 0s 244ms/step - loss: 0.0204 - acc: 0.9929 - val_loss: 0.1387 - val_ac
c: 0.7620
Epoch 299/400
1/1 [==============================] - 0s 246ms/step - loss: 0.0194 - acc: 0.9786 - val_loss: 0.1355 - val_ac
c: 0.7800
Epoch 300/400
1/1 [==============================] - 0s 268ms/step - loss: 0.0201 - acc: 0.9786 - val_loss: 0.1353 - val_ac
c: 0.7740
Epoch 301/400
1/1 [==============================] - 0s 228ms/step - loss: 0.0215 - acc: 0.9643 - val_loss: 0.1343 - val_ac
c: 0.7780
Epoch 302/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0202 - acc: 0.9714 - val_loss: 0.1359 - val_ac
c: 0.7760
Epoch 303/400
1/1 [==============================] - 0s 204ms/step - loss: 0.0205 - acc: 0.9857 - val_loss: 0.1390 - val_ac
c: 0.7760
Epoch 304/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0186 - acc: 1.0000 - val_loss: 0.1422 - val_ac
c: 0.7720
Epoch 305/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0189 - acc: 0.9786 - val_loss: 0.1472 - val_ac
c: 0.7620
Epoch 306/400
1/1 [==============================] - 0s 203ms/step - loss: 0.0203 - acc: 0.9571 - val_loss: 0.1531 - val_ac
c: 0.7540
Epoch 307/400
1/1 [==============================] - 0s 221ms/step - loss: 0.0218 - acc: 0.9714 - val_loss: 0.1530 - val_ac
c: 0.7520
```

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Epoch 308/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0204 - acc: 0.9714 - val_loss: 0.1477 - val_ac
c: 0.7640
Epoch 309/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0208 - acc: 0.9571 - val_loss: 0.1391 - val_ac
c: 0.7880
Epoch 310/400
1/1 [==============================] - 0s 197ms/step - loss: 0.0199 - acc: 0.9857 - val_loss: 0.1340 - val_ac
c: 0.7900
Epoch 311/400
1/1 [==============================] - 0s 226ms/step - loss: 0.0192 - acc: 0.9857 - val_loss: 0.1321 - val_ac
c: 0.7840
Epoch 312/400
1/1 [==============================] - 0s 244ms/step - loss: 0.0218 - acc: 0.9500 - val_loss: 0.1323 - val_ac
c: 0.7780
Epoch 313/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0200 - acc: 0.9786 - val_loss: 0.1337 - val_ac
c: 0.7820
Epoch 314/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0184 - acc: 0.9714 - val_loss: 0.1373 - val_ac
c: 0.7760
Epoch 315/400
1/1 [==============================] - 0s 212ms/step - loss: 0.0210 - acc: 0.9714 - val_loss: 0.1433 - val_ac
c: 0.7580
Epoch 316/400
1/1 [==============================] - 0s 228ms/step - loss: 0.0197 - acc: 0.9714 - val_loss: 0.1497 - val_ac
c: 0.7560
Epoch 317/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0209 - acc: 0.9643 - val_loss: 0.1520 - val_ac
c: 0.7480
Epoch 318/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0194 - acc: 0.9929 - val_loss: 0.1533 - val_ac
c: 0.7480
Epoch 319/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0193 - acc: 1.0000 - val_loss: 0.1532 - val_ac
c: 0.7460
Epoch 320/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0191 - acc: 0.9643 - val_loss: 0.1486 - val_ac
c: 0.7500
Epoch 321/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0200 - acc: 0.9786 - val_loss: 0.1425 - val_ac
c: 0.7600
Epoch 322/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0206 - acc: 0.9929 - val_loss: 0.1382 - val_ac
c: 0.7740
Epoch 323/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0193 - acc: 0.9857 - val_loss: 0.1359 - val_ac
c: 0.7840
Epoch 324/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0197 - acc: 0.9643 - val_loss: 0.1350 - val_ac
c: 0.7840
Epoch 325/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0198 - acc: 0.9786 - val_loss: 0.1344 - val_ac
c: 0.7820
Epoch 326/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0217 - acc: 0.9786 - val_loss: 0.1362 - val_ac
c: 0.7860
Epoch 327/400
1/1 [==============================] - 0s 199ms/step - loss: 0.0187 - acc: 0.9929 - val_loss: 0.1401 - val_ac
c: 0.7800
Epoch 328/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0194 - acc: 0.9714 - val_loss: 0.1464 - val_ac
c: 0.7580
Epoch 329/400
1/1 [==============================] - 0s 232ms/step - loss: 0.0204 - acc: 0.9857 - val_loss: 0.1509 - val_ac
c: 0.7420
Epoch 330/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0202 - acc: 0.9714 - val_loss: 0.1536 - val_ac
c: 0.7340
Epoch 331/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0197 - acc: 0.9786 - val_loss: 0.1529 - val_ac
```

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c: 0.7380
Epoch 332/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0180 - acc: 0.9857 - val_loss: 0.1498 - val_ac
c: 0.7480
Epoch 333/400
1/1 [==============================] - 0s 200ms/step - loss: 0.0200 - acc: 0.9714 - val_loss: 0.1456 - val_ac
c: 0.7540
Epoch 334/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0184 - acc: 0.9714 - val_loss: 0.1412 - val_ac
c: 0.7620
Epoch 335/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0189 - acc: 0.9786 - val_loss: 0.1386 - val_ac
c: 0.7680
Epoch 336/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0215 - acc: 0.9500 - val_loss: 0.1345 - val_ac
c: 0.7820
Epoch 337/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0209 - acc: 0.9786 - val_loss: 0.1347 - val_ac
c: 0.7840
Epoch 338/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0192 - acc: 0.9929 - val_loss: 0.1357 - val_ac
c: 0.7800
Epoch 339/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0187 - acc: 0.9714 - val_loss: 0.1378 - val_ac
c: 0.7780
Epoch 340/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0179 - acc: 0.9857 - val_loss: 0.1400 - val_ac
c: 0.7780
Epoch 341/400
1/1 [==============================] - 0s 159ms/step - loss: 0.0200 - acc: 0.9857 - val_loss: 0.1416 - val_ac
c: 0.7680
Epoch 342/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0187 - acc: 0.9857 - val_loss: 0.1418 - val_ac
c: 0.7680
Epoch 343/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0206 - acc: 0.9714 - val_loss: 0.1403 - val_ac
c: 0.7660
Epoch 344/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0179 - acc: 0.9929 - val_loss: 0.1382 - val_ac
c: 0.7640
Epoch 345/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0214 - acc: 0.9786 - val_loss: 0.1355 - val_ac
c: 0.7620
Epoch 346/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0194 - acc: 0.9929 - val_loss: 0.1344 - val_ac
c: 0.7660
Epoch 347/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0199 - acc: 0.9571 - val_loss: 0.1356 - val_ac
c: 0.7600
Epoch 348/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0187 - acc: 0.9714 - val_loss: 0.1372 - val_ac
c: 0.7640
Epoch 349/400
1/1 [==============================] - 0s 189ms/step - loss: 0.0189 - acc: 0.9714 - val_loss: 0.1393 - val_ac
c: 0.7620
Epoch 350/400
1/1 [==============================] - 0s 228ms/step - loss: 0.0190 - acc: 0.9857 - val_loss: 0.1418 - val_ac
c: 0.7640
Epoch 351/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0220 - acc: 0.9429 - val_loss: 0.1433 - val_ac
c: 0.7660
Epoch 352/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0183 - acc: 0.9929 - val_loss: 0.1451 - val_ac
c: 0.7740
Epoch 353/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0194 - acc: 0.9786 - val_loss: 0.1463 - val_ac
c: 0.7760
Epoch 354/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0184 - acc: 0.9857 - val_loss: 0.1477 - val_ac
c: 0.7780
Epoch 355/400
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1/1 [==============================] - 0s 160ms/step - loss: 0.0215 - acc: 0.9786 - val_loss: 0.1454 - val_ac
c: 0.7740
Epoch 356/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0184 - acc: 0.9857 - val_loss: 0.1428 - val_ac
c: 0.7780
Epoch 357/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0198 - acc: 0.9714 - val_loss: 0.1423 - val_ac
c: 0.7740
Epoch 358/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0200 - acc: 0.9786 - val_loss: 0.1422 - val_ac
c: 0.7760
Epoch 359/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0192 - acc: 0.9786 - val_loss: 0.1417 - val_ac
c: 0.7720
Epoch 360/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0208 - acc: 0.9786 - val_loss: 0.1434 - val_ac
c: 0.7640
Epoch 361/400
1/1 [==============================] - 0s 198ms/step - loss: 0.0193 - acc: 0.9714 - val_loss: 0.1434 - val_ac
c: 0.7620
Epoch 362/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0199 - acc: 0.9786 - val_loss: 0.1467 - val_ac
c: 0.7700
Epoch 363/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0183 - acc: 0.9857 - val_loss: 0.1489 - val_ac
c: 0.7740
Epoch 364/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0174 - acc: 0.9857 - val_loss: 0.1496 - val_ac
c: 0.7660
Epoch 365/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0189 - acc: 0.9714 - val_loss: 0.1462 - val_ac
c: 0.7740
Epoch 366/400
1/1 [==============================] - 0s 155ms/step - loss: 0.0176 - acc: 0.9929 - val_loss: 0.1433 - val_ac
c: 0.7700
Epoch 367/400
1/1 [==============================] - 0s 157ms/step - loss: 0.0180 - acc: 0.9929 - val_loss: 0.1394 - val_ac
c: 0.7700
Epoch 368/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0177 - acc: 0.9929 - val_loss: 0.1367 - val_ac
c: 0.7720
Epoch 369/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0186 - acc: 0.9857 - val_loss: 0.1345 - val_ac
c: 0.7720
Epoch 370/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0192 - acc: 0.9857 - val_loss: 0.1336 - val_ac
c: 0.7800
Epoch 371/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0182 - acc: 0.9857 - val_loss: 0.1340 - val_ac
c: 0.7780
Epoch 372/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0198 - acc: 0.9857 - val_loss: 0.1342 - val_ac
c: 0.7800
Epoch 373/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0198 - acc: 0.9643 - val_loss: 0.1355 - val_ac
c: 0.7780
Epoch 374/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0176 - acc: 0.9857 - val_loss: 0.1369 - val_ac
c: 0.7700
Epoch 375/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0177 - acc: 0.9929 - val_loss: 0.1387 - val_ac
c: 0.7640
Epoch 376/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0179 - acc: 0.9786 - val_loss: 0.1399 - val_ac
c: 0.7680
Epoch 377/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0191 - acc: 0.9643 - val_loss: 0.1377 - val_ac
c: 0.7700
Epoch 378/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0186 - acc: 0.9714 - val_loss: 0.1347 - val_ac
c: 0.7740
```

```
Epoch 379/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0178 - acc: 0.9643 - val_loss: 0.1309 - val_ac
c: 0.7760
Epoch 380/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0173 - acc: 0.9929 - val_loss: 0.1286 - val_ac
c: 0.7780
Epoch 381/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0187 - acc: 0.9714 - val_loss: 0.1291 - val_ac
c: 0.7860
Epoch 382/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0199 - acc: 0.9857 - val_loss: 0.1321 - val_ac
c: 0.7820
Epoch 383/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0179 - acc: 0.9786 - val_loss: 0.1352 - val_ac
c: 0.7740
Epoch 384/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0180 - acc: 0.9929 - val_loss: 0.1374 - val_ac
c: 0.7740
Epoch 385/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0190 - acc: 0.9857 - val_loss: 0.1388 - val_ac
c: 0.7740
Epoch 386/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0174 - acc: 0.9857 - val_loss: 0.1399 - val_ac
c: 0.7760
Epoch 387/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0180 - acc: 0.9786 - val_loss: 0.1395 - val_ac
c: 0.7760
Epoch 388/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0196 - acc: 0.9714 - val_loss: 0.1394 - val_ac
c: 0.7760
Epoch 389/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0182 - acc: 0.9786 - val_loss: 0.1380 - val_ac
c: 0.7720
Epoch 390/400
1/1 [==============================] - 0s 213ms/step - loss: 0.0171 - acc: 0.9857 - val_loss: 0.1373 - val_ac
c: 0.7680
Epoch 391/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0176 - acc: 0.9857 - val_loss: 0.1387 - val_ac
c: 0.7660
Epoch 392/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0184 - acc: 0.9786 - val_loss: 0.1385 - val_ac
c: 0.7700
Epoch 393/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0193 - acc: 0.9786 - val_loss: 0.1376 - val_ac
c: 0.7700
Epoch 394/400
1/1 [==============================] - 0s 212ms/step - loss: 0.0175 - acc: 0.9929 - val_loss: 0.1378 - val_ac
c: 0.7740
Epoch 395/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0205 - acc: 0.9714 - val_loss: 0.1390 - val_ac
c: 0.7780
Epoch 396/400
1/1 [==============================] - 0s 228ms/step - loss: 0.0187 - acc: 0.9714 - val_loss: 0.1401 - val_ac
c: 0.7680
Epoch 397/400
1/1 [==============================] - 0s 207ms/step - loss: 0.0189 - acc: 0.9643 - val_loss: 0.1424 - val_ac
c: 0.7640
Epoch 398/400
1/1 [==============================] - 0s 201ms/step - loss: 0.0182 - acc: 0.9714 - val_loss: 0.1428 - val_ac
c: 0.7600
Epoch 399/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0201 - acc: 0.9643 - val_loss: 0.1431 - val_ac
c: 0.7640
Epoch 400/400
1/1 [==============================] - 0s 211ms/step - loss: 0.0182 - acc: 0.9929 - val_loss: 0.1464 - val_ac
c: 0.7620
```

Out[ ]:
```
<tensorflow.python.keras.callbacks.History at 0x1d54c319148>
```

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       0.64      0.83      0.72       114
    Genetic_Algorithms       0.86      0.88      0.87       156
       Neural_Networks       0.83      0.60      0.70       290
 Probabilistic_Methods       0.79      0.73      0.76       172
Reinforcement_Learning       0.58      0.74      0.65        85
         Rule_Learning       0.62      0.70      0.66        60
                Theory       0.57      0.67      0.62       123

              accuracy                           0.72      1000
             macro avg       0.70      0.74      0.71      1000
          weighted avg       0.74      0.72      0.72      1000
```

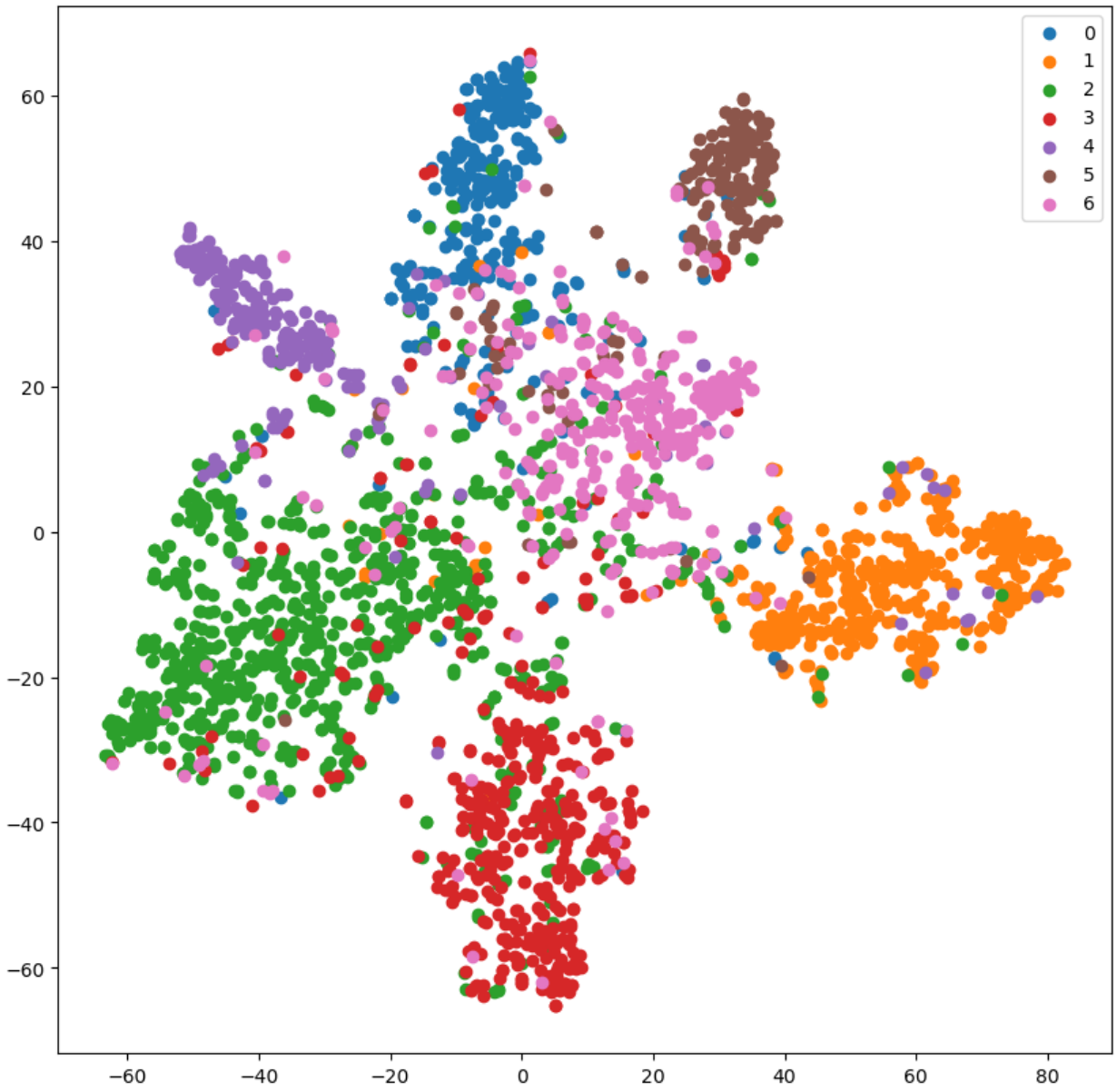
Get hidden layer representation for GCN

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 273ms/step - loss: 0.2185 - acc: 0.1929 - val_loss: 0.4326 - val_ac
c: 0.2720
Epoch 2/400
1/1 [==============================] - ETA: 0s - loss: 0.1758 - acc: 0.3143WARNING:tensorflow:Method (on_trai
n_batch_end) is slow compared to the batch update (0.170995). Check your callbacks.
1/1 [==============================] - 0s 183ms/step - loss: 0.1758 - acc: 0.3143 - val_loss: 0.3995 - val_ac
c: 0.3240
Epoch 3/400
1/1 [==============================] - 0s 195ms/step - loss: 0.1397 - acc: 0.5714 - val_loss: 0.3693 - val_ac
c: 0.4220
Epoch 4/400
1/1 [==============================] - 0s 195ms/step - loss: 0.1108 - acc: 0.7500 - val_loss: 0.3372 - val_ac
c: 0.5280
Epoch 5/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0861 - acc: 0.8143 - val_loss: 0.3042 - val_ac
c: 0.5540
Epoch 6/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0652 - acc: 0.8571 - val_loss: 0.2783 - val_ac
c: 0.5660
Epoch 7/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0562 - acc: 0.8786 - val_loss: 0.2625 - val_ac
c: 0.5940
Epoch 8/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0444 - acc: 0.9571 - val_loss: 0.2655 - val_ac
c: 0.5820
Epoch 9/400
1/1 [==============================] - 0s 238ms/step - loss: 0.0429 - acc: 0.9571 - val_loss: 0.2805 - val_ac
c: 0.5780
Epoch 10/400
1/1 [==============================] - 0s 273ms/step - loss: 0.0436 - acc: 0.9857 - val_loss: 0.3052 - val_ac
c: 0.5780
Epoch 11/400
1/1 [==============================] - 0s 389ms/step - loss: 0.0415 - acc: 0.9929 - val_loss: 0.3342 - val_ac
c: 0.5820
Epoch 12/400
1/1 [==============================] - 0s 283ms/step - loss: 0.0410 - acc: 1.0000 - val_loss: 0.3577 - val_ac
c: 0.5760
Epoch 13/400
1/1 [==============================] - 0s 260ms/step - loss: 0.0407 - acc: 0.9857 - val_loss: 0.3664 - val_ac
c: 0.5780
Epoch 14/400
1/1 [==============================] - 0s 357ms/step - loss: 0.0383 - acc: 1.0000 - val_loss: 0.3708 - val_ac
c: 0.5740
Epoch 15/400
1/1 [==============================] - 0s 287ms/step - loss: 0.0369 - acc: 0.9929 - val_loss: 0.3751 - val_ac
c: 0.5800
Epoch 16/400
1/1 [==============================] - 0s 249ms/step - loss: 0.0348 - acc: 0.9857 - val_loss: 0.3829 - val_ac
c: 0.5840
Epoch 17/400
1/1 [==============================] - 0s 241ms/step - loss: 0.0319 - acc: 0.9857 - val_loss: 0.3856 - val_ac
c: 0.5780
Epoch 18/400
1/1 [==============================] - 0s 230ms/step - loss: 0.0283 - acc: 0.9929 - val_loss: 0.3770 - val_ac
c: 0.5760
Epoch 19/400
1/1 [==============================] - 0s 228ms/step - loss: 0.0270 - acc: 0.9857 - val_loss: 0.3563 - val_ac
c: 0.5980
Epoch 20/400
1/1 [==============================] - 0s 264ms/step - loss: 0.0250 - acc: 0.9857 - val_loss: 0.3525 - val_ac
c: 0.6160
Epoch 21/400
1/1 [==============================] - 0s 233ms/step - loss: 0.0233 - acc: 0.9786 - val_loss: 0.3607 - val_ac
c: 0.6020
Epoch 22/400
1/1 [==============================] - 1s 563ms/step - loss: 0.0225 - acc: 0.9857 - val_loss: 0.3818 - val_ac
c: 0.5660
Epoch 23/400
1/1 [==============================] - 0s 454ms/step - loss: 0.0220 - acc: 0.9643 - val_loss: 0.4130 - val_ac
c: 0.5160
```

```
Epoch 24/400
1/1 [==============================] - 0s 305ms/step - loss: 0.0209 - acc: 0.9857 - val_loss: 0.4197 - val_ac
c: 0.4860
Epoch 25/400
1/1 [==============================] - 0s 410ms/step - loss: 0.0225 - acc: 0.9714 - val_loss: 0.4139 - val_ac
c: 0.4680
Epoch 26/400
1/1 [==============================] - 0s 333ms/step - loss: 0.0239 - acc: 0.9643 - val_loss: 0.3842 - val_ac
c: 0.4860
Epoch 27/400
1/1 [==============================] - 0s 406ms/step - loss: 0.0199 - acc: 0.9857 - val_loss: 0.3616 - val_ac
c: 0.5100
Epoch 28/400
1/1 [==============================] - 0s 310ms/step - loss: 0.0211 - acc: 0.9786 - val_loss: 0.3461 - val_ac
c: 0.5200
Epoch 29/400
1/1 [==============================] - 0s 390ms/step - loss: 0.0238 - acc: 0.9429 - val_loss: 0.3564 - val_ac
c: 0.5060
Epoch 30/400
1/1 [==============================] - 0s 357ms/step - loss: 0.0234 - acc: 0.9714 - val_loss: 0.3607 - val_ac
c: 0.4900
Epoch 31/400
1/1 [==============================] - 0s 487ms/step - loss: 0.0229 - acc: 0.9643 - val_loss: 0.3457 - val_ac
c: 0.5100
Epoch 32/400
1/1 [==============================] - 0s 358ms/step - loss: 0.0204 - acc: 0.9929 - val_loss: 0.3340 - val_ac
c: 0.5280
Epoch 33/400
1/1 [==============================] - 0s 374ms/step - loss: 0.0221 - acc: 0.9857 - val_loss: 0.3332 - val_ac
c: 0.5400
Epoch 34/400
1/1 [==============================] - 0s 295ms/step - loss: 0.0251 - acc: 0.9714 - val_loss: 0.3326 - val_ac
c: 0.5400
Epoch 35/400
1/1 [==============================] - 0s 281ms/step - loss: 0.0214 - acc: 1.0000 - val_loss: 0.3332 - val_ac
c: 0.5440
Epoch 36/400
1/1 [==============================] - 0s 296ms/step - loss: 0.0236 - acc: 0.9929 - val_loss: 0.3353 - val_ac
c: 0.5400
Epoch 37/400
1/1 [==============================] - 0s 328ms/step - loss: 0.0230 - acc: 1.0000 - val_loss: 0.3366 - val_ac
c: 0.5480
Epoch 38/400
1/1 [==============================] - 0s 360ms/step - loss: 0.0229 - acc: 1.0000 - val_loss: 0.3399 - val_ac
c: 0.5440
Epoch 39/400
1/1 [==============================] - 0s 372ms/step - loss: 0.0233 - acc: 1.0000 - val_loss: 0.3449 - val_ac
c: 0.5420
Epoch 40/400
1/1 [==============================] - 0s 220ms/step - loss: 0.0263 - acc: 0.9857 - val_loss: 0.3347 - val_ac
c: 0.5320
Epoch 41/400
1/1 [==============================] - 0s 220ms/step - loss: 0.0235 - acc: 0.9929 - val_loss: 0.3275 - val_ac
c: 0.5200
Epoch 42/400
1/1 [==============================] - 0s 214ms/step - loss: 0.0228 - acc: 1.0000 - val_loss: 0.3235 - val_ac
c: 0.5240
Epoch 43/400
1/1 [==============================] - 0s 220ms/step - loss: 0.0223 - acc: 1.0000 - val_loss: 0.3231 - val_ac
c: 0.5160
Epoch 44/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0242 - acc: 0.9857 - val_loss: 0.3242 - val_ac
c: 0.5200
Epoch 45/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0231 - acc: 0.9929 - val_loss: 0.3214 - val_ac
c: 0.5300
Epoch 46/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0227 - acc: 0.9714 - val_loss: 0.3155 - val_ac
c: 0.5580
Epoch 47/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0217 - acc: 0.9857 - val_loss: 0.3086 - val_ac
```

```
c: 0.5620
Epoch 48/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0204 - acc: 0.9929 - val_loss: 0.3102 - val_ac
c: 0.5680
Epoch 49/400
1/1 [==============================] - 0s 213ms/step - loss: 0.0206 - acc: 0.9786 - val_loss: 0.3140 - val_ac
c: 0.5760
Epoch 50/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0208 - acc: 0.9857 - val_loss: 0.3169 - val_ac
c: 0.5720
Epoch 51/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0204 - acc: 0.9857 - val_loss: 0.3118 - val_ac
c: 0.5820
Epoch 52/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0212 - acc: 0.9857 - val_loss: 0.3079 - val_ac
c: 0.5800
Epoch 53/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0200 - acc: 0.9857 - val_loss: 0.3108 - val_ac
c: 0.5700
Epoch 54/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0197 - acc: 0.9786 - val_loss: 0.3206 - val_ac
c: 0.5400
Epoch 55/400
1/1 [==============================] - 0s 199ms/step - loss: 0.0191 - acc: 0.9857 - val_loss: 0.3325 - val_ac
c: 0.5140
Epoch 56/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0199 - acc: 0.9571 - val_loss: 0.3399 - val_ac
c: 0.5100
Epoch 57/400
1/1 [==============================] - 0s 165ms/step - loss: 0.0185 - acc: 0.9857 - val_loss: 0.3453 - val_ac
c: 0.4920
Epoch 58/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0214 - acc: 0.9500 - val_loss: 0.3475 - val_ac
c: 0.5020
Epoch 59/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0182 - acc: 1.0000 - val_loss: 0.3547 - val_ac
c: 0.5160
Epoch 60/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0182 - acc: 1.0000 - val_loss: 0.3680 - val_ac
c: 0.5160
Epoch 61/400
1/1 [==============================] - 0s 207ms/step - loss: 0.0191 - acc: 0.9929 - val_loss: 0.3801 - val_ac
c: 0.5160
Epoch 62/400
1/1 [==============================] - 0s 195ms/step - loss: 0.0206 - acc: 0.9929 - val_loss: 0.3761 - val_ac
c: 0.5080
Epoch 63/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0215 - acc: 0.9786 - val_loss: 0.3763 - val_ac
c: 0.5060
Epoch 64/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0200 - acc: 1.0000 - val_loss: 0.3756 - val_ac
c: 0.4980
Epoch 65/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0211 - acc: 0.9929 - val_loss: 0.3780 - val_ac
c: 0.5040
Epoch 66/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0221 - acc: 0.9786 - val_loss: 0.3760 - val_ac
c: 0.4980
Epoch 67/400
1/1 [==============================] - 0s 188ms/step - loss: 0.0217 - acc: 0.9786 - val_loss: 0.3763 - val_ac
c: 0.4980
Epoch 68/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0211 - acc: 0.9929 - val_loss: 0.3717 - val_ac
c: 0.4920
Epoch 69/400
1/1 [==============================] - 0s 210ms/step - loss: 0.0213 - acc: 1.0000 - val_loss: 0.3643 - val_ac
c: 0.5080
Epoch 70/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0243 - acc: 0.9714 - val_loss: 0.3603 - val_ac
c: 0.5080
Epoch 71/400
```

```
1/1 [==============================] - 0s 167ms/step - loss: 0.0235 - acc: 0.9786 - val_loss: 0.3644 - val_ac
c: 0.5140
Epoch 72/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0213 - acc: 0.9929 - val_loss: 0.3742 - val_ac
c: 0.5200
Epoch 73/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0251 - acc: 0.9643 - val_loss: 0.3785 - val_ac
c: 0.5140
Epoch 74/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0214 - acc: 0.9929 - val_loss: 0.3860 - val_ac
c: 0.5160
Epoch 75/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0238 - acc: 0.9714 - val_loss: 0.3846 - val_ac
c: 0.5240
Epoch 76/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0270 - acc: 0.9571 - val_loss: 0.3786 - val_ac
c: 0.5180
Epoch 77/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0229 - acc: 0.9786 - val_loss: 0.3664 - val_ac
c: 0.5280
Epoch 78/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0239 - acc: 0.9714 - val_loss: 0.3519 - val_ac
c: 0.5280
Epoch 79/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0221 - acc: 0.9929 - val_loss: 0.3481 - val_ac
c: 0.5200
Epoch 80/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0225 - acc: 0.9929 - val_loss: 0.3506 - val_ac
c: 0.5240
Epoch 81/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0223 - acc: 1.0000 - val_loss: 0.3526 - val_ac
c: 0.5240
Epoch 82/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0250 - acc: 0.9714 - val_loss: 0.3580 - val_ac
c: 0.5220
Epoch 83/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0238 - acc: 0.9929 - val_loss: 0.3668 - val_ac
c: 0.5160
Epoch 84/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0228 - acc: 1.0000 - val_loss: 0.3813 - val_ac
c: 0.5060
Epoch 85/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0228 - acc: 1.0000 - val_loss: 0.3929 - val_ac
c: 0.5080
Epoch 86/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0234 - acc: 0.9929 - val_loss: 0.4007 - val_ac
c: 0.5060
Epoch 87/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0253 - acc: 0.9786 - val_loss: 0.4010 - val_ac
c: 0.5020
Epoch 88/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0251 - acc: 0.9786 - val_loss: 0.4034 - val_ac
c: 0.5240
Epoch 89/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0250 - acc: 0.9714 - val_loss: 0.4212 - val_ac
c: 0.4960
Epoch 90/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0279 - acc: 0.9500 - val_loss: 0.4133 - val_ac
c: 0.5060
Epoch 91/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0242 - acc: 0.9929 - val_loss: 0.4076 - val_ac
c: 0.5020
Epoch 92/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0252 - acc: 0.9857 - val_loss: 0.4068 - val_ac
c: 0.5200
Epoch 93/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0249 - acc: 0.9929 - val_loss: 0.4095 - val_ac
c: 0.5140
Epoch 94/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0244 - acc: 0.9857 - val_loss: 0.4104 - val_ac
c: 0.5280
```

```
Epoch 95/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0289 - acc: 0.9786 - val_loss: 0.3983 - val_ac
c: 0.5400
Epoch 96/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0269 - acc: 0.9714 - val_loss: 0.3834 - val_ac
c: 0.5380
Epoch 97/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0261 - acc: 0.9929 - val_loss: 0.3858 - val_ac
c: 0.5240
Epoch 98/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0293 - acc: 0.9714 - val_loss: 0.3877 - val_ac
c: 0.5220
Epoch 99/400
1/1 [==============================] - 0s 175ms/step - loss: 0.0269 - acc: 0.9786 - val_loss: 0.3835 - val_ac
c: 0.5260
Epoch 100/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0262 - acc: 0.9929 - val_loss: 0.3846 - val_ac
c: 0.5260
Epoch 101/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0327 - acc: 0.9643 - val_loss: 0.3792 - val_ac
c: 0.5200
Epoch 102/400
1/1 [==============================] - 0s 202ms/step - loss: 0.0277 - acc: 0.9857 - val_loss: 0.3750 - val_ac
c: 0.5280
Epoch 103/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0271 - acc: 0.9929 - val_loss: 0.3707 - val_ac
c: 0.5300
Epoch 104/400
1/1 [==============================] - 0s 197ms/step - loss: 0.0270 - acc: 1.0000 - val_loss: 0.3698 - val_ac
c: 0.5480
Epoch 105/400
1/1 [==============================] - 0s 195ms/step - loss: 0.0299 - acc: 0.9571 - val_loss: 0.3728 - val_ac
c: 0.5480
Epoch 106/400
1/1 [==============================] - 0s 203ms/step - loss: 0.0320 - acc: 0.9714 - val_loss: 0.3766 - val_ac
c: 0.5520
Epoch 107/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0287 - acc: 0.9857 - val_loss: 0.3871 - val_ac
c: 0.5360
Epoch 108/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0306 - acc: 0.9714 - val_loss: 0.3879 - val_ac
c: 0.5320
Epoch 109/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0299 - acc: 0.9857 - val_loss: 0.3920 - val_ac
c: 0.5280
Epoch 110/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0282 - acc: 0.9929 - val_loss: 0.3975 - val_ac
c: 0.5200
Epoch 111/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0294 - acc: 0.9857 - val_loss: 0.4070 - val_ac
c: 0.5200
Epoch 112/400
1/1 [==============================] - 0s 190ms/step - loss: 0.0351 - acc: 0.9643 - val_loss: 0.4114 - val_ac
c: 0.5160
Epoch 113/400
1/1 [==============================] - 0s 172ms/step - loss: 0.0300 - acc: 0.9786 - val_loss: 0.4131 - val_ac
c: 0.5120
Epoch 114/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0337 - acc: 0.9643 - val_loss: 0.4187 - val_ac
c: 0.5160
Epoch 115/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0329 - acc: 0.9786 - val_loss: 0.4235 - val_ac
c: 0.5080
Epoch 116/400
1/1 [==============================] - 0s 195ms/step - loss: 0.0306 - acc: 0.9857 - val_loss: 0.4319 - val_ac
c: 0.5140
Epoch 117/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0315 - acc: 0.9857 - val_loss: 0.4376 - val_ac
c: 0.5240
Epoch 118/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0307 - acc: 0.9929 - val_loss: 0.4352 - val_ac
```

```
c: 0.5220
Epoch 119/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0314 - acc: 0.9929 - val_loss: 0.4286 - val_ac
c: 0.5280
Epoch 120/400
1/1 [==============================] - 0s 192ms/step - loss: 0.0318 - acc: 0.9929 - val_loss: 0.4261 - val_ac
c: 0.5300
Epoch 121/400
1/1 [==============================] - 0s 218ms/step - loss: 0.0353 - acc: 0.9786 - val_loss: 0.4202 - val_ac
c: 0.5280
Epoch 122/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0366 - acc: 0.9643 - val_loss: 0.4174 - val_ac
c: 0.5140
Epoch 123/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0325 - acc: 0.9857 - val_loss: 0.4260 - val_ac
c: 0.4820
Epoch 124/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0358 - acc: 0.9571 - val_loss: 0.4375 - val_ac
c: 0.4700
Epoch 125/400
1/1 [==============================] - 0s 230ms/step - loss: 0.0338 - acc: 0.9714 - val_loss: 0.4605 - val_ac
c: 0.4540
Epoch 126/400
1/1 [==============================] - 0s 181ms/step - loss: 0.0369 - acc: 0.9643 - val_loss: 0.4456 - val_ac
c: 0.4640
Epoch 127/400
1/1 [==============================] - 0s 158ms/step - loss: 0.0311 - acc: 1.0000 - val_loss: 0.4373 - val_ac
c: 0.4500
Epoch 128/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0318 - acc: 1.0000 - val_loss: 0.4294 - val_ac
c: 0.4560
Epoch 129/400
1/1 [==============================] - 0s 219ms/step - loss: 0.0337 - acc: 0.9786 - val_loss: 0.4184 - val_ac
c: 0.4600
Epoch 130/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0353 - acc: 0.9571 - val_loss: 0.4115 - val_ac
c: 0.4760
Epoch 131/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0335 - acc: 0.9929 - val_loss: 0.4008 - val_ac
c: 0.4940
Epoch 132/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0333 - acc: 0.9857 - val_loss: 0.3908 - val_ac
c: 0.5060
Epoch 133/400
1/1 [==============================] - 0s 161ms/step - loss: 0.0377 - acc: 0.9500 - val_loss: 0.3901 - val_ac
c: 0.5100
Epoch 134/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0327 - acc: 0.9786 - val_loss: 0.3887 - val_ac
c: 0.5180
Epoch 135/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0349 - acc: 0.9643 - val_loss: 0.3835 - val_ac
c: 0.5160
Epoch 136/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0312 - acc: 1.0000 - val_loss: 0.3800 - val_ac
c: 0.5320
Epoch 137/400
1/1 [==============================] - 0s 160ms/step - loss: 0.0318 - acc: 0.9929 - val_loss: 0.3813 - val_ac
c: 0.5280
Epoch 138/400
1/1 [==============================] - 0s 174ms/step - loss: 0.0330 - acc: 0.9929 - val_loss: 0.3859 - val_ac
c: 0.5260
Epoch 139/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0332 - acc: 0.9786 - val_loss: 0.4027 - val_ac
c: 0.5200
Epoch 140/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0326 - acc: 0.9786 - val_loss: 0.4288 - val_ac
c: 0.5160
Epoch 141/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0341 - acc: 0.9714 - val_loss: 0.4484 - val_ac
c: 0.5000
Epoch 142/400
```

```
1/1 [==============================] - 0s 164ms/step - loss: 0.0342 - acc: 0.9786 - val_loss: 0.4588 - val_ac
c: 0.4760
Epoch 143/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0344 - acc: 0.9714 - val_loss: 0.4529 - val_ac
c: 0.4720
Epoch 144/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0336 - acc: 0.9714 - val_loss: 0.4372 - val_ac
c: 0.4760
Epoch 145/400
1/1 [==============================] - 0s 209ms/step - loss: 0.0320 - acc: 0.9929 - val_loss: 0.4161 - val_ac
c: 0.4860
Epoch 146/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0334 - acc: 0.9714 - val_loss: 0.3973 - val_ac
c: 0.5140
Epoch 147/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0321 - acc: 0.9786 - val_loss: 0.3882 - val_ac
c: 0.5120
Epoch 148/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0327 - acc: 0.9857 - val_loss: 0.3842 - val_ac
c: 0.5280
Epoch 149/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0354 - acc: 0.9643 - val_loss: 0.3893 - val_ac
c: 0.5360
Epoch 150/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0322 - acc: 0.9786 - val_loss: 0.3924 - val_ac
c: 0.5360
Epoch 151/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0326 - acc: 0.9786 - val_loss: 0.4046 - val_ac
c: 0.5300
Epoch 152/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0308 - acc: 0.9857 - val_loss: 0.4102 - val_ac
c: 0.5120
Epoch 153/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0310 - acc: 0.9929 - val_loss: 0.4163 - val_ac
c: 0.5080
Epoch 154/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0323 - acc: 0.9786 - val_loss: 0.4149 - val_ac
c: 0.5100
Epoch 155/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0321 - acc: 0.9857 - val_loss: 0.4201 - val_ac
c: 0.5060
Epoch 156/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0331 - acc: 0.9643 - val_loss: 0.4190 - val_ac
c: 0.4960
Epoch 157/400
1/1 [==============================] - 0s 168ms/step - loss: 0.0304 - acc: 0.9857 - val_loss: 0.4252 - val_ac
c: 0.4940
Epoch 158/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0306 - acc: 0.9786 - val_loss: 0.4364 - val_ac
c: 0.4760
Epoch 159/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0309 - acc: 0.9857 - val_loss: 0.4404 - val_ac
c: 0.4700
Epoch 160/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0310 - acc: 0.9714 - val_loss: 0.4352 - val_ac
c: 0.4800
Epoch 161/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0309 - acc: 0.9857 - val_loss: 0.4320 - val_ac
c: 0.4780
Epoch 162/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0332 - acc: 0.9857 - val_loss: 0.4265 - val_ac
c: 0.4940
Epoch 163/400
1/1 [==============================] - 0s 169ms/step - loss: 0.0301 - acc: 0.9929 - val_loss: 0.4250 - val_ac
c: 0.4960
Epoch 164/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0297 - acc: 0.9857 - val_loss: 0.4280 - val_ac
c: 0.4980
Epoch 165/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0282 - acc: 1.0000 - val_loss: 0.4332 - val_ac
c: 0.4920
```

```
Epoch 166/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0314 - acc: 0.9786 - val_loss: 0.4232 - val_ac
c: 0.5020
Epoch 167/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0307 - acc: 0.9786 - val_loss: 0.4197 - val_ac
c: 0.5080
Epoch 168/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0341 - acc: 0.9571 - val_loss: 0.4097 - val_ac
c: 0.5100
Epoch 169/400
1/1 [==============================] - 0s 164ms/step - loss: 0.0311 - acc: 0.9857 - val_loss: 0.3991 - val_ac
c: 0.5240
Epoch 170/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0297 - acc: 0.9857 - val_loss: 0.3876 - val_ac
c: 0.5320
Epoch 171/400
1/1 [==============================] - 0s 167ms/step - loss: 0.0336 - acc: 0.9571 - val_loss: 0.3787 - val_ac
c: 0.5360
Epoch 172/400
1/1 [==============================] - 0s 176ms/step - loss: 0.0297 - acc: 0.9857 - val_loss: 0.3712 - val_ac
c: 0.5500
Epoch 173/400
1/1 [==============================] - 0s 171ms/step - loss: 0.0299 - acc: 0.9929 - val_loss: 0.3706 - val_ac
c: 0.5480
Epoch 174/400
1/1 [==============================] - 0s 162ms/step - loss: 0.0309 - acc: 0.9714 - val_loss: 0.3830 - val_ac
c: 0.5580
Epoch 175/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0311 - acc: 0.9786 - val_loss: 0.4015 - val_ac
c: 0.5440
Epoch 176/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0349 - acc: 0.9643 - val_loss: 0.4174 - val_ac
c: 0.5280
Epoch 177/400
1/1 [==============================] - 0s 163ms/step - loss: 0.0308 - acc: 0.9929 - val_loss: 0.4320 - val_ac
c: 0.5240
Epoch 178/400
1/1 [==============================] - 0s 179ms/step - loss: 0.0307 - acc: 0.9929 - val_loss: 0.4443 - val_ac
c: 0.5060
Epoch 179/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0319 - acc: 0.9929 - val_loss: 0.4617 - val_ac
c: 0.4920
Epoch 180/400
1/1 [==============================] - 0s 173ms/step - loss: 0.0322 - acc: 0.9857 - val_loss: 0.4717 - val_ac
c: 0.4800
Epoch 181/400
1/1 [==============================] - 0s 224ms/step - loss: 0.0370 - acc: 0.9643 - val_loss: 0.4603 - val_ac
c: 0.4960
Epoch 182/400
1/1 [==============================] - 0s 200ms/step - loss: 0.0380 - acc: 0.9643 - val_loss: 0.4461 - val_ac
c: 0.5100
Epoch 183/400
1/1 [==============================] - 0s 184ms/step - loss: 0.0391 - acc: 0.9500 - val_loss: 0.4436 - val_ac
c: 0.5020
Epoch 184/400
1/1 [==============================] - 0s 186ms/step - loss: 0.0347 - acc: 0.9786 - val_loss: 0.4388 - val_ac
c: 0.5000
Epoch 185/400
1/1 [==============================] - 0s 252ms/step - loss: 0.0358 - acc: 0.9571 - val_loss: 0.4430 - val_ac
c: 0.4940
Epoch 186/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0327 - acc: 0.9929 - val_loss: 0.4499 - val_ac
c: 0.4860
Epoch 187/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0426 - acc: 0.9500 - val_loss: 0.4486 - val_ac
c: 0.4900
Epoch 188/400
1/1 [==============================] - 0s 177ms/step - loss: 0.0412 - acc: 0.9643 - val_loss: 0.4435 - val_ac
c: 0.4860
Epoch 189/400
1/1 [==============================] - 0s 224ms/step - loss: 0.0360 - acc: 0.9643 - val_loss: 0.4333 - val_ac
```

```
c: 0.4940
Epoch 190/400
1/1 [==============================] - 0s 206ms/step - loss: 0.0343 - acc: 0.9929 - val_loss: 0.4245 - val_ac
c: 0.5040
Epoch 191/400
1/1 [==============================] - 0s 182ms/step - loss: 0.0369 - acc: 0.9643 - val_loss: 0.4188 - val_ac
c: 0.4980
Epoch 192/400
1/1 [==============================] - 0s 191ms/step - loss: 0.0374 - acc: 0.9786 - val_loss: 0.4203 - val_ac
c: 0.4840
Epoch 193/400
1/1 [==============================] - 0s 205ms/step - loss: 0.0380 - acc: 0.9786 - val_loss: 0.4235 - val_ac
c: 0.4760
Epoch 194/400
1/1 [==============================] - 0s 200ms/step - loss: 0.0369 - acc: 0.9714 - val_loss: 0.4386 - val_ac
c: 0.4540
Epoch 195/400
1/1 [==============================] - 0s 194ms/step - loss: 0.0362 - acc: 0.9786 - val_loss: 0.4536 - val_ac
c: 0.4440
Epoch 196/400
1/1 [==============================] - 0s 187ms/step - loss: 0.0363 - acc: 0.9857 - val_loss: 0.4643 - val_ac
c: 0.4460
Epoch 197/400
1/1 [==============================] - 0s 200ms/step - loss: 0.0417 - acc: 0.9714 - val_loss: 0.4699 - val_ac
c: 0.4480
Epoch 198/400
1/1 [==============================] - 0s 193ms/step - loss: 0.0396 - acc: 0.9571 - val_loss: 0.4673 - val_ac
c: 0.4440
Epoch 199/400
1/1 [==============================] - 0s 166ms/step - loss: 0.0356 - acc: 0.9929 - val_loss: 0.4679 - val_ac
c: 0.4480
Epoch 200/400
1/1 [==============================] - 0s 170ms/step - loss: 0.0420 - acc: 0.9500 - val_loss: 0.4586 - val_ac
c: 0.4580
Epoch 201/400
1/1 [==============================] - 0s 196ms/step - loss: 0.0367 - acc: 0.9929 - val_loss: 0.4475 - val_ac
c: 0.4540
Epoch 202/400
1/1 [==============================] - 0s 221ms/step - loss: 0.0415 - acc: 0.9571 - val_loss: 0.4405 - val_ac
c: 0.4640
Epoch 203/400
1/1 [==============================] - 0s 180ms/step - loss: 0.0411 - acc: 0.9714 - val_loss: 0.4335 - val_ac
c: 0.4640
Epoch 204/400
1/1 [==============================] - 0s 178ms/step - loss: 0.0351 - acc: 1.0000 - val_loss: 0.4295 - val_ac
c: 0.4620
Epoch 205/400
1/1 [==============================] - 0s 207ms/step - loss: 0.0422 - acc: 0.9714 - val_loss: 0.4335 - val_ac
c: 0.4600
Epoch 206/400
1/1 [==============================] - 0s 185ms/step - loss: 0.0368 - acc: 0.9857 - val_loss: 0.4407 - val_ac
c: 0.4400
Epoch 207/400
1/1 [==============================] - 0s 183ms/step - loss: 0.0379 - acc: 0.9714 - val_loss: 0.4463 - val_ac
c: 0.4440
```

Out[ ]:
```
<tensorflow.python.keras.callbacks.History at 0x1d55a884d08>
```

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

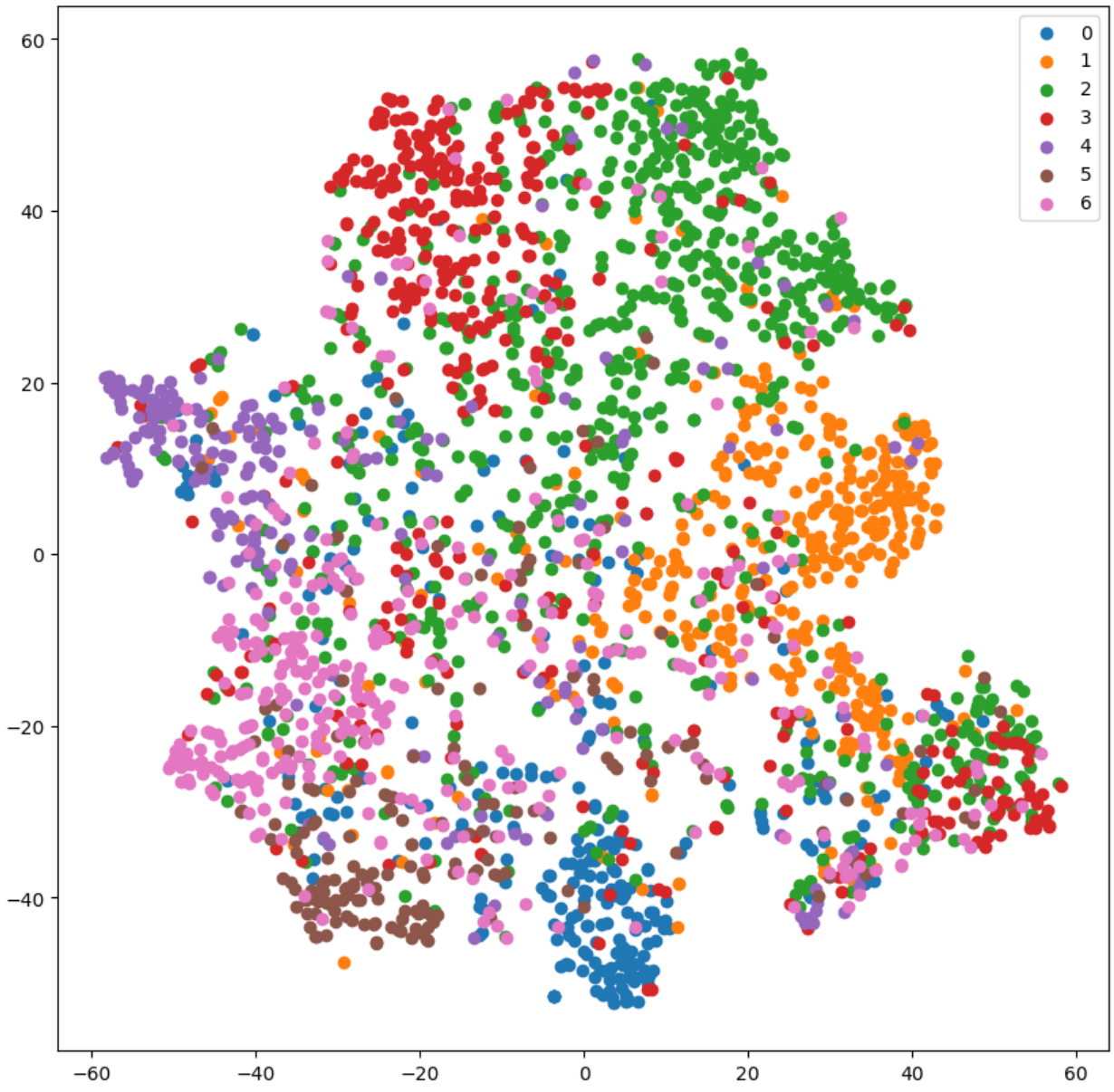
           Case_Based       0.49      0.59      0.53       114
  Genetic_Algorithms        0.67      0.81      0.74       156
      Neural_Networks       0.73      0.52      0.61       290
Probabilistic_Methods       0.66      0.54      0.60       172
Reinforcement_Learning      0.43      0.52      0.47        85
        Rule_Learning       0.43      0.73      0.54        60
               Theory       0.43      0.43      0.43       123

             accuracy                           0.58      1000
            macro avg       0.55      0.59      0.56      1000
         weighted avg       0.60      0.58      0.58      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 ###
```