Exp_5

August 26, 2025

Name:	Tufan Kundu
Registration no:	24MDT0184
Course Name:	Deep Learning Lab
Course Code:	PMDS603P
Experiment:	5
Date:	14 August,2025

0.1 Question1. Use the cifar10 dataset and do necessary pre-processing, and split the data into training, validation, and testing sets. Create a new model using a sequential class with appropriate hidden layers and output layer neurons. Choose appropriate activation functions like sigmoid and relu, etc. And also an appropriate one in the output layer. Choose the error function appropriately and use SGD as the optimizer. Include early stopping technique in your model and run the model for 500 epochs. Try to come up with a better model with decent accuracy.

0.1.1 Importing the necessary libraries

[15]:
```
from tensorflow import keras
from keras.datasets import cifar10
from keras.models import Sequential
from keras.layers import Dense, Flatten, Dropout
from keras.optimizers import SGD
from keras.regularizers import L2
from keras.callbacks import EarlyStopping
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
from keras.utils import to_categorical

import warnings
warnings.filterwarnings("ignore")
```

0.1.2 Loading the dataset

[16]:
```
(x_train,y_train),(x_test,y_test) = cifar10.load_data()
x_subtrain,x_valid,y_subtrain,y_valid = train_test_split(x_train,y_train,␣
 ↪test_size = 0.1, random_state = 42)
```

[17]:
```
x_train = x_train/255
x_test = x_test/255
x_subtrain = x_subtrain/255
x_valid = x_valid/255
```

[18]:
```
## flattening the images
x_subtrain_flat = x_subtrain.reshape(x_subtrain.shape[0], -1)
x_valid_flat = x_valid.reshape(x_valid.shape[0], -1)
x_test_flat = x_test.reshape(x_test.shape[0], -1)
```

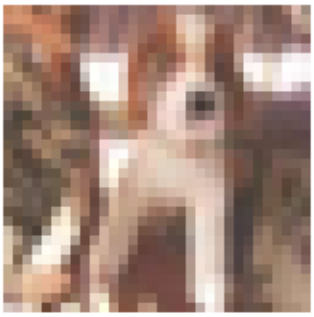
[19]:
```
import numpy as np
# Mapping of label numbers to class names
label_names = {
0: "airplane",
1: "automobile",
2: "bird",
3: "cat",
4: "deer",
5: "dog",
6: "frog",
7: "horse",
8: "ship",
9: "truck"
}
# Picking 5 random indexes
random_indices = np.random.choice(len(x_train), size=5, replace=False)
# Plotting the images with labels
plt.figure(figsize=(2, 10))
for i, idx in enumerate(random_indices):
    plt.subplot(5, 1, i+1)
    plt.imshow(x_train[idx])
    plt.title(label_names[int(y_train[idx])])
    plt.axis('off')
    plt.tight_layout()
plt.show()
```

automobile

automobile

automobile

dog



truck

0.1.3 one hot encoding of target labels

[20]:
```
y_subtrain_cat = to_categorical(y_subtrain, 10)
y_valid_cat = to_categorical(y_valid, 10)
y_test_cat = to_categorical(y_test, 10 )
```

0.1.4 Building the model

[21]:
```
model = Sequential()
model.add(Dense(512, activation = 'relu', input_shape = (3072,)))
model.add(Dropout(0.3))
model.add(Dense(256, activation = 'relu'))
model.add(Dropout(0.3))
model.add(Dense(128, activation = 'relu'))
model.add(Dropout(0.2))
model.add(Dense(10, activation = 'softmax'))
model.summary()
```

```
Model: "sequential_1"
```

Layer (type)	Output Shape	Param #
dense_4 (Dense)	(None, 512)	1,573,376
dropout_3 (Dropout)	(None, 512)	0
dense_5 (Dense)	(None, 256)	131,328
dropout_4 (Dropout)	(None, 256)	0
dense_6 (Dense)	(None, 128)	32,896
dropout_5 (Dropout)	(None, 128)	0
dense_7 (Dense)	(None, 10)	1,290

```
Total params: 1,738,890 (6.63 MB)

Trainable params: 1,738,890 (6.63 MB)
```

Non-trainable params: 0 (0.00 B)

[22]:
```
## SGD Optimizer
sgd = SGD(learning_rate=0.01)

model.compile(loss = 'categorical_crossentropy', optimizer = sgd, metrics =␣
 ↪['accuracy'])
estop = EarlyStopping(monitor = 'val_loss', min_delta = 1e-4, mode = 'min',␣
 ↪patience = 5, verbose = 2, restore_best_weights=True)
history = model.fit(x_subtrain_flat,y_subtrain_cat, batch_size = 128, epochs =␣
 ↪500, verbose = 2, validation_data=(x_valid_flat,y_valid_cat),callbacks=estop)
```

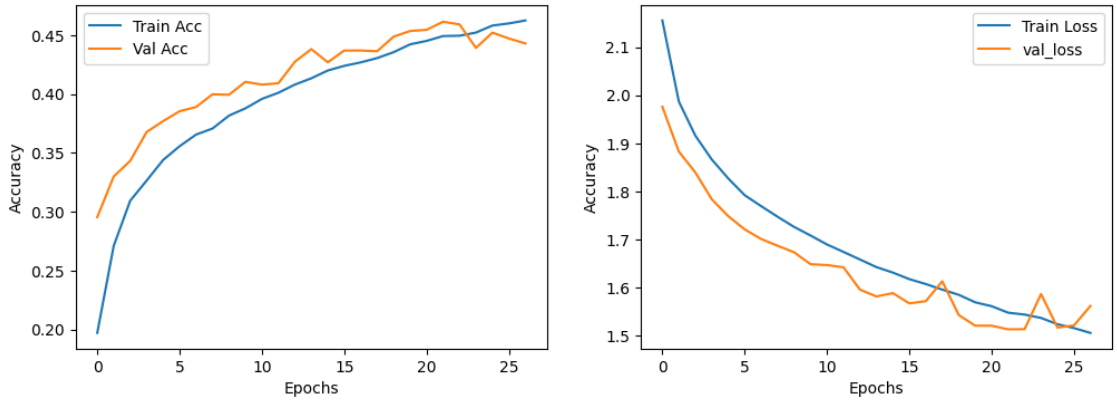
```
Epoch 1/500
352/352 - 4s - 12ms/step - accuracy: 0.1970 - loss: 2.1552 - val_accuracy:
0.2954 - val_loss: 1.9758
Epoch 2/500
352/352 - 4s - 10ms/step - accuracy: 0.2710 - loss: 1.9868 - val_accuracy:
0.3300 - val_loss: 1.8828
Epoch 3/500
352/352 - 3s - 9ms/step - accuracy: 0.3094 - loss: 1.9160 - val_accuracy: 0.3432
- val_loss: 1.8395
Epoch 4/500
352/352 - 3s - 9ms/step - accuracy: 0.3265 - loss: 1.8663 - val_accuracy: 0.3678
- val_loss: 1.7837
Epoch 5/500
352/352 - 3s - 10ms/step - accuracy: 0.3440 - loss: 1.8270 - val_accuracy:
0.3770 - val_loss: 1.7485
Epoch 6/500
352/352 - 3s - 9ms/step - accuracy: 0.3557 - loss: 1.7921 - val_accuracy: 0.3854
- val_loss: 1.7211
Epoch 7/500
352/352 - 3s - 9ms/step - accuracy: 0.3656 - loss: 1.7693 - val_accuracy: 0.3890
- val_loss: 1.7010
Epoch 8/500
352/352 - 3s - 9ms/step - accuracy: 0.3707 - loss: 1.7472 - val_accuracy: 0.3998
- val_loss: 1.6870
Epoch 9/500
352/352 - 3s - 10ms/step - accuracy: 0.3817 - loss: 1.7261 - val_accuracy:
0.3994 - val_loss: 1.6735
Epoch 10/500
352/352 - 3s - 9ms/step - accuracy: 0.3879 - loss: 1.7083 - val_accuracy: 0.4104
- val_loss: 1.6486
Epoch 11/500
352/352 - 3s - 9ms/step - accuracy: 0.3959 - loss: 1.6896 - val_accuracy: 0.4080
- val_loss: 1.6468
Epoch 12/500
352/352 - 3s - 9ms/step - accuracy: 0.4011 - loss: 1.6741 - val_accuracy: 0.4092
```

```
- val_loss: 1.6422
Epoch 13/500
352/352 - 3s - 9ms/step - accuracy: 0.4080 - loss: 1.6584 - val_accuracy: 0.4274
- val_loss: 1.5958
Epoch 14/500
352/352 - 3s - 9ms/step - accuracy: 0.4134 - loss: 1.6426 - val_accuracy: 0.4382
- val_loss: 1.5815
Epoch 15/500
352/352 - 3s - 9ms/step - accuracy: 0.4200 - loss: 1.6312 - val_accuracy: 0.4270
- val_loss: 1.5885
Epoch 16/500
352/352 - 3s - 9ms/step - accuracy: 0.4240 - loss: 1.6176 - val_accuracy: 0.4370
- val_loss: 1.5672
Epoch 17/500
352/352 - 3s - 9ms/step - accuracy: 0.4269 - loss: 1.6074 - val_accuracy: 0.4370
- val_loss: 1.5718
Epoch 18/500
352/352 - 3s - 9ms/step - accuracy: 0.4306 - loss: 1.5958 - val_accuracy: 0.4364
- val_loss: 1.6131
Epoch 19/500
352/352 - 3s - 9ms/step - accuracy: 0.4356 - loss: 1.5850 - val_accuracy: 0.4488
- val_loss: 1.5431
Epoch 20/500
352/352 - 4s - 10ms/step - accuracy: 0.4422 - loss: 1.5694 - val_accuracy:
0.4536 - val_loss: 1.5209
Epoch 21/500
352/352 - 3s - 9ms/step - accuracy: 0.4452 - loss: 1.5613 - val_accuracy: 0.4546
- val_loss: 1.5207
Epoch 22/500
352/352 - 4s - 10ms/step - accuracy: 0.4493 - loss: 1.5479 - val_accuracy:
0.4614 - val_loss: 1.5133
Epoch 23/500
352/352 - 3s - 10ms/step - accuracy: 0.4496 - loss: 1.5439 - val_accuracy:
0.4592 - val_loss: 1.5136
Epoch 24/500
352/352 - 3s - 9ms/step - accuracy: 0.4522 - loss: 1.5369 - val_accuracy: 0.4392
- val_loss: 1.5867
Epoch 25/500
352/352 - 3s - 10ms/step - accuracy: 0.4582 - loss: 1.5238 - val_accuracy:
0.4522 - val_loss: 1.5169
Epoch 26/500
352/352 - 3s - 9ms/step - accuracy: 0.4600 - loss: 1.5158 - val_accuracy: 0.4472
- val_loss: 1.5214
Epoch 27/500
352/352 - 3s - 10ms/step - accuracy: 0.4625 - loss: 1.5058 - val_accuracy:
0.4430 - val_loss: 1.5619
Epoch 27: early stopping
Restoring model weights from the end of the best epoch: 22.
```

[23]:
```
score = model.evaluate(x_test_flat,y_test_cat,verbose = 2)
print("Test loss:", score[0])
print(f"Test Accuracy:{score[1]*100:.2f}%")
```

```
313/313 - 1s - 3ms/step - accuracy: 0.4736 - loss: 1.4778
Test loss: 1.4778025150299072
Test Accuracy:47.36%
```

[24]:
```
plt.figure(figsize=(12,4))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label = 'val_loss')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```



0.2 Question 2: We will try to include some techniques for optimizing the training part. Let us see how one can include a learning rate schedule for SGD, what we discussed in the theory class. Now, first we will try to see the linear learning rate scheduler we discussed in class. here, is taken as 5 and 0 = 0.01 and = 0.001. If you run this code, you can see the way in which we generate the learning rate for different iterations. Compare with what we did in theory and check whether they are the same.

[25]:
```
lr_schedule = keras.optimizers.schedules.PolynomialDecay(
initial_learning_rate = 0.01,
decay_steps = 5,
end_learning_rate = 0.001,
power = 1,
cycle = False
)

for steps in range(10):
    print(f"Step:{steps+1} --> LR= {lr_schedule(steps).numpy():.5f}")
```

```
Step:1 --> LR= 0.01000
Step:2 --> LR= 0.00820
Step:3 --> LR= 0.00640
Step:4 --> LR= 0.00460
Step:5 --> LR= 0.00280
Step:6 --> LR= 0.00100
Step:7 --> LR= 0.00100
Step:8 --> LR= 0.00100
Step:9 --> LR= 0.00100
Step:10 --> LR= 0.00100
```

[26]:
```
lr_schedule = keras.optimizers.schedules.PolynomialDecay(
initial_learning_rate = 0.01,
decay_steps = 5,
end_learning_rate = 0.001,
power = 1,
cycle = True
)
for steps in range(40):
    print(f"Step:{steps+1} --> LR= {lr_schedule(steps).numpy():.5f}")
```

```
Step:1 --> LR= 0.01000
Step:2 --> LR= 0.00820
Step:3 --> LR= 0.00640
Step:4 --> LR= 0.00460
Step:5 --> LR= 0.00280
Step:6 --> LR= 0.00100
Step:7 --> LR= 0.00460
Step:8 --> LR= 0.00370
```

```
Step:9 --> LR= 0.00280
Step:10 --> LR= 0.00190
Step:11 --> LR= 0.00100
Step:12 --> LR= 0.00340
Step:13 --> LR= 0.00280
Step:14 --> LR= 0.00220
Step:15 --> LR= 0.00160
Step:16 --> LR= 0.00100
Step:17 --> LR= 0.00280
Step:18 --> LR= 0.00235
Step:19 --> LR= 0.00190
Step:20 --> LR= 0.00145
Step:21 --> LR= 0.00100
Step:22 --> LR= 0.00244
Step:23 --> LR= 0.00208
Step:24 --> LR= 0.00172
Step:25 --> LR= 0.00136
Step:26 --> LR= 0.00100
Step:27 --> LR= 0.00220
Step:28 --> LR= 0.00190
Step:29 --> LR= 0.00160
Step:30 --> LR= 0.00130
Step:31 --> LR= 0.00100
Step:32 --> LR= 0.00203
Step:33 --> LR= 0.00177
Step:34 --> LR= 0.00151
Step:35 --> LR= 0.00126
Step:36 --> LR= 0.00100
Step:37 --> LR= 0.00190
Step:38 --> LR= 0.00167
Step:39 --> LR= 0.00145
Step:40 --> LR= 0.00122
```

0.3 Now, to incorporate this into the previous Question 1. You have to create a schedule and define the parameters as given below, and use it inside the SGD optimizer you are using in your previous problem.

[27]:
```
lr_schedule = keras.optimizers.schedules.PolynomialDecay(
    initial_learning_rate = 0.01,
    decay_steps = 5,
    end_learning_rate = 0.001,
    power = 1,
    cycle = False
)

optimizers = SGD(learning_rate=lr_schedule)
```

```
model.compile(optimizer = optimizers, loss = 'categorical_crossentropy',␣
 ↪metrics = ['accuracy'])
estop = EarlyStopping(monitor = 'val_loss', min_delta = 1e-4, mode = 'min',␣
 ↪patience = 5, verbose = 2, restore_best_weights=True)
history = model.fit(x_subtrain_flat,y_subtrain_cat, batch_size = 128, epochs =␣
 ↪500, verbose = 2, validation_data = (x_valid_flat, y_valid_cat),␣
 ↪callbacks=estop)
```

```
Epoch 1/500
352/352 - 4s - 12ms/step - accuracy: 0.4615 - loss: 1.5135 - val_accuracy:
0.4640 - val_loss: 1.4908
Epoch 2/500
352/352 - 3s - 9ms/step - accuracy: 0.4641 - loss: 1.5059 - val_accuracy: 0.4680
- val_loss: 1.4864
Epoch 3/500
352/352 - 3s - 10ms/step - accuracy: 0.4647 - loss: 1.5069 - val_accuracy:
0.4636 - val_loss: 1.4871
Epoch 4/500
352/352 - 3s - 10ms/step - accuracy: 0.4617 - loss: 1.5067 - val_accuracy:
0.4658 - val_loss: 1.4841
Epoch 5/500
352/352 - 3s - 10ms/step - accuracy: 0.4645 - loss: 1.5034 - val_accuracy:
0.4690 - val_loss: 1.4834
Epoch 6/500
352/352 - 3s - 10ms/step - accuracy: 0.4680 - loss: 1.5004 - val_accuracy:
0.4682 - val_loss: 1.4830
Epoch 7/500
352/352 - 3s - 9ms/step - accuracy: 0.4683 - loss: 1.4988 - val_accuracy: 0.4680
- val_loss: 1.4801
Epoch 8/500
352/352 - 3s - 9ms/step - accuracy: 0.4697 - loss: 1.4971 - val_accuracy: 0.4690
- val_loss: 1.4791
Epoch 9/500
352/352 - 3s - 9ms/step - accuracy: 0.4679 - loss: 1.5000 - val_accuracy: 0.4706
- val_loss: 1.4797
Epoch 10/500
352/352 - 3s - 10ms/step - accuracy: 0.4682 - loss: 1.4962 - val_accuracy:
0.4704 - val_loss: 1.4772
Epoch 11/500
352/352 - 3s - 10ms/step - accuracy: 0.4654 - loss: 1.4956 - val_accuracy:
0.4698 - val_loss: 1.4783
Epoch 12/500
352/352 - 4s - 11ms/step - accuracy: 0.4696 - loss: 1.4937 - val_accuracy:
0.4698 - val_loss: 1.4793
Epoch 13/500
352/352 - 4s - 10ms/step - accuracy: 0.4707 - loss: 1.4920 - val_accuracy:
0.4720 - val_loss: 1.4741
```

```
Epoch 14/500
352/352 - 3s - 10ms/step - accuracy: 0.4706 - loss: 1.4902 - val_accuracy:
0.4690 - val_loss: 1.4747
Epoch 15/500
352/352 - 3s - 9ms/step - accuracy: 0.4697 - loss: 1.4900 - val_accuracy: 0.4730
- val_loss: 1.4710
Epoch 16/500
352/352 - 4s - 11ms/step - accuracy: 0.4722 - loss: 1.4878 - val_accuracy:
0.4696 - val_loss: 1.4741
Epoch 17/500
352/352 - 6s - 18ms/step - accuracy: 0.4730 - loss: 1.4814 - val_accuracy:
0.4706 - val_loss: 1.4709
Epoch 18/500
352/352 - 6s - 17ms/step - accuracy: 0.4722 - loss: 1.4892 - val_accuracy:
0.4714 - val_loss: 1.4691
Epoch 19/500
352/352 - 5s - 13ms/step - accuracy: 0.4751 - loss: 1.4797 - val_accuracy:
0.4738 - val_loss: 1.4687
Epoch 20/500
352/352 - 4s - 13ms/step - accuracy: 0.4722 - loss: 1.4847 - val_accuracy:
0.4696 - val_loss: 1.4694
Epoch 21/500
352/352 - 4s - 11ms/step - accuracy: 0.4746 - loss: 1.4792 - val_accuracy:
0.4732 - val_loss: 1.4666
Epoch 22/500
352/352 - 4s - 11ms/step - accuracy: 0.4712 - loss: 1.4822 - val_accuracy:
0.4748 - val_loss: 1.4658
Epoch 23/500
352/352 - 4s - 12ms/step - accuracy: 0.4749 - loss: 1.4807 - val_accuracy:
0.4718 - val_loss: 1.4673
Epoch 24/500
352/352 - 4s - 11ms/step - accuracy: 0.4729 - loss: 1.4801 - val_accuracy:
0.4752 - val_loss: 1.4640
Epoch 25/500
352/352 - 5s - 14ms/step - accuracy: 0.4739 - loss: 1.4811 - val_accuracy:
0.4744 - val_loss: 1.4632
Epoch 26/500
352/352 - 5s - 14ms/step - accuracy: 0.4738 - loss: 1.4771 - val_accuracy:
0.4748 - val_loss: 1.4615
Epoch 27/500
352/352 - 5s - 13ms/step - accuracy: 0.4760 - loss: 1.4705 - val_accuracy:
0.4758 - val_loss: 1.4626
Epoch 28/500
352/352 - 3s - 10ms/step - accuracy: 0.4764 - loss: 1.4733 - val_accuracy:
0.4748 - val_loss: 1.4641
Epoch 29/500
352/352 - 3s - 10ms/step - accuracy: 0.4754 - loss: 1.4742 - val_accuracy:
0.4748 - val_loss: 1.4608
```

```
Epoch 30/500
352/352 - 4s - 11ms/step - accuracy: 0.4795 - loss: 1.4685 - val_accuracy:
0.4746 - val_loss: 1.4626
Epoch 31/500
352/352 - 4s - 11ms/step - accuracy: 0.4777 - loss: 1.4673 - val_accuracy:
0.4752 - val_loss: 1.4603
Epoch 32/500
352/352 - 4s - 11ms/step - accuracy: 0.4792 - loss: 1.4651 - val_accuracy:
0.4768 - val_loss: 1.4582
Epoch 33/500
352/352 - 4s - 11ms/step - accuracy: 0.4807 - loss: 1.4655 - val_accuracy:
0.4780 - val_loss: 1.4587
Epoch 34/500
352/352 - 4s - 11ms/step - accuracy: 0.4784 - loss: 1.4640 - val_accuracy:
0.4792 - val_loss: 1.4554
Epoch 35/500
352/352 - 4s - 11ms/step - accuracy: 0.4796 - loss: 1.4627 - val_accuracy:
0.4810 - val_loss: 1.4569
Epoch 36/500
352/352 - 4s - 10ms/step - accuracy: 0.4784 - loss: 1.4614 - val_accuracy:
0.4776 - val_loss: 1.4562
Epoch 37/500
352/352 - 4s - 10ms/step - accuracy: 0.4812 - loss: 1.4609 - val_accuracy:
0.4790 - val_loss: 1.4535
Epoch 38/500
352/352 - 4s - 11ms/step - accuracy: 0.4811 - loss: 1.4633 - val_accuracy:
0.4748 - val_loss: 1.4541
Epoch 39/500
352/352 - 4s - 10ms/step - accuracy: 0.4790 - loss: 1.4598 - val_accuracy:
0.4818 - val_loss: 1.4534
Epoch 40/500
352/352 - 4s - 11ms/step - accuracy: 0.4802 - loss: 1.4594 - val_accuracy:
0.4806 - val_loss: 1.4506
Epoch 41/500
352/352 - 4s - 10ms/step - accuracy: 0.4830 - loss: 1.4576 - val_accuracy:
0.4820 - val_loss: 1.4489
Epoch 42/500
352/352 - 3s - 10ms/step - accuracy: 0.4836 - loss: 1.4546 - val_accuracy:
0.4834 - val_loss: 1.4473
Epoch 43/500
352/352 - 3s - 10ms/step - accuracy: 0.4820 - loss: 1.4574 - val_accuracy:
0.4784 - val_loss: 1.4473
Epoch 44/500
352/352 - 4s - 10ms/step - accuracy: 0.4847 - loss: 1.4513 - val_accuracy:
0.4774 - val_loss: 1.4495
Epoch 45/500
352/352 - 4s - 10ms/step - accuracy: 0.4847 - loss: 1.4523 - val_accuracy:
0.4802 - val_loss: 1.4502
```

```
Epoch 46/500
352/352 - 4s - 10ms/step - accuracy: 0.4840 - loss: 1.4515 - val_accuracy:
0.4782 - val_loss: 1.4451
Epoch 47/500
352/352 - 3s - 10ms/step - accuracy: 0.4857 - loss: 1.4461 - val_accuracy:
0.4802 - val_loss: 1.4444
Epoch 48/500
352/352 - 4s - 10ms/step - accuracy: 0.4854 - loss: 1.4460 - val_accuracy:
0.4830 - val_loss: 1.4419
Epoch 49/500
352/352 - 3s - 10ms/step - accuracy: 0.4847 - loss: 1.4478 - val_accuracy:
0.4814 - val_loss: 1.4448
Epoch 50/500
352/352 - 3s - 10ms/step - accuracy: 0.4844 - loss: 1.4469 - val_accuracy:
0.4850 - val_loss: 1.4414
Epoch 51/500
352/352 - 3s - 10ms/step - accuracy: 0.4868 - loss: 1.4448 - val_accuracy:
0.4792 - val_loss: 1.4425
Epoch 52/500
352/352 - 4s - 10ms/step - accuracy: 0.4872 - loss: 1.4423 - val_accuracy:
0.4854 - val_loss: 1.4410
Epoch 53/500
352/352 - 4s - 10ms/step - accuracy: 0.4882 - loss: 1.4413 - val_accuracy:
0.4834 - val_loss: 1.4408
Epoch 54/500
352/352 - 4s - 10ms/step - accuracy: 0.4854 - loss: 1.4441 - val_accuracy:
0.4812 - val_loss: 1.4401
Epoch 55/500
352/352 - 4s - 11ms/step - accuracy: 0.4870 - loss: 1.4425 - val_accuracy:
0.4830 - val_loss: 1.4392
Epoch 56/500
352/352 - 4s - 11ms/step - accuracy: 0.4871 - loss: 1.4406 - val_accuracy:
0.4872 - val_loss: 1.4389
Epoch 57/500
352/352 - 4s - 11ms/step - accuracy: 0.4895 - loss: 1.4362 - val_accuracy:
0.4832 - val_loss: 1.4387
Epoch 58/500
352/352 - 4s - 10ms/step - accuracy: 0.4866 - loss: 1.4360 - val_accuracy:
0.4836 - val_loss: 1.4346
Epoch 59/500
352/352 - 3s - 10ms/step - accuracy: 0.4887 - loss: 1.4366 - val_accuracy:
0.4858 - val_loss: 1.4331
Epoch 60/500
352/352 - 4s - 10ms/step - accuracy: 0.4890 - loss: 1.4364 - val_accuracy:
0.4852 - val_loss: 1.4352
Epoch 61/500
352/352 - 3s - 10ms/step - accuracy: 0.4881 - loss: 1.4331 - val_accuracy:
0.4860 - val_loss: 1.4348
```

```
Epoch 62/500
352/352 - 3s - 10ms/step - accuracy: 0.4904 - loss: 1.4321 - val_accuracy:
0.4876 - val_loss: 1.4320
Epoch 63/500
352/352 - 4s - 10ms/step - accuracy: 0.4864 - loss: 1.4372 - val_accuracy:
0.4884 - val_loss: 1.4309
Epoch 64/500
352/352 - 4s - 10ms/step - accuracy: 0.4893 - loss: 1.4320 - val_accuracy:
0.4854 - val_loss: 1.4315
Epoch 65/500
352/352 - 4s - 12ms/step - accuracy: 0.4922 - loss: 1.4289 - val_accuracy:
0.4852 - val_loss: 1.4295
Epoch 66/500
352/352 - 4s - 11ms/step - accuracy: 0.4907 - loss: 1.4283 - val_accuracy:
0.4898 - val_loss: 1.4277
Epoch 67/500
352/352 - 4s - 12ms/step - accuracy: 0.4924 - loss: 1.4265 - val_accuracy:
0.4884 - val_loss: 1.4274
Epoch 68/500
352/352 - 4s - 11ms/step - accuracy: 0.4942 - loss: 1.4276 - val_accuracy:
0.4898 - val_loss: 1.4274
Epoch 69/500
352/352 - 4s - 11ms/step - accuracy: 0.4936 - loss: 1.4243 - val_accuracy:
0.4854 - val_loss: 1.4299
Epoch 70/500
352/352 - 4s - 11ms/step - accuracy: 0.4945 - loss: 1.4215 - val_accuracy:
0.4914 - val_loss: 1.4260
Epoch 71/500
352/352 - 4s - 11ms/step - accuracy: 0.4916 - loss: 1.4239 - val_accuracy:
0.4880 - val_loss: 1.4294
Epoch 72/500
352/352 - 4s - 11ms/step - accuracy: 0.4939 - loss: 1.4221 - val_accuracy:
0.4902 - val_loss: 1.4249
Epoch 73/500
352/352 - 4s - 11ms/step - accuracy: 0.4945 - loss: 1.4212 - val_accuracy:
0.4900 - val_loss: 1.4238
Epoch 74/500
352/352 - 4s - 11ms/step - accuracy: 0.4936 - loss: 1.4204 - val_accuracy:
0.4934 - val_loss: 1.4213
Epoch 75/500
352/352 - 3s - 9ms/step - accuracy: 0.4950 - loss: 1.4194 - val_accuracy: 0.4940
- val_loss: 1.4214
Epoch 76/500
352/352 - 3s - 9ms/step - accuracy: 0.4968 - loss: 1.4164 - val_accuracy: 0.4934
- val_loss: 1.4204
Epoch 77/500
352/352 - 3s - 10ms/step - accuracy: 0.4933 - loss: 1.4195 - val_accuracy:
0.4914 - val_loss: 1.4201
```

```
Epoch 78/500
352/352 - 3s - 9ms/step - accuracy: 0.4963 - loss: 1.4169 - val_accuracy: 0.4910
- val_loss: 1.4216
Epoch 79/500
352/352 - 3s - 9ms/step - accuracy: 0.4967 - loss: 1.4117 - val_accuracy: 0.4930
- val_loss: 1.4205
Epoch 80/500
352/352 - 3s - 10ms/step - accuracy: 0.4955 - loss: 1.4146 - val_accuracy:
0.4938 - val_loss: 1.4171
Epoch 81/500
352/352 - 4s - 10ms/step - accuracy: 0.4974 - loss: 1.4121 - val_accuracy:
0.4936 - val_loss: 1.4177
Epoch 82/500
352/352 - 3s - 9ms/step - accuracy: 0.4973 - loss: 1.4099 - val_accuracy: 0.4900
- val_loss: 1.4196
Epoch 83/500
352/352 - 3s - 10ms/step - accuracy: 0.4973 - loss: 1.4088 - val_accuracy:
0.4946 - val_loss: 1.4158
Epoch 84/500
352/352 - 4s - 11ms/step - accuracy: 0.4976 - loss: 1.4079 - val_accuracy:
0.4908 - val_loss: 1.4166
Epoch 85/500
352/352 - 4s - 11ms/step - accuracy: 0.4982 - loss: 1.4096 - val_accuracy:
0.4938 - val_loss: 1.4156
Epoch 86/500
352/352 - 4s - 11ms/step - accuracy: 0.4994 - loss: 1.4031 - val_accuracy:
0.4940 - val_loss: 1.4159
Epoch 87/500
352/352 - 3s - 10ms/step - accuracy: 0.4993 - loss: 1.4046 - val_accuracy:
0.4940 - val_loss: 1.4133
Epoch 88/500
352/352 - 3s - 10ms/step - accuracy: 0.5003 - loss: 1.4064 - val_accuracy:
0.4952 - val_loss: 1.4124
Epoch 89/500
352/352 - 3s - 10ms/step - accuracy: 0.5034 - loss: 1.3976 - val_accuracy:
0.4958 - val_loss: 1.4119
Epoch 90/500
352/352 - 3s - 10ms/step - accuracy: 0.5027 - loss: 1.4039 - val_accuracy:
0.4954 - val_loss: 1.4090
Epoch 91/500
352/352 - 3s - 9ms/step - accuracy: 0.5010 - loss: 1.3993 - val_accuracy: 0.4976
- val_loss: 1.4110
Epoch 92/500
352/352 - 3s - 9ms/step - accuracy: 0.4999 - loss: 1.3990 - val_accuracy: 0.4914
- val_loss: 1.4086
Epoch 93/500
352/352 - 3s - 9ms/step - accuracy: 0.5016 - loss: 1.3971 - val_accuracy: 0.4936
- val_loss: 1.4120
```

```
Epoch 94/500
352/352 - 3s - 9ms/step - accuracy: 0.5023 - loss: 1.3992 - val_accuracy: 0.4924
- val_loss: 1.4081
Epoch 95/500
352/352 - 3s - 9ms/step - accuracy: 0.5007 - loss: 1.3983 - val_accuracy: 0.4958
- val_loss: 1.4091
Epoch 96/500
352/352 - 3s - 10ms/step - accuracy: 0.5037 - loss: 1.3948 - val_accuracy:
0.4952 - val_loss: 1.4062
Epoch 97/500
352/352 - 3s - 9ms/step - accuracy: 0.5012 - loss: 1.3964 - val_accuracy: 0.4960
- val_loss: 1.4045
Epoch 98/500
352/352 - 3s - 9ms/step - accuracy: 0.5015 - loss: 1.3956 - val_accuracy: 0.4946
- val_loss: 1.4051
Epoch 99/500
352/352 - 3s - 9ms/step - accuracy: 0.5063 - loss: 1.3911 - val_accuracy: 0.4966
- val_loss: 1.4047
Epoch 100/500
352/352 - 3s - 10ms/step - accuracy: 0.5050 - loss: 1.3875 - val_accuracy:
0.4962 - val_loss: 1.4064
Epoch 101/500
352/352 - 3s - 9ms/step - accuracy: 0.5029 - loss: 1.3933 - val_accuracy: 0.4976
- val_loss: 1.4035
Epoch 102/500
352/352 - 3s - 10ms/step - accuracy: 0.5043 - loss: 1.3865 - val_accuracy:
0.4950 - val_loss: 1.4041
Epoch 103/500
352/352 - 3s - 9ms/step - accuracy: 0.5046 - loss: 1.3862 - val_accuracy: 0.4970
- val_loss: 1.4027
Epoch 104/500
352/352 - 3s - 9ms/step - accuracy: 0.5042 - loss: 1.3876 - val_accuracy: 0.4988
- val_loss: 1.4002
Epoch 105/500
352/352 - 3s - 10ms/step - accuracy: 0.5028 - loss: 1.3881 - val_accuracy:
0.5006 - val_loss: 1.4026
Epoch 106/500
352/352 - 3s - 9ms/step - accuracy: 0.5074 - loss: 1.3852 - val_accuracy: 0.4976
- val_loss: 1.4020
Epoch 107/500
352/352 - 3s - 9ms/step - accuracy: 0.5074 - loss: 1.3824 - val_accuracy: 0.5010
- val_loss: 1.3992
Epoch 108/500
352/352 - 3s - 9ms/step - accuracy: 0.5091 - loss: 1.3823 - val_accuracy: 0.5006
- val_loss: 1.3984
Epoch 109/500
352/352 - 3s - 9ms/step - accuracy: 0.5104 - loss: 1.3798 - val_accuracy: 0.4988
- val_loss: 1.3979
```

```
Epoch 110/500
352/352 - 3s - 10ms/step - accuracy: 0.5061 - loss: 1.3833 - val_accuracy:
0.4994 - val_loss: 1.3979
Epoch 111/500
352/352 - 4s - 10ms/step - accuracy: 0.5082 - loss: 1.3784 - val_accuracy:
0.5016 - val_loss: 1.3972
Epoch 112/500
352/352 - 3s - 10ms/step - accuracy: 0.5080 - loss: 1.3792 - val_accuracy:
0.4992 - val_loss: 1.3955
Epoch 113/500
352/352 - 3s - 10ms/step - accuracy: 0.5125 - loss: 1.3746 - val_accuracy:
0.5016 - val_loss: 1.3996
Epoch 114/500
352/352 - 3s - 10ms/step - accuracy: 0.5103 - loss: 1.3736 - val_accuracy:
0.5024 - val_loss: 1.3939
Epoch 115/500
352/352 - 3s - 10ms/step - accuracy: 0.5076 - loss: 1.3727 - val_accuracy:
0.5030 - val_loss: 1.3920
Epoch 116/500
352/352 - 3s - 10ms/step - accuracy: 0.5100 - loss: 1.3726 - val_accuracy:
0.5030 - val_loss: 1.3942
Epoch 117/500
352/352 - 3s - 10ms/step - accuracy: 0.5092 - loss: 1.3718 - val_accuracy:
0.4992 - val_loss: 1.3932
Epoch 118/500
352/352 - 4s - 10ms/step - accuracy: 0.5092 - loss: 1.3751 - val_accuracy:
0.5046 - val_loss: 1.3913
Epoch 119/500
352/352 - 4s - 11ms/step - accuracy: 0.5120 - loss: 1.3666 - val_accuracy:
0.5030 - val_loss: 1.3895
Epoch 120/500
352/352 - 4s - 10ms/step - accuracy: 0.5098 - loss: 1.3678 - val_accuracy:
0.4988 - val_loss: 1.3928
Epoch 121/500
352/352 - 4s - 12ms/step - accuracy: 0.5092 - loss: 1.3709 - val_accuracy:
0.5070 - val_loss: 1.3875
Epoch 122/500
352/352 - 5s - 13ms/step - accuracy: 0.5122 - loss: 1.3676 - val_accuracy:
0.5038 - val_loss: 1.3877
Epoch 123/500
352/352 - 4s - 10ms/step - accuracy: 0.5118 - loss: 1.3665 - val_accuracy:
0.5058 - val_loss: 1.3886
Epoch 124/500
352/352 - 4s - 10ms/step - accuracy: 0.5121 - loss: 1.3699 - val_accuracy:
0.5020 - val_loss: 1.3902
Epoch 125/500
352/352 - 4s - 11ms/step - accuracy: 0.5123 - loss: 1.3636 - val_accuracy:
0.5046 - val_loss: 1.3861
```

```
Epoch 126/500
352/352 - 4s - 11ms/step - accuracy: 0.5154 - loss: 1.3591 - val_accuracy:
0.5026 - val_loss: 1.3855
Epoch 127/500
352/352 - 4s - 12ms/step - accuracy: 0.5125 - loss: 1.3635 - val_accuracy:
0.5022 - val_loss: 1.3863
Epoch 128/500
352/352 - 4s - 10ms/step - accuracy: 0.5163 - loss: 1.3614 - val_accuracy:
0.5054 - val_loss: 1.3842
Epoch 129/500
352/352 - 4s - 12ms/step - accuracy: 0.5157 - loss: 1.3562 - val_accuracy:
0.5050 - val_loss: 1.3830
Epoch 130/500
352/352 - 6s - 16ms/step - accuracy: 0.5173 - loss: 1.3605 - val_accuracy:
0.5012 - val_loss: 1.3882
Epoch 131/500
352/352 - 5s - 14ms/step - accuracy: 0.5170 - loss: 1.3569 - val_accuracy:
0.5042 - val_loss: 1.3847
Epoch 132/500
352/352 - 4s - 11ms/step - accuracy: 0.5154 - loss: 1.3571 - val_accuracy:
0.5050 - val_loss: 1.3871
Epoch 133/500
352/352 - 5s - 14ms/step - accuracy: 0.5185 - loss: 1.3532 - val_accuracy:
0.5076 - val_loss: 1.3800
Epoch 134/500
352/352 - 5s - 14ms/step - accuracy: 0.5181 - loss: 1.3555 - val_accuracy:
0.5044 - val_loss: 1.3808
Epoch 135/500
352/352 - 4s - 13ms/step - accuracy: 0.5168 - loss: 1.3541 - val_accuracy:
0.5024 - val_loss: 1.3825
Epoch 136/500
352/352 - 4s - 12ms/step - accuracy: 0.5182 - loss: 1.3513 - val_accuracy:
0.5058 - val_loss: 1.3812
Epoch 137/500
352/352 - 4s - 12ms/step - accuracy: 0.5166 - loss: 1.3571 - val_accuracy:
0.5040 - val_loss: 1.3805
Epoch 138/500
352/352 - 4s - 12ms/step - accuracy: 0.5191 - loss: 1.3504 - val_accuracy:
0.5080 - val_loss: 1.3765
Epoch 139/500
352/352 - 5s - 13ms/step - accuracy: 0.5168 - loss: 1.3500 - val_accuracy:
0.5066 - val_loss: 1.3819
Epoch 140/500
352/352 - 5s - 14ms/step - accuracy: 0.5187 - loss: 1.3469 - val_accuracy:
0.5044 - val_loss: 1.3814
Epoch 141/500
352/352 - 4s - 12ms/step - accuracy: 0.5215 - loss: 1.3445 - val_accuracy:
0.5074 - val_loss: 1.3754
```

```
Epoch 142/500
352/352 - 4s - 11ms/step - accuracy: 0.5217 - loss: 1.3465 - val_accuracy:
0.5080 - val_loss: 1.3759
Epoch 143/500
352/352 - 4s - 11ms/step - accuracy: 0.5204 - loss: 1.3486 - val_accuracy:
0.5104 - val_loss: 1.3756
Epoch 144/500
352/352 - 3s - 10ms/step - accuracy: 0.5202 - loss: 1.3441 - val_accuracy:
0.5096 - val_loss: 1.3744
Epoch 145/500
352/352 - 3s - 10ms/step - accuracy: 0.5204 - loss: 1.3441 - val_accuracy:
0.5072 - val_loss: 1.3755
Epoch 146/500
352/352 - 4s - 10ms/step - accuracy: 0.5200 - loss: 1.3387 - val_accuracy:
0.5008 - val_loss: 1.3794
Epoch 147/500
352/352 - 4s - 10ms/step - accuracy: 0.5225 - loss: 1.3414 - val_accuracy:
0.5056 - val_loss: 1.3747
Epoch 148/500
352/352 - 4s - 10ms/step - accuracy: 0.5216 - loss: 1.3401 - val_accuracy:
0.5098 - val_loss: 1.3760
Epoch 149/500
352/352 - 3s - 10ms/step - accuracy: 0.5234 - loss: 1.3389 - val_accuracy:
0.5096 - val_loss: 1.3726
Epoch 150/500
352/352 - 3s - 10ms/step - accuracy: 0.5216 - loss: 1.3394 - val_accuracy:
0.5076 - val_loss: 1.3700
Epoch 151/500
352/352 - 3s - 10ms/step - accuracy: 0.5220 - loss: 1.3342 - val_accuracy:
0.5088 - val_loss: 1.3728
Epoch 152/500
352/352 - 3s - 10ms/step - accuracy: 0.5262 - loss: 1.3343 - val_accuracy:
0.5098 - val_loss: 1.3694
Epoch 153/500
352/352 - 3s - 10ms/step - accuracy: 0.5234 - loss: 1.3345 - val_accuracy:
0.5116 - val_loss: 1.3691
Epoch 154/500
352/352 - 4s - 10ms/step - accuracy: 0.5219 - loss: 1.3384 - val_accuracy:
0.5070 - val_loss: 1.3725
Epoch 155/500
352/352 - 4s - 10ms/step - accuracy: 0.5237 - loss: 1.3319 - val_accuracy:
0.5062 - val_loss: 1.3706
Epoch 156/500
352/352 - 3s - 10ms/step - accuracy: 0.5232 - loss: 1.3356 - val_accuracy:
0.5102 - val_loss: 1.3698
Epoch 157/500
352/352 - 4s - 10ms/step - accuracy: 0.5245 - loss: 1.3322 - val_accuracy:
0.5114 - val_loss: 1.3675
```

```
Epoch 158/500
352/352 - 4s - 10ms/step - accuracy: 0.5268 - loss: 1.3292 - val_accuracy:
0.5106 - val_loss: 1.3694
Epoch 159/500
352/352 - 3s - 10ms/step - accuracy: 0.5251 - loss: 1.3311 - val_accuracy:
0.5084 - val_loss: 1.3664
Epoch 160/500
352/352 - 4s - 11ms/step - accuracy: 0.5258 - loss: 1.3308 - val_accuracy:
0.5108 - val_loss: 1.3662
Epoch 161/500
352/352 - 3s - 10ms/step - accuracy: 0.5258 - loss: 1.3261 - val_accuracy:
0.5118 - val_loss: 1.3681
Epoch 162/500
352/352 - 3s - 10ms/step - accuracy: 0.5288 - loss: 1.3232 - val_accuracy:
0.5106 - val_loss: 1.3642
Epoch 163/500
352/352 - 4s - 10ms/step - accuracy: 0.5280 - loss: 1.3240 - val_accuracy:
0.5092 - val_loss: 1.3673
Epoch 164/500
352/352 - 4s - 10ms/step - accuracy: 0.5286 - loss: 1.3230 - val_accuracy:
0.5122 - val_loss: 1.3649
Epoch 165/500
352/352 - 4s - 11ms/step - accuracy: 0.5266 - loss: 1.3249 - val_accuracy:
0.5126 - val_loss: 1.3639
Epoch 166/500
352/352 - 4s - 11ms/step - accuracy: 0.5263 - loss: 1.3231 - val_accuracy:
0.5120 - val_loss: 1.3666
Epoch 167/500
352/352 - 4s - 10ms/step - accuracy: 0.5270 - loss: 1.3209 - val_accuracy:
0.5138 - val_loss: 1.3605
Epoch 168/500
352/352 - 4s - 10ms/step - accuracy: 0.5331 - loss: 1.3137 - val_accuracy:
0.5138 - val_loss: 1.3616
Epoch 169/500
352/352 - 4s - 10ms/step - accuracy: 0.5279 - loss: 1.3210 - val_accuracy:
0.5120 - val_loss: 1.3619
Epoch 170/500
352/352 - 3s - 10ms/step - accuracy: 0.5308 - loss: 1.3189 - val_accuracy:
0.5120 - val_loss: 1.3624
Epoch 171/500
352/352 - 3s - 10ms/step - accuracy: 0.5279 - loss: 1.3176 - val_accuracy:
0.5138 - val_loss: 1.3586
Epoch 172/500
352/352 - 3s - 10ms/step - accuracy: 0.5281 - loss: 1.3192 - val_accuracy:
0.5138 - val_loss: 1.3587
Epoch 173/500
352/352 - 3s - 10ms/step - accuracy: 0.5294 - loss: 1.3183 - val_accuracy:
0.5142 - val_loss: 1.3585
```

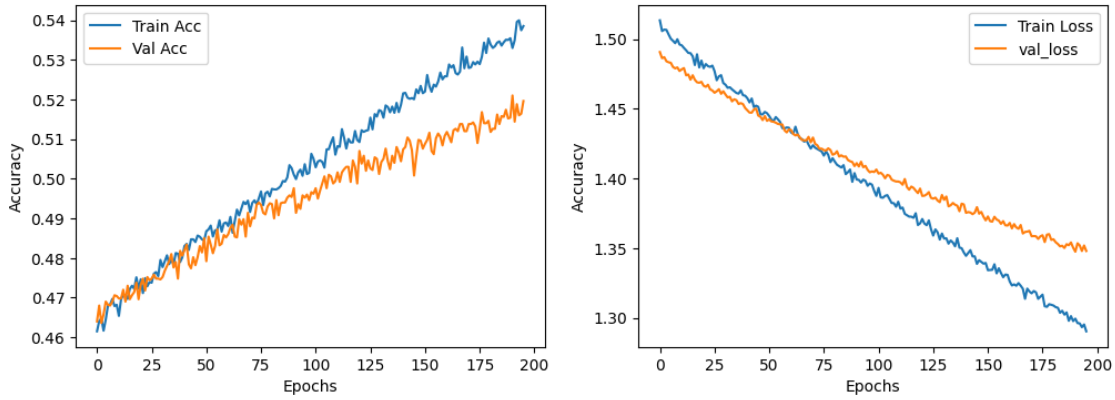
```
Epoch 174/500
352/352 - 3s - 10ms/step - accuracy: 0.5288 - loss: 1.3137 - val_accuracy:
0.5132 - val_loss: 1.3567
Epoch 175/500
352/352 - 4s - 10ms/step - accuracy: 0.5295 - loss: 1.3152 - val_accuracy:
0.5090 - val_loss: 1.3585
Epoch 176/500
352/352 - 3s - 9ms/step - accuracy: 0.5289 - loss: 1.3167 - val_accuracy: 0.5126
- val_loss: 1.3593
Epoch 177/500
352/352 - 3s - 10ms/step - accuracy: 0.5308 - loss: 1.3083 - val_accuracy:
0.5168 - val_loss: 1.3544
Epoch 178/500
352/352 - 3s - 10ms/step - accuracy: 0.5343 - loss: 1.3079 - val_accuracy:
0.5140 - val_loss: 1.3597
Epoch 179/500
352/352 - 3s - 10ms/step - accuracy: 0.5317 - loss: 1.3098 - val_accuracy:
0.5140 - val_loss: 1.3601
Epoch 180/500
352/352 - 3s - 10ms/step - accuracy: 0.5354 - loss: 1.3094 - val_accuracy:
0.5146 - val_loss: 1.3560
Epoch 181/500
352/352 - 3s - 10ms/step - accuracy: 0.5338 - loss: 1.3088 - val_accuracy:
0.5118 - val_loss: 1.3564
Epoch 182/500
352/352 - 3s - 10ms/step - accuracy: 0.5330 - loss: 1.3077 - val_accuracy:
0.5126 - val_loss: 1.3543
Epoch 183/500
352/352 - 3s - 10ms/step - accuracy: 0.5334 - loss: 1.3072 - val_accuracy:
0.5126 - val_loss: 1.3530
Epoch 184/500
352/352 - 3s - 10ms/step - accuracy: 0.5343 - loss: 1.3036 - val_accuracy:
0.5162 - val_loss: 1.3513
Epoch 185/500
352/352 - 4s - 11ms/step - accuracy: 0.5346 - loss: 1.3051 - val_accuracy:
0.5138 - val_loss: 1.3517
Epoch 186/500
352/352 - 4s - 12ms/step - accuracy: 0.5336 - loss: 1.3023 - val_accuracy:
0.5158 - val_loss: 1.3501
Epoch 187/500
352/352 - 4s - 12ms/step - accuracy: 0.5344 - loss: 1.3039 - val_accuracy:
0.5156 - val_loss: 1.3528
Epoch 188/500
352/352 - 4s - 12ms/step - accuracy: 0.5351 - loss: 1.2979 - val_accuracy:
0.5174 - val_loss: 1.3521
Epoch 189/500
352/352 - 4s - 12ms/step - accuracy: 0.5350 - loss: 1.3012 - val_accuracy:
0.5152 - val_loss: 1.3541
```

```
Epoch 190/500
352/352 - 4s - 11ms/step - accuracy: 0.5354 - loss: 1.2977 - val_accuracy:
0.5154 - val_loss: 1.3504
Epoch 191/500
352/352 - 5s - 14ms/step - accuracy: 0.5330 - loss: 1.2994 - val_accuracy:
0.5210 - val_loss: 1.3475
Epoch 192/500
352/352 - 4s - 11ms/step - accuracy: 0.5349 - loss: 1.2962 - val_accuracy:
0.5144 - val_loss: 1.3535
Epoch 193/500
352/352 - 4s - 12ms/step - accuracy: 0.5396 - loss: 1.2960 - val_accuracy:
0.5188 - val_loss: 1.3520
Epoch 194/500
352/352 - 4s - 12ms/step - accuracy: 0.5400 - loss: 1.2933 - val_accuracy:
0.5160 - val_loss: 1.3480
Epoch 195/500
352/352 - 4s - 11ms/step - accuracy: 0.5375 - loss: 1.2952 - val_accuracy:
0.5164 - val_loss: 1.3519
Epoch 196/500
352/352 - 4s - 11ms/step - accuracy: 0.5385 - loss: 1.2903 - val_accuracy:
0.5196 - val_loss: 1.3480
Epoch 196: early stopping
Restoring model weights from the end of the best epoch: 191.
```

[28]:
```
score = model.evaluate(x_test_flat,y_test_cat,verbose = 2)
print("Test loss:", score[0])
print(f"Test Accuracy:{score[1]*100:.2f}%")
```

```
313/313 - 1s - 3ms/step - accuracy: 0.5292 - loss: 1.3208
Test loss: 1.3208357095718384
Test Accuracy:52.92%
```

[29]:
```
plt.figure(figsize=(12,4))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label = 'val_loss')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```



•

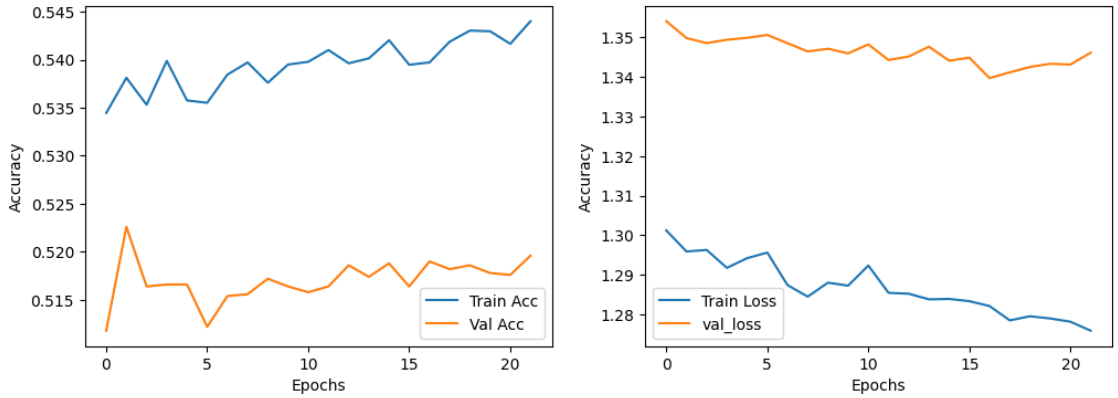
0.4 Question 3: Try cifar10 dataset classification problem with polynomialdecay with power = 2 case and see if there are any improvements.

[30]:
```
lr_schedule = keras.optimizers.schedules.PolynomialDecay(
initial_learning_rate = 0.01,
decay_steps = 5,
end_learning_rate = 0.001,
power = 2,
cycle = False
)
optimizer = SGD(learning_rate=lr_schedule)
model.compile(optimizer=optimizer, loss = 'categorical_crossentropy', metrics =␣
↪['accuracy'])
estop = EarlyStopping(monitor = 'val_loss', min_delta = 1e-4, mode =␣
↪'min',patience = 5, verbose = 2, restore_best_weights = True)
history = model.fit(x_subtrain_flat,y_subtrain_cat, batch_size=128, epochs␣
↪=500, verbose = 2, validation_data=(x_valid_flat,y_valid_cat),␣
↪callbacks=estop)
score = model.evaluate(x_test_flat,y_test_cat,verbose = 2)
print("Test loss:", score[0])
print(f"Test Accuracy:{score[1]*100:.2f}%")
plt.figure(figsize=(12,4))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
```

```
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label = 'val_loss')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```

```
Epoch 1/500
352/352 - 6s - 17ms/step - accuracy: 0.5344 - loss: 1.3012 - val_accuracy:
0.5118 - val_loss: 1.3539
Epoch 2/500
352/352 - 4s - 12ms/step - accuracy: 0.5381 - loss: 1.2959 - val_accuracy:
0.5226 - val_loss: 1.3497
Epoch 3/500
352/352 - 4s - 10ms/step - accuracy: 0.5353 - loss: 1.2963 - val_accuracy:
0.5164 - val_loss: 1.3484
Epoch 4/500
352/352 - 3s - 10ms/step - accuracy: 0.5399 - loss: 1.2918 - val_accuracy:
0.5166 - val_loss: 1.3493
Epoch 5/500
352/352 - 3s - 10ms/step - accuracy: 0.5358 - loss: 1.2942 - val_accuracy:
0.5166 - val_loss: 1.3498
Epoch 6/500
352/352 - 3s - 10ms/step - accuracy: 0.5355 - loss: 1.2956 - val_accuracy:
0.5122 - val_loss: 1.3505
Epoch 7/500
352/352 - 4s - 10ms/step - accuracy: 0.5384 - loss: 1.2874 - val_accuracy:
0.5154 - val_loss: 1.3484
Epoch 8/500
352/352 - 4s - 10ms/step - accuracy: 0.5397 - loss: 1.2845 - val_accuracy:
0.5156 - val_loss: 1.3463
Epoch 9/500
352/352 - 3s - 10ms/step - accuracy: 0.5376 - loss: 1.2881 - val_accuracy:
0.5172 - val_loss: 1.3470
Epoch 10/500
352/352 - 4s - 10ms/step - accuracy: 0.5395 - loss: 1.2873 - val_accuracy:
0.5164 - val_loss: 1.3458
Epoch 11/500
352/352 - 4s - 10ms/step - accuracy: 0.5398 - loss: 1.2924 - val_accuracy:
0.5158 - val_loss: 1.3481
Epoch 12/500
352/352 - 4s - 10ms/step - accuracy: 0.5410 - loss: 1.2855 - val_accuracy:
0.5164 - val_loss: 1.3442
Epoch 13/500
352/352 - 4s - 10ms/step - accuracy: 0.5396 - loss: 1.2853 - val_accuracy:
```

```
0.5186 - val_loss: 1.3450
Epoch 14/500
352/352 - 4s - 10ms/step - accuracy: 0.5401 - loss: 1.2839 - val_accuracy:
0.5174 - val_loss: 1.3475
Epoch 15/500
352/352 - 4s - 11ms/step - accuracy: 0.5420 - loss: 1.2840 - val_accuracy:
0.5188 - val_loss: 1.3440
Epoch 16/500
352/352 - 4s - 11ms/step - accuracy: 0.5395 - loss: 1.2834 - val_accuracy:
0.5164 - val_loss: 1.3448
Epoch 17/500
352/352 - 4s - 11ms/step - accuracy: 0.5397 - loss: 1.2822 - val_accuracy:
0.5190 - val_loss: 1.3396
Epoch 18/500
352/352 - 4s - 11ms/step - accuracy: 0.5419 - loss: 1.2785 - val_accuracy:
0.5182 - val_loss: 1.3411
Epoch 19/500
352/352 - 4s - 11ms/step - accuracy: 0.5430 - loss: 1.2796 - val_accuracy:
0.5186 - val_loss: 1.3424
Epoch 20/500
352/352 - 4s - 10ms/step - accuracy: 0.5430 - loss: 1.2790 - val_accuracy:
0.5178 - val_loss: 1.3432
Epoch 21/500
352/352 - 4s - 10ms/step - accuracy: 0.5416 - loss: 1.2782 - val_accuracy:
0.5176 - val_loss: 1.3430
Epoch 22/500
352/352 - 4s - 10ms/step - accuracy: 0.5440 - loss: 1.2760 - val_accuracy:
0.5196 - val_loss: 1.3460
Epoch 22: early stopping
Restoring model weights from the end of the best epoch: 17.
313/313 - 1s - 3ms/step - accuracy: 0.5311 - loss: 1.3139
Test loss: 1.3138818740844727
Test Accuracy:53.11%
```



-

0.5 Question 4: Next is an exponential decay scheduler which uses this rule for decay. The decay rate is again a hyperparameter.

[31]:
```
lr_schedule = keras.optimizers.schedules.ExponentialDecay(
initial_learning_rate = 0.01,
decay_steps = 10,
decay_rate = 0.96,
staircase = True # false - smooth decay, True = step-wise
)
print("Step | Learning Rate")
for step in range(0,100):
    lr_value = lr_schedule(step).numpy()
    print(f"{step} --> {lr_value}")
```

```
Step | Learning Rate
0 --> 0.009999999776482582
1 --> 0.009999999776482582
2 --> 0.009999999776482582
3 --> 0.009999999776482582
4 --> 0.009999999776482582
5 --> 0.009999999776482582
6 --> 0.009999999776482582
7 --> 0.009999999776482582
8 --> 0.009999999776482582
9 --> 0.009999999776482582
10 --> 0.009599999524652958
11 --> 0.009599999524652958
12 --> 0.009599999524652958
13 --> 0.009599999524652958
14 --> 0.009599999524652958
15 --> 0.009599999524652958
16 --> 0.009599999524652958
17 --> 0.009599999524652958
18 --> 0.009599999524652958
19 --> 0.009599999524652958
20 --> 0.009215999394655228
21 --> 0.009215999394655228
22 --> 0.009215999394655228
23 --> 0.009215999394655228
```

```
24 --> 0.009215999394655228
25 --> 0.009215999394655228
26 --> 0.009215999394655228
27 --> 0.009215999394655228
28 --> 0.009215999394655228
29 --> 0.009215999394655228
30 --> 0.00884735956788063
31 --> 0.00884735956788063
32 --> 0.00884735956788063
33 --> 0.00884735956788063
34 --> 0.00884735956788063
35 --> 0.00884735956788063
36 --> 0.00884735956788063
37 --> 0.00884735956788063
38 --> 0.00884735956788063
39 --> 0.00884735956788063
40 --> 0.008493464440107346
41 --> 0.008493464440107346
42 --> 0.008493464440107346
43 --> 0.008493464440107346
44 --> 0.008493464440107346
45 --> 0.008493464440107346
46 --> 0.008493464440107346
47 --> 0.008493464440107346
48 --> 0.008493464440107346
49 --> 0.008493464440107346
50 --> 0.008153725415468216
51 --> 0.008153725415468216
52 --> 0.008153725415468216
53 --> 0.008153725415468216
54 --> 0.008153725415468216
55 --> 0.008153725415468216
56 --> 0.008153725415468216
57 --> 0.008153725415468216
58 --> 0.008153725415468216
59 --> 0.008153725415468216
60 --> 0.00782757718116045
61 --> 0.00782757718116045
62 --> 0.00782757718116045
63 --> 0.00782757718116045
64 --> 0.00782757718116045
65 --> 0.00782757718116045
66 --> 0.00782757718116045
67 --> 0.00782757718116045
68 --> 0.00782757718116045
69 --> 0.00782757718116045
70 --> 0.007514473516494036
71 --> 0.007514473516494036
```

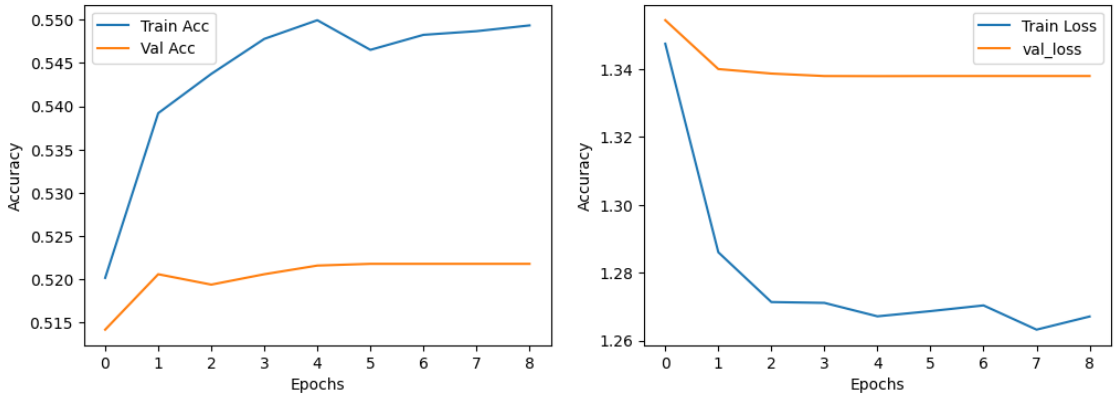
```
72 --> 0.007514473516494036
73 --> 0.007514473516494036
74 --> 0.007514473516494036
75 --> 0.007514473516494036
76 --> 0.007514473516494036
77 --> 0.007514473516494036
78 --> 0.007514473516494036
79 --> 0.007514473516494036
80 --> 0.007213894743472338
81 --> 0.007213894743472338
82 --> 0.007213894743472338
83 --> 0.007213894743472338
84 --> 0.007213894743472338
85 --> 0.007213894743472338
86 --> 0.007213894743472338
87 --> 0.007213894743472338
88 --> 0.007213894743472338
89 --> 0.007213894743472338
90 --> 0.006925338413566351
91 --> 0.006925338413566351
92 --> 0.006925338413566351
93 --> 0.006925338413566351
94 --> 0.006925338413566351
95 --> 0.006925338413566351
96 --> 0.006925338413566351
97 --> 0.006925338413566351
98 --> 0.006925338413566351
99 --> 0.006925338413566351
```

0.5.1 with exponential decay in learning rate schedular

[32]:
```
optimizer = SGD(learning_rate=lr_schedule)
model.compile(optimizer=optimizer, loss = 'categorical_crossentropy', metrics =␣
 ↪['accuracy'])
estop = EarlyStopping(monitor = 'val_loss', min_delta = 1e-4, mode =␣
 ↪'min',patience = 5, verbose = 2, restore_best_weights = True)
history = model.fit(x_subtrain_flat,y_subtrain_cat, batch_size=128, epochs␣
 ↪=500, verbose = 2, validation_data=(x_valid_flat,y_valid_cat),␣
 ↪callbacks=estop)
score = model.evaluate(x_test_flat,y_test_cat,verbose = 2)
print("Test loss:", score[0])
print(f"Test Accuracy:{score[1]*100:.2f}%")
plt.figure(figsize=(12,4))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
```

```
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label = 'val_loss')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```

```
Epoch 1/500
352/352 - 6s - 16ms/step - accuracy: 0.5202 - loss: 1.3475 - val_accuracy:
0.5142 - val_loss: 1.3544
Epoch 2/500
352/352 - 4s - 11ms/step - accuracy: 0.5392 - loss: 1.2861 - val_accuracy:
0.5206 - val_loss: 1.3401
Epoch 3/500
352/352 - 4s - 10ms/step - accuracy: 0.5437 - loss: 1.2714 - val_accuracy:
0.5194 - val_loss: 1.3387
Epoch 4/500
352/352 - 4s - 10ms/step - accuracy: 0.5478 - loss: 1.2711 - val_accuracy:
0.5206 - val_loss: 1.3380
Epoch 5/500
352/352 - 4s - 10ms/step - accuracy: 0.5499 - loss: 1.2672 - val_accuracy:
0.5216 - val_loss: 1.3380
Epoch 6/500
352/352 - 4s - 10ms/step - accuracy: 0.5465 - loss: 1.2687 - val_accuracy:
0.5218 - val_loss: 1.3380
Epoch 7/500
352/352 - 4s - 10ms/step - accuracy: 0.5482 - loss: 1.2704 - val_accuracy:
0.5218 - val_loss: 1.3380
Epoch 8/500
352/352 - 4s - 10ms/step - accuracy: 0.5487 - loss: 1.2633 - val_accuracy:
0.5218 - val_loss: 1.3380
Epoch 9/500
352/352 - 4s - 10ms/step - accuracy: 0.5493 - loss: 1.2671 - val_accuracy:
0.5218 - val_loss: 1.3380
Epoch 9: early stopping
Restoring model weights from the end of the best epoch: 4.
313/313 - 1s - 3ms/step - accuracy: 0.5317 - loss: 1.3105
Test loss: 1.3105202913284302
Test Accuracy:53.17%
```



0.6 Question 5a: We can also use ReduceLROnPlateau to deal with the training part in a different way compared to last two types. Based on the validation loss we can decide when to reduce the learning rate if you are stuck with training part.

[33]:
```
from keras.callbacks import ReduceLROnPlateau
optimizer = SGD(learning_rate = 0.01)
model.compile(optimizer = optimizer, loss = 'categorical_crossentropy', metrics␣
 ↪= ['accuracy'])

reduce_lr = ReduceLROnPlateau(
    monitor = 'val_loss',
    factor = 0.5,
    patience = 3,
    min_delta=0.01,
    verbose = 1,
    min_lr = 1e-5

)

history = model.fit(x_subtrain_flat, y_subtrain_cat, batch_size = 128, epochs =␣
 ↪500, verbose = 2, validation_data = (x_valid_flat, y_valid_cat), callbacks =␣
 ↪[reduce_lr])
score = model.evaluate(x_test_flat,y_test_cat,verbose = 2)
print("Test loss:", score[0])
print(f"Test Accuracy:{score[1]*100:.2f}%")
plt.figure(figsize=(12,4))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
plt.xlabel('Epochs')
```

```
plt.ylabel('Accuracy')
plt.legend()
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label = 'val_loss')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```

```
Epoch 1/500
352/352 - 5s - 15ms/step - accuracy: 0.4967 - loss: 1.4152 - val_accuracy:
0.5016 - val_loss: 1.3878 - learning_rate: 0.0100
Epoch 2/500
352/352 - 4s - 10ms/step - accuracy: 0.5040 - loss: 1.3856 - val_accuracy:
0.4854 - val_loss: 1.4130 - learning_rate: 0.0100
Epoch 3/500
352/352 - 4s - 10ms/step - accuracy: 0.5103 - loss: 1.3779 - val_accuracy:
0.4926 - val_loss: 1.4101 - learning_rate: 0.0100
Epoch 4/500

Epoch 4: ReduceLROnPlateau reducing learning rate to 0.004999999888241291.
352/352 - 4s - 12ms/step - accuracy: 0.5095 - loss: 1.3711 - val_accuracy:
0.4716 - val_loss: 1.4670 - learning_rate: 0.0100
Epoch 5/500
352/352 - 4s - 11ms/step - accuracy: 0.5369 - loss: 1.3013 - val_accuracy:
0.5130 - val_loss: 1.3592 - learning_rate: 0.0050
Epoch 6/500
352/352 - 4s - 10ms/step - accuracy: 0.5378 - loss: 1.2924 - val_accuracy:
0.5158 - val_loss: 1.3577 - learning_rate: 0.0050
Epoch 7/500
352/352 - 4s - 10ms/step - accuracy: 0.5392 - loss: 1.2892 - val_accuracy:
0.5136 - val_loss: 1.3550 - learning_rate: 0.0050
Epoch 8/500

Epoch 8: ReduceLROnPlateau reducing learning rate to 0.0024999999441206455.
352/352 - 4s - 11ms/step - accuracy: 0.5421 - loss: 1.2837 - val_accuracy:
0.5152 - val_loss: 1.3537 - learning_rate: 0.0050
Epoch 9/500
352/352 - 4s - 10ms/step - accuracy: 0.5504 - loss: 1.2559 - val_accuracy:
0.5158 - val_loss: 1.3398 - learning_rate: 0.0025
Epoch 10/500
352/352 - 4s - 11ms/step - accuracy: 0.5510 - loss: 1.2518 - val_accuracy:
0.5266 - val_loss: 1.3260 - learning_rate: 0.0025
Epoch 11/500
352/352 - 4s - 10ms/step - accuracy: 0.5525 - loss: 1.2539 - val_accuracy:
```

```
0.5244 - val_loss: 1.3318 - learning_rate: 0.0025
Epoch 12/500
352/352 - 4s - 10ms/step - accuracy: 0.5519 - loss: 1.2511 - val_accuracy:
0.5224 - val_loss: 1.3261 - learning_rate: 0.0025
Epoch 13/500

Epoch 13: ReduceLROnPlateau reducing learning rate to 0.0012499999720603228.
352/352 - 4s - 11ms/step - accuracy: 0.5527 - loss: 1.2450 - val_accuracy:
0.5282 - val_loss: 1.3245 - learning_rate: 0.0025
Epoch 14/500
352/352 - 4s - 11ms/step - accuracy: 0.5593 - loss: 1.2351 - val_accuracy:
0.5250 - val_loss: 1.3242 - learning_rate: 0.0012
Epoch 15/500
352/352 - 4s - 11ms/step - accuracy: 0.5588 - loss: 1.2340 - val_accuracy:
0.5294 - val_loss: 1.3207 - learning_rate: 0.0012
Epoch 16/500

Epoch 16: ReduceLROnPlateau reducing learning rate to 0.0006249999860301614.
352/352 - 4s - 10ms/step - accuracy: 0.5613 - loss: 1.2278 - val_accuracy:
0.5298 - val_loss: 1.3199 - learning_rate: 0.0012
Epoch 17/500
352/352 - 4s - 10ms/step - accuracy: 0.5577 - loss: 1.2285 - val_accuracy:
0.5302 - val_loss: 1.3151 - learning_rate: 6.2500e-04
Epoch 18/500
352/352 - 4s - 10ms/step - accuracy: 0.5619 - loss: 1.2242 - val_accuracy:
0.5348 - val_loss: 1.3131 - learning_rate: 6.2500e-04
Epoch 19/500
352/352 - 4s - 10ms/step - accuracy: 0.5630 - loss: 1.2231 - val_accuracy:
0.5328 - val_loss: 1.3143 - learning_rate: 6.2500e-04
Epoch 20/500

Epoch 20: ReduceLROnPlateau reducing learning rate to 0.0003124999930150807.
352/352 - 4s - 10ms/step - accuracy: 0.5636 - loss: 1.2205 - val_accuracy:
0.5304 - val_loss: 1.3156 - learning_rate: 6.2500e-04
Epoch 21/500
352/352 - 4s - 10ms/step - accuracy: 0.5664 - loss: 1.2187 - val_accuracy:
0.5302 - val_loss: 1.3148 - learning_rate: 3.1250e-04
Epoch 22/500
352/352 - 4s - 10ms/step - accuracy: 0.5665 - loss: 1.2157 - val_accuracy:
0.5322 - val_loss: 1.3141 - learning_rate: 3.1250e-04
Epoch 23/500

Epoch 23: ReduceLROnPlateau reducing learning rate to 0.00015624999650754035.
352/352 - 4s - 10ms/step - accuracy: 0.5636 - loss: 1.2172 - val_accuracy:
0.5340 - val_loss: 1.3129 - learning_rate: 3.1250e-04
Epoch 24/500
352/352 - 4s - 11ms/step - accuracy: 0.5645 - loss: 1.2130 - val_accuracy:
0.5330 - val_loss: 1.3128 - learning_rate: 1.5625e-04
```

```
Epoch 25/500
352/352 - 4s - 11ms/step - accuracy: 0.5656 - loss: 1.2164 - val_accuracy:
0.5334 - val_loss: 1.3128 - learning_rate: 1.5625e-04
Epoch 26/500

Epoch 26: ReduceLROnPlateau reducing learning rate to 7.812499825377017e-05.
352/352 - 4s - 12ms/step - accuracy: 0.5638 - loss: 1.2190 - val_accuracy:
0.5336 - val_loss: 1.3129 - learning_rate: 1.5625e-04
Epoch 27/500
352/352 - 4s - 11ms/step - accuracy: 0.5670 - loss: 1.2169 - val_accuracy:
0.5332 - val_loss: 1.3123 - learning_rate: 7.8125e-05
Epoch 28/500
352/352 - 4s - 10ms/step - accuracy: 0.5651 - loss: 1.2188 - val_accuracy:
0.5342 - val_loss: 1.3123 - learning_rate: 7.8125e-05
Epoch 29/500

Epoch 29: ReduceLROnPlateau reducing learning rate to 3.9062499126885086e-05.
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2131 - val_accuracy:
0.5336 - val_loss: 1.3127 - learning_rate: 7.8125e-05
Epoch 30/500
352/352 - 4s - 11ms/step - accuracy: 0.5685 - loss: 1.2108 - val_accuracy:
0.5338 - val_loss: 1.3125 - learning_rate: 3.9062e-05
Epoch 31/500
352/352 - 4s - 10ms/step - accuracy: 0.5682 - loss: 1.2104 - val_accuracy:
0.5344 - val_loss: 1.3124 - learning_rate: 3.9062e-05
Epoch 32/500

Epoch 32: ReduceLROnPlateau reducing learning rate to 1.9531249563442543e-05.
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2150 - val_accuracy:
0.5328 - val_loss: 1.3126 - learning_rate: 3.9062e-05
Epoch 33/500
352/352 - 4s - 10ms/step - accuracy: 0.5675 - loss: 1.2134 - val_accuracy:
0.5326 - val_loss: 1.3124 - learning_rate: 1.9531e-05
Epoch 34/500
352/352 - 4s - 11ms/step - accuracy: 0.5656 - loss: 1.2138 - val_accuracy:
0.5336 - val_loss: 1.3124 - learning_rate: 1.9531e-05
Epoch 35/500

Epoch 35: ReduceLROnPlateau reducing learning rate to 1e-05.
352/352 - 4s - 10ms/step - accuracy: 0.5687 - loss: 1.2147 - val_accuracy:
0.5334 - val_loss: 1.3122 - learning_rate: 1.9531e-05
Epoch 36/500
352/352 - 4s - 10ms/step - accuracy: 0.5642 - loss: 1.2153 - val_accuracy:
0.5340 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 37/500
352/352 - 4s - 10ms/step - accuracy: 0.5661 - loss: 1.2160 - val_accuracy:
0.5340 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 38/500
```

```
352/352 - 5s - 15ms/step - accuracy: 0.5654 - loss: 1.2122 - val_accuracy:
0.5342 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 39/500
352/352 - 4s - 12ms/step - accuracy: 0.5649 - loss: 1.2130 - val_accuracy:
0.5344 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 40/500
352/352 - 4s - 12ms/step - accuracy: 0.5662 - loss: 1.2143 - val_accuracy:
0.5330 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 41/500
352/352 - 4s - 12ms/step - accuracy: 0.5666 - loss: 1.2131 - val_accuracy:
0.5328 - val_loss: 1.3123 - learning_rate: 1.0000e-05
Epoch 42/500
352/352 - 4s - 12ms/step - accuracy: 0.5639 - loss: 1.2145 - val_accuracy:
0.5326 - val_loss: 1.3123 - learning_rate: 1.0000e-05
Epoch 43/500
352/352 - 5s - 13ms/step - accuracy: 0.5632 - loss: 1.2149 - val_accuracy:
0.5334 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 44/500
352/352 - 4s - 12ms/step - accuracy: 0.5653 - loss: 1.2154 - val_accuracy:
0.5332 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 45/500
352/352 - 5s - 15ms/step - accuracy: 0.5689 - loss: 1.2099 - val_accuracy:
0.5336 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 46/500
352/352 - 5s - 15ms/step - accuracy: 0.5687 - loss: 1.2126 - val_accuracy:
0.5330 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 47/500
352/352 - 5s - 15ms/step - accuracy: 0.5641 - loss: 1.2175 - val_accuracy:
0.5340 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 48/500
352/352 - 4s - 12ms/step - accuracy: 0.5640 - loss: 1.2135 - val_accuracy:
0.5328 - val_loss: 1.3123 - learning_rate: 1.0000e-05
Epoch 49/500
352/352 - 4s - 10ms/step - accuracy: 0.5674 - loss: 1.2114 - val_accuracy:
0.5334 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 50/500
352/352 - 4s - 11ms/step - accuracy: 0.5669 - loss: 1.2156 - val_accuracy:
0.5332 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 51/500
352/352 - 4s - 11ms/step - accuracy: 0.5650 - loss: 1.2138 - val_accuracy:
0.5338 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 52/500
352/352 - 4s - 11ms/step - accuracy: 0.5650 - loss: 1.2144 - val_accuracy:
0.5334 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 53/500
352/352 - 4s - 10ms/step - accuracy: 0.5658 - loss: 1.2143 - val_accuracy:
0.5332 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 54/500
```

```
352/352 - 4s - 11ms/step - accuracy: 0.5647 - loss: 1.2148 - val_accuracy:
0.5332 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 55/500
352/352 - 4s - 11ms/step - accuracy: 0.5671 - loss: 1.2107 - val_accuracy:
0.5324 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 56/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2140 - val_accuracy:
0.5332 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 57/500
352/352 - 4s - 10ms/step - accuracy: 0.5690 - loss: 1.2084 - val_accuracy:
0.5330 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 58/500
352/352 - 4s - 10ms/step - accuracy: 0.5679 - loss: 1.2125 - val_accuracy:
0.5330 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 59/500
352/352 - 4s - 11ms/step - accuracy: 0.5652 - loss: 1.2130 - val_accuracy:
0.5332 - val_loss: 1.3123 - learning_rate: 1.0000e-05
Epoch 60/500
352/352 - 4s - 11ms/step - accuracy: 0.5658 - loss: 1.2159 - val_accuracy:
0.5330 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 61/500
352/352 - 4s - 11ms/step - accuracy: 0.5661 - loss: 1.2131 - val_accuracy:
0.5330 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 62/500
352/352 - 4s - 11ms/step - accuracy: 0.5660 - loss: 1.2123 - val_accuracy:
0.5326 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 63/500
352/352 - 4s - 12ms/step - accuracy: 0.5689 - loss: 1.2135 - val_accuracy:
0.5328 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 64/500
352/352 - 5s - 13ms/step - accuracy: 0.5673 - loss: 1.2101 - val_accuracy:
0.5332 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 65/500
352/352 - 4s - 10ms/step - accuracy: 0.5648 - loss: 1.2131 - val_accuracy:
0.5334 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 66/500
352/352 - 5s - 14ms/step - accuracy: 0.5687 - loss: 1.2125 - val_accuracy:
0.5336 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 67/500
352/352 - 7s - 20ms/step - accuracy: 0.5650 - loss: 1.2169 - val_accuracy:
0.5336 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 68/500
352/352 - 5s - 15ms/step - accuracy: 0.5661 - loss: 1.2158 - val_accuracy:
0.5334 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 69/500
352/352 - 4s - 11ms/step - accuracy: 0.5649 - loss: 1.2152 - val_accuracy:
0.5334 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 70/500
```

```
352/352 - 5s - 14ms/step - accuracy: 0.5660 - loss: 1.2155 - val_accuracy:
0.5340 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 71/500
352/352 - 6s - 16ms/step - accuracy: 0.5676 - loss: 1.2151 - val_accuracy:
0.5332 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 72/500
352/352 - 4s - 12ms/step - accuracy: 0.5665 - loss: 1.2127 - val_accuracy:
0.5332 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 73/500
352/352 - 4s - 11ms/step - accuracy: 0.5666 - loss: 1.2119 - val_accuracy:
0.5336 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 74/500
352/352 - 4s - 11ms/step - accuracy: 0.5670 - loss: 1.2104 - val_accuracy:
0.5330 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 75/500
352/352 - 4s - 11ms/step - accuracy: 0.5686 - loss: 1.2103 - val_accuracy:
0.5332 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 76/500
352/352 - 4s - 11ms/step - accuracy: 0.5683 - loss: 1.2126 - val_accuracy:
0.5334 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 77/500
352/352 - 4s - 11ms/step - accuracy: 0.5678 - loss: 1.2104 - val_accuracy:
0.5334 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 78/500
352/352 - 4s - 11ms/step - accuracy: 0.5648 - loss: 1.2136 - val_accuracy:
0.5330 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 79/500
352/352 - 4s - 11ms/step - accuracy: 0.5682 - loss: 1.2086 - val_accuracy:
0.5324 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 80/500
352/352 - 4s - 11ms/step - accuracy: 0.5679 - loss: 1.2100 - val_accuracy:
0.5332 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 81/500
352/352 - 4s - 10ms/step - accuracy: 0.5669 - loss: 1.2148 - val_accuracy:
0.5322 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 82/500
352/352 - 4s - 11ms/step - accuracy: 0.5637 - loss: 1.2137 - val_accuracy:
0.5328 - val_loss: 1.3122 - learning_rate: 1.0000e-05
Epoch 83/500
352/352 - 4s - 11ms/step - accuracy: 0.5646 - loss: 1.2134 - val_accuracy:
0.5324 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 84/500
352/352 - 5s - 13ms/step - accuracy: 0.5638 - loss: 1.2131 - val_accuracy:
0.5326 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 85/500
352/352 - 5s - 15ms/step - accuracy: 0.5655 - loss: 1.2126 - val_accuracy:
0.5326 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 86/500
```

```
352/352 - 5s - 14ms/step - accuracy: 0.5670 - loss: 1.2138 - val_accuracy:
0.5326 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 87/500
352/352 - 4s - 11ms/step - accuracy: 0.5680 - loss: 1.2100 - val_accuracy:
0.5334 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 88/500
352/352 - 4s - 12ms/step - accuracy: 0.5664 - loss: 1.2145 - val_accuracy:
0.5330 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 89/500
352/352 - 4s - 11ms/step - accuracy: 0.5657 - loss: 1.2123 - val_accuracy:
0.5324 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 90/500
352/352 - 4s - 10ms/step - accuracy: 0.5673 - loss: 1.2117 - val_accuracy:
0.5326 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 91/500
352/352 - 4s - 10ms/step - accuracy: 0.5657 - loss: 1.2145 - val_accuracy:
0.5326 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 92/500
352/352 - 4s - 12ms/step - accuracy: 0.5646 - loss: 1.2145 - val_accuracy:
0.5328 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 93/500
352/352 - 4s - 10ms/step - accuracy: 0.5673 - loss: 1.2163 - val_accuracy:
0.5326 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 94/500
352/352 - 4s - 11ms/step - accuracy: 0.5680 - loss: 1.2110 - val_accuracy:
0.5318 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 95/500
352/352 - 4s - 11ms/step - accuracy: 0.5671 - loss: 1.2112 - val_accuracy:
0.5326 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 96/500
352/352 - 4s - 11ms/step - accuracy: 0.5679 - loss: 1.2126 - val_accuracy:
0.5320 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 97/500
352/352 - 4s - 10ms/step - accuracy: 0.5665 - loss: 1.2151 - val_accuracy:
0.5326 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 98/500
352/352 - 4s - 10ms/step - accuracy: 0.5621 - loss: 1.2188 - val_accuracy:
0.5322 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 99/500
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2126 - val_accuracy:
0.5326 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 100/500
352/352 - 4s - 11ms/step - accuracy: 0.5682 - loss: 1.2102 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 101/500
352/352 - 4s - 10ms/step - accuracy: 0.5712 - loss: 1.2071 - val_accuracy:
0.5320 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 102/500
```

```
352/352 - 4s - 11ms/step - accuracy: 0.5678 - loss: 1.2083 - val_accuracy:
0.5322 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 103/500
352/352 - 4s - 11ms/step - accuracy: 0.5660 - loss: 1.2130 - val_accuracy:
0.5326 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 104/500
352/352 - 4s - 11ms/step - accuracy: 0.5679 - loss: 1.2141 - val_accuracy:
0.5326 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 105/500
352/352 - 4s - 11ms/step - accuracy: 0.5660 - loss: 1.2163 - val_accuracy:
0.5326 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 106/500
352/352 - 4s - 10ms/step - accuracy: 0.5692 - loss: 1.2101 - val_accuracy:
0.5322 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 107/500
352/352 - 4s - 11ms/step - accuracy: 0.5655 - loss: 1.2125 - val_accuracy:
0.5324 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 108/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2137 - val_accuracy:
0.5322 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 109/500
352/352 - 4s - 10ms/step - accuracy: 0.5659 - loss: 1.2157 - val_accuracy:
0.5320 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 110/500
352/352 - 4s - 10ms/step - accuracy: 0.5648 - loss: 1.2138 - val_accuracy:
0.5322 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 111/500
352/352 - 4s - 11ms/step - accuracy: 0.5640 - loss: 1.2149 - val_accuracy:
0.5322 - val_loss: 1.3121 - learning_rate: 1.0000e-05
Epoch 112/500
352/352 - 4s - 11ms/step - accuracy: 0.5676 - loss: 1.2129 - val_accuracy:
0.5322 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 113/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2112 - val_accuracy:
0.5320 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 114/500
352/352 - 4s - 10ms/step - accuracy: 0.5653 - loss: 1.2107 - val_accuracy:
0.5324 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 115/500
352/352 - 4s - 10ms/step - accuracy: 0.5675 - loss: 1.2118 - val_accuracy:
0.5320 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 116/500
352/352 - 4s - 10ms/step - accuracy: 0.5647 - loss: 1.2110 - val_accuracy:
0.5322 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 117/500
352/352 - 4s - 10ms/step - accuracy: 0.5663 - loss: 1.2126 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 118/500
```

```
352/352 - 4s - 11ms/step - accuracy: 0.5663 - loss: 1.2123 - val_accuracy:
0.5326 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 119/500
352/352 - 4s - 11ms/step - accuracy: 0.5658 - loss: 1.2094 - val_accuracy:
0.5330 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 120/500
352/352 - 4s - 11ms/step - accuracy: 0.5657 - loss: 1.2170 - val_accuracy:
0.5322 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 121/500
352/352 - 4s - 11ms/step - accuracy: 0.5677 - loss: 1.2116 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 122/500
352/352 - 4s - 10ms/step - accuracy: 0.5687 - loss: 1.2092 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 123/500
352/352 - 4s - 10ms/step - accuracy: 0.5671 - loss: 1.2141 - val_accuracy:
0.5330 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 124/500
352/352 - 4s - 11ms/step - accuracy: 0.5636 - loss: 1.2172 - val_accuracy:
0.5332 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 125/500
352/352 - 4s - 11ms/step - accuracy: 0.5652 - loss: 1.2161 - val_accuracy:
0.5326 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 126/500
352/352 - 4s - 10ms/step - accuracy: 0.5674 - loss: 1.2136 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 127/500
352/352 - 4s - 10ms/step - accuracy: 0.5643 - loss: 1.2121 - val_accuracy:
0.5324 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 128/500
352/352 - 4s - 10ms/step - accuracy: 0.5661 - loss: 1.2112 - val_accuracy:
0.5328 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 129/500
352/352 - 4s - 10ms/step - accuracy: 0.5665 - loss: 1.2101 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 130/500
352/352 - 4s - 10ms/step - accuracy: 0.5659 - loss: 1.2148 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 131/500
352/352 - 4s - 10ms/step - accuracy: 0.5639 - loss: 1.2157 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 132/500
352/352 - 4s - 10ms/step - accuracy: 0.5681 - loss: 1.2107 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 133/500
352/352 - 4s - 10ms/step - accuracy: 0.5652 - loss: 1.2085 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 134/500
```

```
352/352 - 4s - 11ms/step - accuracy: 0.5671 - loss: 1.2120 - val_accuracy:
0.5326 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 135/500
352/352 - 4s - 11ms/step - accuracy: 0.5703 - loss: 1.2091 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 136/500
352/352 - 4s - 11ms/step - accuracy: 0.5671 - loss: 1.2130 - val_accuracy:
0.5320 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 137/500
352/352 - 4s - 10ms/step - accuracy: 0.5673 - loss: 1.2127 - val_accuracy:
0.5314 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 138/500
352/352 - 4s - 11ms/step - accuracy: 0.5671 - loss: 1.2130 - val_accuracy:
0.5320 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 139/500
352/352 - 4s - 11ms/step - accuracy: 0.5657 - loss: 1.2129 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 140/500
352/352 - 4s - 10ms/step - accuracy: 0.5654 - loss: 1.2171 - val_accuracy:
0.5324 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 141/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2142 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 142/500
352/352 - 4s - 10ms/step - accuracy: 0.5634 - loss: 1.2166 - val_accuracy:
0.5326 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 143/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2125 - val_accuracy:
0.5332 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 144/500
352/352 - 4s - 11ms/step - accuracy: 0.5638 - loss: 1.2177 - val_accuracy:
0.5328 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 145/500
352/352 - 4s - 10ms/step - accuracy: 0.5674 - loss: 1.2123 - val_accuracy:
0.5324 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 146/500
352/352 - 4s - 10ms/step - accuracy: 0.5650 - loss: 1.2147 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 147/500
352/352 - 4s - 10ms/step - accuracy: 0.5694 - loss: 1.2079 - val_accuracy:
0.5328 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 148/500
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2092 - val_accuracy:
0.5320 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 149/500
352/352 - 4s - 10ms/step - accuracy: 0.5640 - loss: 1.2139 - val_accuracy:
0.5326 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 150/500
```

```
352/352 - 4s - 11ms/step - accuracy: 0.5669 - loss: 1.2147 - val_accuracy:
0.5318 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 151/500
352/352 - 4s - 11ms/step - accuracy: 0.5643 - loss: 1.2104 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 152/500
352/352 - 4s - 10ms/step - accuracy: 0.5702 - loss: 1.2132 - val_accuracy:
0.5322 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 153/500
352/352 - 4s - 10ms/step - accuracy: 0.5675 - loss: 1.2128 - val_accuracy:
0.5328 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 154/500
352/352 - 4s - 10ms/step - accuracy: 0.5650 - loss: 1.2122 - val_accuracy:
0.5326 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 155/500
352/352 - 4s - 10ms/step - accuracy: 0.5658 - loss: 1.2156 - val_accuracy:
0.5324 - val_loss: 1.3120 - learning_rate: 1.0000e-05
Epoch 156/500
352/352 - 4s - 10ms/step - accuracy: 0.5670 - loss: 1.2149 - val_accuracy:
0.5322 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 157/500
352/352 - 4s - 10ms/step - accuracy: 0.5658 - loss: 1.2165 - val_accuracy:
0.5326 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 158/500
352/352 - 4s - 10ms/step - accuracy: 0.5671 - loss: 1.2110 - val_accuracy:
0.5334 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 159/500
352/352 - 4s - 10ms/step - accuracy: 0.5687 - loss: 1.2099 - val_accuracy:
0.5324 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 160/500
352/352 - 4s - 10ms/step - accuracy: 0.5689 - loss: 1.2127 - val_accuracy:
0.5336 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 161/500
352/352 - 4s - 11ms/step - accuracy: 0.5646 - loss: 1.2144 - val_accuracy:
0.5324 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 162/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2138 - val_accuracy:
0.5324 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 163/500
352/352 - 4s - 10ms/step - accuracy: 0.5634 - loss: 1.2136 - val_accuracy:
0.5322 - val_loss: 1.3119 - learning_rate: 1.0000e-05
Epoch 164/500
352/352 - 4s - 10ms/step - accuracy: 0.5675 - loss: 1.2118 - val_accuracy:
0.5324 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 165/500
352/352 - 4s - 11ms/step - accuracy: 0.5671 - loss: 1.2121 - val_accuracy:
0.5330 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 166/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5654 - loss: 1.2126 - val_accuracy:
0.5326 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 167/500
352/352 - 4s - 10ms/step - accuracy: 0.5643 - loss: 1.2151 - val_accuracy:
0.5324 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 168/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2108 - val_accuracy:
0.5326 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 169/500
352/352 - 4s - 11ms/step - accuracy: 0.5660 - loss: 1.2146 - val_accuracy:
0.5326 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 170/500
352/352 - 4s - 10ms/step - accuracy: 0.5657 - loss: 1.2097 - val_accuracy:
0.5324 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 171/500
352/352 - 4s - 10ms/step - accuracy: 0.5652 - loss: 1.2117 - val_accuracy:
0.5328 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 172/500
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2119 - val_accuracy:
0.5326 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 173/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2134 - val_accuracy:
0.5320 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 174/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2131 - val_accuracy:
0.5324 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 175/500
352/352 - 4s - 10ms/step - accuracy: 0.5668 - loss: 1.2124 - val_accuracy:
0.5318 - val_loss: 1.3118 - learning_rate: 1.0000e-05
Epoch 176/500
352/352 - 3s - 10ms/step - accuracy: 0.5667 - loss: 1.2147 - val_accuracy:
0.5312 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 177/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2114 - val_accuracy:
0.5322 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 178/500
352/352 - 4s - 10ms/step - accuracy: 0.5675 - loss: 1.2119 - val_accuracy:
0.5320 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 179/500
352/352 - 4s - 10ms/step - accuracy: 0.5671 - loss: 1.2139 - val_accuracy:
0.5322 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 180/500
352/352 - 4s - 10ms/step - accuracy: 0.5654 - loss: 1.2109 - val_accuracy:
0.5318 - val_loss: 1.3117 - learning_rate: 1.0000e-05
Epoch 181/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2126 - val_accuracy:
0.5324 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 182/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2131 - val_accuracy:
0.5322 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 183/500
352/352 - 4s - 10ms/step - accuracy: 0.5668 - loss: 1.2105 - val_accuracy:
0.5318 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 184/500
352/352 - 4s - 10ms/step - accuracy: 0.5651 - loss: 1.2155 - val_accuracy:
0.5318 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 185/500
352/352 - 4s - 10ms/step - accuracy: 0.5670 - loss: 1.2091 - val_accuracy:
0.5318 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 186/500
352/352 - 4s - 11ms/step - accuracy: 0.5645 - loss: 1.2131 - val_accuracy:
0.5316 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 187/500
352/352 - 4s - 10ms/step - accuracy: 0.5662 - loss: 1.2126 - val_accuracy:
0.5318 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 188/500
352/352 - 4s - 10ms/step - accuracy: 0.5645 - loss: 1.2149 - val_accuracy:
0.5324 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 189/500
352/352 - 4s - 10ms/step - accuracy: 0.5655 - loss: 1.2143 - val_accuracy:
0.5324 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 190/500
352/352 - 4s - 10ms/step - accuracy: 0.5694 - loss: 1.2089 - val_accuracy:
0.5318 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 191/500
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2144 - val_accuracy:
0.5320 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 192/500
352/352 - 3s - 10ms/step - accuracy: 0.5670 - loss: 1.2144 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 193/500
352/352 - 4s - 10ms/step - accuracy: 0.5661 - loss: 1.2141 - val_accuracy:
0.5324 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 194/500
352/352 - 4s - 10ms/step - accuracy: 0.5682 - loss: 1.2103 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 195/500
352/352 - 4s - 10ms/step - accuracy: 0.5654 - loss: 1.2119 - val_accuracy:
0.5328 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 196/500
352/352 - 4s - 10ms/step - accuracy: 0.5640 - loss: 1.2148 - val_accuracy:
0.5320 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 197/500
352/352 - 4s - 10ms/step - accuracy: 0.5662 - loss: 1.2156 - val_accuracy:
0.5320 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 198/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5652 - loss: 1.2147 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 199/500
352/352 - 4s - 10ms/step - accuracy: 0.5658 - loss: 1.2137 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 200/500
352/352 - 4s - 10ms/step - accuracy: 0.5679 - loss: 1.2111 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 201/500
352/352 - 4s - 11ms/step - accuracy: 0.5681 - loss: 1.2148 - val_accuracy:
0.5328 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 202/500
352/352 - 4s - 10ms/step - accuracy: 0.5664 - loss: 1.2153 - val_accuracy:
0.5324 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 203/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2113 - val_accuracy:
0.5324 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 204/500
352/352 - 4s - 10ms/step - accuracy: 0.5664 - loss: 1.2126 - val_accuracy:
0.5320 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 205/500
352/352 - 4s - 10ms/step - accuracy: 0.5660 - loss: 1.2127 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 206/500
352/352 - 4s - 10ms/step - accuracy: 0.5653 - loss: 1.2125 - val_accuracy:
0.5316 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 207/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2134 - val_accuracy:
0.5314 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 208/500
352/352 - 4s - 10ms/step - accuracy: 0.5685 - loss: 1.2101 - val_accuracy:
0.5320 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 209/500
352/352 - 3s - 10ms/step - accuracy: 0.5632 - loss: 1.2134 - val_accuracy:
0.5320 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 210/500
352/352 - 3s - 10ms/step - accuracy: 0.5665 - loss: 1.2099 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 211/500
352/352 - 3s - 10ms/step - accuracy: 0.5671 - loss: 1.2134 - val_accuracy:
0.5316 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 212/500
352/352 - 4s - 10ms/step - accuracy: 0.5668 - loss: 1.2111 - val_accuracy:
0.5324 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 213/500
352/352 - 3s - 10ms/step - accuracy: 0.5669 - loss: 1.2092 - val_accuracy:
0.5318 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 214/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5696 - loss: 1.2085 - val_accuracy:
0.5318 - val_loss: 1.3116 - learning_rate: 1.0000e-05
Epoch 215/500
352/352 - 3s - 10ms/step - accuracy: 0.5680 - loss: 1.2070 - val_accuracy:
0.5320 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 216/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2118 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 217/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2114 - val_accuracy:
0.5320 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 218/500
352/352 - 4s - 10ms/step - accuracy: 0.5657 - loss: 1.2147 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 219/500
352/352 - 4s - 10ms/step - accuracy: 0.5688 - loss: 1.2078 - val_accuracy:
0.5328 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 220/500
352/352 - 4s - 10ms/step - accuracy: 0.5668 - loss: 1.2099 - val_accuracy:
0.5320 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 221/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2118 - val_accuracy:
0.5326 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 222/500
352/352 - 4s - 11ms/step - accuracy: 0.5683 - loss: 1.2116 - val_accuracy:
0.5326 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 223/500
352/352 - 4s - 11ms/step - accuracy: 0.5666 - loss: 1.2094 - val_accuracy:
0.5316 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 224/500
352/352 - 4s - 10ms/step - accuracy: 0.5692 - loss: 1.2077 - val_accuracy:
0.5316 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 225/500
352/352 - 3s - 10ms/step - accuracy: 0.5667 - loss: 1.2139 - val_accuracy:
0.5326 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 226/500
352/352 - 3s - 10ms/step - accuracy: 0.5667 - loss: 1.2146 - val_accuracy:
0.5320 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 227/500
352/352 - 4s - 10ms/step - accuracy: 0.5697 - loss: 1.2061 - val_accuracy:
0.5320 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 228/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2112 - val_accuracy:
0.5322 - val_loss: 1.3115 - learning_rate: 1.0000e-05
Epoch 229/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2079 - val_accuracy:
0.5324 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 230/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5667 - loss: 1.2131 - val_accuracy:
0.5322 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 231/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2089 - val_accuracy:
0.5324 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 232/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2137 - val_accuracy:
0.5324 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 233/500
352/352 - 4s - 10ms/step - accuracy: 0.5660 - loss: 1.2136 - val_accuracy:
0.5324 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 234/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2085 - val_accuracy:
0.5338 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 235/500
352/352 - 3s - 10ms/step - accuracy: 0.5642 - loss: 1.2145 - val_accuracy:
0.5332 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 236/500
352/352 - 4s - 10ms/step - accuracy: 0.5686 - loss: 1.2141 - val_accuracy:
0.5326 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 237/500
352/352 - 4s - 10ms/step - accuracy: 0.5691 - loss: 1.2132 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 238/500
352/352 - 4s - 10ms/step - accuracy: 0.5650 - loss: 1.2125 - val_accuracy:
0.5326 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 239/500
352/352 - 4s - 10ms/step - accuracy: 0.5680 - loss: 1.2103 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 240/500
352/352 - 4s - 10ms/step - accuracy: 0.5671 - loss: 1.2144 - val_accuracy:
0.5324 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 241/500
352/352 - 4s - 10ms/step - accuracy: 0.5655 - loss: 1.2112 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 242/500
352/352 - 4s - 10ms/step - accuracy: 0.5671 - loss: 1.2100 - val_accuracy:
0.5328 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 243/500
352/352 - 4s - 10ms/step - accuracy: 0.5645 - loss: 1.2155 - val_accuracy:
0.5328 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 244/500
352/352 - 4s - 10ms/step - accuracy: 0.5661 - loss: 1.2112 - val_accuracy:
0.5326 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 245/500
352/352 - 4s - 10ms/step - accuracy: 0.5708 - loss: 1.2107 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 246/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2105 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 247/500
352/352 - 4s - 10ms/step - accuracy: 0.5681 - loss: 1.2103 - val_accuracy:
0.5318 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 248/500
352/352 - 4s - 11ms/step - accuracy: 0.5700 - loss: 1.2073 - val_accuracy:
0.5326 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 249/500
352/352 - 4s - 11ms/step - accuracy: 0.5685 - loss: 1.2081 - val_accuracy:
0.5324 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 250/500
352/352 - 4s - 10ms/step - accuracy: 0.5662 - loss: 1.2116 - val_accuracy:
0.5322 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 251/500
352/352 - 4s - 10ms/step - accuracy: 0.5681 - loss: 1.2138 - val_accuracy:
0.5326 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 252/500
352/352 - 4s - 10ms/step - accuracy: 0.5656 - loss: 1.2141 - val_accuracy:
0.5322 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 253/500
352/352 - 4s - 10ms/step - accuracy: 0.5659 - loss: 1.2145 - val_accuracy:
0.5324 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 254/500
352/352 - 4s - 10ms/step - accuracy: 0.5659 - loss: 1.2133 - val_accuracy:
0.5326 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 255/500
352/352 - 4s - 10ms/step - accuracy: 0.5665 - loss: 1.2101 - val_accuracy:
0.5318 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 256/500
352/352 - 4s - 10ms/step - accuracy: 0.5695 - loss: 1.2102 - val_accuracy:
0.5318 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 257/500
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2057 - val_accuracy:
0.5320 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 258/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2070 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 259/500
352/352 - 3s - 10ms/step - accuracy: 0.5671 - loss: 1.2127 - val_accuracy:
0.5326 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 260/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2126 - val_accuracy:
0.5314 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 261/500
352/352 - 4s - 10ms/step - accuracy: 0.5656 - loss: 1.2131 - val_accuracy:
0.5322 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 262/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5644 - loss: 1.2105 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 263/500
352/352 - 4s - 10ms/step - accuracy: 0.5663 - loss: 1.2142 - val_accuracy:
0.5320 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 264/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2103 - val_accuracy:
0.5320 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 265/500
352/352 - 4s - 10ms/step - accuracy: 0.5648 - loss: 1.2100 - val_accuracy:
0.5324 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 266/500
352/352 - 4s - 10ms/step - accuracy: 0.5681 - loss: 1.2128 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 267/500
352/352 - 4s - 10ms/step - accuracy: 0.5655 - loss: 1.2147 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 268/500
352/352 - 4s - 10ms/step - accuracy: 0.5642 - loss: 1.2097 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 269/500
352/352 - 4s - 11ms/step - accuracy: 0.5683 - loss: 1.2112 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 270/500
352/352 - 4s - 10ms/step - accuracy: 0.5689 - loss: 1.2099 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 271/500
352/352 - 4s - 10ms/step - accuracy: 0.5675 - loss: 1.2095 - val_accuracy:
0.5328 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 272/500
352/352 - 4s - 10ms/step - accuracy: 0.5685 - loss: 1.2091 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 273/500
352/352 - 4s - 10ms/step - accuracy: 0.5680 - loss: 1.2085 - val_accuracy:
0.5322 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 274/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2104 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 275/500
352/352 - 4s - 10ms/step - accuracy: 0.5670 - loss: 1.2099 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 276/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2085 - val_accuracy:
0.5324 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 277/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2117 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 278/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5665 - loss: 1.2106 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 279/500
352/352 - 4s - 10ms/step - accuracy: 0.5688 - loss: 1.2119 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 280/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2159 - val_accuracy:
0.5320 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 281/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2087 - val_accuracy:
0.5322 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 282/500
352/352 - 4s - 10ms/step - accuracy: 0.5704 - loss: 1.2149 - val_accuracy:
0.5320 - val_loss: 1.3114 - learning_rate: 1.0000e-05
Epoch 283/500
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2097 - val_accuracy:
0.5316 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 284/500
352/352 - 4s - 10ms/step - accuracy: 0.5685 - loss: 1.2112 - val_accuracy:
0.5324 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 285/500
352/352 - 4s - 11ms/step - accuracy: 0.5686 - loss: 1.2094 - val_accuracy:
0.5324 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 286/500
352/352 - 4s - 11ms/step - accuracy: 0.5675 - loss: 1.2061 - val_accuracy:
0.5330 - val_loss: 1.3113 - learning_rate: 1.0000e-05
Epoch 287/500
352/352 - 4s - 11ms/step - accuracy: 0.5636 - loss: 1.2125 - val_accuracy:
0.5328 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 288/500
352/352 - 4s - 10ms/step - accuracy: 0.5673 - loss: 1.2109 - val_accuracy:
0.5324 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 289/500
352/352 - 4s - 10ms/step - accuracy: 0.5664 - loss: 1.2098 - val_accuracy:
0.5326 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 290/500
352/352 - 4s - 10ms/step - accuracy: 0.5667 - loss: 1.2095 - val_accuracy:
0.5322 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 291/500
352/352 - 4s - 10ms/step - accuracy: 0.5657 - loss: 1.2120 - val_accuracy:
0.5326 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 292/500
352/352 - 4s - 10ms/step - accuracy: 0.5687 - loss: 1.2122 - val_accuracy:
0.5322 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 293/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2139 - val_accuracy:
0.5320 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 294/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2087 - val_accuracy:
0.5322 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 295/500
352/352 - 4s - 10ms/step - accuracy: 0.5648 - loss: 1.2131 - val_accuracy:
0.5318 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 296/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2101 - val_accuracy:
0.5320 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 297/500
352/352 - 4s - 10ms/step - accuracy: 0.5673 - loss: 1.2109 - val_accuracy:
0.5324 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 298/500
352/352 - 3s - 10ms/step - accuracy: 0.5659 - loss: 1.2107 - val_accuracy:
0.5320 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 299/500
352/352 - 3s - 10ms/step - accuracy: 0.5659 - loss: 1.2146 - val_accuracy:
0.5328 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 300/500
352/352 - 4s - 10ms/step - accuracy: 0.5688 - loss: 1.2113 - val_accuracy:
0.5324 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 301/500
352/352 - 3s - 10ms/step - accuracy: 0.5673 - loss: 1.2104 - val_accuracy:
0.5326 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 302/500
352/352 - 4s - 10ms/step - accuracy: 0.5691 - loss: 1.2075 - val_accuracy:
0.5330 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 303/500
352/352 - 4s - 10ms/step - accuracy: 0.5688 - loss: 1.2053 - val_accuracy:
0.5330 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 304/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2080 - val_accuracy:
0.5330 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 305/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2103 - val_accuracy:
0.5328 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 306/500
352/352 - 4s - 10ms/step - accuracy: 0.5667 - loss: 1.2137 - val_accuracy:
0.5328 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 307/500
352/352 - 4s - 11ms/step - accuracy: 0.5700 - loss: 1.2066 - val_accuracy:
0.5324 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 308/500
352/352 - 4s - 10ms/step - accuracy: 0.5694 - loss: 1.2112 - val_accuracy:
0.5326 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 309/500
352/352 - 4s - 10ms/step - accuracy: 0.5679 - loss: 1.2116 - val_accuracy:
0.5322 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 310/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5650 - loss: 1.2101 - val_accuracy:
0.5326 - val_loss: 1.3112 - learning_rate: 1.0000e-05
Epoch 311/500
352/352 - 4s - 12ms/step - accuracy: 0.5672 - loss: 1.2090 - val_accuracy:
0.5326 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 312/500
352/352 - 4s - 10ms/step - accuracy: 0.5674 - loss: 1.2124 - val_accuracy:
0.5326 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 313/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2124 - val_accuracy:
0.5326 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 314/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2102 - val_accuracy:
0.5320 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 315/500
352/352 - 4s - 10ms/step - accuracy: 0.5648 - loss: 1.2108 - val_accuracy:
0.5316 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 316/500
352/352 - 4s - 10ms/step - accuracy: 0.5680 - loss: 1.2112 - val_accuracy:
0.5328 - val_loss: 1.3111 - learning_rate: 1.0000e-05
Epoch 317/500
352/352 - 4s - 10ms/step - accuracy: 0.5663 - loss: 1.2096 - val_accuracy:
0.5326 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 318/500
352/352 - 4s - 10ms/step - accuracy: 0.5708 - loss: 1.2068 - val_accuracy:
0.5326 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 319/500
352/352 - 4s - 10ms/step - accuracy: 0.5689 - loss: 1.2088 - val_accuracy:
0.5332 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 320/500
352/352 - 4s - 10ms/step - accuracy: 0.5682 - loss: 1.2076 - val_accuracy:
0.5326 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 321/500
352/352 - 4s - 12ms/step - accuracy: 0.5662 - loss: 1.2134 - val_accuracy:
0.5330 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 322/500
352/352 - 4s - 11ms/step - accuracy: 0.5680 - loss: 1.2112 - val_accuracy:
0.5328 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 323/500
352/352 - 4s - 10ms/step - accuracy: 0.5655 - loss: 1.2091 - val_accuracy:
0.5322 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 324/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2101 - val_accuracy:
0.5328 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 325/500
352/352 - 4s - 10ms/step - accuracy: 0.5681 - loss: 1.2091 - val_accuracy:
0.5328 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 326/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5652 - loss: 1.2163 - val_accuracy:
0.5318 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 327/500
352/352 - 4s - 10ms/step - accuracy: 0.5667 - loss: 1.2127 - val_accuracy:
0.5318 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 328/500
352/352 - 4s - 10ms/step - accuracy: 0.5654 - loss: 1.2139 - val_accuracy:
0.5318 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 329/500
352/352 - 4s - 10ms/step - accuracy: 0.5668 - loss: 1.2088 - val_accuracy:
0.5320 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 330/500
352/352 - 4s - 11ms/step - accuracy: 0.5672 - loss: 1.2109 - val_accuracy:
0.5316 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 331/500
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2084 - val_accuracy:
0.5326 - val_loss: 1.3110 - learning_rate: 1.0000e-05
Epoch 332/500
352/352 - 4s - 10ms/step - accuracy: 0.5704 - loss: 1.2072 - val_accuracy:
0.5318 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 333/500
352/352 - 4s - 10ms/step - accuracy: 0.5665 - loss: 1.2129 - val_accuracy:
0.5322 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 334/500
352/352 - 4s - 10ms/step - accuracy: 0.5655 - loss: 1.2155 - val_accuracy:
0.5322 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 335/500
352/352 - 4s - 10ms/step - accuracy: 0.5656 - loss: 1.2075 - val_accuracy:
0.5322 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 336/500
352/352 - 4s - 11ms/step - accuracy: 0.5673 - loss: 1.2084 - val_accuracy:
0.5324 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 337/500
352/352 - 4s - 11ms/step - accuracy: 0.5674 - loss: 1.2089 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 338/500
352/352 - 4s - 11ms/step - accuracy: 0.5668 - loss: 1.2133 - val_accuracy:
0.5318 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 339/500
352/352 - 4s - 10ms/step - accuracy: 0.5701 - loss: 1.2071 - val_accuracy:
0.5322 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 340/500
352/352 - 4s - 10ms/step - accuracy: 0.5662 - loss: 1.2112 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 341/500
352/352 - 4s - 11ms/step - accuracy: 0.5669 - loss: 1.2049 - val_accuracy:
0.5316 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 342/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5673 - loss: 1.2094 - val_accuracy:
0.5318 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 343/500
352/352 - 4s - 10ms/step - accuracy: 0.5676 - loss: 1.2079 - val_accuracy:
0.5318 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 344/500
352/352 - 4s - 10ms/step - accuracy: 0.5659 - loss: 1.2136 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 345/500
352/352 - 4s - 10ms/step - accuracy: 0.5651 - loss: 1.2090 - val_accuracy:
0.5328 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 346/500
352/352 - 4s - 10ms/step - accuracy: 0.5691 - loss: 1.2107 - val_accuracy:
0.5322 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 347/500
352/352 - 4s - 10ms/step - accuracy: 0.5647 - loss: 1.2107 - val_accuracy:
0.5322 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 348/500
352/352 - 4s - 11ms/step - accuracy: 0.5663 - loss: 1.2089 - val_accuracy:
0.5316 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 349/500
352/352 - 4s - 11ms/step - accuracy: 0.5670 - loss: 1.2128 - val_accuracy:
0.5318 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 350/500
352/352 - 4s - 10ms/step - accuracy: 0.5662 - loss: 1.2132 - val_accuracy:
0.5314 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 351/500
352/352 - 4s - 10ms/step - accuracy: 0.5685 - loss: 1.2103 - val_accuracy:
0.5316 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 352/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2065 - val_accuracy:
0.5320 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 353/500
352/352 - 4s - 11ms/step - accuracy: 0.5654 - loss: 1.2126 - val_accuracy:
0.5312 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 354/500
352/352 - 5s - 14ms/step - accuracy: 0.5660 - loss: 1.2116 - val_accuracy:
0.5310 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 355/500
352/352 - 5s - 13ms/step - accuracy: 0.5674 - loss: 1.2161 - val_accuracy:
0.5324 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 356/500
352/352 - 4s - 11ms/step - accuracy: 0.5716 - loss: 1.2057 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 357/500
352/352 - 4s - 11ms/step - accuracy: 0.5668 - loss: 1.2111 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 358/500
```

```
352/352 - 4s - 12ms/step - accuracy: 0.5655 - loss: 1.2101 - val_accuracy:
0.5318 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 359/500
352/352 - 4s - 13ms/step - accuracy: 0.5656 - loss: 1.2125 - val_accuracy:
0.5320 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 360/500
352/352 - 4s - 12ms/step - accuracy: 0.5673 - loss: 1.2075 - val_accuracy:
0.5322 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 361/500
352/352 - 4s - 11ms/step - accuracy: 0.5655 - loss: 1.2131 - val_accuracy:
0.5322 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 362/500
352/352 - 4s - 11ms/step - accuracy: 0.5664 - loss: 1.2109 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 363/500
352/352 - 5s - 13ms/step - accuracy: 0.5676 - loss: 1.2088 - val_accuracy:
0.5324 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 364/500
352/352 - 5s - 13ms/step - accuracy: 0.5666 - loss: 1.2098 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 365/500
352/352 - 6s - 18ms/step - accuracy: 0.5649 - loss: 1.2096 - val_accuracy:
0.5322 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 366/500
352/352 - 6s - 16ms/step - accuracy: 0.5674 - loss: 1.2119 - val_accuracy:
0.5318 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 367/500
352/352 - 7s - 19ms/step - accuracy: 0.5681 - loss: 1.2094 - val_accuracy:
0.5320 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 368/500
352/352 - 7s - 21ms/step - accuracy: 0.5681 - loss: 1.2131 - val_accuracy:
0.5322 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 369/500
352/352 - 4s - 12ms/step - accuracy: 0.5656 - loss: 1.2144 - val_accuracy:
0.5324 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 370/500
352/352 - 4s - 12ms/step - accuracy: 0.5664 - loss: 1.2093 - val_accuracy:
0.5322 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 371/500
352/352 - 5s - 14ms/step - accuracy: 0.5674 - loss: 1.2111 - val_accuracy:
0.5324 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 372/500
352/352 - 4s - 11ms/step - accuracy: 0.5677 - loss: 1.2124 - val_accuracy:
0.5326 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 373/500
352/352 - 4s - 11ms/step - accuracy: 0.5685 - loss: 1.2095 - val_accuracy:
0.5328 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 374/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2083 - val_accuracy:
0.5328 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 375/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2111 - val_accuracy:
0.5328 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 376/500
352/352 - 4s - 10ms/step - accuracy: 0.5666 - loss: 1.2130 - val_accuracy:
0.5330 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 377/500
352/352 - 4s - 10ms/step - accuracy: 0.5679 - loss: 1.2081 - val_accuracy:
0.5324 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 378/500
352/352 - 4s - 10ms/step - accuracy: 0.5671 - loss: 1.2091 - val_accuracy:
0.5322 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 379/500
352/352 - 4s - 11ms/step - accuracy: 0.5663 - loss: 1.2131 - val_accuracy:
0.5326 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 380/500
352/352 - 4s - 10ms/step - accuracy: 0.5704 - loss: 1.2063 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 381/500
352/352 - 4s - 10ms/step - accuracy: 0.5674 - loss: 1.2108 - val_accuracy:
0.5328 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 382/500
352/352 - 4s - 11ms/step - accuracy: 0.5671 - loss: 1.2082 - val_accuracy:
0.5334 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 383/500
352/352 - 4s - 10ms/step - accuracy: 0.5688 - loss: 1.2078 - val_accuracy:
0.5326 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 384/500
352/352 - 4s - 10ms/step - accuracy: 0.5664 - loss: 1.2088 - val_accuracy:
0.5330 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 385/500
352/352 - 4s - 10ms/step - accuracy: 0.5657 - loss: 1.2129 - val_accuracy:
0.5334 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 386/500
352/352 - 4s - 10ms/step - accuracy: 0.5701 - loss: 1.2058 - val_accuracy:
0.5326 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 387/500
352/352 - 4s - 10ms/step - accuracy: 0.5663 - loss: 1.2110 - val_accuracy:
0.5328 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 388/500
352/352 - 4s - 11ms/step - accuracy: 0.5665 - loss: 1.2127 - val_accuracy:
0.5330 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 389/500
352/352 - 4s - 11ms/step - accuracy: 0.5670 - loss: 1.2118 - val_accuracy:
0.5328 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 390/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5672 - loss: 1.2098 - val_accuracy:
0.5330 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 391/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2088 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 392/500
352/352 - 4s - 10ms/step - accuracy: 0.5657 - loss: 1.2099 - val_accuracy:
0.5326 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 393/500
352/352 - 4s - 10ms/step - accuracy: 0.5646 - loss: 1.2086 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 394/500
352/352 - 4s - 10ms/step - accuracy: 0.5686 - loss: 1.2059 - val_accuracy:
0.5332 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 395/500
352/352 - 4s - 10ms/step - accuracy: 0.5688 - loss: 1.2084 - val_accuracy:
0.5330 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 396/500
352/352 - 4s - 10ms/step - accuracy: 0.5639 - loss: 1.2132 - val_accuracy:
0.5320 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 397/500
352/352 - 4s - 10ms/step - accuracy: 0.5694 - loss: 1.2086 - val_accuracy:
0.5318 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 398/500
352/352 - 4s - 10ms/step - accuracy: 0.5684 - loss: 1.2056 - val_accuracy:
0.5324 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 399/500
352/352 - 4s - 10ms/step - accuracy: 0.5656 - loss: 1.2121 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 400/500
352/352 - 4s - 11ms/step - accuracy: 0.5659 - loss: 1.2103 - val_accuracy:
0.5330 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 401/500
352/352 - 4s - 10ms/step - accuracy: 0.5660 - loss: 1.2070 - val_accuracy:
0.5330 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 402/500
352/352 - 4s - 10ms/step - accuracy: 0.5668 - loss: 1.2074 - val_accuracy:
0.5324 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 403/500
352/352 - 4s - 10ms/step - accuracy: 0.5668 - loss: 1.2107 - val_accuracy:
0.5322 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 404/500
352/352 - 4s - 11ms/step - accuracy: 0.5647 - loss: 1.2140 - val_accuracy:
0.5328 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 405/500
352/352 - 4s - 10ms/step - accuracy: 0.5677 - loss: 1.2098 - val_accuracy:
0.5326 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 406/500
```

```
352/352 - 4s - 10ms/step - accuracy: 0.5635 - loss: 1.2146 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 407/500
352/352 - 4s - 10ms/step - accuracy: 0.5714 - loss: 1.2073 - val_accuracy:
0.5320 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 408/500
352/352 - 4s - 10ms/step - accuracy: 0.5661 - loss: 1.2069 - val_accuracy:
0.5322 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 409/500
352/352 - 4s - 11ms/step - accuracy: 0.5686 - loss: 1.2090 - val_accuracy:
0.5322 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 410/500
352/352 - 4s - 11ms/step - accuracy: 0.5664 - loss: 1.2066 - val_accuracy:
0.5326 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 411/500
352/352 - 4s - 12ms/step - accuracy: 0.5648 - loss: 1.2087 - val_accuracy:
0.5322 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 412/500
352/352 - 4s - 12ms/step - accuracy: 0.5662 - loss: 1.2077 - val_accuracy:
0.5328 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 413/500
352/352 - 4s - 11ms/step - accuracy: 0.5680 - loss: 1.2067 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 414/500
352/352 - 4s - 11ms/step - accuracy: 0.5663 - loss: 1.2112 - val_accuracy:
0.5326 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 415/500
352/352 - 4s - 11ms/step - accuracy: 0.5681 - loss: 1.2070 - val_accuracy:
0.5324 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 416/500
352/352 - 4s - 11ms/step - accuracy: 0.5684 - loss: 1.2080 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 417/500
352/352 - 4s - 13ms/step - accuracy: 0.5696 - loss: 1.2067 - val_accuracy:
0.5322 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 418/500
352/352 - 8s - 21ms/step - accuracy: 0.5667 - loss: 1.2100 - val_accuracy:
0.5320 - val_loss: 1.3109 - learning_rate: 1.0000e-05
Epoch 419/500
352/352 - 7s - 20ms/step - accuracy: 0.5662 - loss: 1.2073 - val_accuracy:
0.5318 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 420/500
352/352 - 6s - 18ms/step - accuracy: 0.5655 - loss: 1.2131 - val_accuracy:
0.5320 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 421/500
352/352 - 7s - 19ms/step - accuracy: 0.5674 - loss: 1.2077 - val_accuracy:
0.5320 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 422/500
```

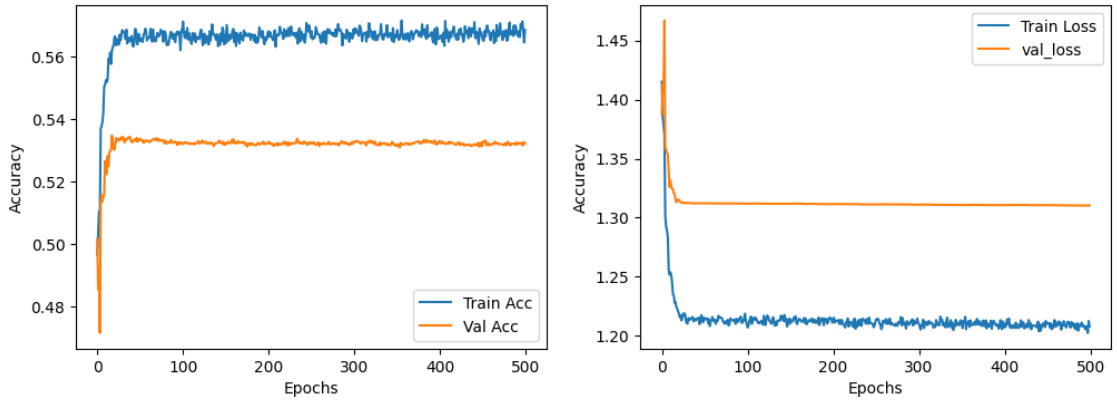
```
352/352 - 6s - 17ms/step - accuracy: 0.5654 - loss: 1.2109 - val_accuracy:
0.5326 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 423/500
352/352 - 6s - 16ms/step - accuracy: 0.5687 - loss: 1.2114 - val_accuracy:
0.5324 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 424/500
352/352 - 7s - 21ms/step - accuracy: 0.5675 - loss: 1.2062 - val_accuracy:
0.5318 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 425/500
352/352 - 6s - 17ms/step - accuracy: 0.5690 - loss: 1.2078 - val_accuracy:
0.5324 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 426/500
352/352 - 7s - 19ms/step - accuracy: 0.5667 - loss: 1.2081 - val_accuracy:
0.5318 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 427/500
352/352 - 6s - 17ms/step - accuracy: 0.5672 - loss: 1.2102 - val_accuracy:
0.5320 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 428/500
352/352 - 10s - 28ms/step - accuracy: 0.5648 - loss: 1.2070 - val_accuracy:
0.5322 - val_loss: 1.3108 - learning_rate: 1.0000e-05
Epoch 429/500
352/352 - 5s - 14ms/step - accuracy: 0.5656 - loss: 1.2134 - val_accuracy:
0.5316 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 430/500
352/352 - 5s - 15ms/step - accuracy: 0.5698 - loss: 1.2095 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 431/500
352/352 - 6s - 17ms/step - accuracy: 0.5677 - loss: 1.2108 - val_accuracy:
0.5318 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 432/500
352/352 - 6s - 16ms/step - accuracy: 0.5684 - loss: 1.2055 - val_accuracy:
0.5318 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 433/500
352/352 - 5s - 15ms/step - accuracy: 0.5672 - loss: 1.2091 - val_accuracy:
0.5318 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 434/500
352/352 - 6s - 16ms/step - accuracy: 0.5659 - loss: 1.2086 - val_accuracy:
0.5320 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 435/500
352/352 - 5s - 15ms/step - accuracy: 0.5693 - loss: 1.2087 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 436/500
352/352 - 6s - 17ms/step - accuracy: 0.5673 - loss: 1.2084 - val_accuracy:
0.5318 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 437/500
352/352 - 6s - 16ms/step - accuracy: 0.5665 - loss: 1.2082 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 438/500
```

```
352/352 - 5s - 14ms/step - accuracy: 0.5691 - loss: 1.2072 - val_accuracy:
0.5314 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 439/500
352/352 - 5s - 15ms/step - accuracy: 0.5682 - loss: 1.2098 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 440/500
352/352 - 6s - 17ms/step - accuracy: 0.5677 - loss: 1.2121 - val_accuracy:
0.5318 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 441/500
352/352 - 5s - 13ms/step - accuracy: 0.5711 - loss: 1.2037 - val_accuracy:
0.5320 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 442/500
352/352 - 6s - 17ms/step - accuracy: 0.5660 - loss: 1.2097 - val_accuracy:
0.5320 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 443/500
352/352 - 7s - 20ms/step - accuracy: 0.5679 - loss: 1.2043 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 444/500
352/352 - 7s - 21ms/step - accuracy: 0.5679 - loss: 1.2068 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 445/500
352/352 - 11s - 30ms/step - accuracy: 0.5656 - loss: 1.2094 - val_accuracy:
0.5324 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 446/500
352/352 - 5s - 14ms/step - accuracy: 0.5641 - loss: 1.2107 - val_accuracy:
0.5324 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 447/500
352/352 - 4s - 11ms/step - accuracy: 0.5691 - loss: 1.2100 - val_accuracy:
0.5312 - val_loss: 1.3107 - learning_rate: 1.0000e-05
Epoch 448/500
352/352 - 4s - 12ms/step - accuracy: 0.5670 - loss: 1.2073 - val_accuracy:
0.5320 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 449/500
352/352 - 4s - 12ms/step - accuracy: 0.5678 - loss: 1.2126 - val_accuracy:
0.5326 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 450/500
352/352 - 4s - 11ms/step - accuracy: 0.5662 - loss: 1.2103 - val_accuracy:
0.5314 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 451/500
352/352 - 4s - 12ms/step - accuracy: 0.5652 - loss: 1.2101 - val_accuracy:
0.5328 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 452/500
352/352 - 4s - 11ms/step - accuracy: 0.5651 - loss: 1.2109 - val_accuracy:
0.5330 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 453/500
352/352 - 4s - 11ms/step - accuracy: 0.5683 - loss: 1.2105 - val_accuracy:
0.5328 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 454/500
```

```
352/352 - 4s - 11ms/step - accuracy: 0.5665 - loss: 1.2067 - val_accuracy:
0.5332 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 455/500
352/352 - 6s - 17ms/step - accuracy: 0.5692 - loss: 1.2106 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 456/500
352/352 - 6s - 18ms/step - accuracy: 0.5700 - loss: 1.2055 - val_accuracy:
0.5322 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 457/500
352/352 - 4s - 12ms/step - accuracy: 0.5679 - loss: 1.2085 - val_accuracy:
0.5324 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 458/500
352/352 - 6s - 16ms/step - accuracy: 0.5683 - loss: 1.2069 - val_accuracy:
0.5316 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 459/500
352/352 - 5s - 13ms/step - accuracy: 0.5663 - loss: 1.2133 - val_accuracy:
0.5318 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 460/500
352/352 - 4s - 12ms/step - accuracy: 0.5652 - loss: 1.2122 - val_accuracy:
0.5318 - val_loss: 1.3105 - learning_rate: 1.0000e-05
Epoch 461/500
352/352 - 4s - 12ms/step - accuracy: 0.5676 - loss: 1.2079 - val_accuracy:
0.5320 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 462/500
352/352 - 4s - 12ms/step - accuracy: 0.5671 - loss: 1.2109 - val_accuracy:
0.5322 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 463/500
352/352 - 4s - 12ms/step - accuracy: 0.5685 - loss: 1.2086 - val_accuracy:
0.5320 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 464/500
352/352 - 6s - 17ms/step - accuracy: 0.5643 - loss: 1.2122 - val_accuracy:
0.5322 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 465/500
352/352 - 4s - 12ms/step - accuracy: 0.5676 - loss: 1.2097 - val_accuracy:
0.5328 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 466/500
352/352 - 4s - 11ms/step - accuracy: 0.5650 - loss: 1.2114 - val_accuracy:
0.5324 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 467/500
352/352 - 4s - 13ms/step - accuracy: 0.5702 - loss: 1.2052 - val_accuracy:
0.5322 - val_loss: 1.3106 - learning_rate: 1.0000e-05
Epoch 468/500
352/352 - 6s - 16ms/step - accuracy: 0.5667 - loss: 1.2084 - val_accuracy:
0.5324 - val_loss: 1.3105 - learning_rate: 1.0000e-05
Epoch 469/500
352/352 - 5s - 15ms/step - accuracy: 0.5665 - loss: 1.2091 - val_accuracy:
0.5320 - val_loss: 1.3105 - learning_rate: 1.0000e-05
Epoch 470/500
```

```
352/352 - 5s - 13ms/step - accuracy: 0.5678 - loss: 1.2124 - val_accuracy:
0.5322 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 471/500
352/352 - 4s - 12ms/step - accuracy: 0.5707 - loss: 1.2085 - val_accuracy:
0.5320 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 472/500
352/352 - 4s - 12ms/step - accuracy: 0.5671 - loss: 1.2081 - val_accuracy:
0.5320 - val_loss: 1.3105 - learning_rate: 1.0000e-05
Epoch 473/500
352/352 - 4s - 12ms/step - accuracy: 0.5671 - loss: 1.2070 - val_accuracy:
0.5320 - val_loss: 1.3105 - learning_rate: 1.0000e-05
Epoch 474/500
352/352 - 4s - 12ms/step - accuracy: 0.5653 - loss: 1.2116 - val_accuracy:
0.5318 - val_loss: 1.3105 - learning_rate: 1.0000e-05
Epoch 475/500
352/352 - 4s - 12ms/step - accuracy: 0.5682 - loss: 1.2118 - val_accuracy:
0.5318 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 476/500
352/352 - 4s - 12ms/step - accuracy: 0.5666 - loss: 1.2116 - val_accuracy:
0.5316 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 477/500
352/352 - 5s - 14ms/step - accuracy: 0.5665 - loss: 1.2079 - val_accuracy:
0.5324 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 478/500
352/352 - 5s - 15ms/step - accuracy: 0.5685 - loss: 1.2070 - val_accuracy:
0.5320 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 479/500
352/352 - 6s - 16ms/step - accuracy: 0.5651 - loss: 1.2117 - val_accuracy:
0.5318 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 480/500
352/352 - 4s - 12ms/step - accuracy: 0.5657 - loss: 1.2093 - val_accuracy:
0.5328 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 481/500
352/352 - 4s - 13ms/step - accuracy: 0.5688 - loss: 1.2106 - val_accuracy:
0.5322 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 482/500
352/352 - 4s - 12ms/step - accuracy: 0.5710 - loss: 1.2068 - val_accuracy:
0.5320 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 483/500
352/352 - 4s - 12ms/step - accuracy: 0.5671 - loss: 1.2101 - val_accuracy:
0.5316 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 484/500
352/352 - 4s - 11ms/step - accuracy: 0.5674 - loss: 1.2053 - val_accuracy:
0.5322 - val_loss: 1.3105 - learning_rate: 1.0000e-05
Epoch 485/500
352/352 - 4s - 12ms/step - accuracy: 0.5682 - loss: 1.2059 - val_accuracy:
0.5322 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 486/500
```

```
352/352 - 5s - 14ms/step - accuracy: 0.5667 - loss: 1.2107 - val_accuracy:
0.5322 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 487/500
352/352 - 5s - 13ms/step - accuracy: 0.5700 - loss: 1.2043 - val_accuracy:
0.5322 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 488/500
352/352 - 7s - 21ms/step - accuracy: 0.5670 - loss: 1.2092 - val_accuracy:
0.5318 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 489/500
352/352 - 5s - 14ms/step - accuracy: 0.5700 - loss: 1.2093 - val_accuracy:
0.5320 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 490/500
352/352 - 4s - 11ms/step - accuracy: 0.5685 - loss: 1.2082 - val_accuracy:
0.5326 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 491/500
352/352 - 4s - 10ms/step - accuracy: 0.5678 - loss: 1.2113 - val_accuracy:
0.5320 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 492/500
352/352 - 4s - 11ms/step - accuracy: 0.5664 - loss: 1.2081 - val_accuracy:
0.5320 - val_loss: 1.3102 - learning_rate: 1.0000e-05
Epoch 493/500
352/352 - 5s - 13ms/step - accuracy: 0.5682 - loss: 1.2087 - val_accuracy:
0.5324 - val_loss: 1.3102 - learning_rate: 1.0000e-05
Epoch 494/500
352/352 - 5s - 14ms/step - accuracy: 0.5663 - loss: 1.2079 - val_accuracy:
0.5324 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 495/500
352/352 - 4s - 12ms/step - accuracy: 0.5705 - loss: 1.2055 - val_accuracy:
0.5322 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 496/500
352/352 - 4s - 10ms/step - accuracy: 0.5691 - loss: 1.2081 - val_accuracy:
0.5324 - val_loss: 1.3103 - learning_rate: 1.0000e-05
Epoch 497/500
352/352 - 4s - 10ms/step - accuracy: 0.5713 - loss: 1.2068 - val_accuracy:
0.5316 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 498/500
352/352 - 4s - 12ms/step - accuracy: 0.5684 - loss: 1.2025 - val_accuracy:
0.5326 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 499/500
352/352 - 5s - 14ms/step - accuracy: 0.5646 - loss: 1.2126 - val_accuracy:
0.5320 - val_loss: 1.3104 - learning_rate: 1.0000e-05
Epoch 500/500
352/352 - 4s - 12ms/step - accuracy: 0.5686 - loss: 1.2080 - val_accuracy:
0.5324 - val_loss: 1.3104 - learning_rate: 1.0000e-05
313/313 - 1s - 3ms/step - accuracy: 0.5390 - loss: 1.2856
Test loss: 1.2855595350265503
Test Accuracy:53.90%
```



0.7 Question 5: Now for adding momentum and nesterov momemtum you can try these in your question 1 soln and check your results in both the cases

0.7.1 With classical momentum

[34]:
```
optimizer = SGD(learning_rate=0.01, momentum = 0.9)
model.compile(optimizer=optimizer, loss = 'categorical_crossentropy',metrics =␣
 ↪['accuracy'])
estop = EarlyStopping(monitor = 'val_loss', min_delta = 1e-4, mode =␣
 ↪'min',patience = 5, verbose = 2, restore_best_weights = True)
history = model.fit(x_subtrain_flat,y_subtrain_cat, batch_size=128, epochs␣
 ↪=500, verbose = 2, validation_data=(x_valid_flat,y_valid_cat), callbacks =␣
 ↪[estop])
score = model.evaluate(x_test_flat,y_test_cat,verbose = 2)
print("Test loss:", score[0])
print(f"Test Accuracy:{score[1]*100:.2f}%")
plt.figure(figsize=(12,4))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label = 'val_loss')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
```

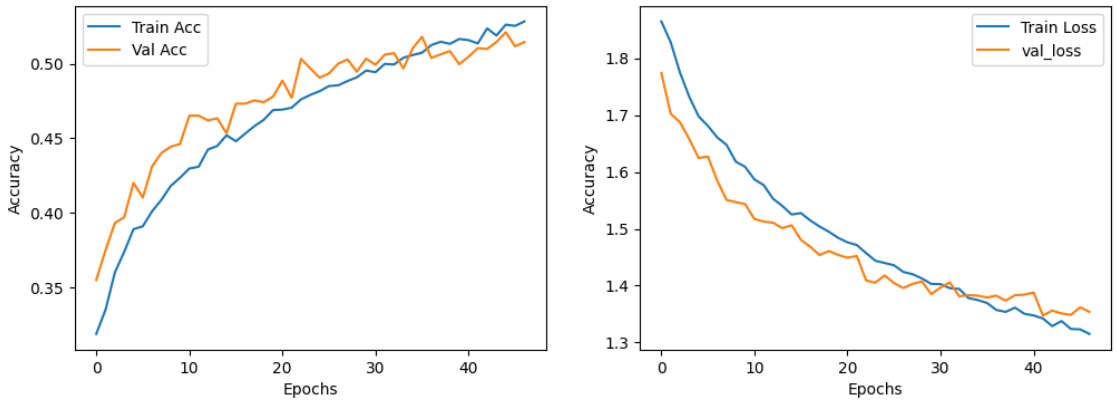
```
plt.show()
```

```
Epoch 1/500
352/352 - 7s - 21ms/step - accuracy: 0.3191 - loss: 1.8647 - val_accuracy:
0.3552 - val_loss: 1.7741
Epoch 2/500
352/352 - 5s - 15ms/step - accuracy: 0.3354 - loss: 1.8284 - val_accuracy:
0.3752 - val_loss: 1.7025
Epoch 3/500
352/352 - 5s - 14ms/step - accuracy: 0.3603 - loss: 1.7748 - val_accuracy:
0.3934 - val_loss: 1.6874
Epoch 4/500
352/352 - 5s - 13ms/step - accuracy: 0.3740 - loss: 1.7322 - val_accuracy:
0.3972 - val_loss: 1.6578
Epoch 5/500
352/352 - 5s - 13ms/step - accuracy: 0.3892 - loss: 1.6978 - val_accuracy:
0.4202 - val_loss: 1.6247
Epoch 6/500
352/352 - 4s - 13ms/step - accuracy: 0.3912 - loss: 1.6811 - val_accuracy:
0.4104 - val_loss: 1.6270
Epoch 7/500
352/352 - 5s - 15ms/step - accuracy: 0.4012 - loss: 1.6608 - val_accuracy:
0.4312 - val_loss: 1.5849
Epoch 8/500
352/352 - 5s - 13ms/step - accuracy: 0.4089 - loss: 1.6477 - val_accuracy:
0.4402 - val_loss: 1.5507
Epoch 9/500
352/352 - 5s - 13ms/step - accuracy: 0.4181 - loss: 1.6181 - val_accuracy:
0.4444 - val_loss: 1.5469
Epoch 10/500
352/352 - 4s - 13ms/step - accuracy: 0.4236 - loss: 1.6089 - val_accuracy:
0.4462 - val_loss: 1.5434
Epoch 11/500
352/352 - 4s - 12ms/step - accuracy: 0.4298 - loss: 1.5869 - val_accuracy:
0.4652 - val_loss: 1.5173
Epoch 12/500
352/352 - 4s - 12ms/step - accuracy: 0.4310 - loss: 1.5768 - val_accuracy:
0.4652 - val_loss: 1.5127
Epoch 13/500
352/352 - 4s - 12ms/step - accuracy: 0.4425 - loss: 1.5529 - val_accuracy:
0.4620 - val_loss: 1.5108
Epoch 14/500
352/352 - 4s - 12ms/step - accuracy: 0.4449 - loss: 1.5402 - val_accuracy:
0.4634 - val_loss: 1.5011
Epoch 15/500
352/352 - 5s - 13ms/step - accuracy: 0.4521 - loss: 1.5251 - val_accuracy:
```

```
0.4534 - val_loss: 1.5062
Epoch 16/500
352/352 - 5s - 13ms/step - accuracy: 0.4481 - loss: 1.5277 - val_accuracy:
0.4732 - val_loss: 1.4805
Epoch 17/500
352/352 - 4s - 13ms/step - accuracy: 0.4531 - loss: 1.5147 - val_accuracy:
0.4732 - val_loss: 1.4685
Epoch 18/500
352/352 - 4s - 12ms/step - accuracy: 0.4582 - loss: 1.5039 - val_accuracy:
0.4754 - val_loss: 1.4538
Epoch 19/500
352/352 - 4s - 12ms/step - accuracy: 0.4624 - loss: 1.4948 - val_accuracy:
0.4742 - val_loss: 1.4609
Epoch 20/500
352/352 - 4s - 12ms/step - accuracy: 0.4689 - loss: 1.4840 - val_accuracy:
0.4780 - val_loss: 1.4541
Epoch 21/500
352/352 - 4s - 12ms/step - accuracy: 0.4692 - loss: 1.4762 - val_accuracy:
0.4886 - val_loss: 1.4491
Epoch 22/500
352/352 - 4s - 12ms/step - accuracy: 0.4705 - loss: 1.4714 - val_accuracy:
0.4772 - val_loss: 1.4521
Epoch 23/500
352/352 - 4s - 12ms/step - accuracy: 0.4760 - loss: 1.4573 - val_accuracy:
0.5032 - val_loss: 1.4091
Epoch 24/500
352/352 - 4s - 12ms/step - accuracy: 0.4791 - loss: 1.4438 - val_accuracy:
0.4968 - val_loss: 1.4052
Epoch 25/500
352/352 - 4s - 12ms/step - accuracy: 0.4815 - loss: 1.4398 - val_accuracy:
0.4906 - val_loss: 1.4179
Epoch 26/500
352/352 - 4s - 12ms/step - accuracy: 0.4850 - loss: 1.4358 - val_accuracy:
0.4934 - val_loss: 1.4045
Epoch 27/500
352/352 - 4s - 12ms/step - accuracy: 0.4855 - loss: 1.4241 - val_accuracy:
0.5000 - val_loss: 1.3958
Epoch 28/500
352/352 - 4s - 12ms/step - accuracy: 0.4884 - loss: 1.4201 - val_accuracy:
0.5028 - val_loss: 1.4031
Epoch 29/500
352/352 - 4s - 12ms/step - accuracy: 0.4908 - loss: 1.4126 - val_accuracy:
0.4946 - val_loss: 1.4075
Epoch 30/500
352/352 - 4s - 12ms/step - accuracy: 0.4954 - loss: 1.4029 - val_accuracy:
0.5034 - val_loss: 1.3851
Epoch 31/500
352/352 - 4s - 12ms/step - accuracy: 0.4942 - loss: 1.4026 - val_accuracy:
```

```
0.4992 - val_loss: 1.3967
Epoch 32/500
352/352 - 4s - 12ms/step - accuracy: 0.4998 - loss: 1.3955 - val_accuracy:
0.5060 - val_loss: 1.4057
Epoch 33/500
352/352 - 5s - 13ms/step - accuracy: 0.4994 - loss: 1.3943 - val_accuracy:
0.5070 - val_loss: 1.3814
Epoch 34/500
352/352 - 5s - 13ms/step - accuracy: 0.5039 - loss: 1.3782 - val_accuracy:
0.4968 - val_loss: 1.3832
Epoch 35/500
352/352 - 5s - 14ms/step - accuracy: 0.5057 - loss: 1.3747 - val_accuracy:
0.5102 - val_loss: 1.3824
Epoch 36/500
352/352 - 5s - 13ms/step - accuracy: 0.5073 - loss: 1.3695 - val_accuracy:
0.5180 - val_loss: 1.3792
Epoch 37/500
352/352 - 5s - 14ms/step - accuracy: 0.5124 - loss: 1.3572 - val_accuracy:
0.5038 - val_loss: 1.3824
Epoch 38/500
352/352 - 5s - 15ms/step - accuracy: 0.5147 - loss: 1.3539 - val_accuracy:
0.5062 - val_loss: 1.3736
Epoch 39/500
352/352 - 5s - 14ms/step - accuracy: 0.5132 - loss: 1.3613 - val_accuracy:
0.5084 - val_loss: 1.3833
Epoch 40/500
352/352 - 5s - 15ms/step - accuracy: 0.5165 - loss: 1.3506 - val_accuracy:
0.4996 - val_loss: 1.3840
Epoch 41/500
352/352 - 5s - 15ms/step - accuracy: 0.5157 - loss: 1.3476 - val_accuracy:
0.5046 - val_loss: 1.3879
Epoch 42/500
352/352 - 5s - 15ms/step - accuracy: 0.5136 - loss: 1.3423 - val_accuracy:
0.5104 - val_loss: 1.3475
Epoch 43/500
352/352 - 5s - 15ms/step - accuracy: 0.5236 - loss: 1.3288 - val_accuracy:
0.5098 - val_loss: 1.3560
Epoch 44/500
352/352 - 5s - 15ms/step - accuracy: 0.5188 - loss: 1.3377 - val_accuracy:
0.5144 - val_loss: 1.3511
Epoch 45/500
352/352 - 5s - 15ms/step - accuracy: 0.5261 - loss: 1.3239 - val_accuracy:
0.5210 - val_loss: 1.3485
Epoch 46/500
352/352 - 5s - 14ms/step - accuracy: 0.5253 - loss: 1.3231 - val_accuracy:
0.5116 - val_loss: 1.3619
Epoch 47/500
352/352 - 5s - 14ms/step - accuracy: 0.5282 - loss: 1.3151 - val_accuracy:
```

```
0.5144 - val_loss: 1.3540
Epoch 47: early stopping
Restoring model weights from the end of the best epoch: 42.
313/313 - 1s - 3ms/step - accuracy: 0.5268 - loss: 1.3293
Test loss: 1.3293324708938599
Test Accuracy:52.68%
```



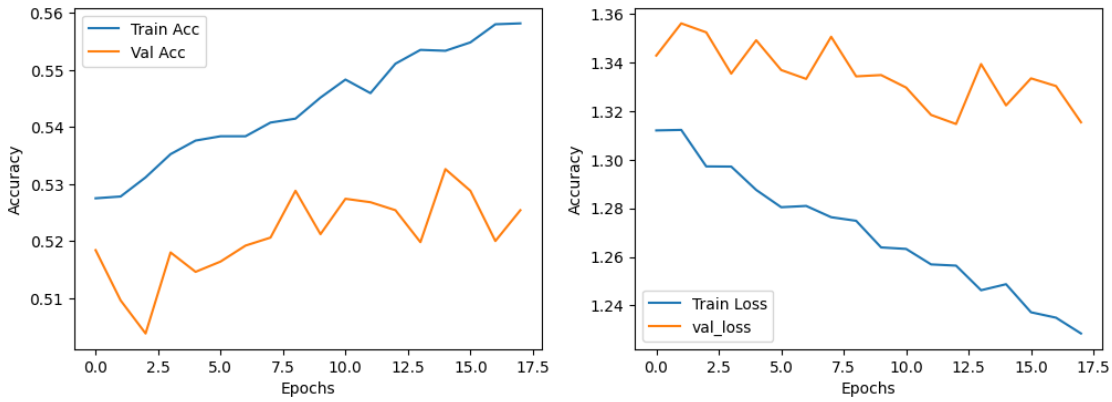
0.7.2 with nestrov_momentum

[35]:
```
optimizer = SGD(learning_rate=0.01, momentum = 0.9, nesterov=True)
model.compile(optimizer=optimizer, loss = 'categorical_crossentropy',metrics =␣
 ↪['accuracy'])
estop = EarlyStopping(monitor = 'val_loss', min_delta = 1e-4, mode =␣
 ↪'min',patience = 5, verbose = 2, restore_best_weights = True)
history = model.fit(x_subtrain_flat,y_subtrain_cat, batch_size=128, epochs␣
 ↪=500, verbose = 2, validation_data=(x_valid_flat,y_valid_cat), callbacks =␣
 ↪[estop])
score = model.evaluate(x_test_flat,y_test_cat,verbose = 2)
print("Test loss:", score[0])
print(f"Test Accuracy:{score[1]*100:.2f}%")
plt.figure(figsize=(12,4))
plt.subplot(1,2,1)
plt.plot(history.history['accuracy'], label='Train Acc')
plt.plot(history.history['val_accuracy'], label='Val Acc')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.subplot(1,2,2)
plt.plot(history.history['loss'], label='Train Loss')
plt.plot(history.history['val_loss'], label = 'val_loss')
```

```
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()
plt.show()
```

```
Epoch 1/500
352/352 - 9s - 26ms/step - accuracy: 0.5275 - loss: 1.3120 - val_accuracy:
0.5184 - val_loss: 1.3427
Epoch 2/500
352/352 - 6s - 16ms/step - accuracy: 0.5278 - loss: 1.3122 - val_accuracy:
0.5096 - val_loss: 1.3560
Epoch 3/500
352/352 - 6s - 16ms/step - accuracy: 0.5312 - loss: 1.2972 - val_accuracy:
0.5038 - val_loss: 1.3523
Epoch 4/500
352/352 - 6s - 17ms/step - accuracy: 0.5352 - loss: 1.2971 - val_accuracy:
0.5180 - val_loss: 1.3353
Epoch 5/500
352/352 - 5s - 14ms/step - accuracy: 0.5376 - loss: 1.2875 - val_accuracy:
0.5146 - val_loss: 1.3490
Epoch 6/500
352/352 - 5s - 15ms/step - accuracy: 0.5384 - loss: 1.2804 - val_accuracy:
0.5164 - val_loss: 1.3368
Epoch 7/500
352/352 - 5s - 14ms/step - accuracy: 0.5384 - loss: 1.2809 - val_accuracy:
0.5192 - val_loss: 1.3331
Epoch 8/500
352/352 - 5s - 14ms/step - accuracy: 0.5408 - loss: 1.2763 - val_accuracy:
0.5206 - val_loss: 1.3505
Epoch 9/500
352/352 - 5s - 14ms/step - accuracy: 0.5414 - loss: 1.2748 - val_accuracy:
0.5288 - val_loss: 1.3342
Epoch 10/500
352/352 - 5s - 13ms/step - accuracy: 0.5451 - loss: 1.2639 - val_accuracy:
0.5212 - val_loss: 1.3347
Epoch 11/500
352/352 - 5s - 13ms/step - accuracy: 0.5483 - loss: 1.2633 - val_accuracy:
0.5274 - val_loss: 1.3296
Epoch 12/500
352/352 - 5s - 14ms/step - accuracy: 0.5459 - loss: 1.2569 - val_accuracy:
0.5268 - val_loss: 1.3183
Epoch 13/500
352/352 - 5s - 15ms/step - accuracy: 0.5511 - loss: 1.2564 - val_accuracy:
0.5254 - val_loss: 1.3146
Epoch 14/500
352/352 - 5s - 14ms/step - accuracy: 0.5535 - loss: 1.2463 - val_accuracy:
```

```
0.5198 - val_loss: 1.3392
Epoch 15/500
352/352 - 5s - 14ms/step - accuracy: 0.5533 - loss: 1.2487 - val_accuracy:
0.5326 - val_loss: 1.3223
Epoch 16/500
352/352 - 5s - 13ms/step - accuracy: 0.5548 - loss: 1.2372 - val_accuracy:
0.5288 - val_loss: 1.3334
Epoch 17/500
352/352 - 5s - 14ms/step - accuracy: 0.5580 - loss: 1.2350 - val_accuracy:
0.5200 - val_loss: 1.3302
Epoch 18/500
352/352 - 5s - 14ms/step - accuracy: 0.5581 - loss: 1.2285 - val_accuracy:
0.5254 - val_loss: 1.3153
Epoch 18: early stopping
Restoring model weights from the end of the best epoch: 13.
313/313 - 1s - 3ms/step - accuracy: 0.5387 - loss: 1.2893
Test loss: 1.2892712354660034
Test Accuracy:53.87%
```



0.8 Challenging question: Try to hand-code how momentum and Nesterov momentum can be incorporated in a simple neural network model with two inputs, x1 and x2,(take random values) in the input layer and one neuron in the output layer. Note that there is no hidden layer. Use sigmoid as activation in the output layer.(use the error as mean squared error).

[42]:
```
import numpy as np

## seed for reproducibility
np.random.seed(42)
```

```
## Sigmoid activation function
def sigmoid(z):
    return 1 / (1 + np.exp(-z))

## Derivative of sigmoid
def sigmoid_deriv(out):
    return out * (1 - out)

## MSE loss
def compute_loss(out, y):
    return np.mean((out - y) ** 2 / 2)

## Sample dataset (OR Gate dataset)
X_train = np.array([[0, 0], [0, 1], [1, 0], [1, 1]])
y_train = np.array([[0], [1], [1], [1]])

## Vanilla Gradient Descent
def train_vanilla(X, y, epochs=1000, lr=0.5):
    N = X.shape[0]
    w = np.random.randn(2, 1)  # Weights
    b = np.random.randn(1)     # Bias
    for epoch in range(epochs):
        ## Forward pass
        z = np.dot(X, w) + b
        out = sigmoid(z)
        ## Loss
        loss = compute_loss(out, y)
        ## Backward pass
        dout = (out - y) / N
        dz = dout * sigmoid_deriv(out)
        dw = np.dot(X.T, dz)
        db = np.sum(dz, axis=0)
        ## Update weights
        w -= lr * dw
        b -= lr * db
    ## Final loss and predictions
    z = np.dot(X, w) + b
    o = sigmoid(z)
    out = (o>0.5).astype(int)
    final_loss = compute_loss(o, y)
    return w, b, final_loss, out

## Gradient Descent with Momentum
def train_momentum(X, y, epochs=1000, lr=0.5, mu=0.9):
    N = X.shape[0]
    w = np.random.randn(2, 1)
    b = np.random.randn(1)
```

```
    v_w = np.zeros((2, 1))  # Velocity for weights
    v_b = np.zeros(1)       # Velocity for bias
    for epoch in range(epochs):
        ## Forward pass
        z = np.dot(X, w) + b
        out = sigmoid(z)
        ## Loss
        loss = compute_loss(out, y)
        ## Backward pass
        dout = (out - y) / N
        dz = dout * sigmoid_deriv(out)
        dw = np.dot(X.T, dz)
        db = np.sum(dz, axis=0)
        ## Updating velocities
        v_w = mu * v_w - lr * dw
        v_b = mu * v_b - lr * db
        ## Updating weights and biases
        w += v_w
        b += v_b
    ## Final prediction
    z = np.dot(X, w) + b
    o = sigmoid(z)
    out = (o>0.5).astype(int)
    final_loss = compute_loss(o, y)
    return w, b, final_loss, out

## Gradient Descent with Nesterov Momentum
def train_nesterov(X, y, epochs=1000, lr=0.5, mu=0.9):
    N = X.shape[0]
    w = np.random.randn(2, 1)
    b = np.random.randn(1)
    v_w = np.zeros((2, 1))
    v_b = np.zeros(1)
    for epoch in range(epochs):
        ## Lookahead position
        w_ahead = w + mu * v_w
        b_ahead = b + mu * v_b
        ## Forward pass at lookahead
        z = np.dot(X, w_ahead) + b_ahead
        out = sigmoid(z)
        # Loss
        loss = compute_loss(out, y)
        # Backward pass at lookahead
        dout = (out - y) / N
        dz = dout * sigmoid_deriv(out)
        dw = np.dot(X.T, dz)
        db = np.sum(dz, axis=0)
```

```
        # Updating velocities
        v_w = mu * v_w - lr * dw
        v_b = mu * v_b - lr * db
        # Updating weights
        w += v_w
        b += v_b
    # Final prediction
    z = np.dot(X, w) + b
    o = sigmoid(z)
    out = (o>0.5).astype(int)
    final_loss = compute_loss(o, y)
    return w, b, final_loss, out

np.random.seed(42)
w_v, b_v, loss_v, out_v = train_vanilla(X_train, y_train)
print("Vanilla GD: w =", w_v.ravel(), "b =", b_v, "loss =", loss_v)
print("Predictions:", out_v.ravel())

np.random.seed(42)
w_m, b_m, loss_m, out_m = train_momentum(X_train, y_train)
print("\nMomentum: w =", w_m.ravel(), "b =", b_m, "loss =", loss_m)
print("Predictions:", out_m.ravel())

np.random.seed(42)
w_n, b_n, loss_n, out_n = train_nesterov(X_train, y_train)
print("\nNesterov: w =", w_n.ravel(), "b =", b_n, "loss =", loss_n)
print("Predictions:", out_n.ravel())
```

```
Vanilla GD: w = [3.58622733 3.57819032] b = [-1.49365719] loss =
0.007241584326092204
Predictions: [0 1 1 1]

Momentum: w = [6.46907779 6.46910994] b = [-2.99074734] loss =
0.0005101717749310835
Predictions: [0 1 1 1]

Nesterov: w = [6.46409582 6.4641271 ] b = [-2.988218] loss =
0.0005126219819523002
Predictions: [0 1 1 1]
```