1. **Below is a simple CNN model using TensorFlow and Keras suitable for classifying CIFAR-10 images. This model will be your baseline for experimenting with different optimization techniques.**

import tensorflow as tf

from tensorflow.keras import layers, models

def create\_baseline\_cnn\_model():

model = models.Sequential()

# Convolutional base

model.add(layers.Conv2D(32, (3, 3), activation='relu', input\_shape=(32, 32, 3)))

model.add(layers.MaxPooling2D((2, 2)))

model.add(layers.Conv2D(64, (3, 3), activation='relu'))

model.add(layers.MaxPooling2D((2, 2)))

model.add(layers.Conv2D(64, (3, 3), activation='relu'))

# Adding dense layers on top

model.add(layers.Flatten())

model.add(layers.Dense(64, activation='relu'))

model.add(layers.Dense(10)) # No activation on the last layer because we'll use the 'from\_logits=True' setting in the loss function

return model

# Create the model

model = create\_baseline\_cnn\_model()

# Compile the model

model.compile(optimizer='adam', # This will be swapped out for other optimizers during experimentation

loss=tf.keras.losses.SparseCategoricalCrossentropy(from\_logits=True),

metrics=['accuracy'])

model.summary()

from tensorflow.keras.datasets import cifar10

from tensorflow.keras.utils import to\_categorical

# Load and prepare the CIFAR-10 dataset

(train\_images, train\_labels), (test\_images, test\_labels) = cifar10.load\_data()

# Normalize pixel values to be between 0 and 1

train\_images, test\_images = train\_images / 255.0, test\_images / 255.0

# Train the model

history = model.fit(train\_images, train\_labels, epochs=10,

validation\_data=(test\_images, test\_labels))

# Evaluate the model

test\_loss, test\_acc = model.evaluate(test\_images, test\_labels, verbose=2)

print('\nTest accuracy:', test\_acc)

Output:

Test accuracy: 0.7207000255584717

1. **Python code to experiment with different optimization algorithms to see how they affect model's accuracy and training efficiency.**

from tensorflow.keras import layers, models

def create\_cnn\_model():

model = models.Sequential([

layers.Conv2D(32, (3, 3), activation='relu', input\_shape=(32, 32, 3)),

layers.MaxPooling2D((2, 2)),

layers.Conv2D(64, (3, 3), activation='relu'),

layers.MaxPooling2D((2, 2)),

layers.Conv2D(64, (3, 3), activation='relu'),

layers.Flatten(),

layers.Dense(64, activation='relu'),

layers.Dense(10)

])

return model

import tensorflow as tf

from tensorflow.keras.datasets import cifar10

from tensorflow.keras.utils import to\_categorical

def train\_and\_evaluate\_model(optimizer):

# Load and prepare the CIFAR-10 dataset

(train\_images, train\_labels), (test\_images, test\_labels) = cifar10.load\_data()

train\_images, test\_images = train\_images / 255.0, test\_images / 255.0

# Create the model

model = create\_cnn\_model()

# Compile the model with the given optimizer

model.compile(optimizer=optimizer,

loss=tf.keras.losses.SparseCategoricalCrossentropy(from\_logits=True),

metrics=['accuracy'])

# Train the model

history = model.fit(train\_images, train\_labels, epochs=10,

validation\_data=(test\_images, test\_labels), verbose=2)

# Evaluate the model

test\_loss, test\_acc = model.evaluate(test\_images, test\_labels, verbose=2)

print(f'\nTest accuracy with {optimizer}:', test\_acc)

# Optimizers to test

optimizers = ['adam', 'sgd', 'rmsprop', 'adamax']

for opt in optimizers:

print(f"\nTraining with {opt} optimizer:")

train\_and\_evaluate\_model(opt)

Output:

Training with adam optimizer:

Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz

170498071/170498071 [==============================] - 2s 0us/step

Epoch 1/10

1563/1563 - 62s - loss: 1.4959 - accuracy: 0.4600 - val\_loss: 1.2584 - val\_accuracy: 0.5504 - 62s/epoch - 40ms/step

Epoch 2/10

1563/1563 - 58s - loss: 1.1229 - accuracy: 0.6033 - val\_loss: 1.0283 - val\_accuracy: 0.6351 - 58s/epoch - 37ms/step

Epoch 3/10

1563/1563 - 58s - loss: 0.9518 - accuracy: 0.6657 - val\_loss: 0.9566 - val\_accuracy: 0.6610 - 58s/epoch - 37ms/step

Epoch 4/10

1563/1563 - 56s - loss: 0.8500 - accuracy: 0.7020 - val\_loss: 0.8726 - val\_accuracy: 0.6912 - 56s/epoch - 36ms/step

Epoch 5/10

1563/1563 - 57s - loss: 0.7757 - accuracy: 0.7287 - val\_loss: 0.8854 - val\_accuracy: 0.6921 - 57s/epoch - 37ms/step

Epoch 6/10

1563/1563 - 55s - loss: 0.7169 - accuracy: 0.7498 - val\_loss: 0.8512 - val\_accuracy: 0.7121 - 55s/epoch - 35ms/step

Epoch 7/10

1563/1563 - 57s - loss: 0.6622 - accuracy: 0.7684 - val\_loss: 0.8623 - val\_accuracy: 0.7081 - 57s/epoch - 37ms/step

Epoch 8/10

1563/1563 - 57s - loss: 0.6140 - accuracy: 0.7842 - val\_loss: 0.8579 - val\_accuracy: 0.7109 - 57s/epoch - 36ms/step

Epoch 9/10

1563/1563 - 64s - loss: 0.5656 - accuracy: 0.8016 - val\_loss: 0.8766 - val\_accuracy: 0.7146 - 64s/epoch - 41ms/step

Epoch 10/10

1563/1563 - 57s - loss: 0.5284 - accuracy: 0.8137 - val\_loss: 0.8711 - val\_accuracy: 0.7071 - 57s/epoch - 37ms/step

313/313 - 4s - loss: 0.8711 - accuracy: 0.7071 - 4s/epoch - 13ms/step

Test accuracy with adam: 0.707099974155426

Training with sgd optimizer:

Epoch 1/10

1563/1563 - 58s - loss: 2.0869 - accuracy: 0.2283 - val\_loss: 1.9494 - val\_accuracy: 0.2901 - 58s/epoch - 37ms/step

Epoch 2/10

1563/1563 - 58s - loss: 1.7292 - accuracy: 0.3738 - val\_loss: 1.5474 - val\_accuracy: 0.4467 - 58s/epoch - 37ms/step

Epoch 3/10

1563/1563 - 56s - loss: 1.5028 - accuracy: 0.4573 - val\_loss: 1.4089 - val\_accuracy: 0.4924 - 56s/epoch - 36ms/step

Epoch 4/10

1563/1563 - 57s - loss: 1.3756 - accuracy: 0.5085 - val\_loss: 1.3624 - val\_accuracy: 0.5052 - 57s/epoch - 36ms/step

Epoch 5/10

1563/1563 - 57s - loss: 1.2864 - accuracy: 0.5420 - val\_loss: 1.3249 - val\_accuracy: 0.5301 - 57s/epoch - 36ms/step

Epoch 6/10

1563/1563 - 57s - loss: 1.2136 - accuracy: 0.5719 - val\_loss: 1.2479 - val\_accuracy: 0.5607 - 57s/epoch - 36ms/step

Epoch 7/10

1563/1563 - 55s - loss: 1.1509 - accuracy: 0.5957 - val\_loss: 1.2408 - val\_accuracy: 0.5634 - 55s/epoch - 35ms/step

Epoch 8/10

1563/1563 - 56s - loss: 1.0995 - accuracy: 0.6143 - val\_loss: 1.2341 - val\_accuracy: 0.5703 - 56s/epoch - 36ms/step

Epoch 9/10

1563/1563 - 63s - loss: 1.0512 - accuracy: 0.6309 - val\_loss: 1.1543 - val\_accuracy: 0.5961 - 63s/epoch - 40ms/step

Epoch 10/10

1563/1563 - 55s - loss: 1.0093 - accuracy: 0.6458 - val\_loss: 1.1143 - val\_accuracy: 0.6165 - 55s/epoch - 35ms/step

313/313 - 3s - loss: 1.1143 - accuracy: 0.6165 - 3s/epoch - 10ms/step

Test accuracy with sgd: 0.6165000200271606

Training with rmsprop optimizer:

Epoch 1/10

1563/1563 - 59s - loss: 1.5465 - accuracy: 0.4409 - val\_loss: 1.3408 - val\_accuracy: 0.5210 - 59s/epoch - 37ms/step

Epoch 2/10

1563/1563 - 57s - loss: 1.1299 - accuracy: 0.6024 - val\_loss: 1.0957 - val\_accuracy: 0.6090 - 57s/epoch - 37ms/step

Epoch 3/10

1563/1563 - 56s - loss: 0.9655 - accuracy: 0.6645 - val\_loss: 0.9622 - val\_accuracy: 0.6684 - 56s/epoch - 36ms/step

Epoch 4/10

1563/1563 - 55s - loss: 0.8609 - accuracy: 0.7009 - val\_loss: 1.0130 - val\_accuracy: 0.6521 - 55s/epoch - 35ms/step

Epoch 5/10

1563/1563 - 57s - loss: 0.7779 - accuracy: 0.7312 - val\_loss: 1.1263 - val\_accuracy: 0.6425 - 57s/epoch - 36ms/step

Epoch 6/10

1563/1563 - 58s - loss: 0.7148 - accuracy: 0.7535 - val\_loss: 0.9511 - val\_accuracy: 0.6848 - 58s/epoch - 37ms/step

Epoch 7/10

1563/1563 - 57s - loss: 0.6611 - accuracy: 0.7716 - val\_loss: 0.9086 - val\_accuracy: 0.7043 - 57s/epoch - 37ms/step

Epoch 8/10

1563/1563 - 57s - loss: 0.6155 - accuracy: 0.7866 - val\_loss: 0.9010 - val\_accuracy: 0.7103 - 57s/epoch - 36ms/step

Epoch 9/10

1563/1563 - 60s - loss: 0.5709 - accuracy: 0.8015 - val\_loss: 0.9861 - val\_accuracy: 0.6950 - 60s/epoch - 38ms/step

Epoch 10/10

1563/1563 - 57s - loss: 0.5348 - accuracy: 0.8142 - val\_loss: 0.9530 - val\_accuracy: 0.7088 - 57s/epoch - 37ms/step

313/313 - 3s - loss: 0.9530 - accuracy: 0.7088 - 3s/epoch - 10ms/step

Test accuracy with rmsprop: 0.7088000178337097

Training with adamax optimizer:

Epoch 1/10

1563/1563 - 59s - loss: 1.6552 - accuracy: 0.3975 - val\_loss: 1.4745 - val\_accuracy: 0.4779 - 59s/epoch - 38ms/step

Epoch 2/10

1563/1563 - 57s - loss: 1.3317 - accuracy: 0.5245 - val\_loss: 1.2578 - val\_accuracy: 0.5545 - 57s/epoch - 37ms/step

Epoch 3/10

1563/1563 - 59s - loss: 1.1884 - accuracy: 0.5822 - val\_loss: 1.1245 - val\_accuracy: 0.6053 - 59s/epoch - 38ms/step

Epoch 4/10

1563/1563 - 58s - loss: 1.0830 - accuracy: 0.6208 - val\_loss: 1.0498 - val\_accuracy: 0.6320 - 58s/epoch - 37ms/step

Epoch 5/10

1563/1563 - 59s - loss: 1.0060 - accuracy: 0.6491 - val\_loss: 1.0017 - val\_accuracy: 0.6489 - 59s/epoch - 38ms/step

Epoch 6/10

1563/1563 - 59s - loss: 0.9438 - accuracy: 0.6701 - val\_loss: 0.9346 - val\_accuracy: 0.6751 - 59s/epoch - 38ms/step

Epoch 7/10

1563/1563 - 58s - loss: 0.8881 - accuracy: 0.6918 - val\_loss: 0.9120 - val\_accuracy: 0.6853 - 58s/epoch - 37ms/step

Epoch 8/10

1563/1563 - 64s - loss: 0.8396 - accuracy: 0.7094 - val\_loss: 0.9523 - val\_accuracy: 0.6641 - 64s/epoch - 41ms/step

Epoch 9/10

1563/1563 - 58s - loss: 0.7936 - accuracy: 0.7239 - val\_loss: 0.9434 - val\_accuracy: 0.6768 - 58s/epoch - 37ms/step

Epoch 10/10

1563/1563 - 59s - loss: 0.7581 - accuracy: 0.7386 - val\_loss: 0.8495 - val\_accuracy: 0.7099 - 59s/epoch - 38ms/step

313/313 - 4s - loss: 0.8495 - accuracy: 0.7099 - 4s/epoch - 12ms/step

Test accuracy with adamax: 0.7099000215530396

1. **Python code that incorporates several suggested adjustments to refine the performance of Convolutional Neural Network (CNN) model on the CIFAR-10 dataset. These adjustments include experimenting with learning rate changes, adding momentum to the SGD optimizer, introducing a learning rate scheduler, and implementing dropout for regularization.**

from tensorflow.keras import layers, models

def create\_cnn\_model\_with\_dropout():

model = models.Sequential([

layers.Conv2D(32, (3, 3), activation='relu', input\_shape=(32, 32, 3)),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.2), # Dropout layer after pooling

layers.Conv2D(64, (3, 3), activation='relu'),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.3), # Another dropout layer after the second pooling

layers.Conv2D(64, (3, 3), activation='relu'),

layers.Flatten(),

layers.Dense(64, activation='relu'),

layers.Dropout(0.4), # Dropout before the final dense layer

layers.Dense(10)

])

return model

import tensorflow as tf

def get\_optimizer(opt\_name):

if opt\_name == "sgd":

return tf.keras.optimizers.SGD(learning\_rate=0.01, momentum=0.9) # Added momentum

elif opt\_name == "adam":

return tf.keras.optimizers.Adam(learning\_rate=0.001)

elif opt\_name == "rmsprop":

return tf.keras.optimizers.RMSprop(learning\_rate=0.001)

elif opt\_name == "adamax":

return tf.keras.optimizers.Adamax(learning\_rate=0.002) # Adjusted learning rate

else:

return tf.keras.optimizers.Adam() # Default case

from tensorflow.keras.callbacks import LearningRateScheduler

import numpy as np

def scheduler(epoch, lr):

if epoch < 10:

return lr

else:

return lr \* np.exp(-0.1)

def train\_and\_evaluate\_model(optimizer\_name):

# Load and prepare the CIFAR-10 dataset

(train\_images, train\_labels), (test\_images, test\_labels) = cifar10.load\_data()

train\_images, test\_images = train\_images / 255.0, test\_images / 255.0

# Create the model with dropout

model = create\_cnn\_model\_with\_dropout()

# Get optimizer

optimizer = get\_optimizer(optimizer\_name)

# Compile the model with the selected optimizer

model.compile(optimizer=optimizer,

loss=tf.keras.losses.SparseCategoricalCrossentropy(from\_logits=True),

metrics=['accuracy'])

# Setup callbacks

callback\_list = [LearningRateScheduler(scheduler, verbose=1)]

# Train the model

history = model.fit(train\_images, train\_labels, epochs=20,

validation\_data=(test\_images, test\_labels),

callbacks=callback\_list, verbose=2)

# Evaluate the model

test\_loss, test\_acc = model.evaluate(test\_images, test\_labels, verbose=2)

print(f'\nTest accuracy with {optimizer\_name}:', test\_acc)

# Optimizers to test

optimizers = ['adam', 'sgd', 'rmsprop', 'adamax']

for opt in optimizers:

print(f"\nTraining with {opt} optimizer:")

train\_and\_evaluate\_model(opt)

Below is the output:

Training with adam optimizer:

Epoch 1: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 1/20

1563/1563 - 66s - loss: 1.7745 - accuracy: 0.3439 - val\_loss: 1.3567 - val\_accuracy: 0.5094 - lr: 0.0010 - 66s/epoch - 42ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 2/20

1563/1563 - 63s - loss: 1.3965 - accuracy: 0.5007 - val\_loss: 1.1731 - val\_accuracy: 0.5860 - lr: 0.0010 - 63s/epoch - 40ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 3/20

1563/1563 - 63s - loss: 1.2522 - accuracy: 0.5582 - val\_loss: 1.1155 - val\_accuracy: 0.6122 - lr: 0.0010 - 63s/epoch - 40ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 4/20

1563/1563 - 63s - loss: 1.1669 - accuracy: 0.5934 - val\_loss: 1.0019 - val\_accuracy: 0.6551 - lr: 0.0010 - 63s/epoch - 40ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 5/20

1563/1563 - 63s - loss: 1.0960 - accuracy: 0.6182 - val\_loss: 0.9553 - val\_accuracy: 0.6682 - lr: 0.0010 - 63s/epoch - 40ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 6/20

1563/1563 - 61s - loss: 1.0485 - accuracy: 0.6359 - val\_loss: 0.9562 - val\_accuracy: 0.6692 - lr: 0.0010 - 61s/epoch - 39ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 7/20

1563/1563 - 62s - loss: 1.0124 - accuracy: 0.6499 - val\_loss: 0.8988 - val\_accuracy: 0.6879 - lr: 0.0010 - 62s/epoch - 39ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 8/20

1563/1563 - 62s - loss: 0.9849 - accuracy: 0.6580 - val\_loss: 0.8590 - val\_accuracy: 0.7053 - lr: 0.0010 - 62s/epoch - 39ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 9/20

1563/1563 - 62s - loss: 0.9620 - accuracy: 0.6682 - val\_loss: 0.8374 - val\_accuracy: 0.7117 - lr: 0.0010 - 62s/epoch - 39ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 10/20

1563/1563 - 65s - loss: 0.9378 - accuracy: 0.6753 - val\_loss: 0.8268 - val\_accuracy: 0.7160 - lr: 0.0010 - 65s/epoch - 42ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.0009048374610134307.

Epoch 11/20

1563/1563 - 62s - loss: 0.9021 - accuracy: 0.6874 - val\_loss: 0.8039 - val\_accuracy: 0.7182 - lr: 9.0484e-04 - 62s/epoch - 40ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.0008187307807475673.

Epoch 12/20

1563/1563 - 62s - loss: 0.8762 - accuracy: 0.6964 - val\_loss: 0.8493 - val\_accuracy: 0.7130 - lr: 8.1873e-04 - 62s/epoch - 40ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.0007408182609837606.

Epoch 13/20

1563/1563 - 63s - loss: 0.8567 - accuracy: 0.7050 - val\_loss: 0.7967 - val\_accuracy: 0.7248 - lr: 7.4082e-04 - 63s/epoch - 40ms/step

Epoch 14: LearningRateScheduler setting learning rate to 0.0006703200923609524.

Epoch 14/20

1563/1563 - 62s - loss: 0.8271 - accuracy: 0.7150 - val\_loss: 0.7883 - val\_accuracy: 0.7279 - lr: 6.7032e-04 - 62s/epoch - 39ms/step

Epoch 15: LearningRateScheduler setting learning rate to 0.000606530675391766.

Epoch 15/20

1563/1563 - 60s - loss: 0.8067 - accuracy: 0.7191 - val\_loss: 0.7926 - val\_accuracy: 0.7267 - lr: 6.0653e-04 - 60s/epoch - 39ms/step

Epoch 16: LearningRateScheduler setting learning rate to 0.0005488116682245179.

Epoch 16/20

1563/1563 - 63s - loss: 0.7863 - accuracy: 0.7265 - val\_loss: 0.7586 - val\_accuracy: 0.7416 - lr: 5.4881e-04 - 63s/epoch - 41ms/step

Epoch 17: LearningRateScheduler setting learning rate to 0.0004965853504160465.

Epoch 17/20

1563/1563 - 62s - loss: 0.7759 - accuracy: 0.7310 - val\_loss: 0.7803 - val\_accuracy: 0.7345 - lr: 4.9659e-04 - 62s/epoch - 39ms/step

Epoch 18: LearningRateScheduler setting learning rate to 0.0004493289874054642.

Epoch 18/20

1563/1563 - 63s - loss: 0.7564 - accuracy: 0.7354 - val\_loss: 0.7543 - val\_accuracy: 0.7407 - lr: 4.4933e-04 - 63s/epoch - 41ms/step

Epoch 19: LearningRateScheduler setting learning rate to 0.0004065696690041351.

Epoch 19/20

1563/1563 - 61s - loss: 0.7444 - accuracy: 0.7413 - val\_loss: 0.7409 - val\_accuracy: 0.7458 - lr: 4.0657e-04 - 61s/epoch - 39ms/step

Epoch 20: LearningRateScheduler setting learning rate to 0.00036787943756223617.

Epoch 20/20

1563/1563 - 62s - loss: 0.7347 - accuracy: 0.7459 - val\_loss: 0.7479 - val\_accuracy: 0.7455 - lr: 3.6788e-04 - 62s/epoch - 40ms/step

313/313 - 3s - loss: 0.7479 - accuracy: 0.7455 - 3s/epoch - 10ms/step

Test accuracy with adam: 0.7455000281333923

Training with sgd optimizer:

Epoch 1: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 1/20

1563/1563 - 64s - loss: 1.8826 - accuracy: 0.3007 - val\_loss: 1.5089 - val\_accuracy: 0.4397 - lr: 0.0100 - 64s/epoch - 41ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 2/20

1563/1563 - 62s - loss: 1.5177 - accuracy: 0.4508 - val\_loss: 1.3641 - val\_accuracy: 0.5025 - lr: 0.0100 - 62s/epoch - 39ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 3/20

1563/1563 - 60s - loss: 1.3805 - accuracy: 0.5069 - val\_loss: 1.2060 - val\_accuracy: 0.5745 - lr: 0.0100 - 60s/epoch - 38ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 4/20

1563/1563 - 60s - loss: 1.3100 - accuracy: 0.5370 - val\_loss: 1.1699 - val\_accuracy: 0.5760 - lr: 0.0100 - 60s/epoch - 38ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 5/20

1563/1563 - 59s - loss: 1.2461 - accuracy: 0.5576 - val\_loss: 1.1379 - val\_accuracy: 0.5941 - lr: 0.0100 - 59s/epoch - 38ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 6/20

1563/1563 - 62s - loss: 1.2034 - accuracy: 0.5762 - val\_loss: 1.1182 - val\_accuracy: 0.6108 - lr: 0.0100 - 62s/epoch - 39ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 7/20

1563/1563 - 60s - loss: 1.1681 - accuracy: 0.5920 - val\_loss: 1.0472 - val\_accuracy: 0.6330 - lr: 0.0100 - 60s/epoch - 38ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 8/20

1563/1563 - 62s - loss: 1.1478 - accuracy: 0.5982 - val\_loss: 1.0556 - val\_accuracy: 0.6229 - lr: 0.0100 - 62s/epoch - 40ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 9/20

1563/1563 - 62s - loss: 1.1145 - accuracy: 0.6124 - val\_loss: 1.0307 - val\_accuracy: 0.6344 - lr: 0.0100 - 62s/epoch - 40ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 10/20

1563/1563 - 73s - loss: 1.0997 - accuracy: 0.6135 - val\_loss: 0.9663 - val\_accuracy: 0.6593 - lr: 0.0100 - 73s/epoch - 47ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.009048373978112673.

Epoch 11/20

1563/1563 - 60s - loss: 1.0711 - accuracy: 0.6249 - val\_loss: 0.9375 - val\_accuracy: 0.6746 - lr: 0.0090 - 60s/epoch - 38ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.008187307702138734.

Epoch 12/20

1563/1563 - 60s - loss: 1.0279 - accuracy: 0.6409 - val\_loss: 1.1265 - val\_accuracy: 0.6132 - lr: 0.0082 - 60s/epoch - 38ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.007408182609837607.

Epoch 13/20

1563/1563 - 62s - loss: 0.9937 - accuracy: 0.6518 - val\_loss: 0.9073 - val\_accuracy: 0.6825 - lr: 0.0074 - 62s/epoch - 40ms/step

Epoch 14: LearningRateScheduler setting learning rate to 0.006703200818272585.

Epoch 14/20

1563/1563 - 59s - loss: 0.9684 - accuracy: 0.6617 - val\_loss: 0.9027 - val\_accuracy: 0.6943 - lr: 0.0067 - 59s/epoch - 38ms/step

Epoch 15: LearningRateScheduler setting learning rate to 0.006065306859254599.

Epoch 15/20

1563/1563 - 60s - loss: 0.9423 - accuracy: 0.6718 - val\_loss: 0.9131 - val\_accuracy: 0.6923 - lr: 0.0061 - 60s/epoch - 39ms/step

Epoch 16: LearningRateScheduler setting learning rate to 0.005488116471571301.

Epoch 16/20

1563/1563 - 62s - loss: 0.9180 - accuracy: 0.6807 - val\_loss: 0.8599 - val\_accuracy: 0.7039 - lr: 0.0055 - 62s/epoch - 40ms/step

Epoch 17: LearningRateScheduler setting learning rate to 0.0049658529774757685.

Epoch 17/20

1563/1563 - 60s - loss: 0.8935 - accuracy: 0.6892 - val\_loss: 0.8773 - val\_accuracy: 0.7000 - lr: 0.0050 - 60s/epoch - 38ms/step

Epoch 18: LearningRateScheduler setting learning rate to 0.004493289558043824.

Epoch 18/20

1563/1563 - 61s - loss: 0.8761 - accuracy: 0.6939 - val\_loss: 0.8944 - val\_accuracy: 0.6922 - lr: 0.0045 - 61s/epoch - 39ms/step

Epoch 19: LearningRateScheduler setting learning rate to 0.004065696584704411.

Epoch 19/20

1563/1563 - 62s - loss: 0.8536 - accuracy: 0.7026 - val\_loss: 0.8327 - val\_accuracy: 0.7145 - lr: 0.0041 - 62s/epoch - 39ms/step

Epoch 20: LearningRateScheduler setting learning rate to 0.0036787944282908316.

Epoch 20/20

1563/1563 - 61s - loss: 0.8330 - accuracy: 0.7083 - val\_loss: 0.8102 - val\_accuracy: 0.7243 - lr: 0.0037 - 61s/epoch - 39ms/step

313/313 - 3s - loss: 0.8102 - accuracy: 0.7243 - 3s/epoch - 10ms/step

Test accuracy with sgd: 0.7243000268936157

Training with rmsprop optimizer:

Epoch 1: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 1/20

1563/1563 - 62s - loss: 1.7006 - accuracy: 0.3791 - val\_loss: 1.2912 - val\_accuracy: 0.5516 - lr: 0.0010 - 62s/epoch - 39ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 2/20

1563/1563 - 61s - loss: 1.3287 - accuracy: 0.5314 - val\_loss: 1.3137 - val\_accuracy: 0.5353 - lr: 0.0010 - 61s/epoch - 39ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 3/20

1563/1563 - 59s - loss: 1.2095 - accuracy: 0.5807 - val\_loss: 1.0408 - val\_accuracy: 0.6289 - lr: 0.0010 - 59s/epoch - 38ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 4/20

1563/1563 - 60s - loss: 1.1399 - accuracy: 0.6099 - val\_loss: 1.2648 - val\_accuracy: 0.5812 - lr: 0.0010 - 60s/epoch - 38ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 5/20

1563/1563 - 61s - loss: 1.1253 - accuracy: 0.6213 - val\_loss: 1.0329 - val\_accuracy: 0.6617 - lr: 0.0010 - 61s/epoch - 39ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 6/20

1563/1563 - 62s - loss: 1.1226 - accuracy: 0.6272 - val\_loss: 1.0326 - val\_accuracy: 0.6497 - lr: 0.0010 - 62s/epoch - 40ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 7/20

1563/1563 - 59s - loss: 1.1360 - accuracy: 0.6273 - val\_loss: 1.0317 - val\_accuracy: 0.6745 - lr: 0.0010 - 59s/epoch - 38ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 8/20

1563/1563 - 62s - loss: 1.1522 - accuracy: 0.6230 - val\_loss: 1.1174 - val\_accuracy: 0.6455 - lr: 0.0010 - 62s/epoch - 40ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 9/20

1563/1563 - 62s - loss: 1.1726 - accuracy: 0.6177 - val\_loss: 1.5602 - val\_accuracy: 0.5057 - lr: 0.0010 - 62s/epoch - 40ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 10/20

1563/1563 - 66s - loss: 1.1847 - accuracy: 0.6149 - val\_loss: 1.0894 - val\_accuracy: 0.6450 - lr: 0.0010 - 66s/epoch - 42ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.0009048374610134307.

Epoch 11/20

1563/1563 - 60s - loss: 1.1636 - accuracy: 0.6225 - val\_loss: 1.3300 - val\_accuracy: 0.5492 - lr: 9.0484e-04 - 60s/epoch - 38ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.0008187307807475673.

Epoch 12/20

1563/1563 - 62s - loss: 1.1495 - accuracy: 0.6301 - val\_loss: 1.2355 - val\_accuracy: 0.5912 - lr: 8.1873e-04 - 62s/epoch - 40ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.0007408182609837606.

Epoch 13/20

1563/1563 - 62s - loss: 1.1418 - accuracy: 0.6300 - val\_loss: 1.2339 - val\_accuracy: 0.5936 - lr: 7.4082e-04 - 62s/epoch - 40ms/step

Epoch 14: LearningRateScheduler setting learning rate to 0.0006703200923609524.

Epoch 14/20

1563/1563 - 60s - loss: 1.1318 - accuracy: 0.6329 - val\_loss: 1.0547 - val\_accuracy: 0.6550 - lr: 6.7032e-04 - 60s/epoch - 39ms/step

Epoch 15: LearningRateScheduler setting learning rate to 0.000606530675391766.

Epoch 15/20

1563/1563 - 60s - loss: 1.1255 - accuracy: 0.6332 - val\_loss: 1.1158 - val\_accuracy: 0.6493 - lr: 6.0653e-04 - 60s/epoch - 39ms/step

Epoch 16: LearningRateScheduler setting learning rate to 0.0005488116682245179.

Epoch 16/20

1563/1563 - 62s - loss: 1.1118 - accuracy: 0.6374 - val\_loss: 0.9982 - val\_accuracy: 0.6802 - lr: 5.4881e-04 - 62s/epoch - 39ms/step

Epoch 17: LearningRateScheduler setting learning rate to 0.0004965853504160465.

Epoch 17/20

1563/1563 - 60s - loss: 1.1066 - accuracy: 0.6413 - val\_loss: 1.0255 - val\_accuracy: 0.6674 - lr: 4.9659e-04 - 60s/epoch - 39ms/step

Epoch 18: LearningRateScheduler setting learning rate to 0.0004493289874054642.

Epoch 18/20

1563/1563 - 60s - loss: 1.0981 - accuracy: 0.6440 - val\_loss: 1.0434 - val\_accuracy: 0.6607 - lr: 4.4933e-04 - 60s/epoch - 38ms/step

Epoch 19: LearningRateScheduler setting learning rate to 0.0004065696690041351.

Epoch 19/20

1563/1563 - 61s - loss: 1.0984 - accuracy: 0.6437 - val\_loss: 1.0727 - val\_accuracy: 0.6697 - lr: 4.0657e-04 - 61s/epoch - 39ms/step

Epoch 20: LearningRateScheduler setting learning rate to 0.00036787943756223617.

Epoch 20/20

1563/1563 - 61s - loss: 1.0894 - accuracy: 0.6510 - val\_loss: 0.9900 - val\_accuracy: 0.6830 - lr: 3.6788e-04 - 61s/epoch - 39ms/step

313/313 - 4s - loss: 0.9900 - accuracy: 0.6830 - 4s/epoch - 13ms/step

Test accuracy with rmsprop: 0.6830000281333923

Training with adamax optimizer:

Epoch 1: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 1/20

1563/1563 - 63s - loss: 1.8128 - accuracy: 0.3267 - val\_loss: 1.4663 - val\_accuracy: 0.4738 - lr: 0.0020 - 63s/epoch - 41ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 2/20

1563/1563 - 64s - loss: 1.4656 - accuracy: 0.4711 - val\_loss: 1.3068 - val\_accuracy: 0.5393 - lr: 0.0020 - 64s/epoch - 41ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 3/20

1563/1563 - 62s - loss: 1.3205 - accuracy: 0.5301 - val\_loss: 1.1706 - val\_accuracy: 0.5805 - lr: 0.0020 - 62s/epoch - 40ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 4/20

1563/1563 - 64s - loss: 1.2164 - accuracy: 0.5723 - val\_loss: 1.0973 - val\_accuracy: 0.6141 - lr: 0.0020 - 64s/epoch - 41ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 5/20

1563/1563 - 63s - loss: 1.1457 - accuracy: 0.5984 - val\_loss: 1.0324 - val\_accuracy: 0.6394 - lr: 0.0020 - 63s/epoch - 40ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 6/20

1563/1563 - 61s - loss: 1.0916 - accuracy: 0.6204 - val\_loss: 0.9659 - val\_accuracy: 0.6626 - lr: 0.0020 - 61s/epoch - 39ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 7/20

1563/1563 - 63s - loss: 1.0383 - accuracy: 0.6381 - val\_loss: 0.9453 - val\_accuracy: 0.6701 - lr: 0.0020 - 63s/epoch - 40ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 8/20

1563/1563 - 63s - loss: 0.9950 - accuracy: 0.6522 - val\_loss: 0.9144 - val\_accuracy: 0.6871 - lr: 0.0020 - 63s/epoch - 40ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 9/20

1563/1563 - 62s - loss: 0.9678 - accuracy: 0.6649 - val\_loss: 0.8534 - val\_accuracy: 0.6996 - lr: 0.0020 - 62s/epoch - 40ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 10/20

1563/1563 - 65s - loss: 0.9396 - accuracy: 0.6755 - val\_loss: 0.8608 - val\_accuracy: 0.6952 - lr: 0.0020 - 65s/epoch - 42ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.0018096749220268614.

Epoch 11/20

1563/1563 - 62s - loss: 0.9109 - accuracy: 0.6842 - val\_loss: 0.8223 - val\_accuracy: 0.7124 - lr: 0.0018 - 62s/epoch - 39ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.0016374615614951347.

Epoch 12/20

1563/1563 - 62s - loss: 0.8806 - accuracy: 0.6933 - val\_loss: 0.8483 - val\_accuracy: 0.7044 - lr: 0.0016 - 62s/epoch - 40ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.0014816365219675212.

Epoch 13/20

1563/1563 - 61s - loss: 0.8589 - accuracy: 0.7020 - val\_loss: 0.7896 - val\_accuracy: 0.7280 - lr: 0.0015 - 61s/epoch - 39ms/step

Epoch 14: LearningRateScheduler setting learning rate to 0.0013406401847219048.

Epoch 14/20

1563/1563 - 60s - loss: 0.8399 - accuracy: 0.7081 - val\_loss: 0.8105 - val\_accuracy: 0.7199 - lr: 0.0013 - 60s/epoch - 38ms/step

Epoch 15: LearningRateScheduler setting learning rate to 0.001213061350783532.

Epoch 15/20

1563/1563 - 63s - loss: 0.8179 - accuracy: 0.7164 - val\_loss: 0.7735 - val\_accuracy: 0.7337 - lr: 0.0012 - 63s/epoch - 40ms/step

Epoch 16: LearningRateScheduler setting learning rate to 0.0010976233364490358.

Epoch 16/20

1563/1563 - 60s - loss: 0.8036 - accuracy: 0.7199 - val\_loss: 0.7735 - val\_accuracy: 0.7351 - lr: 0.0011 - 60s/epoch - 39ms/step

Epoch 17: LearningRateScheduler setting learning rate to 0.000993170700832093.

Epoch 17/20

1563/1563 - 63s - loss: 0.7832 - accuracy: 0.7277 - val\_loss: 0.7553 - val\_accuracy: 0.7378 - lr: 9.9317e-04 - 63s/epoch - 40ms/step

Epoch 18: LearningRateScheduler setting learning rate to 0.0008986579748109283.

Epoch 18/20

1563/1563 - 63s - loss: 0.7755 - accuracy: 0.7295 - val\_loss: 0.7443 - val\_accuracy: 0.7461 - lr: 8.9866e-04 - 63s/epoch - 40ms/step

Epoch 19: LearningRateScheduler setting learning rate to 0.0008131393380082702.

Epoch 19/20

1563/1563 - 62s - loss: 0.7601 - accuracy: 0.7353 - val\_loss: 0.7460 - val\_accuracy: 0.7456 - lr: 8.1314e-04 - 62s/epoch - 40ms/step

Epoch 20: LearningRateScheduler setting learning rate to 0.0007357588751244723.

Epoch 20/20

1563/1563 - 62s - loss: 0.7557 - accuracy: 0.7367 - val\_loss: 0.7321 - val\_accuracy: 0.7490 - lr: 7.3576e-04 - 62s/epoch - 40ms/step

313/313 - 3s - loss: 0.7321 - accuracy: 0.7490 - 3s/epoch - 10ms/step

Test accuracy with adamax: 0.7490000128746033

1. **To further improve the performance of CNN model on the CIFAR-10 dataset, I'll incorporate a few adjustments, including additional regularization techniques like L2 regularization, and the use of Batch Normalization. Additionally, I'll adjust the learning rate schedules more finely for each optimizer to optimize their performance.**

from tensorflow.keras import layers, models, regularizers

def create\_advanced\_cnn\_model():

model = models.Sequential([

layers.Conv2D(32, (3, 3), padding='same', activation='relu', input\_shape=(32, 32, 3)),

layers.BatchNormalization(),

layers.Conv2D(32, (3, 3), activation='relu'),

layers.BatchNormalization(),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.2),

layers.Conv2D(64, (3, 3), padding='same', activation='relu'),

layers.BatchNormalization(),

layers.Conv2D(64, (3, 3), activation='relu'),

layers.BatchNormalization(),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.3),

layers.Conv2D(128, (3, 3), padding='same', activation='relu'),

layers.BatchNormalization(),

layers.Conv2D(128, (3, 3), activation='relu'),

layers.BatchNormalization(),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.4),

layers.Flatten(),

layers.Dense(128, activation='relu', kernel\_regularizer=regularizers.l2(0.01)),

layers.Dropout(0.5),

layers.Dense(10)

])

return model

import tensorflow as tf

def get\_optimizer(opt\_name):

if opt\_name == "sgd":

return tf.keras.optimizers.SGD(learning\_rate=0.01, momentum=0.9)

elif opt\_name == "adam":

return tf.keras.optimizers.Adam(learning\_rate=0.001)

elif opt\_name == "rmsprop":

return tf.keras.optimizers.RMSprop(learning\_rate=0.001)

elif opt\_name == "adamax":

return tf.keras.optimizers.Adamax(learning\_rate=0.002)

else:

return tf.keras.optimizers.Adam() # Default case

from tensorflow.keras.datasets import cifar10

from tensorflow.keras.callbacks import LearningRateScheduler

import numpy as np

def scheduler(epoch, lr):

if epoch < 10:

return lr

elif epoch < 20:

return lr \* 0.5

else:

return lr \* 0.1

def train\_and\_evaluate\_model(optimizer\_name):

(train\_images, train\_labels), (test\_images, test\_labels) = cifar10.load\_data()

train\_images, test\_images = train\_images / 255.0, test\_images / 255.0

model = create\_advanced\_cnn\_model()

optimizer = get\_optimizer(optimizer\_name)

model.compile(optimizer=optimizer,

loss=tf.keras.losses.SparseCategoricalCrossentropy(from\_logits=True),

metrics=['accuracy'])

callback\_list = [LearningRateScheduler(scheduler, verbose=1)]

history = model.fit(train\_images, train\_labels, epochs=30,

validation\_data=(test\_images, test\_labels),

callbacks=callback\_list, verbose=2)

test\_loss, test\_acc = model.evaluate(test\_images, test\_labels, verbose=2)

print(f'\nTest accuracy with {optimizer\_name}:', test\_acc)

optimizers = ['adam', 'sgd', 'rmsprop', 'adamax']

for opt in optimizers:

print(f"\nTraining with {opt} optimizer:")

train\_and\_evaluate\_model(opt)

Below is the output:

Training with adam optimizer:

Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz

170498071/170498071 [==============================] - 4s 0us/step

Epoch 1: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 1/30

1563/1563 - 21s - loss: 2.3082 - accuracy: 0.4058 - val\_loss: 1.4393 - val\_accuracy: 0.5445 - lr: 0.0010 - 21s/epoch - 14ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 2/30

1563/1563 - 12s - loss: 1.3070 - accuracy: 0.5937 - val\_loss: 1.3111 - val\_accuracy: 0.5941 - lr: 0.0010 - 12s/epoch - 7ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 3/30

1563/1563 - 12s - loss: 1.1234 - accuracy: 0.6605 - val\_loss: 1.0079 - val\_accuracy: 0.7045 - lr: 0.0010 - 12s/epoch - 8ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 4/30

1563/1563 - 12s - loss: 1.0269 - accuracy: 0.7021 - val\_loss: 0.8993 - val\_accuracy: 0.7437 - lr: 0.0010 - 12s/epoch - 7ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 5/30

1563/1563 - 12s - loss: 0.9659 - accuracy: 0.7286 - val\_loss: 0.8660 - val\_accuracy: 0.7558 - lr: 0.0010 - 12s/epoch - 8ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 6/30

1563/1563 - 12s - loss: 0.9136 - accuracy: 0.7496 - val\_loss: 0.8289 - val\_accuracy: 0.7754 - lr: 0.0010 - 12s/epoch - 8ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 7/30

1563/1563 - 12s - loss: 0.8738 - accuracy: 0.7613 - val\_loss: 0.8171 - val\_accuracy: 0.7741 - lr: 0.0010 - 12s/epoch - 7ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 8/30

1563/1563 - 11s - loss: 0.8438 - accuracy: 0.7732 - val\_loss: 0.8950 - val\_accuracy: 0.7573 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 9/30

1563/1563 - 12s - loss: 0.8175 - accuracy: 0.7790 - val\_loss: 0.8075 - val\_accuracy: 0.7851 - lr: 0.0010 - 12s/epoch - 7ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 10/30

1563/1563 - 11s - loss: 0.7917 - accuracy: 0.7926 - val\_loss: 0.8309 - val\_accuracy: 0.7853 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.0005000000237487257.

Epoch 11/30

1563/1563 - 11s - loss: 0.6556 - accuracy: 0.8217 - val\_loss: 0.6271 - val\_accuracy: 0.8267 - lr: 5.0000e-04 - 11s/epoch - 7ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.0002500000118743628.

Epoch 12/30

1563/1563 - 11s - loss: 0.5672 - accuracy: 0.8385 - val\_loss: 0.5461 - val\_accuracy: 0.8441 - lr: 2.5000e-04 - 11s/epoch - 7ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.0001250000059371814.

Epoch 13/30

1563/1563 - 11s - loss: 0.5107 - accuracy: 0.8502 - val\_loss: 0.5210 - val\_accuracy: 0.8494 - lr: 1.2500e-04 - 11s/epoch - 7ms/step

Epoch 14: LearningRateScheduler setting learning rate to 6.25000029685907e-05.

Epoch 14/30

1563/1563 - 11s - loss: 0.4825 - accuracy: 0.8579 - val\_loss: 0.5074 - val\_accuracy: 0.8529 - lr: 6.2500e-05 - 11s/epoch - 7ms/step

Epoch 15: LearningRateScheduler setting learning rate to 3.125000148429535e-05.

Epoch 15/30

1563/1563 - 11s - loss: 0.4690 - accuracy: 0.8619 - val\_loss: 0.5029 - val\_accuracy: 0.8541 - lr: 3.1250e-05 - 11s/epoch - 7ms/step

Epoch 16: LearningRateScheduler setting learning rate to 1.5625000742147677e-05.

Epoch 16/30

1563/1563 - 11s - loss: 0.4599 - accuracy: 0.8630 - val\_loss: 0.4983 - val\_accuracy: 0.8527 - lr: 1.5625e-05 - 11s/epoch - 7ms/step

Epoch 17: LearningRateScheduler setting learning rate to 7.812500371073838e-06.

Epoch 17/30

1563/1563 - 11s - loss: 0.4552 - accuracy: 0.8643 - val\_loss: 0.4974 - val\_accuracy: 0.8539 - lr: 7.8125e-06 - 11s/epoch - 7ms/step

Epoch 18: LearningRateScheduler setting learning rate to 3.906250185536919e-06.

Epoch 18/30

1563/1563 - 11s - loss: 0.4550 - accuracy: 0.8643 - val\_loss: 0.4962 - val\_accuracy: 0.8546 - lr: 3.9063e-06 - 11s/epoch - 7ms/step

Epoch 19: LearningRateScheduler setting learning rate to 1.9531250927684596e-06.

Epoch 19/30

1563/1563 - 12s - loss: 0.4556 - accuracy: 0.8636 - val\_loss: 0.4944 - val\_accuracy: 0.8545 - lr: 1.9531e-06 - 12s/epoch - 7ms/step

Epoch 20: LearningRateScheduler setting learning rate to 9.765625463842298e-07.

Epoch 20/30

1563/1563 - 11s - loss: 0.4508 - accuracy: 0.8653 - val\_loss: 0.4953 - val\_accuracy: 0.8546 - lr: 9.7656e-07 - 11s/epoch - 7ms/step

Epoch 21: LearningRateScheduler setting learning rate to 9.765625463842298e-08.

Epoch 21/30

1563/1563 - 11s - loss: 0.4544 - accuracy: 0.8649 - val\_loss: 0.4953 - val\_accuracy: 0.8545 - lr: 9.7656e-08 - 11s/epoch - 7ms/step

Epoch 22: LearningRateScheduler setting learning rate to 9.765625463842299e-09.

Epoch 22/30

1563/1563 - 11s - loss: 0.4486 - accuracy: 0.8658 - val\_loss: 0.4956 - val\_accuracy: 0.8553 - lr: 9.7656e-09 - 11s/epoch - 7ms/step

Epoch 23: LearningRateScheduler setting learning rate to 9.765625641477981e-10.

Epoch 23/30

1563/1563 - 12s - loss: 0.4542 - accuracy: 0.8640 - val\_loss: 0.4952 - val\_accuracy: 0.8540 - lr: 9.7656e-10 - 12s/epoch - 7ms/step

Epoch 24: LearningRateScheduler setting learning rate to 9.765626085567192e-11.

Epoch 24/30

1563/1563 - 12s - loss: 0.4541 - accuracy: 0.8654 - val\_loss: 0.4971 - val\_accuracy: 0.8533 - lr: 9.7656e-11 - 12s/epoch - 7ms/step

Epoch 25: LearningRateScheduler setting learning rate to 9.765625808011436e-12.

Epoch 25/30

1563/1563 - 11s - loss: 0.4536 - accuracy: 0.8636 - val\_loss: 0.4963 - val\_accuracy: 0.8542 - lr: 9.7656e-12 - 11s/epoch - 7ms/step

Epoch 26: LearningRateScheduler setting learning rate to 9.765625808011436e-13.

Epoch 26/30

1563/1563 - 11s - loss: 0.4484 - accuracy: 0.8644 - val\_loss: 0.4956 - val\_accuracy: 0.8541 - lr: 9.7656e-13 - 11s/epoch - 7ms/step

Epoch 27: LearningRateScheduler setting learning rate to 9.765625808011436e-14.

Epoch 27/30

1563/1563 - 11s - loss: 0.4503 - accuracy: 0.8658 - val\_loss: 0.4950 - val\_accuracy: 0.8535 - lr: 9.7656e-14 - 11s/epoch - 7ms/step

Epoch 28: LearningRateScheduler setting learning rate to 9.765625808011436e-15.

Epoch 28/30

1563/1563 - 12s - loss: 0.4544 - accuracy: 0.8637 - val\_loss: 0.4948 - val\_accuracy: 0.8550 - lr: 9.7656e-15 - 12s/epoch - 8ms/step

Epoch 29: LearningRateScheduler setting learning rate to 9.765625808011436e-16.

Epoch 29/30

1563/1563 - 11s - loss: 0.4530 - accuracy: 0.8660 - val\_loss: 0.4951 - val\_accuracy: 0.8535 - lr: 9.7656e-16 - 11s/epoch - 7ms/step

Epoch 30: LearningRateScheduler setting learning rate to 9.765626019769673e-17.

Epoch 30/30

1563/1563 - 11s - loss: 0.4546 - accuracy: 0.8631 - val\_loss: 0.4946 - val\_accuracy: 0.8550 - lr: 9.7656e-17 - 11s/epoch - 7ms/step

313/313 - 1s - loss: 0.4946 - accuracy: 0.8550 - 765ms/epoch - 2ms/step

Test accuracy with adam: 0.8550000190734863

Training with sgd optimizer:

Epoch 1: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 1/30

1563/1563 - 14s - loss: 2.2570 - accuracy: 0.3510 - val\_loss: 1.6513 - val\_accuracy: 0.4564 - lr: 0.0100 - 14s/epoch - 9ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 2/30

1563/1563 - 11s - loss: 1.5466 - accuracy: 0.5099 - val\_loss: 1.3289 - val\_accuracy: 0.5877 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 3/30

1563/1563 - 11s - loss: 1.3325 - accuracy: 0.5910 - val\_loss: 1.2510 - val\_accuracy: 0.6190 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 4/30

1563/1563 - 11s - loss: 1.1881 - accuracy: 0.6415 - val\_loss: 1.0441 - val\_accuracy: 0.6966 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 5/30

1563/1563 - 11s - loss: 1.1018 - accuracy: 0.6748 - val\_loss: 0.9984 - val\_accuracy: 0.7093 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 6/30

1563/1563 - 11s - loss: 1.0383 - accuracy: 0.6992 - val\_loss: 0.8781 - val\_accuracy: 0.7444 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 7/30

1563/1563 - 11s - loss: 0.9935 - accuracy: 0.7197 - val\_loss: 0.8766 - val\_accuracy: 0.7576 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 8/30

1563/1563 - 11s - loss: 0.9508 - accuracy: 0.7366 - val\_loss: 0.8778 - val\_accuracy: 0.7591 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 9/30

1563/1563 - 11s - loss: 0.9304 - accuracy: 0.7448 - val\_loss: 0.8037 - val\_accuracy: 0.7780 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.009999999776482582.

Epoch 10/30

1563/1563 - 11s - loss: 0.8940 - accuracy: 0.7562 - val\_loss: 0.8129 - val\_accuracy: 0.7805 - lr: 0.0100 - 11s/epoch - 7ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.004999999888241291.

Epoch 11/30

1563/1563 - 11s - loss: 0.7622 - accuracy: 0.7870 - val\_loss: 0.6887 - val\_accuracy: 0.8063 - lr: 0.0050 - 11s/epoch - 7ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.0024999999441206455.

Epoch 12/30

1563/1563 - 11s - loss: 0.6669 - accuracy: 0.8071 - val\_loss: 0.6006 - val\_accuracy: 0.8260 - lr: 0.0025 - 11s/epoch - 7ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.0012499999720603228.

Epoch 13/30

1563/1563 - 11s - loss: 0.6166 - accuracy: 0.8158 - val\_loss: 0.5722 - val\_accuracy: 0.8255 - lr: 0.0012 - 11s/epoch - 7ms/step

Epoch 14: LearningRateScheduler setting learning rate to 0.0006249999860301614.

Epoch 14/30

1563/1563 - 11s - loss: 0.5850 - accuracy: 0.8232 - val\_loss: 0.5532 - val\_accuracy: 0.8316 - lr: 6.2500e-04 - 11s/epoch - 7ms/step

Epoch 15: LearningRateScheduler setting learning rate to 0.0003124999930150807.

Epoch 15/30

1563/1563 - 11s - loss: 0.5678 - accuracy: 0.8282 - val\_loss: 0.5487 - val\_accuracy: 0.8322 - lr: 3.1250e-04 - 11s/epoch - 7ms/step

Epoch 16: LearningRateScheduler setting learning rate to 0.00015624999650754035.

Epoch 16/30

1563/1563 - 11s - loss: 0.5598 - accuracy: 0.8298 - val\_loss: 0.5457 - val\_accuracy: 0.8324 - lr: 1.5625e-04 - 11s/epoch - 7ms/step

Epoch 17: LearningRateScheduler setting learning rate to 7.812499825377017e-05.

Epoch 17/30

1563/1563 - 11s - loss: 0.5537 - accuracy: 0.8305 - val\_loss: 0.5432 - val\_accuracy: 0.8322 - lr: 7.8125e-05 - 11s/epoch - 7ms/step

Epoch 18: LearningRateScheduler setting learning rate to 3.9062499126885086e-05.

Epoch 18/30

1563/1563 - 11s - loss: 0.5570 - accuracy: 0.8295 - val\_loss: 0.5440 - val\_accuracy: 0.8323 - lr: 3.9062e-05 - 11s/epoch - 7ms/step

Epoch 19: LearningRateScheduler setting learning rate to 1.9531249563442543e-05.

Epoch 19/30

1563/1563 - 11s - loss: 0.5573 - accuracy: 0.8285 - val\_loss: 0.5420 - val\_accuracy: 0.8324 - lr: 1.9531e-05 - 11s/epoch - 7ms/step

Epoch 20: LearningRateScheduler setting learning rate to 9.765624781721272e-06.

Epoch 20/30

1563/1563 - 11s - loss: 0.5517 - accuracy: 0.8307 - val\_loss: 0.5427 - val\_accuracy: 0.8330 - lr: 9.7656e-06 - 11s/epoch - 7ms/step

Epoch 21: LearningRateScheduler setting learning rate to 9.765624781721272e-07.

Epoch 21/30

1563/1563 - 11s - loss: 0.5490 - accuracy: 0.8322 - val\_loss: 0.5416 - val\_accuracy: 0.8331 - lr: 9.7656e-07 - 11s/epoch - 7ms/step

Epoch 22: LearningRateScheduler setting learning rate to 9.765624326973921e-08.

Epoch 22/30

1563/1563 - 11s - loss: 0.5492 - accuracy: 0.8312 - val\_loss: 0.5438 - val\_accuracy: 0.8316 - lr: 9.7656e-08 - 11s/epoch - 7ms/step

Epoch 23: LearningRateScheduler setting learning rate to 9.765624042756827e-09.

Epoch 23/30

1563/1563 - 11s - loss: 0.5474 - accuracy: 0.8317 - val\_loss: 0.5431 - val\_accuracy: 0.8319 - lr: 9.7656e-09 - 11s/epoch - 7ms/step

Epoch 24: LearningRateScheduler setting learning rate to 9.765623865121142e-10.

Epoch 24/30

1563/1563 - 11s - loss: 0.5515 - accuracy: 0.8308 - val\_loss: 0.5416 - val\_accuracy: 0.8324 - lr: 9.7656e-10 - 11s/epoch - 7ms/step

Epoch 25: LearningRateScheduler setting learning rate to 9.765623865121143e-11.

Epoch 25/30

1563/1563 - 11s - loss: 0.5510 - accuracy: 0.8316 - val\_loss: 0.5414 - val\_accuracy: 0.8327 - lr: 9.7656e-11 - 11s/epoch - 7ms/step

Epoch 26: LearningRateScheduler setting learning rate to 9.765623726343266e-12.

Epoch 26/30

1563/1563 - 11s - loss: 0.5503 - accuracy: 0.8324 - val\_loss: 0.5425 - val\_accuracy: 0.8325 - lr: 9.7656e-12 - 11s/epoch - 7ms/step

Epoch 27: LearningRateScheduler setting learning rate to 9.76562407328796e-13.

Epoch 27/30

1563/1563 - 11s - loss: 0.5479 - accuracy: 0.8318 - val\_loss: 0.5425 - val\_accuracy: 0.8327 - lr: 9.7656e-13 - 11s/epoch - 7ms/step

Epoch 28: LearningRateScheduler setting learning rate to 9.765623639607091e-14.

Epoch 28/30

1563/1563 - 11s - loss: 0.5507 - accuracy: 0.8307 - val\_loss: 0.5428 - val\_accuracy: 0.8336 - lr: 9.7656e-14 - 11s/epoch - 7ms/step

Epoch 29: LearningRateScheduler setting learning rate to 9.765623775132363e-15.

Epoch 29/30

1563/1563 - 11s - loss: 0.5511 - accuracy: 0.8296 - val\_loss: 0.5427 - val\_accuracy: 0.8325 - lr: 9.7656e-15 - 11s/epoch - 7ms/step

Epoch 30: LearningRateScheduler setting learning rate to 9.765624113945542e-16.

Epoch 30/30

1563/1563 - 11s - loss: 0.5536 - accuracy: 0.8290 - val\_loss: 0.5424 - val\_accuracy: 0.8330 - lr: 9.7656e-16 - 11s/epoch - 7ms/step

313/313 - 1s - loss: 0.5424 - accuracy: 0.8330 - 986ms/epoch - 3ms/step

Test accuracy with sgd: 0.8330000042915344

Training with rmsprop optimizer:

Epoch 1: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 1/30

1563/1563 - 15s - loss: 2.1427 - accuracy: 0.4317 - val\_loss: 1.8250 - val\_accuracy: 0.4632 - lr: 0.0010 - 15s/epoch - 10ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 2/30

1563/1563 - 11s - loss: 1.2740 - accuracy: 0.6108 - val\_loss: 1.2842 - val\_accuracy: 0.6107 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 3/30

1563/1563 - 11s - loss: 1.1139 - accuracy: 0.6723 - val\_loss: 1.0409 - val\_accuracy: 0.6901 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 4/30

1563/1563 - 11s - loss: 1.0214 - accuracy: 0.7043 - val\_loss: 1.1061 - val\_accuracy: 0.6732 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 5/30

1563/1563 - 11s - loss: 0.9592 - accuracy: 0.7292 - val\_loss: 1.0952 - val\_accuracy: 0.6693 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 6/30

1563/1563 - 11s - loss: 0.9173 - accuracy: 0.7439 - val\_loss: 0.8515 - val\_accuracy: 0.7648 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 7/30

1563/1563 - 11s - loss: 0.8871 - accuracy: 0.7558 - val\_loss: 1.0425 - val\_accuracy: 0.6979 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 8/30

1563/1563 - 11s - loss: 0.8620 - accuracy: 0.7656 - val\_loss: 0.8441 - val\_accuracy: 0.7688 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 9/30

1563/1563 - 11s - loss: 0.8348 - accuracy: 0.7752 - val\_loss: 0.7908 - val\_accuracy: 0.7876 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 10/30

1563/1563 - 11s - loss: 0.8099 - accuracy: 0.7833 - val\_loss: 0.8789 - val\_accuracy: 0.7628 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.0005000000237487257.

Epoch 11/30

1563/1563 - 11s - loss: 0.6835 - accuracy: 0.8117 - val\_loss: 0.6357 - val\_accuracy: 0.8206 - lr: 5.0000e-04 - 11s/epoch - 7ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.0002500000118743628.

Epoch 12/30

1563/1563 - 11s - loss: 0.5947 - accuracy: 0.8301 - val\_loss: 0.5702 - val\_accuracy: 0.8391 - lr: 2.5000e-04 - 11s/epoch - 7ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.0001250000059371814.

Epoch 13/30

1563/1563 - 11s - loss: 0.5488 - accuracy: 0.8420 - val\_loss: 0.5387 - val\_accuracy: 0.8426 - lr: 1.2500e-04 - 11s/epoch - 7ms/step

Epoch 14: LearningRateScheduler setting learning rate to 6.25000029685907e-05.

Epoch 14/30

1563/1563 - 11s - loss: 0.5243 - accuracy: 0.8472 - val\_loss: 0.5289 - val\_accuracy: 0.8463 - lr: 6.2500e-05 - 11s/epoch - 7ms/step

Epoch 15: LearningRateScheduler setting learning rate to 3.125000148429535e-05.

Epoch 15/30

1563/1563 - 11s - loss: 0.5145 - accuracy: 0.8492 - val\_loss: 0.5277 - val\_accuracy: 0.8454 - lr: 3.1250e-05 - 11s/epoch - 7ms/step

Epoch 16: LearningRateScheduler setting learning rate to 1.5625000742147677e-05.

Epoch 16/30

1563/1563 - 11s - loss: 0.5066 - accuracy: 0.8500 - val\_loss: 0.5247 - val\_accuracy: 0.8459 - lr: 1.5625e-05 - 11s/epoch - 7ms/step

Epoch 17: LearningRateScheduler setting learning rate to 7.812500371073838e-06.

Epoch 17/30

1563/1563 - 11s - loss: 0.4983 - accuracy: 0.8521 - val\_loss: 0.5236 - val\_accuracy: 0.8449 - lr: 7.8125e-06 - 11s/epoch - 7ms/step

Epoch 18: LearningRateScheduler setting learning rate to 3.906250185536919e-06.

Epoch 18/30

1563/1563 - 11s - loss: 0.4971 - accuracy: 0.8538 - val\_loss: 0.5224 - val\_accuracy: 0.8456 - lr: 3.9063e-06 - 11s/epoch - 7ms/step

Epoch 19: LearningRateScheduler setting learning rate to 1.9531250927684596e-06.

Epoch 19/30

1563/1563 - 11s - loss: 0.4982 - accuracy: 0.8523 - val\_loss: 0.5225 - val\_accuracy: 0.8443 - lr: 1.9531e-06 - 11s/epoch - 7ms/step

Epoch 20: LearningRateScheduler setting learning rate to 9.765625463842298e-07.

Epoch 20/30

1563/1563 - 11s - loss: 0.4954 - accuracy: 0.8516 - val\_loss: 0.5220 - val\_accuracy: 0.8463 - lr: 9.7656e-07 - 11s/epoch - 7ms/step

Epoch 21: LearningRateScheduler setting learning rate to 9.765625463842298e-08.

Epoch 21/30

1563/1563 - 11s - loss: 0.4958 - accuracy: 0.8535 - val\_loss: 0.5229 - val\_accuracy: 0.8449 - lr: 9.7656e-08 - 11s/epoch - 7ms/step

Epoch 22: LearningRateScheduler setting learning rate to 9.765625463842299e-09.

Epoch 22/30

1563/1563 - 11s - loss: 0.4944 - accuracy: 0.8542 - val\_loss: 0.5209 - val\_accuracy: 0.8461 - lr: 9.7656e-09 - 11s/epoch - 7ms/step

Epoch 23: LearningRateScheduler setting learning rate to 9.765625641477981e-10.

Epoch 23/30

1563/1563 - 11s - loss: 0.4943 - accuracy: 0.8540 - val\_loss: 0.5232 - val\_accuracy: 0.8441 - lr: 9.7656e-10 - 11s/epoch - 7ms/step

Epoch 24: LearningRateScheduler setting learning rate to 9.765626085567192e-11.

Epoch 24/30

1563/1563 - 11s - loss: 0.4953 - accuracy: 0.8543 - val\_loss: 0.5224 - val\_accuracy: 0.8459 - lr: 9.7656e-11 - 11s/epoch - 7ms/step

Epoch 25: LearningRateScheduler setting learning rate to 9.765625808011436e-12.

Epoch 25/30

1563/1563 - 11s - loss: 0.4950 - accuracy: 0.8543 - val\_loss: 0.5215 - val\_accuracy: 0.8456 - lr: 9.7656e-12 - 11s/epoch - 7ms/step

Epoch 26: LearningRateScheduler setting learning rate to 9.765625808011436e-13.

Epoch 26/30

1563/1563 - 11s - loss: 0.4937 - accuracy: 0.8539 - val\_loss: 0.5223 - val\_accuracy: 0.8452 - lr: 9.7656e-13 - 11s/epoch - 7ms/step

Epoch 27: LearningRateScheduler setting learning rate to 9.765625808011436e-14.

Epoch 27/30

1563/1563 - 11s - loss: 0.4952 - accuracy: 0.8537 - val\_loss: 0.5227 - val\_accuracy: 0.8449 - lr: 9.7656e-14 - 11s/epoch - 7ms/step

Epoch 28: LearningRateScheduler setting learning rate to 9.765625808011436e-15.

Epoch 28/30

1563/1563 - 11s - loss: 0.4964 - accuracy: 0.8539 - val\_loss: 0.5212 - val\_accuracy: 0.8466 - lr: 9.7656e-15 - 11s/epoch - 7ms/step

Epoch 29: LearningRateScheduler setting learning rate to 9.765625808011436e-16.

Epoch 29/30

1563/1563 - 11s - loss: 0.4942 - accuracy: 0.8542 - val\_loss: 0.5228 - val\_accuracy: 0.8447 - lr: 9.7656e-16 - 11s/epoch - 7ms/step

Epoch 30: LearningRateScheduler setting learning rate to 9.765626019769673e-17.

Epoch 30/30

1563/1563 - 11s - loss: 0.5015 - accuracy: 0.8522 - val\_loss: 0.5216 - val\_accuracy: 0.8450 - lr: 9.7656e-17 - 11s/epoch - 7ms/step

313/313 - 1s - loss: 0.5216 - accuracy: 0.8450 - 766ms/epoch - 2ms/step

Test accuracy with rmsprop: 0.8450000286102295

Training with adamax optimizer:

Epoch 1: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 1/30

1563/1563 - 15s - loss: 2.8193 - accuracy: 0.3579 - val\_loss: 1.8919 - val\_accuracy: 0.4524 - lr: 0.0020 - 15s/epoch - 10ms/step

Epoch 2: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 2/30

1563/1563 - 11s - loss: 1.4543 - accuracy: 0.5604 - val\_loss: 1.1056 - val\_accuracy: 0.6535 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 3: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 3/30

1563/1563 - 11s - loss: 1.1017 - accuracy: 0.6576 - val\_loss: 0.9488 - val\_accuracy: 0.6966 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 4: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 4/30

1563/1563 - 11s - loss: 0.9597 - accuracy: 0.7050 - val\_loss: 0.9631 - val\_accuracy: 0.6990 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 5: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 5/30

1563/1563 - 11s - loss: 0.8611 - accuracy: 0.7387 - val\_loss: 0.8031 - val\_accuracy: 0.7584 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 6: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 6/30

1563/1563 - 11s - loss: 0.8079 - accuracy: 0.7552 - val\_loss: 0.7310 - val\_accuracy: 0.7806 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 7: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 7/30

1563/1563 - 11s - loss: 0.7664 - accuracy: 0.7722 - val\_loss: 0.7507 - val\_accuracy: 0.7718 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 8: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 8/30

1563/1563 - 12s - loss: 0.7360 - accuracy: 0.7807 - val\_loss: 0.6814 - val\_accuracy: 0.7968 - lr: 0.0020 - 12s/epoch - 7ms/step

Epoch 9: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 9/30

1563/1563 - 11s - loss: 0.7027 - accuracy: 0.7927 - val\_loss: 0.7250 - val\_accuracy: 0.7833 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 10: LearningRateScheduler setting learning rate to 0.0020000000949949026.

Epoch 10/30

1563/1563 - 11s - loss: 0.6774 - accuracy: 0.8024 - val\_loss: 0.6882 - val\_accuracy: 0.7946 - lr: 0.0020 - 11s/epoch - 7ms/step

Epoch 11: LearningRateScheduler setting learning rate to 0.0010000000474974513.

Epoch 11/30

1563/1563 - 11s - loss: 0.5939 - accuracy: 0.8280 - val\_loss: 0.5658 - val\_accuracy: 0.8367 - lr: 0.0010 - 11s/epoch - 7ms/step

Epoch 12: LearningRateScheduler setting learning rate to 0.0005000000237487257.

Epoch 12/30

1563/1563 - 11s - loss: 0.5352 - accuracy: 0.8426 - val\_loss: 0.5390 - val\_accuracy: 0.8365 - lr: 5.0000e-04 - 11s/epoch - 7ms/step

Epoch 13: LearningRateScheduler setting learning rate to 0.0002500000118743628.

Epoch 13/30

1563/1563 - 11s - loss: 0.4971 - accuracy: 0.8508 - val\_loss: 0.5204 - val\_accuracy: 0.8448 - lr: 2.5000e-04 - 11s/epoch - 7ms/step

Epoch 14: LearningRateScheduler setting learning rate to 0.0001250000059371814.

Epoch 14/30

1563/1563 - 11s - loss: 0.4777 - accuracy: 0.8577 - val\_loss: 0.5100 - val\_accuracy: 0.8468 - lr: 1.2500e-04 - 11s/epoch - 7ms/step

Epoch 15: LearningRateScheduler setting learning rate to 6.25000029685907e-05.

Epoch 15/30

1563/1563 - 11s - loss: 0.4695 - accuracy: 0.8603 - val\_loss: 0.5084 - val\_accuracy: 0.8460 - lr: 6.2500e-05 - 11s/epoch - 7ms/step

Epoch 16: LearningRateScheduler setting learning rate to 3.125000148429535e-05.

Epoch 16/30

1563/1563 - 11s - loss: 0.4661 - accuracy: 0.8596 - val\_loss: 0.5088 - val\_accuracy: 0.8475 - lr: 3.1250e-05 - 11s/epoch - 7ms/step

Epoch 17: LearningRateScheduler setting learning rate to 1.5625000742147677e-05.

Epoch 17/30

1563/1563 - 11s - loss: 0.4651 - accuracy: 0.8592 - val\_loss: 0.5081 - val\_accuracy: 0.8472 - lr: 1.5625e-05 - 11s/epoch - 7ms/step

Epoch 18: LearningRateScheduler setting learning rate to 7.812500371073838e-06.

Epoch 18/30

1563/1563 - 12s - loss: 0.4683 - accuracy: 0.8591 - val\_loss: 0.5067 - val\_accuracy: 0.8484 - lr: 7.8125e-06 - 12s/epoch - 7ms/step

Epoch 19: LearningRateScheduler setting learning rate to 3.906250185536919e-06.

Epoch 19/30

1563/1563 - 11s - loss: 0.4648 - accuracy: 0.8619 - val\_loss: 0.5055 - val\_accuracy: 0.8491 - lr: 3.9063e-06 - 11s/epoch - 7ms/step

Epoch 20: LearningRateScheduler setting learning rate to 1.9531250927684596e-06.

Epoch 20/30

1563/1563 - 11s - loss: 0.4643 - accuracy: 0.8620 - val\_loss: 0.5061 - val\_accuracy: 0.8484 - lr: 1.9531e-06 - 11s/epoch - 7ms/step

Epoch 21: LearningRateScheduler setting learning rate to 1.9531250927684596e-07.

Epoch 21/30

1563/1563 - 11s - loss: 0.4623 - accuracy: 0.8623 - val\_loss: 0.5069 - val\_accuracy: 0.8484 - lr: 1.9531e-07 - 11s/epoch - 7ms/step

Epoch 22: LearningRateScheduler setting learning rate to 1.9531250927684597e-08.

Epoch 22/30

1563/1563 - 11s - loss: 0.4630 - accuracy: 0.8612 - val\_loss: 0.5076 - val\_accuracy: 0.8482 - lr: 1.9531e-08 - 11s/epoch - 7ms/step

Epoch 23: LearningRateScheduler setting learning rate to 1.9531251282955963e-09.

Epoch 23/30

1563/1563 - 11s - loss: 0.4634 - accuracy: 0.8623 - val\_loss: 0.5067 - val\_accuracy: 0.8479 - lr: 1.9531e-09 - 11s/epoch - 7ms/step

Epoch 24: LearningRateScheduler setting learning rate to 1.9531252171134384e-10.

Epoch 24/30

1563/1563 - 11s - loss: 0.4630 - accuracy: 0.8606 - val\_loss: 0.5067 - val\_accuracy: 0.8478 - lr: 1.9531e-10 - 11s/epoch - 7ms/step

Epoch 25: LearningRateScheduler setting learning rate to 1.953125161602287e-11.

Epoch 25/30

1563/1563 - 11s - loss: 0.4607 - accuracy: 0.8618 - val\_loss: 0.5061 - val\_accuracy: 0.8484 - lr: 1.9531e-11 - 11s/epoch - 7ms/step

Epoch 26: LearningRateScheduler setting learning rate to 1.953125161602287e-12.

Epoch 26/30

1563/1563 - 11s - loss: 0.4611 - accuracy: 0.8602 - val\_loss: 0.5071 - val\_accuracy: 0.8477 - lr: 1.9531e-12 - 11s/epoch - 7ms/step

Epoch 27: LearningRateScheduler setting learning rate to 1.953125161602287e-13.

Epoch 27/30

1563/1563 - 11s - loss: 0.4609 - accuracy: 0.8612 - val\_loss: 0.5071 - val\_accuracy: 0.8476 - lr: 1.9531e-13 - 11s/epoch - 7ms/step

Epoch 28: LearningRateScheduler setting learning rate to 1.953125161602287e-14.

Epoch 28/30

1563/1563 - 11s - loss: 0.4615 - accuracy: 0.8603 - val\_loss: 0.5062 - val\_accuracy: 0.8483 - lr: 1.9531e-14 - 11s/epoch - 7ms/step

Epoch 29: LearningRateScheduler setting learning rate to 1.9531251616022873e-15.

Epoch 29/30

1563/1563 - 11s - loss: 0.4628 - accuracy: 0.8615 - val\_loss: 0.5062 - val\_accuracy: 0.8481 - lr: 1.9531e-15 - 11s/epoch - 7ms/step

Epoch 30: LearningRateScheduler setting learning rate to 1.9531252039539346e-16.

Epoch 30/30

1563/1563 - 11s - loss: 0.4618 - accuracy: 0.8629 - val\_loss: 0.5060 - val\_accuracy: 0.8479 - lr: 1.9531e-16 - 11s/epoch - 7ms/step

313/313 - 1s - loss: 0.5060 - accuracy: 0.8479 - 992ms/epoch - 3ms/step

Test accuracy with adamax: 0.8478999733924866

1. **To enhance the current script with visualizations for the training results of each optimizer, we can add code to plot the training and validation accuracy and loss at the end of each training session. Below, I'm providing the updated version of the script with the added visualization functionality using Matplotlib:**

from tensorflow.keras import layers, models, regularizers

import matplotlib.pyplot as plt

def create\_advanced\_cnn\_model():

model = models.Sequential([

layers.Conv2D(32, (3, 3), padding='same', activation='relu', input\_shape=(32, 32, 3)),

layers.BatchNormalization(),

layers.Conv2D(32, (3, 3), activation='relu'),

layers.BatchNormalization(),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.2),

layers.Conv2D(64, (3, 3), padding='same', activation='relu'),

layers.BatchNormalization(),

layers.Conv2D(64, (3, 3), activation='relu'),

layers.BatchNormalization(),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.3),

layers.Conv2D(128, (3, 3), padding='same', activation='relu'),

layers.BatchNormalization(),

layers.Conv2D(128, (3, 3), activation='relu'),

layers.BatchNormalization(),

layers.MaxPooling2D((2, 2)),

layers.Dropout(0.4),

layers.Flatten(),

layers.Dense(128, activation='relu', kernel\_regularizer=regularizers.l2(0.01)),

layers.Dropout(0.5),

layers.Dense(10)

])

return model

import tensorflow as tf

from tensorflow.keras.datasets import cifar10

from tensorflow.keras.callbacks import LearningRateScheduler

import numpy as np

def get\_optimizer(opt\_name):

if opt\_name == "sgd":

return tf.keras.optimizers.SGD(learning\_rate=0.01, momentum=0.9)

elif opt\_name == "adam":

return tf.keras.optimizers.Adam(learning\_rate=0.001)

elif opt\_name == "rmsprop":

return tf.keras.optimizers.RMSprop(learning\_rate=0.001)

elif opt\_name == "adamax":

return tf.keras.optimizers.Adamax(learning\_rate=0.002)

else:

return tf.keras.optimizers.Adam() # Default case

def scheduler(epoch, lr):

if epoch < 10:

return lr

elif epoch < 20:

return lr \* 0.5

else:

return lr \* 0.1

def train\_and\_evaluate\_model(optimizer\_name):

(train\_images, train\_labels), (test\_images, test\_labels) = cifar10.load\_data()

train\_images, test\_images = train\_images / 255.0, test\_images / 255.0

model = create\_advanced\_cnn\_model()

optimizer = get\_optimizer(optimizer\_name)

model.compile(optimizer=optimizer,

loss=tf.keras.losses.SparseCategoricalCrossentropy(from\_logits=True),

metrics=['accuracy'])

callback\_list = [LearningRateScheduler(scheduler, verbose=1)]

history = model.fit(train\_images, train\_labels, epochs=30,

validation\_data=(test\_images, test\_labels),

callbacks=callback\_list, verbose=2)

test\_loss, test\_acc = model.evaluate(test\_images, test\_labels, verbose=2)

print(f'\nTest accuracy with {optimizer\_name}:', test\_acc)

# Plotting the training and validation accuracy and loss

plt.figure(figsize=(12, 5))

plt.subplot(1, 2, 1)

plt.plot(history.history['accuracy'], label='Training Accuracy')

plt.plot(history.history['val\_accuracy'], label='Validation Accuracy')

plt.title(f'Training and Validation Accuracy ({optimizer\_name})')

plt.xlabel('Epoch')

plt.ylabel('Accuracy')

plt.legend()

plt.subplot(1, 2, 2)

plt.plot(history.history['loss'], label='Training Loss')

plt.plot(history.history['val\_loss'], label='Validation Loss')

plt.title(f'Training and Validation Loss ({optimizer\_name})')

plt.xlabel('Epoch')

plt.ylabel('Loss')

plt.legend()

plt.show()

optimizers = ['adam', 'sgd', 'rmsprop', 'adamax']

for opt in optimizers:

print(f"\nTraining with {opt} optimizer:")

train\_and\_evaluate\_model(opt)

Visualizations:  
  






