

```
In [ ]: # import some libraries
import numpy as np
import tensorflow as tf
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
```



```
In [ ]: # Load the dataset
num_classes = 10
cifar10 = tf.keras.datasets.cifar10
(x_learn, y_learn), (x_test, y_test) = cifar10.load_data()

# Normalize the data in [0 1]
print("Normalizing training set..")
x_learn = np.asarray(x_learn, dtype=np.float32) / 255 # Normalizing training set
print("Normalizing test set..")
x_test = np.asarray(x_test, dtype=np.float32) / 255 # Normalizing test set
```

Normalizing training set..
Normalizing test set..


```
In [ ]: # split in training and validation
x_train, x_val, y_train, y_val = train_test_split(x_learn, y_learn, test_size=0.25)
```



```
In [ ]: # Standardizing the data
def standardize_dataset(X):
    image_means = []
    image_stds = []

    for image in X:
        image_means.append(np.mean(image)) # Computing the image mean
        image_stds.append(np.std(image)) # Computing the image standard deviation

    dataset_mean = np.mean(image_means) # Computing the dataset mean
    dataset_std = np.mean(image_stds) # Computing the dataset standard deviation
    return [dataset_mean, dataset_std] # For every image we subtract to it the dataset mean and divide by the dataset std
```

dataset_mean, dataset_std = standardize_dataset(x_train)


```
print("Standardizing training set..")
x_train = (x_train-dataset_mean)/dataset_std # Standardizing the training set
print("Standardizing validation set..")
x_val = (x_val-dataset_mean)/dataset_std # Standardizing the test set
print("Standardizing test set..")
x_test = (x_test-dataset_mean)/dataset_std # Standardizing the test set
```



```
# one hot encode target values
y_train = tf.keras.utils.to_categorical(y_train)
y_val = tf.keras.utils.to_categorical(y_val)
y_test = tf.keras.utils.to_categorical(y_test)
```



```
print("Size of the training set")
print("x_train", x_train.shape)
print("y_train", y_train.shape)

print("Size of the validation set")
print("x_val", x_val.shape)
print("y_val", y_val.shape)

print("Size of the test set")
print("x_test", x_test.shape)
print("y_test", y_test.shape)
```

```
Standardizing training set..  
Standardizing validation set..  
Standardizing test set..  
Size of the training set  
x_train (37500, 32, 32, 3)  
y_train (37500, 10)  
Size of the validation set  
x_val (12500, 32, 32, 3)  
y_val (12500, 10)  
Size of the test set  
x_test (10000, 32, 32, 3)  
y_test (10000, 10)
```

Plot some sample from the training set

```
In [ ]: class_names = ['Airplane', 'Automobile', 'Bird', 'Cat', 'Deer',  
                  'Dog', 'Frog', 'Horse', 'Ship', 'Truck']  
  
plt.figure(figsize=(6,6))  
for i in range(16):  
    plt.subplot(4,4,i+1)  
    plt.xticks([])  
    plt.yticks([])  
    plt.grid(False)  
    plt.imshow(x_learn[i], cmap=plt.cm.binary)  
    plt.xlabel(class_names[y_learn[i,0]])  
plt.show()
```



Build a Model

```
In [ ]: from tensorflow import keras  
from keras.layers import Flatten  
from keras.models import Sequential  
from keras.layers import Dense  
from keras import layers, regularizers  
from keras.layers import Dropout, Conv2D, Activation, MaxPooling2D, BatchNormalization  
  
tf.keras.backend.clear_session()
```

```
np.random.seed(42)
tf.random.set_seed(42)

num_filters_1=32
num_filters_2=64
num_filters_3=128
filter_size=3
pool_size=2

l2_norm = .0001
model = Sequential()
model.add(Conv2D(num_filters_1,filter_size, padding='same',
                kernel_regularizer=regularizers.l2(l2_norm), input_shape=x_train.shape))
model.add(BatchNormalization())

model.add(Conv2D(num_filters_1, filter_size, padding='same',
                kernel_regularizer=regularizers.l2(l2_norm),activation='elu'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=pool_size))
model.add(Dropout(0.2))
model.add(Conv2D(num_filters_2, filter_size, padding='same',
                kernel_regularizer=regularizers.l2(l2_norm),activation='elu'))
model.add(BatchNormalization())

model.add(Conv2D(num_filters_2, filter_size, padding='same',
                kernel_regularizer=regularizers.l2(l2_norm),activation='elu'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=pool_size))
model.add(Dropout(0.3))
model.add(Conv2D(num_filters_3, filter_size, padding='same',
                kernel_regularizer=regularizers.l2(l2_norm),activation='elu'))
model.add(BatchNormalization())
model.add(Conv2D(num_filters_3, filter_size, padding='same',
                kernel_regularizer=regularizers.l2(l2_norm),activation='elu'))
model.add(BatchNormalization())
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Dropout(0.4))

model.add(Flatten())
model.add(Dense(num_classes, activation='softmax'))

model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 32, 32, 32)	896
batch_normalization (BatchNormalization)	(None, 32, 32, 32)	128
conv2d_1 (Conv2D)	(None, 32, 32, 32)	9248
batch_normalization_1 (BatchNormalization)	(None, 32, 32, 32)	128
conv2d (Conv2D)	(None, 32, 32, 32)	896
batch_normalization (BatchNormalization)	(None, 32, 32, 32)	128
conv2d_1 (Conv2D)	(None, 32, 32, 32)	9248
batch_normalization_1 (BatchNormalization)	(None, 32, 32, 32)	128
max_pooling2d (MaxPooling2D)	(None, 16, 16, 32)	0
dropout (Dropout)	(None, 16, 16, 32)	0
conv2d_2 (Conv2D)	(None, 16, 16, 64)	18496
batch_normalization_2 (BatchNormalization)	(None, 16, 16, 64)	256
conv2d_3 (Conv2D)	(None, 16, 16, 64)	36928
batch_normalization_3 (BatchNormalization)	(None, 16, 16, 64)	256
max_pooling2d_1 (MaxPooling2D)	(None, 8, 8, 64)	0
dropout_1 (Dropout)	(None, 8, 8, 64)	0
conv2d_4 (Conv2D)	(None, 8, 8, 128)	73856
batch_normalization_4 (BatchNormalization)	(None, 8, 8, 128)	512
conv2d_5 (Conv2D)	(None, 8, 8, 128)	147584
batch_normalization_5 (BatchNormalization)	(None, 8, 8, 128)	512
max_pooling2d_2 (MaxPooling2D)	(None, 4, 4, 128)	0
dropout_2 (Dropout)	(None, 4, 4, 128)	0
flatten (Flatten)	(None, 2048)	0
dense (Dense)	(None, 10)	20490

```
=====
Total params: 309,290
Trainable params: 308,394
Non-trainable params: 896
```

```
In [ ]: from keras.optimizers import Adam, SGD, Adadelta, Adagrad, Adamax, Nadam, RMSprop

rms = RMSprop(learning_rate=0.001,rho=0.9,epsilon=None,decay=0.00001)
adamax = Adamax(lr=0.002,beta_1=0.9,beta_2=0.999,epsilon=None,decay=0.0)
nadam = Nadam(lr=0.002,beta_1=0.9,beta_2=0.999,epsilon=None,schedule_decay=0.004)
# Losses      https://keras.io/losses/
loss = ['categorical_crossentropy']

# Metrics      https://www.tensorflow.org/api_docs/python/tf/metrics
metrics = ['accuracy','precision','recall']

# Compile the model you created before using
# rms optimizer as optimizer
# categorical crossentropy as loss function
# accuracy as metric
def lr_schedule(epoch):
    lrate = 0.001
    if epoch > 30:
        lrate = 0.0005
    if epoch > 50:
        lrate = 0.0003
    return lrate

model.compile(optimizer=nadam,
              loss=loss[0],
              metrics=[metrics[0]],
              )
```

```
c:\Users\user\AppData\Local\Programs\Python\Python310\lib\site-packages\keras\optimizers\optimizer_v2\adamax.py:95: UserWarning: The `lr` argument is deprecated, use `learning_rate` instead.
    super(Adamax, self).__init__(name, **kwargs)
c:\Users\user\AppData\Local\Programs\Python\Python310\lib\site-packages\keras\optimizers\optimizer_v2\nadam.py:78: UserWarning: The `lr` argument is deprecated, use `learning_rate` instead.
    super(Nadam, self).__init__(name, **kwargs)
```

```
In [ ]: batch_size = 64
epochs = 200
from tensorflow import keras
from keras.callbacks import ModelCheckpoint, EarlyStopping
import os

from keras.preprocessing.image import ImageDataGenerator
datagen = ImageDataGenerator( rotation_range=90,
                             width_shift_range=0.1, height_shift_range=0.1,
                             horizontal_flip=True)
datagen.fit(x_train)

es_callback = EarlyStopping(monitor='val_accuracy', patience=20, verbose=1)

checkpoint_path = "output/cp.ckpt"
checkpoint_dir = os.path.dirname(checkpoint_path)
cp_callback = ModelCheckpoint(checkpoint_path, monitor='val_accuracy', save_best_only=True)
lr_scheduler = tf.keras.callbacks.ReduceLROnPlateau(factor=0.5, patience=5)
#lr_scheduler=keras.callbacks.LearningRateScheduler(lr_schedule)
history = model.fit(datagen.flow(x_train,y_train,batch_size=batch_size),
```

```
validation_data=(x_val, y_val), epochs=epochs,
callbacks=[lr_scheduler,es_callback,cp_callback], verbose=1)
```

Epoch 1/200

586/586 [=====] - ETA: 0s - loss: 2.2327 - accuracy: 0.32
20

WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

586/586 [=====] - 128s 213ms/step - loss: 2.2327 - accuracy: 0.3220 - val_loss: 1.8386 - val_accuracy: 0.4187 - lr: 0.0020

Epoch 2/200

586/586 [=====] - ETA: 0s - loss: 1.6936 - accuracy: 0.43
58

WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

586/586 [=====] - 115s 196ms/step - loss: 1.6936 - accuracy: 0.4358 - val_loss: 1.7825 - val_accuracy: 0.4570 - lr: 0.0020

Epoch 3/200

586/586 [=====] - ETA: 0s - loss: 1.4586 - accuracy: 0.50
98

WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

586/586 [=====] - 131s 224ms/step - loss: 1.4586 - accuracy: 0.5098 - val_loss: 1.4827 - val_accuracy: 0.5202 - lr: 0.0020

Epoch 4/200

586/586 [=====] - ETA: 0s - loss: 1.3420 - accuracy: 0.54
75

WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

586/586 [=====] - 142s 243ms/step - loss: 1.3420 - accuracy: 0.5475 - val_loss: 1.3613 - val_accuracy: 0.5656 - lr: 0.0020

Epoch 5/200

586/586 [=====] - ETA: 0s - loss: 1.2772 - accuracy: 0.57
85

WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

INFO:tensorflow:Assets written to: output\cp.ckpt\assets

586/586 [=====] - 151s 258ms/step - loss: 1.2772 - accuracy: 0.5785 - val_loss: 1.2616 - val_accuracy: 0.5994 - lr: 0.0020

Epoch 6/200

586/586 [=====] - ETA: 0s - loss: 1.2421 - accuracy: 0.59
69

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
586/586 [=====] - 151s 258ms/step - loss: 1.2421 - accuracy: 0.5969 - val_loss: 1.2724 - val_accuracy: 0.6067 - lr: 0.0020  
Epoch 7/200  
586/586 [=====] - ETA: 0s - loss: 1.2134 - accuracy: 0.6136  
36  
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
586/586 [=====] - 150s 255ms/step - loss: 1.2134 - accuracy: 0.6136 - val_loss: 1.1622 - val_accuracy: 0.6487 - lr: 0.0020  
Epoch 8/200  
586/586 [=====] - ETA: 0s - loss: 1.2018 - accuracy: 0.6224  
24  
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
586/586 [=====] - 151s 257ms/step - loss: 1.2018 - accuracy: 0.6224 - val_loss: 1.1298 - val_accuracy: 0.6610 - lr: 0.0020  
Epoch 9/200  
586/586 [=====] - 148s 253ms/step - loss: 1.1867 - accuracy: 0.6358 - val_loss: 1.2625 - val_accuracy: 0.6415 - lr: 0.0020  
Epoch 10/200  
586/586 [=====] - 148s 253ms/step - loss: 1.1749 - accuracy: 0.6442 - val_loss: 1.1777 - val_accuracy: 0.6558 - lr: 0.0020  
Epoch 11/200  
586/586 [=====] - ETA: 0s - loss: 1.1687 - accuracy: 0.6493  
93  
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
586/586 [=====] - 162s 276ms/step - loss: 1.1687 - accuracy: 0.6493 - val_loss: 1.1417 - val_accuracy: 0.6721 - lr: 0.0020  
Epoch 12/200  
586/586 [=====] - ETA: 0s - loss: 1.1627 - accuracy: 0.6563  
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets  
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
586/586 [=====] - 183s 313ms/step - loss: 1.1627 - accuracy: 0.6563 - val_loss: 1.1529 - val_accuracy: 0.6782 - lr: 0.0020
Epoch 13/200
586/586 [=====] - 196s 335ms/step - loss: 1.1538 - accuracy: 0.6589 - val_loss: 1.1675 - val_accuracy: 0.6690 - lr: 0.0020
Epoch 14/200
586/586 [=====] - ETA: 0s - loss: 1.0779 - accuracy: 0.6884
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 206s 351ms/step - loss: 1.0779 - accuracy: 0.6884 - val_loss: 1.0587 - val_accuracy: 0.7018 - lr: 0.0010
Epoch 15/200
586/586 [=====] - 178s 304ms/step - loss: 1.0466 - accuracy: 0.6975 - val_loss: 1.1062 - val_accuracy: 0.6954 - lr: 0.0010
Epoch 16/200
586/586 [=====] - ETA: 0s - loss: 1.0304 - accuracy: 0.7002
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 207s 352ms/step - loss: 1.0304 - accuracy: 0.7002 - val_loss: 1.0433 - val_accuracy: 0.7034 - lr: 0.0010
Epoch 17/200
586/586 [=====] - ETA: 0s - loss: 1.0196 - accuracy: 0.7044
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 206s 352ms/step - loss: 1.0196 - accuracy: 0.7044 - val_loss: 0.9483 - val_accuracy: 0.7341 - lr: 0.0010
Epoch 18/200
586/586 [=====] - 203s 346ms/step - loss: 1.0120 - accuracy: 0.7059 - val_loss: 1.0469 - val_accuracy: 0.7045 - lr: 0.0010
Epoch 19/200
586/586 [=====] - 201s 343ms/step - loss: 1.0011 - accuracy: 0.7055 - val_loss: 0.9374 - val_accuracy: 0.7315 - lr: 0.0010
Epoch 20/200
586/586 [=====] - ETA: 0s - loss: 0.9878 - accuracy: 0.7115
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
586/586 [=====] - 206s 352ms/step - loss: 0.9878 - accuracy: 0.7115 - val_loss: 0.9266 - val_accuracy: 0.7430 - lr: 0.0010
Epoch 21/200
586/586 [=====] - 199s 340ms/step - loss: 0.9795 - accuracy: 0.7123 - val_loss: 0.9615 - val_accuracy: 0.7339 - lr: 0.0010
Epoch 22/200
586/586 [=====] - 203s 347ms/step - loss: 0.9732 - accuracy: 0.7155 - val_loss: 1.0567 - val_accuracy: 0.7006 - lr: 0.0010
Epoch 23/200
586/586 [=====] - 199s 339ms/step - loss: 0.9687 - accuracy: 0.7163 - val_loss: 0.9342 - val_accuracy: 0.7369 - lr: 0.0010
Epoch 24/200
586/586 [=====] - 196s 334ms/step - loss: 0.9635 - accuracy: 0.7186 - val_loss: 1.0331 - val_accuracy: 0.7106 - lr: 0.0010
Epoch 25/200
586/586 [=====] - ETA: 0s - loss: 0.9595 - accuracy: 0.7183
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 205s 349ms/step - loss: 0.9595 - accuracy: 0.7183 - val_loss: 0.8998 - val_accuracy: 0.7475 - lr: 0.0010
Epoch 26/200
586/586 [=====] - 200s 341ms/step - loss: 0.9528 - accuracy: 0.7195 - val_loss: 0.9898 - val_accuracy: 0.7234 - lr: 0.0010
Epoch 27/200
586/586 [=====] - 200s 341ms/step - loss: 0.9531 - accuracy: 0.7254 - val_loss: 0.9352 - val_accuracy: 0.7435 - lr: 0.0010
Epoch 28/200
586/586 [=====] - 204s 348ms/step - loss: 0.9458 - accuracy: 0.7265 - val_loss: 0.9561 - val_accuracy: 0.7316 - lr: 0.0010
Epoch 29/200
586/586 [=====] - 203s 345ms/step - loss: 0.9477 - accuracy: 0.7255 - val_loss: 0.9494 - val_accuracy: 0.7364 - lr: 0.0010
Epoch 30/200
586/586 [=====] - ETA: 0s - loss: 0.9414 - accuracy: 0.7298
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 213s 363ms/step - loss: 0.9414 - accuracy: 0.7298 - val_loss: 0.9039 - val_accuracy: 0.7501 - lr: 0.0010
Epoch 31/200
586/586 [=====] - ETA: 0s - loss: 0.8932 - accuracy: 0.7430
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 191s 326ms/step - loss: 0.8932 - accuracy: 0.7430 - val_loss: 0.8790 - val_accuracy: 0.7598 - lr: 5.0000e-04
Epoch 32/200
586/586 [=====] - ETA: 0s - loss: 0.8798 - accuracy: 0.7474
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 194s 331ms/step - loss: 0.8798 - accuracy: 0.7474 - val_loss: 0.8412 - val_accuracy: 0.7690 - lr: 5.0000e-04
Epoch 33/200
586/586 [=====] - 174s 297ms/step - loss: 0.8709 - accuracy: 0.7496 - val_loss: 0.8819 - val_accuracy: 0.7551 - lr: 5.0000e-04
Epoch 34/200
586/586 [=====] - 169s 289ms/step - loss: 0.8598 - accuracy: 0.7522 - val_loss: 0.8792 - val_accuracy: 0.7572 - lr: 5.0000e-04
Epoch 35/200
586/586 [=====] - ETA: 0s - loss: 0.8547 - accuracy: 0.7533
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 175s 298ms/step - loss: 0.8547 - accuracy: 0.7533 - val_loss: 0.8163 - val_accuracy: 0.7763 - lr: 5.0000e-04
Epoch 36/200
586/586 [=====] - 165s 281ms/step - loss: 0.8477 - accuracy: 0.7566 - val_loss: 0.8096 - val_accuracy: 0.7755 - lr: 5.0000e-04
Epoch 37/200
586/586 [=====] - 173s 296ms/step - loss: 0.8378 - accuracy: 0.7557 - val_loss: 0.8682 - val_accuracy: 0.7641 - lr: 5.0000e-04
Epoch 38/200
586/586 [=====] - 176s 300ms/step - loss: 0.8417 - accuracy: 0.7558 - val_loss: 0.8250 - val_accuracy: 0.7714 - lr: 5.0000e-04
Epoch 39/200
586/586 [=====] - 167s 285ms/step - loss: 0.8361 - accuracy: 0.7574 - val_loss: 0.8248 - val_accuracy: 0.7709 - lr: 5.0000e-04
Epoch 40/200
586/586 [=====] - ETA: 0s - loss: 0.8311 - accuracy: 0.7593
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 164s 280ms/step - loss: 0.8311 - accuracy: 0.7593 - val_loss: 0.8021 - val_accuracy: 0.7786 - lr: 5.0000e-04
Epoch 41/200
586/586 [=====] - 156s 267ms/step - loss: 0.8237 - accuracy: 0.7616 - val_loss: 0.8571 - val_accuracy: 0.7627 - lr: 5.0000e-04
Epoch 42/200
586/586 [=====] - ETA: 0s - loss: 0.8254 - accuracy: 0.783
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
586/586 [=====] - 159s 271ms/step - loss: 0.8254 - accuracy: 0.7583 - val_loss: 0.7881 - val_accuracy: 0.7801 - lr: 5.0000e-04
Epoch 43/200
586/586 [=====] - 158s 270ms/step - loss: 0.8142 - accuracy: 0.7631 - val_loss: 0.8261 - val_accuracy: 0.7733 - lr: 5.0000e-04
Epoch 44/200
586/586 [=====] - 158s 270ms/step - loss: 0.8132 - accuracy: 0.7627 - val_loss: 0.8205 - val_accuracy: 0.7701 - lr: 5.0000e-04
Epoch 45/200
586/586 [=====] - 158s 270ms/step - loss: 0.8031 - accuracy: 0.7661 - val_loss: 0.8278 - val_accuracy: 0.7685 - lr: 5.0000e-04
Epoch 46/200
586/586 [=====] - 158s 269ms/step - loss: 0.8079 - accuracy: 0.7652 - val_loss: 0.7984 - val_accuracy: 0.7786 - lr: 5.0000e-04
Epoch 47/200
586/586 [=====] - ETA: 0s - loss: 0.8053 - accuracy: 0.7655
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
```

```
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
586/586 [=====] - 160s 273ms/step - loss: 0.8053 - accuracy: 0.7655 - val_loss: 0.7630 - val_accuracy: 0.7882 - lr: 5.0000e-04
```

```
Epoch 48/200
```

```
586/586 [=====] - 158s 269ms/step - loss: 0.8071 - accuracy: 0.7636 - val_loss: 0.8332 - val_accuracy: 0.7688 - lr: 5.0000e-04
```

```
Epoch 49/200
```

```
586/586 [=====] - 159s 272ms/step - loss: 0.8031 - accuracy: 0.7659 - val_loss: 0.7871 - val_accuracy: 0.7780 - lr: 5.0000e-04
```

```
Epoch 50/200
```

```
586/586 [=====] - 159s 271ms/step - loss: 0.8021 - accuracy: 0.7652 - val_loss: 0.7876 - val_accuracy: 0.7816 - lr: 5.0000e-04
```

```
Epoch 51/200
```

```
586/586 [=====] - 159s 271ms/step - loss: 0.7965 - accuracy: 0.7691 - val_loss: 0.8169 - val_accuracy: 0.7708 - lr: 5.0000e-04
```

```
Epoch 52/200
```

```
586/586 [=====] - ETA: 0s - loss: 0.8054 - accuracy: 0.7649
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
```

```
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
586/586 [=====] - 160s 273ms/step - loss: 0.8054 - accuracy: 0.7649 - val_loss: 0.7456 - val_accuracy: 0.7936 - lr: 5.0000e-04
```

```
Epoch 53/200
```

```
586/586 [=====] - 157s 267ms/step - loss: 0.7936 - accuracy: 0.7690 - val_loss: 0.7731 - val_accuracy: 0.7818 - lr: 5.0000e-04
```

```
Epoch 54/200
```

```
586/586 [=====] - ETA: 0s - loss: 0.7899 - accuracy: 0.7703
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
```

```
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
586/586 [=====] - 159s 272ms/step - loss: 0.7899 - accuracy: 0.7703 - val_loss: 0.7415 - val_accuracy: 0.7946 - lr: 5.0000e-04
Epoch 55/200
586/586 [=====] - 157s 269ms/step - loss: 0.7866 - accuracy: 0.7692 - val_loss: 0.7836 - val_accuracy: 0.7823 - lr: 5.0000e-04
Epoch 56/200
586/586 [=====] - 161s 274ms/step - loss: 0.7903 - accuracy: 0.7691 - val_loss: 0.7866 - val_accuracy: 0.7822 - lr: 5.0000e-04
Epoch 57/200
586/586 [=====] - 158s 270ms/step - loss: 0.7826 - accuracy: 0.7734 - val_loss: 0.7873 - val_accuracy: 0.7818 - lr: 5.0000e-04
Epoch 58/200
586/586 [=====] - 161s 275ms/step - loss: 0.7823 - accuracy: 0.7714 - val_loss: 0.8132 - val_accuracy: 0.7721 - lr: 5.0000e-04
Epoch 59/200
586/586 [=====] - 159s 272ms/step - loss: 0.7827 - accuracy: 0.7726 - val_loss: 0.7784 - val_accuracy: 0.7845 - lr: 5.0000e-04
Epoch 60/200
586/586 [=====] - 160s 273ms/step - loss: 0.7545 - accuracy: 0.7806 - val_loss: 0.7610 - val_accuracy: 0.7882 - lr: 2.5000e-04
Epoch 61/200
586/586 [=====] - 161s 275ms/step - loss: 0.7473 - accuracy: 0.7838 - val_loss: 0.7966 - val_accuracy: 0.7782 - lr: 2.5000e-04
Epoch 62/200
586/586 [=====] - ETA: 0s - loss: 0.7445 - accuracy: 0.7833
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 163s 278ms/step - loss: 0.7445 - accuracy: 0.7833 - val_loss: 0.7263 - val_accuracy: 0.7990 - lr: 2.5000e-04
Epoch 63/200
586/586 [=====] - 161s 275ms/step - loss: 0.7338 - accuracy: 0.7857 - val_loss: 0.7458 - val_accuracy: 0.7959 - lr: 2.5000e-04
Epoch 64/200
586/586 [=====] - ETA: 0s - loss: 0.7351 - accuracy: 0.7860
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

```
586/586 [=====] - 163s 278ms/step - loss: 0.7351 - accuracy: 0.7860 - val_loss: 0.6788 - val_accuracy: 0.8084 - lr: 2.5000e-04
Epoch 65/200
586/586 [=====] - 157s 269ms/step - loss: 0.7249 - accuracy: 0.7907 - val_loss: 0.7615 - val_accuracy: 0.7910 - lr: 2.5000e-04
Epoch 66/200
586/586 [=====] - 160s 273ms/step - loss: 0.7279 - accuracy: 0.7871 - val_loss: 0.7300 - val_accuracy: 0.7952 - lr: 2.5000e-04
Epoch 67/200
586/586 [=====] - 163s 278ms/step - loss: 0.7253 - accuracy: 0.7882 - val_loss: 0.7216 - val_accuracy: 0.8016 - lr: 2.5000e-04
Epoch 68/200
586/586 [=====] - 161s 275ms/step - loss: 0.7250 - accuracy: 0.7858 - val_loss: 0.7098 - val_accuracy: 0.8054 - lr: 2.5000e-04
Epoch 69/200
586/586 [=====] - 163s 279ms/step - loss: 0.7211 - accuracy: 0.7884 - val_loss: 0.7088 - val_accuracy: 0.8047 - lr: 2.5000e-04
Epoch 70/200
586/586 [=====] - ETA: 0s - loss: 0.7065 - accuracy: 0.7919
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 167s 284ms/step - loss: 0.7065 - accuracy: 0.7919 - val_loss: 0.6943 - val_accuracy: 0.8100 - lr: 1.2500e-04
Epoch 71/200
586/586 [=====] - 159s 271ms/step - loss: 0.7002 - accuracy: 0.7961 - val_loss: 0.7093 - val_accuracy: 0.8064 - lr: 1.2500e-04
Epoch 72/200
586/586 [=====] - 159s 271ms/step - loss: 0.6996 - accuracy: 0.7974 - val_loss: 0.6937 - val_accuracy: 0.8094 - lr: 1.2500e-04
Epoch 73/200
586/586 [=====] - 158s 270ms/step - loss: 0.6992 - accuracy: 0.7946 - val_loss: 0.7041 - val_accuracy: 0.8051 - lr: 1.2500e-04
Epoch 74/200
586/586 [=====] - 159s 271ms/step - loss: 0.6920 - accuracy: 0.7964 - val_loss: 0.6982 - val_accuracy: 0.8088 - lr: 1.2500e-04
Epoch 75/200
586/586 [=====] - ETA: 0s - loss: 0.6844 - accuracy: 0.8010
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 159s 272ms/step - loss: 0.6844 - accuracy: 0.8010 - val_loss: 0.6941 - val_accuracy: 0.8110 - lr: 6.2500e-05
Epoch 76/200
586/586 [=====] - 154s 263ms/step - loss: 0.6774 - accuracy: 0.8026 - val_loss: 0.6941 - val_accuracy: 0.8095 - lr: 6.2500e-05
Epoch 77/200
586/586 [=====] - 154s 263ms/step - loss: 0.6731 - accuracy: 0.8048 - val_loss: 0.6990 - val_accuracy: 0.8091 - lr: 6.2500e-05
Epoch 78/200
586/586 [=====] - 158s 270ms/step - loss: 0.6749 - accuracy: 0.8044 - val_loss: 0.6921 - val_accuracy: 0.8105 - lr: 6.2500e-05
Epoch 79/200
586/586 [=====] - ETA: 0s - loss: 0.6732 - accuracy: 0.8046
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
586/586 [=====] - 159s 271ms/step - loss: 0.6732 - accuracy: 0.8046 - val_loss: 0.6819 - val_accuracy: 0.8142 - lr: 6.2500e-05
Epoch 80/200
586/586 [=====] - 159s 272ms/step - loss: 0.6686 - accuracy: 0.8038 - val_loss: 0.6905 - val_accuracy: 0.8107 - lr: 3.1250e-05
Epoch 81/200
586/586 [=====] - 160s 272ms/step - loss: 0.6658 - accuracy: 0.8066 - val_loss: 0.6945 - val_accuracy: 0.8094 - lr: 3.1250e-05
Epoch 82/200
586/586 [=====] - 159s 272ms/step - loss: 0.6711 - accuracy: 0.8047 - val_loss: 0.6846 - val_accuracy: 0.8142 - lr: 3.1250e-05
Epoch 83/200
586/586 [=====] - 160s 273ms/step - loss: 0.6698 - accuracy: 0.8058 - val_loss: 0.6812 - val_accuracy: 0.8138 - lr: 3.1250e-05
Epoch 84/200
586/586 [=====] - ETA: 0s - loss: 0.6654 - accuracy: 0.8060
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op, _jit_compiled_convolution_op while saving (showing 5 of 6). These functions will not be directly callable after loading.
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
INFO:tensorflow:Assets written to: output\cp.ckpt\assets
```

586/586 [=====] - 164s 279ms/step - loss: 0.6654 - accuracy: 0.8060 - val_loss: 0.6759 - val_accuracy: 0.8172 - lr: 3.1250e-05
Epoch 85/200
586/586 [=====] - 156s 267ms/step - loss: 0.6628 - accuracy: 0.8087 - val_loss: 0.6885 - val_accuracy: 0.8123 - lr: 3.1250e-05
Epoch 86/200
586/586 [=====] - 156s 266ms/step - loss: 0.6657 - accuracy: 0.8051 - val_loss: 0.6757 - val_accuracy: 0.8151 - lr: 3.1250e-05
Epoch 87/200
586/586 [=====] - 157s 268ms/step - loss: 0.6643 - accuracy: 0.8082 - val_loss: 0.6717 - val_accuracy: 0.8163 - lr: 3.1250e-05
Epoch 88/200
586/586 [=====] - 160s 272ms/step - loss: 0.6624 - accuracy: 0.8078 - val_loss: 0.6756 - val_accuracy: 0.8151 - lr: 3.1250e-05
Epoch 89/200
586/586 [=====] - 156s 266ms/step - loss: 0.6606 - accuracy: 0.8076 - val_loss: 0.6778 - val_accuracy: 0.8146 - lr: 3.1250e-05
Epoch 90/200
586/586 [=====] - 154s 263ms/step - loss: 0.6551 - accuracy: 0.8100 - val_loss: 0.6744 - val_accuracy: 0.8154 - lr: 3.1250e-05
Epoch 91/200
586/586 [=====] - 158s 270ms/step - loss: 0.6610 - accuracy: 0.8078 - val_loss: 0.6741 - val_accuracy: 0.8170 - lr: 3.1250e-05
Epoch 92/200
586/586 [=====] - 158s 269ms/step - loss: 0.6652 - accuracy: 0.8059 - val_loss: 0.6782 - val_accuracy: 0.8143 - lr: 3.1250e-05
Epoch 93/200
586/586 [=====] - 158s 270ms/step - loss: 0.6620 - accuracy: 0.8074 - val_loss: 0.6758 - val_accuracy: 0.8139 - lr: 1.5625e-05
Epoch 94/200
586/586 [=====] - 158s 270ms/step - loss: 0.6659 - accuracy: 0.8043 - val_loss: 0.6746 - val_accuracy: 0.8151 - lr: 1.5625e-05
Epoch 95/200
586/586 [=====] - 160s 273ms/step - loss: 0.6561 - accuracy: 0.8106 - val_loss: 0.6822 - val_accuracy: 0.8126 - lr: 1.5625e-05
Epoch 96/200
586/586 [=====] - 160s 272ms/step - loss: 0.6598 - accuracy: 0.8061 - val_loss: 0.6818 - val_accuracy: 0.8132 - lr: 1.5625e-05
Epoch 97/200
586/586 [=====] - 158s 269ms/step - loss: 0.6582 - accuracy: 0.8094 - val_loss: 0.6731 - val_accuracy: 0.8160 - lr: 1.5625e-05
Epoch 98/200
586/586 [=====] - 158s 270ms/step - loss: 0.6580 - accuracy: 0.8084 - val_loss: 0.6733 - val_accuracy: 0.8161 - lr: 7.8125e-06
Epoch 99/200
586/586 [=====] - 159s 271ms/step - loss: 0.6495 - accuracy: 0.8134 - val_loss: 0.6738 - val_accuracy: 0.8151 - lr: 7.8125e-06
Epoch 100/200
586/586 [=====] - 158s 270ms/step - loss: 0.6580 - accuracy: 0.8094 - val_loss: 0.6696 - val_accuracy: 0.8159 - lr: 7.8125e-06
Epoch 101/200
586/586 [=====] - 162s 276ms/step - loss: 0.6557 - accuracy: 0.8080 - val_loss: 0.6674 - val_accuracy: 0.8166 - lr: 7.8125e-06
Epoch 102/200
586/586 [=====] - 159s 270ms/step - loss: 0.6513 - accuracy: 0.8107 - val_loss: 0.6766 - val_accuracy: 0.8144 - lr: 7.8125e-06
Epoch 103/200
586/586 [=====] - 157s 268ms/step - loss: 0.6566 - accuracy: 0.8067 - val_loss: 0.6742 - val_accuracy: 0.8158 - lr: 7.8125e-06
Epoch 104/200
586/586 [=====] - 158s 270ms/step - loss: 0.6566 - accuracy: 0.8082 - val_loss: 0.6710 - val_accuracy: 0.8167 - lr: 7.8125e-06
Epoch 104: early stopping

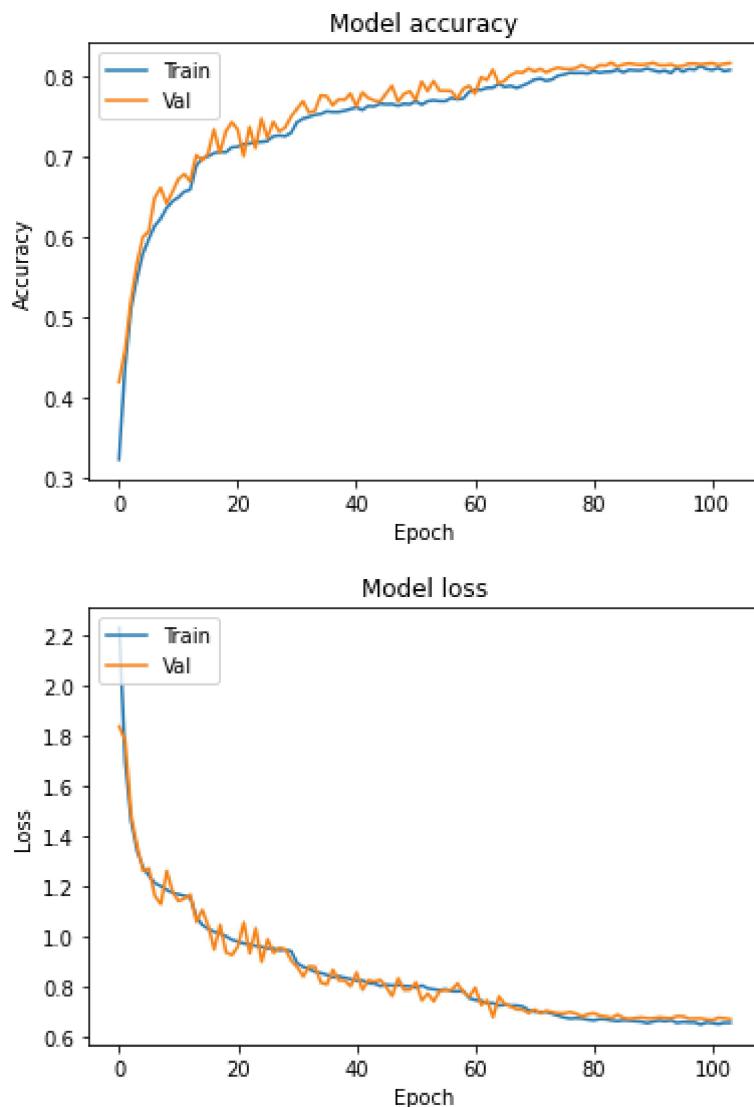
```
In [ ]: keras.models.load_model('output\\cp.ckpt')
Out[ ]: <keras.engine.sequential.Sequential at 0x1a5495af580>
```

Training history visualization

```
In [ ]: def plot_history(history):
    # Plot training & validation accuracy values
    plt.plot(history.history['accuracy'])
    plt.plot(history.history['val_accuracy'])
    plt.title('Model accuracy')
    plt.ylabel('Accuracy')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Val'], loc='upper left')
    plt.show()

    # Plot training & validation Loss values
    plt.plot(history.history['loss'])
    plt.plot(history.history['val_loss'])
    plt.title('Model loss')
    plt.ylabel('Loss')
    plt.xlabel('Epoch')
    plt.legend(['Train', 'Val'], loc='upper left')
    plt.show()
```

```
In [ ]: plot_history(history)
```



Evaluate the model

```
In [ ]: __, train_acc = model.evaluate(x_train, y_train, verbose=1)
__, val_acc = model.evaluate(x_val, y_val, verbose=1)

__, test_acc = model.evaluate(x_test, y_test, verbose=1)
print('Train: %.3f, val: %.3f,Test: %.3f' % (train_acc, val_acc, test_acc))

1172/1172 [=====] - 45s 39ms/step - loss: 0.5646 - accuracy: 0.8434
391/391 [=====] - 17s 43ms/step - loss: 0.6710 - accuracy: 0.8167
313/313 [=====] - 12s 39ms/step - loss: 0.6983 - accuracy: 0.8064
Train: 0.843, val: 0.817,Test: 0.806
```