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Deep Learning Homework 3 📚 💻 (50 points)

TensorFlow, Keras, NumPy

In this problem, you are asked to train and test the LeNet for entire CIFAR-10 colorful image dataset. You need to modify LeNet for this problem.

Performance requirement and submission are detailed as follows:

– The test accuracy should achieve above 50%

– You need to submit three results:

1. network without dropout/batch normalization
2. network with one additional dropout layer
3. network with one additional batch normalization
4.

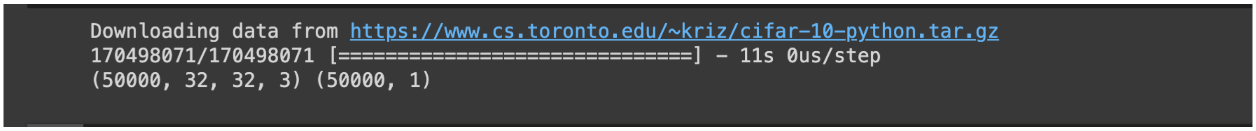
Compare the results in your submission. – What to submit: Submission should include your source codes and screen snapshot of your train and test accuracy, plus the training time

Code and Output:

```
from matplotlib import pyplot as plt
import tensorflow as tf
import pandas as pd
import numpy as np
```

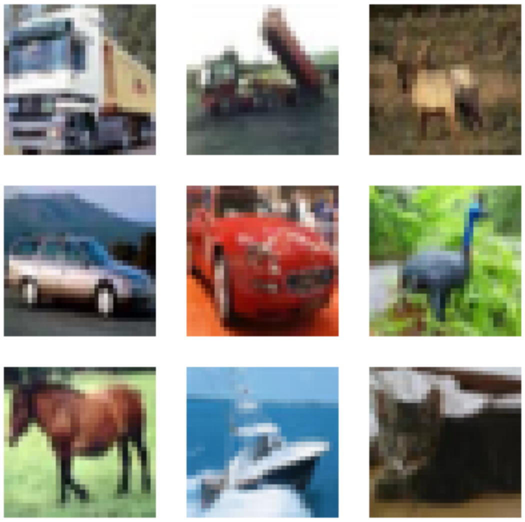
#*Load the cifar10 dataset*:

```
cifar10 = tf.keras.datasets.cifar10
(x_train, y_train), (x_test, y_test) = cifar10.load_data()
print(x_train.shape, y_train.shape)
```

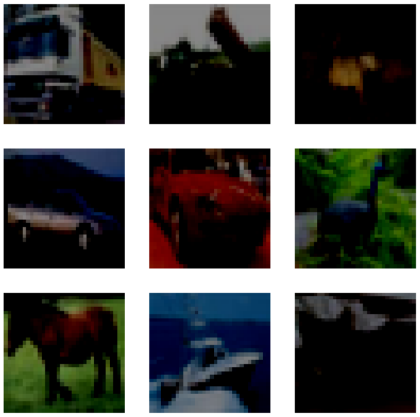


```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 [==============================] - 11s 0us/step
(50000, 32, 32, 3) (50000, 1)
```

```
plt.figure(figsize=(5,5))
for i in range(1, 10):
  plt.subplot(3, 3, i)
  plt.axis('off')
  plt.imshow(x_train[i])
plt.show()
```

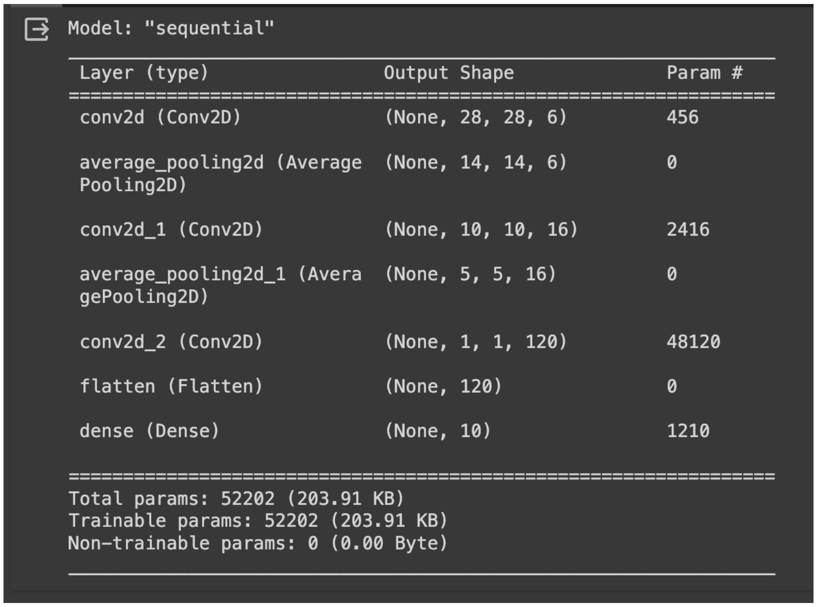


```
#Data Pre-Processing : Normalize

x_train, x_test = x_train/float(255), x_test/float(255)
x_train -= np.mean(x_train)
x_test -= np.mean(x_test)

ytrain=tf.keras.utils.to_categorical(y_train)
ytest=tf.keras.utils.to_categorical(y_test)
```



#1. Network without dropout/batch normalization.

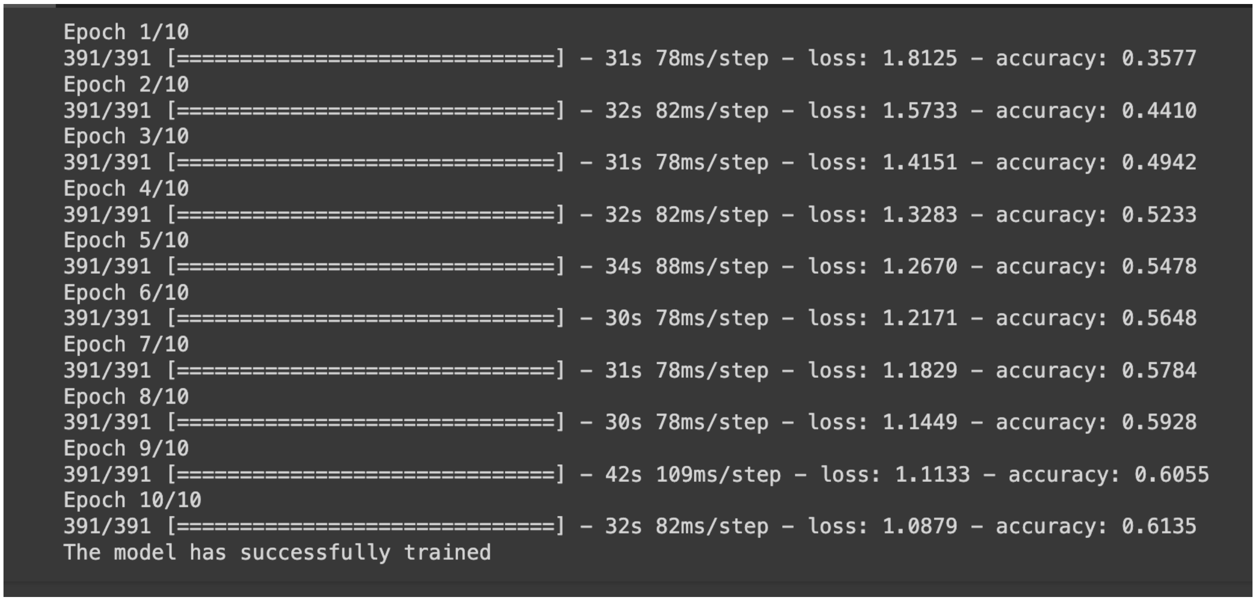
```
model = tf.keras.models.Sequential()

#conv1
model.add(tf.keras.layers.Conv2D(filters = 6, kernel_size=(5,5), padding= 'valid',
                        strides = (1,1), activation='tanh', input_shape=(32,32,3)))
#avgpooling1
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2,2), strides=2, padding='valid'))

#conv2
model.add(tf.keras.layers.Conv2D(filters = 16, kernel_size = (5,5), padding= 'valid',
strides = (1,1), activation='tanh'))

##avgpooling2
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2,2), strides=2, padding='valid'))

#conv3
model.add(tf.keras.layers.Conv2D(filters = 120, kernel_size = (5,5), padding= 'valid',
strides = (1,1), activation='tanh'))

#fully-connected network
model.add(tf.keras.layers.Flatten())

model.add(tf.keras.layers.Dense(10, activation=tf.nn.softmax))

model.compile(optimizer=tf.keras.optimizers.SGD(learning_rate=0.004,
momentum=0.9),
          loss=tf.keras.losses.sparse_categorical_crossentropy,
          metrics=['accuracy'])


model.summary()
```



```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 28, 28, 6)         456

 average_pooling2d (Average  (None, 14, 14, 6)         0
 Pooling2D)

 conv2d_1 (Conv2D)           (None, 10, 10, 16)        2416

 average_pooling2d_1 (Avera  (None, 5, 5, 16)          0
 gePooling2D)

 conv2d_2 (Conv2D)           (None, 1, 1, 120)         48120

 flatten (Flatten)           (None, 120)               0

 dense (Dense)               (None, 10)                1210

=================================================================
Total params: 52202 (203.91 KB)
Trainable params: 52202 (203.91 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

#Training Model

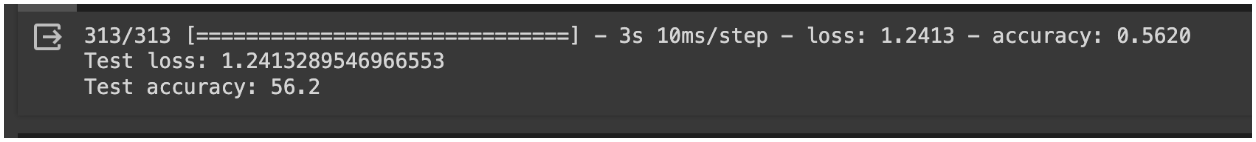
```
model_history = model.fit(x_train, y_train, batch_size = 128, epochs=10)
print("The model has successfully trained")

model.save('sample.model')
```



```
Epoch 1/10
391/391 [==============================] - 31s 78ms/step - loss: 1.8125 - accuracy: 0.3577
Epoch 2/10
391/391 [==============================] - 32s 82ms/step - loss: 1.5733 - accuracy: 0.4410
Epoch 3/10
391/391 [==============================] - 31s 78ms/step - loss: 1.4151 - accuracy: 0.4942
Epoch 4/10
391/391 [==============================] - 32s 82ms/step - loss: 1.3283 - accuracy: 0.5233
Epoch 5/10
391/391 [==============================] - 34s 88ms/step - loss: 1.2670 - accuracy: 0.5478
Epoch 6/10
391/391 [==============================] - 30s 78ms/step - loss: 1.2171 - accuracy: 0.5648
Epoch 7/10
391/391 [==============================] - 31s 78ms/step - loss: 1.1829 - accuracy: 0.5784
Epoch 8/10
391/391 [==============================] - 30s 78ms/step - loss: 1.1449 - accuracy: 0.5928
Epoch 9/10
391/391 [==============================] - 42s 109ms/step - loss: 1.1133 - accuracy: 0.6055
Epoch 10/10
391/391 [==============================] - 32s 82ms/step - loss: 1.0879 - accuracy: 0.6135
The model has successfully trained
```

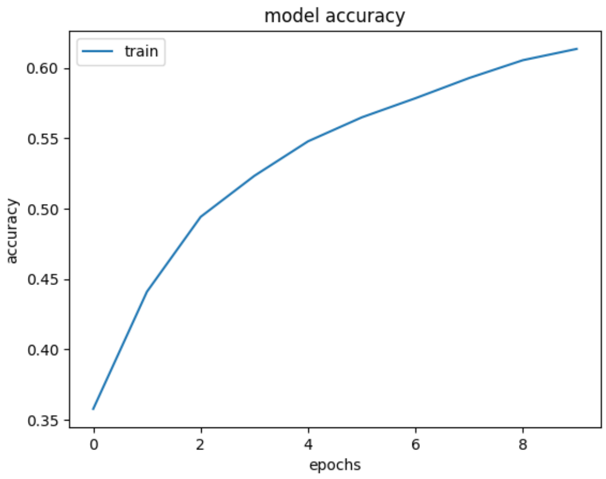
#Model Evaluation

```
s_model = tf.keras.models.load_model('sample.model')
loss, accuracy = s_model.evaluate(x_test, y_test)
print('Test loss:', loss)
print('Test accuracy:', np.round((accuracy)*100, 2))
```



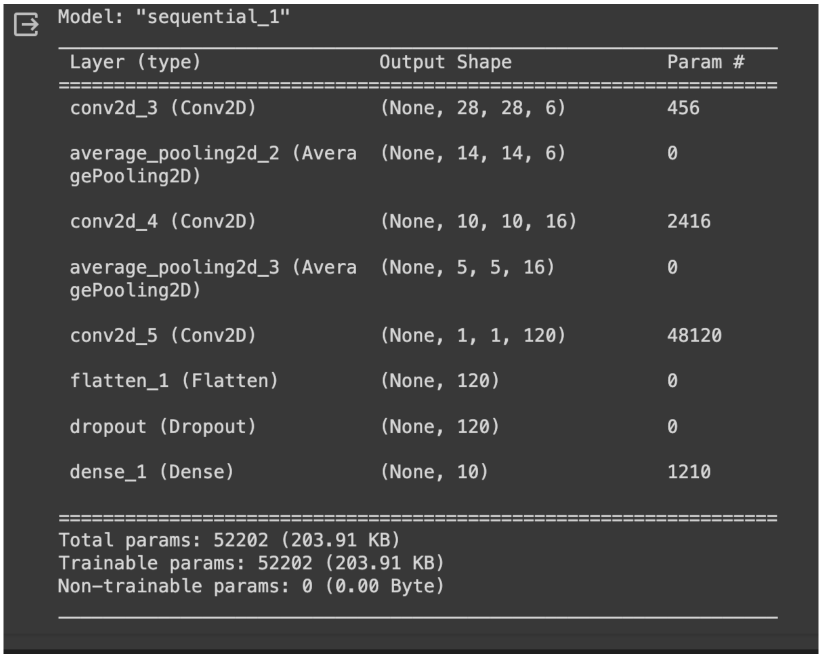
```
313/313 [==============================] - 3s 10ms/step - loss: 1.2413 - accuracy: 0.5620
Test loss: 1.2413289546966553
Test accuracy: 56.2
```

```
plt.plot(model_history.history['accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epochs')
plt.legend(['train'], loc = 'upper left')
plt.show
```



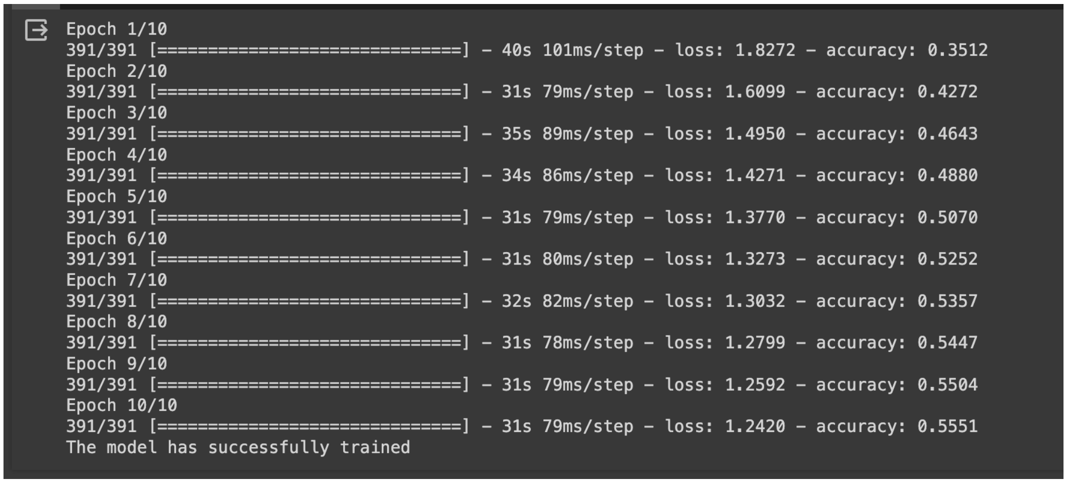
#2. Network with one additional dropout layer

```
model = tf.keras.models.Sequential()

#conv1
model.add(tf.keras.layers.Conv2D(filters = 6, kernel_size=(5,5), padding= 'valid',
                         strides = (1,1), activation='tanh', input_shape=(32,32,3)))
#avgpooling1
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2,2), strides=2, padding='valid'))

#conv2
model.add(tf.keras.layers.Conv2D(filters = 16, kernel_size = (5,5), padding= 'valid', strides = (1,1),
activation='tanh'))

##avgpooling2
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2,2), strides=2, padding='valid'))

#conv3
model.add(tf.keras.layers.Conv2D(filters = 120, kernel_size = (5,5), padding= 'valid', strides =
(1,1), activation='tanh'))

#fully-connected network
model.add(tf.keras.layers.Flatten())

#dropout
model.add(tf.keras.layers.Dropout(0.25))

model.add(tf.keras.layers.Dense(10, activation=tf.nn.softmax))

model.compile(optimizer=tf.keras.optimizers.SGD(learning_rate=0.02, momentum=0.9),
          loss=tf.keras.losses.sparse_categorical_crossentropy,
          metrics=['accuracy'])


model.summary()
```



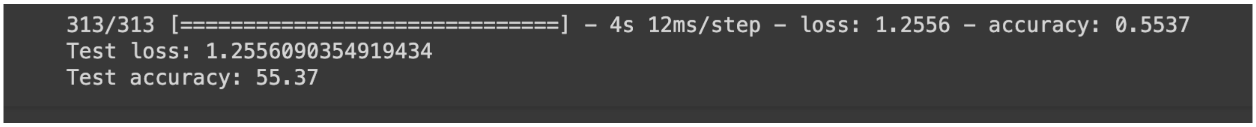
```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_3 (Conv2D)           (None, 28, 28, 6)         456

 average_pooling2d_2 (Avera  (None, 14, 14, 6)         0
 gePooling2D)

 conv2d_4 (Conv2D)           (None, 10, 10, 16)        2416

 average_pooling2d_3 (Avera  (None, 5, 5, 16)          0
 gePooling2D)

 conv2d_5 (Conv2D)           (None, 1, 1, 120)         48120

 flatten_1 (Flatten)         (None, 120)               0

 dropout (Dropout)           (None, 120)               0

 dense_1 (Dense)             (None, 10)                1210

=================================================================
Total params: 52202 (203.91 KB)
Trainable params: 52202 (203.91 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

```
model_hist = model.fit(x_train, y_train, batch_size = 128, epochs=10)
print("The model has successfully trained")

model.save('sample1.model')
```



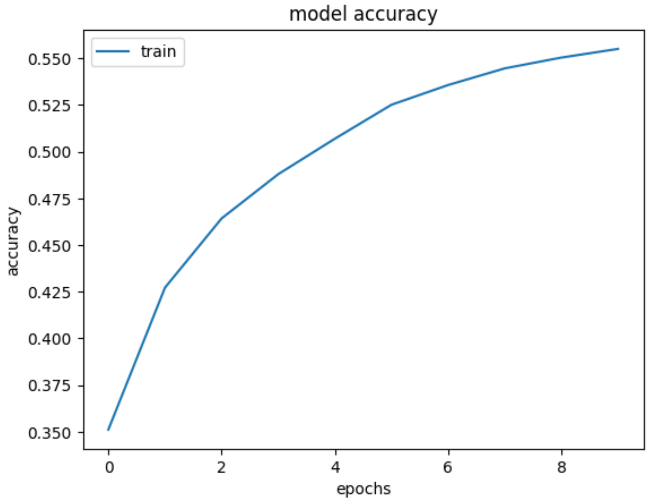
```
Epoch 1/10
391/391 [==============================] - 40s 101ms/step - loss: 1.8272 - accuracy: 0.3512
Epoch 2/10
391/391 [==============================] - 31s 79ms/step - loss: 1.6099 - accuracy: 0.4272
Epoch 3/10
391/391 [==============================] - 35s 89ms/step - loss: 1.4950 - accuracy: 0.4643
Epoch 4/10
391/391 [==============================] - 34s 86ms/step - loss: 1.4271 - accuracy: 0.4880
Epoch 5/10
391/391 [==============================] - 31s 79ms/step - loss: 1.3770 - accuracy: 0.5070
Epoch 6/10
391/391 [==============================] - 31s 80ms/step - loss: 1.3273 - accuracy: 0.5252
Epoch 7/10
391/391 [==============================] - 32s 82ms/step - loss: 1.3032 - accuracy: 0.5357
Epoch 8/10
391/391 [==============================] - 31s 78ms/step - loss: 1.2799 - accuracy: 0.5447
Epoch 9/10
391/391 [==============================] - 31s 79ms/step - loss: 1.2592 - accuracy: 0.5504
Epoch 10/10
391/391 [==============================] - 31s 79ms/step - loss: 1.2420 - accuracy: 0.5551
The model has successfully trained
```

```
s2_model = tf.keras.models.load_model('sample1.model')
loss, accuracy = s2_model.evaluate(x_test, y_test)
print('Test loss:', loss)
print('Test accuracy:', np.round((accuracy)*100, 2))
```



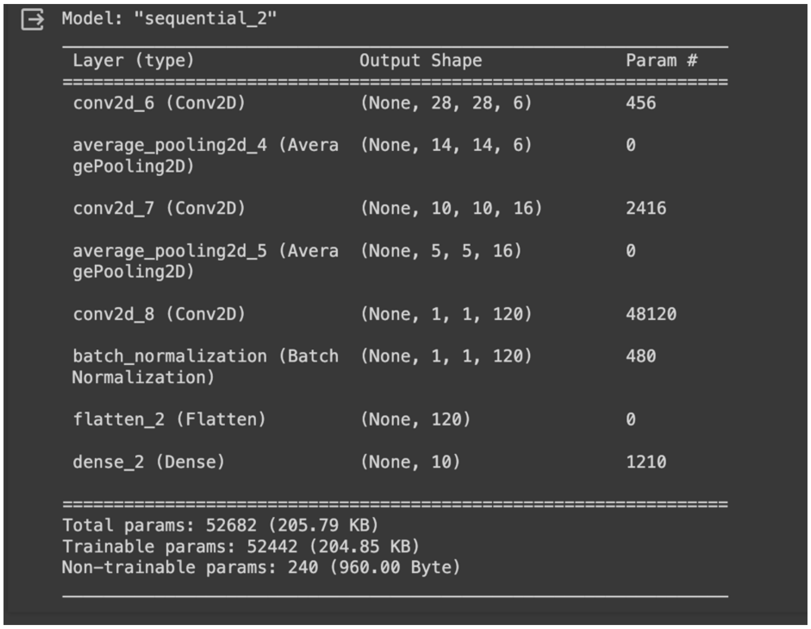
```
313/313 [==============================] - 4s 12ms/step - loss: 1.2556 - accuracy: 0.5537
Test loss: 1.2556090354919434
Test accuracy: 55.37
```

```
plt.plot(model_hist.history['accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epochs')
plt.legend(['train'], loc = 'upper left')
plt.show
```



#3. Network with one additional batch normalization

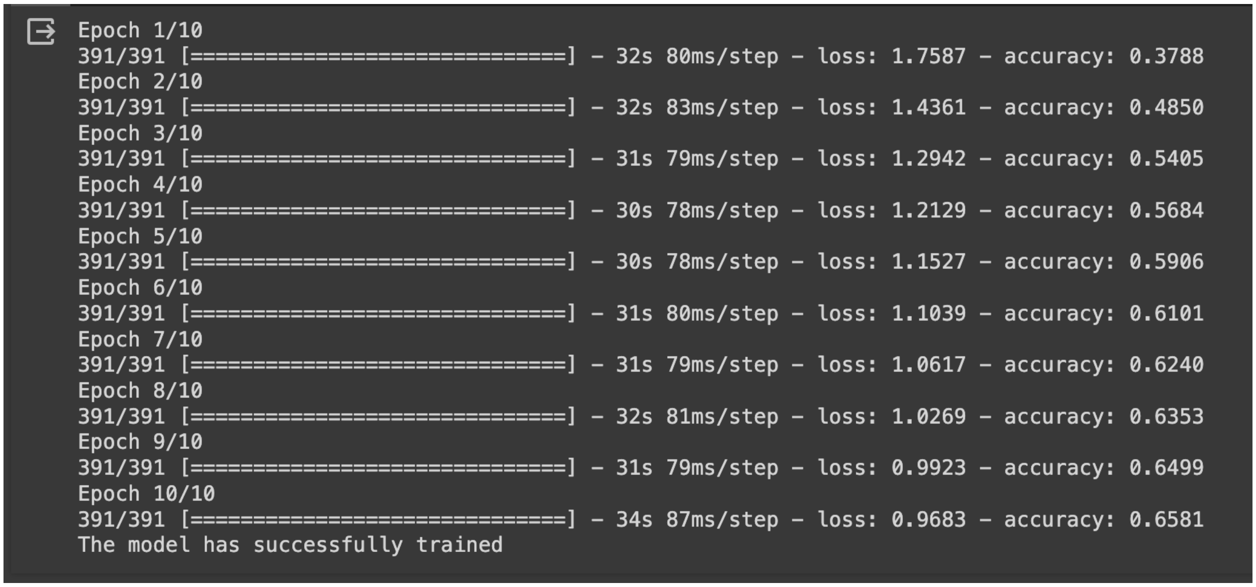
```
model = tf.keras.models.Sequential()

#conv1
model.add(tf.keras.layers.Conv2D(filters = 6, kernel_size=(5,5), padding= 'valid',
                        strides = (1,1), activation='tanh', input_shape=(32,32,3)))

#avgpooling1
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2,2), strides=2, padding='valid'))

#conv2
model.add(tf.keras.layers.Conv2D(filters = 16, kernel_size = (5,5), padding= 'valid', strides = (1,1),
activation='tanh'))

##avgpooling2
model.add(tf.keras.layers.AveragePooling2D(pool_size=(2,2), strides=2, padding='valid'))

#conv3
model.add(tf.keras.layers.Conv2D(filters = 120, kernel_size = (5,5), padding= 'valid', strides = (1,1),
activation='tanh'))

#BatchNormalization
model.add(tf.keras.layers.BatchNormalization())

#fully-connected network
model.add(tf.keras.layers.Flatten())

model.add(tf.keras.layers.Dense(10, activation=tf.nn.softmax))

model.compile(optimizer=tf.keras.optimizers.SGD(learning_rate=0.02, momentum=0.9),
         loss=tf.keras.losses.sparse_categorical_crossentropy,
         metrics=['accuracy'])


model.summary()
```



```
Model: "sequential_2"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_6 (Conv2D)           (None, 28, 28, 6)         456

 average_pooling2d_4 (Avera  (None, 14, 14, 6)         0
 gePooling2D)

 conv2d_7 (Conv2D)           (None, 10, 10, 16)        2416

 average_pooling2d_5 (Avera  (None, 5, 5, 16)          0
 gePooling2D)

 conv2d_8 (Conv2D)           (None, 1, 1, 120)         48120

 batch_normalization (Batch  (None, 1, 1, 120)         480
 Normalization)

 flatten_2 (Flatten)         (None, 120)               0

 dense_2 (Dense)             (None, 10)                1210

=================================================================
Total params: 52682 (205.79 KB)
Trainable params: 52442 (204.85 KB)
Non-trainable params: 240 (960.00 Byte)
_________________________________________________________________
```

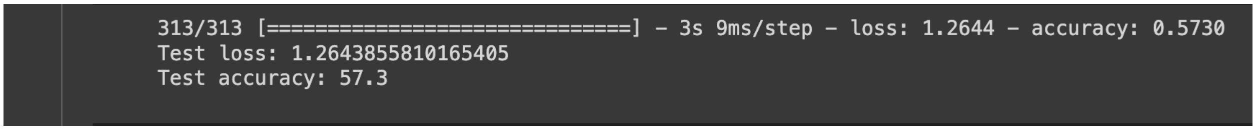
model_his = model.fit(x_train, y_train, batch_size = 128, epochs=10)
print("The model has successfully trained")

model.save('sample2.model')



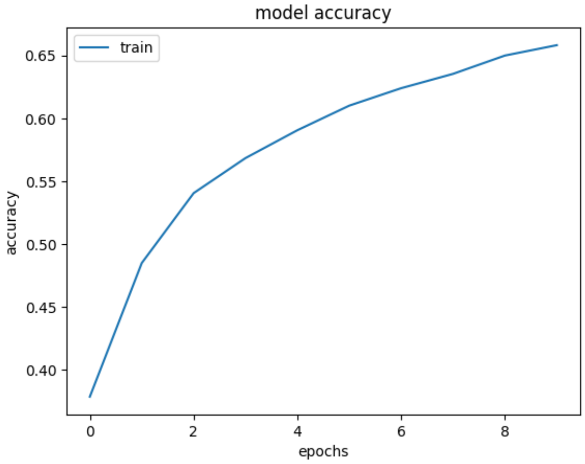
```
Epoch 1/10
391/391 [==============================] - 32s 80ms/step - loss: 1.7587 - accuracy: 0.3788
Epoch 2/10
391/391 [==============================] - 32s 83ms/step - loss: 1.4361 - accuracy: 0.4850
Epoch 3/10
391/391 [==============================] - 31s 79ms/step - loss: 1.2942 - accuracy: 0.5405
Epoch 4/10
391/391 [==============================] - 30s 78ms/step - loss: 1.2129 - accuracy: 0.5684
Epoch 5/10
391/391 [==============================] - 30s 78ms/step - loss: 1.1527 - accuracy: 0.5906
Epoch 6/10
391/391 [==============================] - 31s 80ms/step - loss: 1.1039 - accuracy: 0.6101
Epoch 7/10
391/391 [==============================] - 31s 79ms/step - loss: 1.0617 - accuracy: 0.6240
Epoch 8/10
391/391 [==============================] - 32s 81ms/step - loss: 1.0269 - accuracy: 0.6353
Epoch 9/10
391/391 [==============================] - 31s 79ms/step - loss: 0.9923 - accuracy: 0.6499
Epoch 10/10
391/391 [==============================] - 34s 87ms/step - loss: 0.9683 - accuracy: 0.6581
The model has successfully trained
```

s3_model = tf.keras.models.load_model('sample2.model')
loss, accuracy = s3_model.evaluate(x_test, y_test)
print('Test loss:', loss)
print('Test accuracy:', np.round((accuracy)*100, 2))



```
313/313 [==============================] - 3s 9ms/step - loss: 1.2644 - accuracy: 0.5730
Test loss: 1.2643855810165405
Test accuracy: 57.3
```

```
plt.plot(model_his.history['accuracy'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epochs')
plt.legend(['train'], loc = 'upper left')
plt.show
```


model accuracy
train
accuracy
epochs