

[!\[\]\(919a2cb85b99741a73c0c31a427236a8_img.jpg\) Open in Colab](#)

(https://colab.research.google.com/github/oliverfoster27/Practical-Machine-Learning/blob/master/Week%205/Homework_Week_5.ipynb)

```
In [2]: import numpy as np  
  
import matplotlib.pyplot as plt  
  
from keras.callbacks import EarlyStopping  
from keras.datasets import cifar10  
from keras.models import Sequential  
from keras.layers.core import Dense, Dropout, Flatten  
from keras.layers.convolutional import Conv2D  
from keras.optimizers import Adam  
from keras.layers.pooling import MaxPooling2D  
from keras.utils import to_categorical  
  
import keras.backend as K
```

Using TensorFlow backend.

```
In [3]: (X_train, Y_train), (X_test, Y_test) = cifar10.load_data()  
X_train = X_train / 255.0  
X_test = X_test / 255.0  
y_train_cat = to_categorical(Y_train)  
y_test_cat = to_categorical(Y_test)  
X_train.shape, y_test_cat.shape
```

Downloading data from <https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz>
170500096/170498071 [=====] - 45s 0us/step

Out[3]: ((50000, 32, 32, 3), (10000, 10))

```
In [4]: fig = plt.figure()
for i in range(9):
    plt.subplot(3,3,i+1)
    plt.tight_layout()
    plt.imshow(X_train[i], interpolation='none')
    plt.title("Digit: {}".format(Y_train[i]))
    plt.xticks([])
    plt.yticks([])
```



```
In [5]: np.unique(Y_train)
```

```
Out[5]: array([0, 1, 2, 3, 4, 5, 6, 7, 8, 9], dtype=uint8)
```

```
In [0]: from keras.layers import Dense, Flatten, Conv2D, MaxPool2D, Dropout, BatchNormalization
from keras.optimizers import Adam
from keras.callbacks import EarlyStopping
from keras import regularizers
import math
```

```
In [7]: K.clear_session()

model = Sequential()

"""

Section 1: two instances of 40 3x3 kernel convolution Layers with
batch normalization and 2x2 max pooling
20% Dropout
"""

model.add(Conv2D(40, (3, 3), activation='elu', padding='same',
                 kernel_regularizer=regularizers.l2(0.001),
                 input_shape=(32, 32, 3)))
model.add(Conv2D(40, (3, 3), activation='elu', padding='same',
                 kernel_regularizer=regularizers.l2(0.001)))
model.add(BatchNormalization())
model.add(MaxPool2D(pool_size=(2, 2)))
model.add(Dropout(0.2))

"""

Section 2: two instances of 80 3x3 kernel convolution Layers with
batch normalization and 2x2 max pooling
30% Dropout
"""

model.add(Conv2D(80, (3, 3), activation='elu', padding='same',
                 kernel_regularizer=regularizers.l2(0.001)))
model.add(Conv2D(80, (3, 3), activation='elu', padding='same',
                 kernel_regularizer=regularizers.l2(0.001)))
model.add(BatchNormalization())
model.add(MaxPool2D(pool_size=(2, 2)))
model.add(Dropout(0.3))

"""

Section 3: two instances of 160 3x3 kernel convolution Layers with
batch normalization and 2x2 max pooling
40% Dropout
"""

model.add(Conv2D(160, (3, 3), activation='elu', padding='same',
                 kernel_regularizer=regularizers.l2(0.001)))
model.add(Conv2D(160, (3, 3), activation='elu', padding='same',
                 kernel_regularizer=regularizers.l2(0.001)))
model.add(BatchNormalization())
model.add(MaxPool2D(pool_size=(2, 2)))
model.add(Dropout(0.4))

"""

Section 4: Dense Layer with softmax output
40% Dropout
"""

model.add(Flatten())
model.add(Dropout(0.4))
model.add(Dense(10, activation='softmax',
               kernel_regularizer=regularizers.l2(0.001)))

# Early stopping callback criteria
es = EarlyStopping(monitor='val_acc', mode='max', verbose=1, patience=30)
callbacks_list = [es]
```

```
# Learning rate schedule with constant decay
start_learning_rate = 10e-5
end_learning_rate = 10e-7
epochs = 300
decay_rate = (start_learning_rate - end_learning_rate) / epochs

optimizer = Adam(lr=start_learning_rate, decay=decay_rate)
model.compile(optimizer=optimizer,
              loss='categorical_crossentropy',
              metrics=['accuracy'])

model.summary()

h = model.fit(X_train, y_train_cat, batch_size=128,
               callbacks=callbacks_list, epochs=epochs,
               verbose=1, validation_split=0.3)
```

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/op_def_library.py:263: colocate_with (from tensorflow.python.framework.ops) is deprecated and will be removed in a future version.

Instructions for updating:

Colocations handled automatically by placer.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:3445: calling dropout (from tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future version.

Instructions for updating:

Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.

Layer (type)	Output Shape	Param #
<hr/>		
conv2d_1 (Conv2D)	(None, 32, 32, 40)	1120
conv2d_2 (Conv2D)	(None, 32, 32, 40)	14440
batch_normalization_1 (Batch Normalization)	(None, 32, 32, 40)	160
max_pooling2d_1 (MaxPooling2D)	(None, 16, 16, 40)	0
dropout_1 (Dropout)	(None, 16, 16, 40)	0
conv2d_3 (Conv2D)	(None, 16, 16, 80)	28880
conv2d_4 (Conv2D)	(None, 16, 16, 80)	57680
batch_normalization_2 (Batch Normalization)	(None, 16, 16, 80)	320
max_pooling2d_2 (MaxPooling2D)	(None, 8, 8, 80)	0
dropout_2 (Dropout)	(None, 8, 8, 80)	0
conv2d_5 (Conv2D)	(None, 8, 8, 160)	115360
conv2d_6 (Conv2D)	(None, 8, 8, 160)	230560
batch_normalization_3 (Batch Normalization)	(None, 8, 8, 160)	640
max_pooling2d_3 (MaxPooling2D)	(None, 4, 4, 160)	0
dropout_3 (Dropout)	(None, 4, 4, 160)	0
flatten_1 (Flatten)	(None, 2560)	0
dropout_4 (Dropout)	(None, 2560)	0
dense_1 (Dense)	(None, 10)	25610
<hr/>		
Total params:	474,770	
Trainable params:	474,210	
Non-trainable params:	560	

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/tensorflow/python/ops/math_ops.py:3066: to_int32 (from tensorflow.python.ops.math_ops) is deprecated and will be removed in a future version.

Instructions for updating:

Use tf.cast instead.

Train on 35000 samples, validate on 15000 samples

Epoch 1/300

```
35000/35000 [=====] - 24s 678us/step - loss: 3.6735
- acc: 0.2573 - val_loss: 2.3627 - val_acc: 0.4087
```

Epoch 2/300

```
35000/35000 [=====] - 19s 555us/step - loss: 2.9063
- acc: 0.3429 - val_loss: 2.3515 - val_acc: 0.4125
```

Epoch 3/300

```
35000/35000 [=====] - 19s 552us/step - loss: 2.5607
- acc: 0.3890 - val_loss: 1.9087 - val_acc: 0.5012
```

Epoch 4/300

```
35000/35000 [=====] - 19s 546us/step - loss: 2.3245
- acc: 0.4299 - val_loss: 2.0222 - val_acc: 0.4804
```

Epoch 5/300

```
35000/35000 [=====] - 19s 556us/step - loss: 2.1709
- acc: 0.4670 - val_loss: 1.8113 - val_acc: 0.5485
```

Epoch 6/300

```
35000/35000 [=====] - 19s 556us/step - loss: 2.0335
- acc: 0.4987 - val_loss: 2.2792 - val_acc: 0.4277
```

Epoch 7/300

```
35000/35000 [=====] - 19s 550us/step - loss: 1.9343
- acc: 0.5257 - val_loss: 1.8618 - val_acc: 0.5279
```

Epoch 8/300

```
35000/35000 [=====] - 19s 554us/step - loss: 1.8330
- acc: 0.5500 - val_loss: 1.7275 - val_acc: 0.5589
```

Epoch 9/300

```
35000/35000 [=====] - 19s 556us/step - loss: 1.7568
- acc: 0.5689 - val_loss: 1.7179 - val_acc: 0.5656
```

Epoch 10/300

```
35000/35000 [=====] - 19s 551us/step - loss: 1.7006
- acc: 0.5853 - val_loss: 1.7084 - val_acc: 0.5828
```

Epoch 11/300

```
35000/35000 [=====] - 19s 550us/step - loss: 1.6325
- acc: 0.5978 - val_loss: 1.7519 - val_acc: 0.5639
```

Epoch 12/300

```
35000/35000 [=====] - 19s 553us/step - loss: 1.5778
- acc: 0.6163 - val_loss: 1.6745 - val_acc: 0.6104
```

Epoch 13/300

```
35000/35000 [=====] - 19s 553us/step - loss: 1.5309
- acc: 0.6257 - val_loss: 1.9464 - val_acc: 0.5100
```

Epoch 14/300

```
35000/35000 [=====] - 19s 549us/step - loss: 1.4868
- acc: 0.6372 - val_loss: 1.4079 - val_acc: 0.6618
```

Epoch 15/300

```
35000/35000 [=====] - 19s 548us/step - loss: 1.4461
- acc: 0.6511 - val_loss: 1.4644 - val_acc: 0.6383
```

Epoch 16/300

```
35000/35000 [=====] - 19s 550us/step - loss: 1.4020
- acc: 0.6590 - val_loss: 1.5125 - val_acc: 0.6395
```

Epoch 17/300

```
35000/35000 [=====] - 19s 551us/step - loss: 1.3586
- acc: 0.6731 - val_loss: 1.2843 - val_acc: 0.7005
```

Epoch 18/300

```
35000/35000 [=====] - 19s 553us/step - loss: 1.3281
- acc: 0.6798 - val_loss: 1.2962 - val_acc: 0.6899
```

```
Epoch 19/300
35000/35000 [=====] - 19s 555us/step - loss: 1.3020
- acc: 0.6836 - val_loss: 1.2992 - val_acc: 0.6912
Epoch 20/300
35000/35000 [=====] - 19s 552us/step - loss: 1.2659
- acc: 0.6967 - val_loss: 1.4452 - val_acc: 0.6601
Epoch 21/300
35000/35000 [=====] - 19s 546us/step - loss: 1.2361
- acc: 0.7035 - val_loss: 1.2177 - val_acc: 0.7090
Epoch 22/300
35000/35000 [=====] - 19s 551us/step - loss: 1.2126
- acc: 0.7049 - val_loss: 1.2069 - val_acc: 0.7255
Epoch 23/300
35000/35000 [=====] - 19s 548us/step - loss: 1.1915
- acc: 0.7129 - val_loss: 1.1140 - val_acc: 0.7399
Epoch 24/300
35000/35000 [=====] - 19s 550us/step - loss: 1.1604
- acc: 0.7207 - val_loss: 1.1346 - val_acc: 0.7317
Epoch 25/300
35000/35000 [=====] - 19s 555us/step - loss: 1.1367
- acc: 0.7280 - val_loss: 1.1522 - val_acc: 0.7220
Epoch 26/300
35000/35000 [=====] - 19s 546us/step - loss: 1.1068
- acc: 0.7357 - val_loss: 1.1047 - val_acc: 0.7424
Epoch 27/300
35000/35000 [=====] - 19s 549us/step - loss: 1.0865
- acc: 0.7406 - val_loss: 1.1557 - val_acc: 0.7267
Epoch 28/300
35000/35000 [=====] - 19s 545us/step - loss: 1.0667
- acc: 0.7440 - val_loss: 1.0394 - val_acc: 0.7561
Epoch 29/300
35000/35000 [=====] - 19s 546us/step - loss: 1.0441
- acc: 0.7505 - val_loss: 1.0269 - val_acc: 0.7623
Epoch 30/300
35000/35000 [=====] - 19s 549us/step - loss: 1.0278
- acc: 0.7541 - val_loss: 1.0288 - val_acc: 0.7591
Epoch 31/300
35000/35000 [=====] - 19s 550us/step - loss: 1.0096
- acc: 0.7593 - val_loss: 1.1789 - val_acc: 0.7149
Epoch 32/300
35000/35000 [=====] - 19s 550us/step - loss: 0.9877
- acc: 0.7669 - val_loss: 1.0320 - val_acc: 0.7538
Epoch 33/300
35000/35000 [=====] - 19s 547us/step - loss: 0.9715
- acc: 0.7681 - val_loss: 1.1030 - val_acc: 0.7315
Epoch 34/300
35000/35000 [=====] - 19s 547us/step - loss: 0.9561
- acc: 0.7740 - val_loss: 0.9886 - val_acc: 0.7681
Epoch 35/300
35000/35000 [=====] - 19s 548us/step - loss: 0.9380
- acc: 0.7784 - val_loss: 0.9955 - val_acc: 0.7629
Epoch 36/300
35000/35000 [=====] - 19s 548us/step - loss: 0.9224
- acc: 0.7803 - val_loss: 0.9952 - val_acc: 0.7633
Epoch 37/300
35000/35000 [=====] - 19s 549us/step - loss: 0.9079
- acc: 0.7855 - val_loss: 0.9782 - val_acc: 0.7700
```

```
Epoch 38/300
35000/35000 [=====] - 19s 545us/step - loss: 0.8896
- acc: 0.7935 - val_loss: 1.0194 - val_acc: 0.7579
Epoch 39/300
35000/35000 [=====] - 19s 548us/step - loss: 0.8797
- acc: 0.7935 - val_loss: 1.0072 - val_acc: 0.7653
Epoch 40/300
35000/35000 [=====] - 19s 547us/step - loss: 0.8633
- acc: 0.7982 - val_loss: 0.9005 - val_acc: 0.7921
Epoch 41/300
35000/35000 [=====] - 19s 547us/step - loss: 0.8505
- acc: 0.8027 - val_loss: 0.9963 - val_acc: 0.7634
Epoch 42/300
35000/35000 [=====] - 19s 548us/step - loss: 0.8353
- acc: 0.8052 - val_loss: 0.9426 - val_acc: 0.7825
Epoch 43/300
35000/35000 [=====] - 19s 549us/step - loss: 0.8255
- acc: 0.8068 - val_loss: 0.8985 - val_acc: 0.7929
Epoch 44/300
35000/35000 [=====] - 19s 546us/step - loss: 0.8111
- acc: 0.8129 - val_loss: 0.9205 - val_acc: 0.7842
Epoch 45/300
35000/35000 [=====] - 19s 549us/step - loss: 0.8000
- acc: 0.8139 - val_loss: 0.9058 - val_acc: 0.7849
Epoch 46/300
35000/35000 [=====] - 19s 550us/step - loss: 0.7931
- acc: 0.8153 - val_loss: 0.8329 - val_acc: 0.8102
Epoch 47/300
35000/35000 [=====] - 19s 551us/step - loss: 0.7731
- acc: 0.8208 - val_loss: 0.8372 - val_acc: 0.8064
Epoch 48/300
35000/35000 [=====] - 19s 544us/step - loss: 0.7689
- acc: 0.8233 - val_loss: 0.8383 - val_acc: 0.8025
Epoch 49/300
35000/35000 [=====] - 19s 547us/step - loss: 0.7553
- acc: 0.8293 - val_loss: 0.8871 - val_acc: 0.7926
Epoch 50/300
35000/35000 [=====] - 19s 547us/step - loss: 0.7530
- acc: 0.8266 - val_loss: 0.8252 - val_acc: 0.8077
Epoch 51/300
35000/35000 [=====] - 19s 549us/step - loss: 0.7376
- acc: 0.8310 - val_loss: 0.8204 - val_acc: 0.8077
Epoch 52/300
35000/35000 [=====] - 19s 555us/step - loss: 0.7303
- acc: 0.8347 - val_loss: 0.8806 - val_acc: 0.7950
Epoch 53/300
35000/35000 [=====] - 19s 552us/step - loss: 0.7186
- acc: 0.8357 - val_loss: 0.8359 - val_acc: 0.8059
Epoch 54/300
35000/35000 [=====] - 19s 552us/step - loss: 0.7070
- acc: 0.8433 - val_loss: 0.8347 - val_acc: 0.8037
Epoch 55/300
35000/35000 [=====] - 19s 550us/step - loss: 0.7020
- acc: 0.8428 - val_loss: 0.8379 - val_acc: 0.8048
Epoch 56/300
35000/35000 [=====] - 19s 550us/step - loss: 0.6967
- acc: 0.8406 - val_loss: 0.8076 - val_acc: 0.8145
```

```
Epoch 57/300
35000/35000 [=====] - 20s 558us/step - loss: 0.6829
- acc: 0.8477 - val_loss: 0.8023 - val_acc: 0.8133
Epoch 58/300
35000/35000 [=====] - 19s 552us/step - loss: 0.6728
- acc: 0.8490 - val_loss: 0.7786 - val_acc: 0.8222
Epoch 59/300
35000/35000 [=====] - 19s 548us/step - loss: 0.6700
- acc: 0.8520 - val_loss: 0.7865 - val_acc: 0.8195
Epoch 60/300
35000/35000 [=====] - 19s 556us/step - loss: 0.6592
- acc: 0.8531 - val_loss: 0.8377 - val_acc: 0.8034
Epoch 61/300
35000/35000 [=====] - 19s 556us/step - loss: 0.6500
- acc: 0.8561 - val_loss: 0.8364 - val_acc: 0.8037
Epoch 62/300
35000/35000 [=====] - 19s 553us/step - loss: 0.6401
- acc: 0.8599 - val_loss: 0.7896 - val_acc: 0.8163
Epoch 63/300
35000/35000 [=====] - 19s 551us/step - loss: 0.6374
- acc: 0.8605 - val_loss: 0.7981 - val_acc: 0.8177
Epoch 64/300
35000/35000 [=====] - 19s 550us/step - loss: 0.6244
- acc: 0.8643 - val_loss: 0.7670 - val_acc: 0.8219
Epoch 65/300
35000/35000 [=====] - 19s 550us/step - loss: 0.6265
- acc: 0.8642 - val_loss: 0.7873 - val_acc: 0.8170
Epoch 66/300
35000/35000 [=====] - 19s 551us/step - loss: 0.6166
- acc: 0.8656 - val_loss: 0.7941 - val_acc: 0.8137
Epoch 67/300
35000/35000 [=====] - 19s 555us/step - loss: 0.6133
- acc: 0.8662 - val_loss: 0.7619 - val_acc: 0.8239
Epoch 68/300
35000/35000 [=====] - 19s 557us/step - loss: 0.6066
- acc: 0.8669 - val_loss: 0.7629 - val_acc: 0.8235
Epoch 69/300
35000/35000 [=====] - 19s 557us/step - loss: 0.6023
- acc: 0.8685 - val_loss: 0.7969 - val_acc: 0.8163
Epoch 70/300
35000/35000 [=====] - 19s 552us/step - loss: 0.5898
- acc: 0.8729 - val_loss: 0.7659 - val_acc: 0.8256
Epoch 71/300
35000/35000 [=====] - 19s 552us/step - loss: 0.5839
- acc: 0.8761 - val_loss: 0.7964 - val_acc: 0.8113
Epoch 72/300
35000/35000 [=====] - 19s 552us/step - loss: 0.5776
- acc: 0.8749 - val_loss: 0.7696 - val_acc: 0.8218
Epoch 73/300
35000/35000 [=====] - 19s 557us/step - loss: 0.5678
- acc: 0.8815 - val_loss: 0.7650 - val_acc: 0.8259
Epoch 74/300
35000/35000 [=====] - 19s 556us/step - loss: 0.5663
- acc: 0.8785 - val_loss: 0.7823 - val_acc: 0.8197
Epoch 75/300
35000/35000 [=====] - 19s 548us/step - loss: 0.5604
- acc: 0.8815 - val_loss: 0.7404 - val_acc: 0.8301
```

```
Epoch 76/300
35000/35000 [=====] - 19s 550us/step - loss: 0.5578
- acc: 0.8818 - val_loss: 0.8116 - val_acc: 0.8144
Epoch 77/300
35000/35000 [=====] - 19s 549us/step - loss: 0.5510
- acc: 0.8851 - val_loss: 0.7330 - val_acc: 0.8317
Epoch 78/300
35000/35000 [=====] - 19s 546us/step - loss: 0.5510
- acc: 0.8826 - val_loss: 0.8092 - val_acc: 0.8134
Epoch 79/300
35000/35000 [=====] - 19s 549us/step - loss: 0.5422
- acc: 0.8843 - val_loss: 0.8001 - val_acc: 0.8184
Epoch 80/300
35000/35000 [=====] - 19s 552us/step - loss: 0.5320
- acc: 0.8882 - val_loss: 0.7462 - val_acc: 0.8300
Epoch 81/300
35000/35000 [=====] - 19s 552us/step - loss: 0.5282
- acc: 0.8917 - val_loss: 0.7444 - val_acc: 0.8324
Epoch 82/300
35000/35000 [=====] - 19s 549us/step - loss: 0.5240
- acc: 0.8941 - val_loss: 0.7783 - val_acc: 0.8199
Epoch 83/300
35000/35000 [=====] - 19s 549us/step - loss: 0.5227
- acc: 0.8952 - val_loss: 0.7885 - val_acc: 0.8153
Epoch 84/300
35000/35000 [=====] - 19s 556us/step - loss: 0.5202
- acc: 0.8935 - val_loss: 0.7474 - val_acc: 0.8317
Epoch 85/300
35000/35000 [=====] - 20s 558us/step - loss: 0.5141
- acc: 0.8950 - val_loss: 0.7266 - val_acc: 0.8325
Epoch 86/300
35000/35000 [=====] - 19s 554us/step - loss: 0.5080
- acc: 0.8985 - val_loss: 0.7768 - val_acc: 0.8237
Epoch 87/300
35000/35000 [=====] - 19s 554us/step - loss: 0.5008
- acc: 0.8979 - val_loss: 0.7598 - val_acc: 0.8292
Epoch 88/300
35000/35000 [=====] - 19s 554us/step - loss: 0.4938
- acc: 0.9023 - val_loss: 0.7513 - val_acc: 0.8318
Epoch 89/300
35000/35000 [=====] - 19s 544us/step - loss: 0.4903
- acc: 0.9016 - val_loss: 0.7287 - val_acc: 0.8353
Epoch 90/300
35000/35000 [=====] - 19s 548us/step - loss: 0.4891
- acc: 0.9010 - val_loss: 0.7544 - val_acc: 0.8315
Epoch 91/300
35000/35000 [=====] - 20s 558us/step - loss: 0.4866
- acc: 0.9049 - val_loss: 0.7075 - val_acc: 0.8405
Epoch 92/300
35000/35000 [=====] - 19s 555us/step - loss: 0.4829
- acc: 0.9037 - val_loss: 0.8787 - val_acc: 0.7982
Epoch 93/300
35000/35000 [=====] - 19s 555us/step - loss: 0.4807
- acc: 0.9048 - val_loss: 0.7140 - val_acc: 0.8397
Epoch 94/300
35000/35000 [=====] - 19s 555us/step - loss: 0.4711
- acc: 0.9090 - val_loss: 0.7910 - val_acc: 0.8257
```

```
Epoch 95/300
35000/35000 [=====] - 19s 556us/step - loss: 0.4661
- acc: 0.9119 - val_loss: 0.7917 - val_acc: 0.8273
Epoch 96/300
35000/35000 [=====] - 19s 551us/step - loss: 0.4684
- acc: 0.9085 - val_loss: 0.7636 - val_acc: 0.8277
Epoch 97/300
35000/35000 [=====] - 19s 552us/step - loss: 0.4640
- acc: 0.9101 - val_loss: 0.7612 - val_acc: 0.8311
Epoch 98/300
35000/35000 [=====] - 19s 552us/step - loss: 0.4536
- acc: 0.9135 - val_loss: 0.7628 - val_acc: 0.8325
Epoch 99/300
35000/35000 [=====] - 19s 544us/step - loss: 0.4528
- acc: 0.9138 - val_loss: 0.8193 - val_acc: 0.8173
Epoch 100/300
35000/35000 [=====] - 19s 542us/step - loss: 0.4567
- acc: 0.9125 - val_loss: 0.7555 - val_acc: 0.8329
Epoch 101/300
35000/35000 [=====] - 19s 546us/step - loss: 0.4522
- acc: 0.9144 - val_loss: 0.7564 - val_acc: 0.8287
Epoch 102/300
35000/35000 [=====] - 19s 544us/step - loss: 0.4483
- acc: 0.9147 - val_loss: 0.7563 - val_acc: 0.8392
Epoch 103/300
35000/35000 [=====] - 19s 547us/step - loss: 0.4386
- acc: 0.9189 - val_loss: 0.7591 - val_acc: 0.8342
Epoch 104/300
35000/35000 [=====] - 19s 551us/step - loss: 0.4367
- acc: 0.9191 - val_loss: 0.7211 - val_acc: 0.8397
Epoch 105/300
35000/35000 [=====] - 19s 548us/step - loss: 0.4396
- acc: 0.9174 - val_loss: 0.7758 - val_acc: 0.8297
Epoch 106/300
35000/35000 [=====] - 19s 548us/step - loss: 0.4297
- acc: 0.9211 - val_loss: 0.7422 - val_acc: 0.8363
Epoch 107/300
35000/35000 [=====] - 19s 547us/step - loss: 0.4261
- acc: 0.9221 - val_loss: 0.7913 - val_acc: 0.8251
Epoch 108/300
35000/35000 [=====] - 19s 546us/step - loss: 0.4238
- acc: 0.9219 - val_loss: 0.7600 - val_acc: 0.8316
Epoch 109/300
35000/35000 [=====] - 19s 548us/step - loss: 0.4233
- acc: 0.9215 - val_loss: 0.7336 - val_acc: 0.8401
Epoch 110/300
35000/35000 [=====] - 19s 547us/step - loss: 0.4234
- acc: 0.9212 - val_loss: 0.7339 - val_acc: 0.8367
Epoch 111/300
35000/35000 [=====] - 19s 549us/step - loss: 0.4216
- acc: 0.9225 - val_loss: 0.7491 - val_acc: 0.8327
Epoch 112/300
35000/35000 [=====] - 19s 545us/step - loss: 0.4149
- acc: 0.9250 - val_loss: 0.7567 - val_acc: 0.8354
Epoch 113/300
35000/35000 [=====] - 19s 547us/step - loss: 0.4146
- acc: 0.9245 - val_loss: 0.7743 - val_acc: 0.8319
```

```
Epoch 114/300
35000/35000 [=====] - 19s 549us/step - loss: 0.4142
- acc: 0.9246 - val_loss: 0.7913 - val_acc: 0.8292
Epoch 115/300
35000/35000 [=====] - 19s 547us/step - loss: 0.4117
- acc: 0.9267 - val_loss: 0.7268 - val_acc: 0.8429
Epoch 116/300
35000/35000 [=====] - 19s 546us/step - loss: 0.4052
- acc: 0.9297 - val_loss: 0.7524 - val_acc: 0.8365
Epoch 117/300
35000/35000 [=====] - 19s 546us/step - loss: 0.3977
- acc: 0.9317 - val_loss: 0.7531 - val_acc: 0.8349
Epoch 118/300
35000/35000 [=====] - 19s 545us/step - loss: 0.4040
- acc: 0.9278 - val_loss: 0.7425 - val_acc: 0.8383
Epoch 119/300
35000/35000 [=====] - 19s 550us/step - loss: 0.3995
- acc: 0.9304 - val_loss: 0.7363 - val_acc: 0.8397
Epoch 120/300
35000/35000 [=====] - 19s 547us/step - loss: 0.4009
- acc: 0.9303 - val_loss: 0.7271 - val_acc: 0.8462
Epoch 121/300
35000/35000 [=====] - 19s 544us/step - loss: 0.3933
- acc: 0.9320 - val_loss: 0.7387 - val_acc: 0.8415
Epoch 122/300
35000/35000 [=====] - 19s 549us/step - loss: 0.3941
- acc: 0.9315 - val_loss: 0.7809 - val_acc: 0.8349
Epoch 123/300
35000/35000 [=====] - 19s 551us/step - loss: 0.3929
- acc: 0.9315 - val_loss: 0.7462 - val_acc: 0.8375
Epoch 124/300
35000/35000 [=====] - 19s 547us/step - loss: 0.3898
- acc: 0.9331 - val_loss: 0.7579 - val_acc: 0.8388
Epoch 125/300
35000/35000 [=====] - 19s 548us/step - loss: 0.3837
- acc: 0.9341 - val_loss: 0.7381 - val_acc: 0.8431
Epoch 126/300
35000/35000 [=====] - 19s 550us/step - loss: 0.3866
- acc: 0.9340 - val_loss: 0.7270 - val_acc: 0.8439
Epoch 127/300
35000/35000 [=====] - 19s 549us/step - loss: 0.3800
- acc: 0.9354 - val_loss: 0.7675 - val_acc: 0.8332
Epoch 128/300
35000/35000 [=====] - 19s 545us/step - loss: 0.3795
- acc: 0.9357 - val_loss: 0.7373 - val_acc: 0.8404
Epoch 129/300
35000/35000 [=====] - 19s 547us/step - loss: 0.3861
- acc: 0.9333 - val_loss: 0.7873 - val_acc: 0.8335
Epoch 130/300
35000/35000 [=====] - 19s 545us/step - loss: 0.3769
- acc: 0.9369 - val_loss: 0.7690 - val_acc: 0.8351
Epoch 131/300
35000/35000 [=====] - 19s 546us/step - loss: 0.3749
- acc: 0.9367 - val_loss: 0.8038 - val_acc: 0.8331
Epoch 132/300
35000/35000 [=====] - 19s 545us/step - loss: 0.3791
- acc: 0.9348 - val_loss: 0.7140 - val_acc: 0.8445
```

```
Epoch 133/300
35000/35000 [=====] - 19s 546us/step - loss: 0.3734
- acc: 0.9358 - val_loss: 0.8158 - val_acc: 0.8261
Epoch 134/300
35000/35000 [=====] - 19s 547us/step - loss: 0.3746
- acc: 0.9379 - val_loss: 0.7402 - val_acc: 0.8425
Epoch 135/300
35000/35000 [=====] - 19s 546us/step - loss: 0.3612
- acc: 0.9418 - val_loss: 0.7221 - val_acc: 0.8479
Epoch 136/300
35000/35000 [=====] - 19s 547us/step - loss: 0.3641
- acc: 0.9401 - val_loss: 0.8306 - val_acc: 0.8287
Epoch 137/300
35000/35000 [=====] - 19s 545us/step - loss: 0.3640
- acc: 0.9400 - val_loss: 0.7590 - val_acc: 0.8339
Epoch 138/300
35000/35000 [=====] - 19s 547us/step - loss: 0.3667
- acc: 0.9397 - val_loss: 0.7361 - val_acc: 0.8451
Epoch 139/300
35000/35000 [=====] - 19s 545us/step - loss: 0.3626
- acc: 0.9408 - val_loss: 0.7462 - val_acc: 0.8402
Epoch 140/300
35000/35000 [=====] - 19s 546us/step - loss: 0.3591
- acc: 0.9416 - val_loss: 0.7359 - val_acc: 0.8457
Epoch 141/300
35000/35000 [=====] - 19s 550us/step - loss: 0.3602
- acc: 0.9408 - val_loss: 0.7492 - val_acc: 0.8428
Epoch 142/300
35000/35000 [=====] - 19s 547us/step - loss: 0.3556
- acc: 0.9432 - val_loss: 0.8081 - val_acc: 0.8321
Epoch 143/300
35000/35000 [=====] - 19s 553us/step - loss: 0.3593
- acc: 0.9415 - val_loss: 0.7485 - val_acc: 0.8421
Epoch 144/300
35000/35000 [=====] - 19s 547us/step - loss: 0.3574
- acc: 0.9423 - val_loss: 0.7205 - val_acc: 0.8461
Epoch 145/300
35000/35000 [=====] - 19s 553us/step - loss: 0.3513
- acc: 0.9431 - val_loss: 0.7531 - val_acc: 0.8382
Epoch 146/300
35000/35000 [=====] - 19s 553us/step - loss: 0.3498
- acc: 0.9448 - val_loss: 0.7686 - val_acc: 0.8372
Epoch 147/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3510
- acc: 0.9440 - val_loss: 0.7274 - val_acc: 0.8442
Epoch 148/300
35000/35000 [=====] - 19s 556us/step - loss: 0.3503
- acc: 0.9441 - val_loss: 0.7703 - val_acc: 0.8404
Epoch 149/300
35000/35000 [=====] - 20s 561us/step - loss: 0.3483
- acc: 0.9464 - val_loss: 0.7706 - val_acc: 0.8391
Epoch 150/300
35000/35000 [=====] - 20s 567us/step - loss: 0.3494
- acc: 0.9434 - val_loss: 0.7962 - val_acc: 0.8354
Epoch 151/300
35000/35000 [=====] - 20s 567us/step - loss: 0.3405
- acc: 0.9471 - val_loss: 0.7198 - val_acc: 0.8485
```

```
Epoch 152/300
35000/35000 [=====] - 20s 561us/step - loss: 0.3480
- acc: 0.9439 - val_loss: 0.7582 - val_acc: 0.8434
Epoch 153/300
35000/35000 [=====] - 20s 563us/step - loss: 0.3412
- acc: 0.9467 - val_loss: 0.7456 - val_acc: 0.8424
Epoch 154/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3413
- acc: 0.9467 - val_loss: 0.7186 - val_acc: 0.8477
Epoch 155/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3403
- acc: 0.9461 - val_loss: 0.7485 - val_acc: 0.8449
Epoch 156/300
35000/35000 [=====] - 19s 552us/step - loss: 0.3362
- acc: 0.9477 - val_loss: 0.7481 - val_acc: 0.8389
Epoch 157/300
35000/35000 [=====] - 19s 557us/step - loss: 0.3350
- acc: 0.9486 - val_loss: 0.7275 - val_acc: 0.8439
Epoch 158/300
35000/35000 [=====] - 20s 558us/step - loss: 0.3425
- acc: 0.9462 - val_loss: 0.7491 - val_acc: 0.8444
Epoch 159/300
35000/35000 [=====] - 20s 557us/step - loss: 0.3348
- acc: 0.9475 - val_loss: 0.7830 - val_acc: 0.8364
Epoch 160/300
35000/35000 [=====] - 20s 561us/step - loss: 0.3319
- acc: 0.9497 - val_loss: 0.7336 - val_acc: 0.8479
Epoch 161/300
35000/35000 [=====] - 20s 559us/step - loss: 0.3359
- acc: 0.9476 - val_loss: 0.7411 - val_acc: 0.8441
Epoch 162/300
35000/35000 [=====] - 19s 553us/step - loss: 0.3311
- acc: 0.9504 - val_loss: 0.7179 - val_acc: 0.8507
Epoch 163/300
35000/35000 [=====] - 20s 559us/step - loss: 0.3250
- acc: 0.9516 - val_loss: 0.7487 - val_acc: 0.8450
Epoch 164/300
35000/35000 [=====] - 20s 558us/step - loss: 0.3278
- acc: 0.9497 - val_loss: 0.8017 - val_acc: 0.8316
Epoch 165/300
35000/35000 [=====] - 19s 555us/step - loss: 0.3285
- acc: 0.9517 - val_loss: 0.7296 - val_acc: 0.8459
Epoch 166/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3308
- acc: 0.9498 - val_loss: 0.7821 - val_acc: 0.8365
Epoch 167/300
35000/35000 [=====] - 19s 557us/step - loss: 0.3256
- acc: 0.9505 - val_loss: 0.7259 - val_acc: 0.8454
Epoch 168/300
35000/35000 [=====] - 19s 549us/step - loss: 0.3268
- acc: 0.9497 - val_loss: 0.7335 - val_acc: 0.8449
Epoch 169/300
35000/35000 [=====] - 19s 551us/step - loss: 0.3219
- acc: 0.9522 - val_loss: 0.7537 - val_acc: 0.8454
Epoch 170/300
35000/35000 [=====] - 19s 550us/step - loss: 0.3232
- acc: 0.9513 - val_loss: 0.7553 - val_acc: 0.8439
```

```
Epoch 171/300
35000/35000 [=====] - 19s 552us/step - loss: 0.3182
- acc: 0.9531 - val_loss: 0.7541 - val_acc: 0.8442
Epoch 172/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3158
- acc: 0.9538 - val_loss: 0.8175 - val_acc: 0.8325
Epoch 173/300
35000/35000 [=====] - 19s 556us/step - loss: 0.3250
- acc: 0.9498 - val_loss: 0.7583 - val_acc: 0.8463
Epoch 174/300
35000/35000 [=====] - 19s 556us/step - loss: 0.3194
- acc: 0.9531 - val_loss: 0.7469 - val_acc: 0.8455
Epoch 175/300
35000/35000 [=====] - 19s 557us/step - loss: 0.3191
- acc: 0.9513 - val_loss: 0.7437 - val_acc: 0.8413
Epoch 176/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3197
- acc: 0.9513 - val_loss: 0.8216 - val_acc: 0.8321
Epoch 177/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3170
- acc: 0.9528 - val_loss: 0.8212 - val_acc: 0.8347
Epoch 178/300
35000/35000 [=====] - 19s 548us/step - loss: 0.3124
- acc: 0.9545 - val_loss: 0.7634 - val_acc: 0.8400
Epoch 179/300
35000/35000 [=====] - 19s 554us/step - loss: 0.3158
- acc: 0.9542 - val_loss: 0.7673 - val_acc: 0.8456
Epoch 180/300
35000/35000 [=====] - 19s 556us/step - loss: 0.3106
- acc: 0.9552 - val_loss: 0.7829 - val_acc: 0.8367
Epoch 181/300
35000/35000 [=====] - 20s 557us/step - loss: 0.3141
- acc: 0.9533 - val_loss: 0.7408 - val_acc: 0.8512
Epoch 182/300
35000/35000 [=====] - 19s 557us/step - loss: 0.3088
- acc: 0.9559 - val_loss: 0.7329 - val_acc: 0.8491
Epoch 183/300
35000/35000 [=====] - 19s 551us/step - loss: 0.3097
- acc: 0.9550 - val_loss: 0.7984 - val_acc: 0.8389
Epoch 184/300
35000/35000 [=====] - 19s 548us/step - loss: 0.3051
- acc: 0.9566 - val_loss: 0.7933 - val_acc: 0.8319
Epoch 185/300
35000/35000 [=====] - 19s 553us/step - loss: 0.3076
- acc: 0.9562 - val_loss: 0.7783 - val_acc: 0.8385
Epoch 186/300
35000/35000 [=====] - 19s 555us/step - loss: 0.3067
- acc: 0.9547 - val_loss: 0.7743 - val_acc: 0.8413
Epoch 187/300
35000/35000 [=====] - 22s 640us/step - loss: 0.3107
- acc: 0.9546 - val_loss: 0.7638 - val_acc: 0.8429
Epoch 188/300
35000/35000 [=====] - 20s 563us/step - loss: 0.3018
- acc: 0.9570 - val_loss: 0.7367 - val_acc: 0.8450
Epoch 189/300
35000/35000 [=====] - 20s 564us/step - loss: 0.3035
- acc: 0.9573 - val_loss: 0.7344 - val_acc: 0.8489
```

```
Epoch 190/300
35000/35000 [=====] - 20s 562us/step - loss: 0.3045
- acc: 0.9561 - val_loss: 0.8582 - val_acc: 0.8303
Epoch 191/300
35000/35000 [=====] - 20s 559us/step - loss: 0.3000
- acc: 0.9579 - val_loss: 0.7889 - val_acc: 0.8323
Epoch 192/300
35000/35000 [=====] - 20s 562us/step - loss: 0.3015
- acc: 0.9565 - val_loss: 0.8175 - val_acc: 0.8389
Epoch 193/300
35000/35000 [=====] - 20s 560us/step - loss: 0.3048
- acc: 0.9559 - val_loss: 0.7766 - val_acc: 0.8393
Epoch 194/300
35000/35000 [=====] - 20s 559us/step - loss: 0.3045
- acc: 0.9562 - val_loss: 0.7613 - val_acc: 0.8472
Epoch 195/300
35000/35000 [=====] - 19s 553us/step - loss: 0.2970
- acc: 0.9595 - val_loss: 0.7280 - val_acc: 0.8491
Epoch 196/300
35000/35000 [=====] - 19s 549us/step - loss: 0.2980
- acc: 0.9577 - val_loss: 0.7532 - val_acc: 0.8435
Epoch 197/300
35000/35000 [=====] - 19s 552us/step - loss: 0.3029
- acc: 0.9569 - val_loss: 0.8002 - val_acc: 0.8417
Epoch 198/300
35000/35000 [=====] - 20s 558us/step - loss: 0.2962
- acc: 0.9594 - val_loss: 0.7711 - val_acc: 0.8422
Epoch 199/300
35000/35000 [=====] - 19s 550us/step - loss: 0.2958
- acc: 0.9590 - val_loss: 0.7816 - val_acc: 0.8390
Epoch 200/300
35000/35000 [=====] - 19s 551us/step - loss: 0.2962
- acc: 0.9590 - val_loss: 0.7595 - val_acc: 0.8468
Epoch 201/300
35000/35000 [=====] - 19s 555us/step - loss: 0.2950
- acc: 0.9581 - val_loss: 0.7636 - val_acc: 0.8456
Epoch 202/300
35000/35000 [=====] - 19s 552us/step - loss: 0.2938
- acc: 0.9599 - val_loss: 0.8012 - val_acc: 0.8399
Epoch 203/300
35000/35000 [=====] - 19s 552us/step - loss: 0.2931
- acc: 0.9594 - val_loss: 0.7670 - val_acc: 0.8453
Epoch 204/300
35000/35000 [=====] - 19s 551us/step - loss: 0.2894
- acc: 0.9605 - val_loss: 0.7587 - val_acc: 0.8462
Epoch 205/300
35000/35000 [=====] - 19s 549us/step - loss: 0.2895
- acc: 0.9611 - val_loss: 0.8140 - val_acc: 0.8375
Epoch 206/300
35000/35000 [=====] - 19s 552us/step - loss: 0.2886
- acc: 0.9622 - val_loss: 0.7651 - val_acc: 0.8436
Epoch 207/300
35000/35000 [=====] - 19s 554us/step - loss: 0.2887
- acc: 0.9602 - val_loss: 0.7462 - val_acc: 0.8477
Epoch 208/300
35000/35000 [=====] - 20s 560us/step - loss: 0.2855
- acc: 0.9617 - val_loss: 0.7659 - val_acc: 0.8434
```

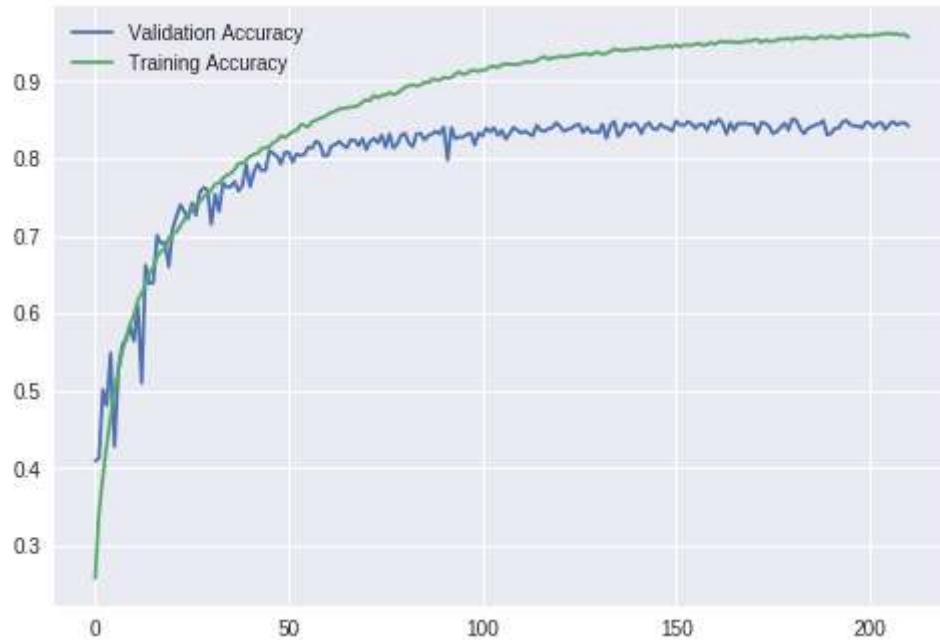
```
Epoch 209/300  
35000/35000 [=====] - 19s 549us/step - loss: 0.2883  
- acc: 0.9593 - val_loss: 0.7481 - val_acc: 0.8456  
Epoch 210/300  
35000/35000 [=====] - 19s 551us/step - loss: 0.2885  
- acc: 0.9603 - val_loss: 0.7392 - val_acc: 0.8461  
Epoch 211/300  
35000/35000 [=====] - 19s 552us/step - loss: 0.2992  
- acc: 0.9567 - val_loss: 0.7521 - val_acc: 0.8418  
Epoch 00211: early stopping
```

In [8]:

```
plt.plot(h.history['val_acc'], label='Validation Accuracy')  
plt.plot(h.history['acc'], label='Training Accuracy')  
plt.legend()
```

Out[8]:

```
<matplotlib.legend.Legend at 0x7f18f164f748>
```



In [9]:

```
# Evaluate the model on the test set  
scores = model.evaluate(X_test, y_test_cat, verbose=0)  
print("%s: %.2f%%" % (model.metrics_names[1], scores[1]*100))
```

acc: 84.32%