In [ ]:

```
# Install TensorFlow
# !pip install -q tensorflow-gpu==2.0.0-beta1

try:
  %tensorflow_version 2.x  # Colab only.
except Exception:
  pass

import tensorflow as tf
print(tf.__version__)
```

```
`%tensorflow_version` only switches the major version: 1.x or 2.x.
You set: `2.x  # Colab only.`. This will be interpreted as: `2.x`.


TensorFlow 2.x selected.
2.2.0-rc2
```

In [ ]:

```
# additional imports

import numpy as np
import matplotlib.pyplot as plt
from tensorflow.keras.layers import Input, Conv2D, Dense, Flatten, Dropout, GlobalMaxPo
from tensorflow.keras.models import Model
```

In [ ]:

```
# Load in the data
cifar10 = tf.keras.datasets.cifar10

(x_train, y_train), (x_test, y_test) = cifar10.load_data()
x_train, x_test = x_train / 255.0, x_test / 255.0
y_train, y_test = y_train.flatten(), y_test.flatten()
print("x_train.shape:", x_train.shape)
print("y_train.shape", y_train.shape)
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170500096/170498071 [==============================] - 13s 0us/step
x_train.shape: (50000, 32, 32, 3)
y_train.shape (50000,)
```

In [ ]:

```
# number of classes
K = len(set(y_train))
print("number of classes:", K)
```

```
number of classes: 10
```

In [ ]:

```
# Build the model using the functional API
i = Input(shape=x_train[0].shape)
# x = Conv2D(32, (3, 3), strides=2, activation='relu')(i)
# x = Conv2D(64, (3, 3), strides=2, activation='relu')(x)
# x = Conv2D(128, (3, 3), strides=2, activation='relu')(x)

x = Conv2D(32, (3, 3), activation='relu', padding='same')(i)
x = BatchNormalization()(x)
x = Conv2D(32, (3, 3), activation='relu', padding='same')(x)
x = BatchNormalization()(x)
x = MaxPooling2D((2, 2))(x)
```

```
# x = Dropout(0.2)(x)
x = Conv2D(64, (3, 3), activation='relu', padding='same')(x)
x = BatchNormalization()(x)
x = Conv2D(64, (3, 3), activation='relu', padding='same')(x)
x = BatchNormalization()(x)
x = MaxPooling2D((2, 2))(x)
# x = Dropout(0.2)(x)
x = Conv2D(128, (3, 3), activation='relu', padding='same')(x)
x = BatchNormalization()(x)
x = Conv2D(128, (3, 3), activation='relu', padding='same')(x)
x = BatchNormalization()(x)
x = MaxPooling2D((2, 2))(x)
# x = Dropout(0.2)(x)

# x = GlobalMaxPooling2D()(x)
x = Flatten()(x)
x = Dropout(0.2)(x)
x = Dense(1024, activation='relu')(x)
x = Dropout(0.2)(x)
x = Dense(K, activation='softmax')(x)

model = Model(i, x)
```

In [ ]:

```
# Compile
# Note: make sure you are using the GPU for this!
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
```

In [ ]:

```
# Fit
r = model.fit(x_train, y_train, validation_data=(x_test, y_test), epochs=50)
```

```
Epoch 1/50
1465/1563 [===========================>..] - ETA: 0s - loss: 1.2974 - accuracy: 0.5487
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
<ipython-input-7-8848f77f4588> in <module>()
----> 1 r = model.fit(x_train, y_train, validation_data=(x_test, y_test), epochs=50)

/usr/local/lib/python3.6/dist-packages/tensorflow/python/keras/engine/training.py in _me
thod_wrapper(self, *args, **kwargs)
     64   def _method_wrapper(self, *args, **kwargs):
     65     if not self._in_multi_worker_mode():  # pylint: disable=protected-access
---> 66       return method(self, *args, **kwargs)
     67
     68     # Running inside `run_distribute_coordinator` already.

/usr/local/lib/python3.6/dist-packages/tensorflow/python/keras/engine/training.py in fit
(self, x, y, batch_size, epochs, verbose, callbacks, validation_split, validation_data,
shuffle, class_weight, sample_weight, initial_epoch, steps_per_epoch, validation_steps,
validation_batch_size, validation_freq, max_queue_size, workers, use_multiprocessing, **
kwargs)
    790                 context.async_wait()
    791               logs = tmp_logs  # No error, now safe to assign to logs.
--> 792               callbacks.on_train_batch_end(step, logs)
    793         epoch_logs = copy.copy(logs)
    794

/usr/local/lib/python3.6/dist-packages/tensorflow/python/keras/callbacks.py in on_train_
```

```
batch_end(self, batch, logs)
    387     """
    388     if self._should_call_train_batch_hooks:
--> 389       logs = self._process_logs(logs)
    390       self._call_batch_hook(ModeKeys.TRAIN, 'end', batch, logs=logs)
    391

/usr/local/lib/python3.6/dist-packages/tensorflow/python/keras/callbacks.py in _process_
logs(self, logs)
    263     """Turns tensors into numpy arrays or Python scalars."""
    264     if logs:
--> 265       return tf_utils.to_numpy_or_python_type(logs)
    266     return {}
    267

/usr/local/lib/python3.6/dist-packages/tensorflow/python/keras/utils/tf_utils.py in to_n
umpy_or_python_type(tensors)
    521     return t  # Don't turn ragged or sparse tensors to NumPy.
    522
--> 523   return nest.map_structure(_to_single_numpy_or_python_type, tensors)
    524

/usr/local/lib/python3.6/dist-packages/tensorflow/python/util/nest.py in map_structure(f
unc, *structure, **kwargs)
    615
    616   return pack_sequence_as(
--> 617       structure[0], [func(*x) for x in entries],
    618       expand_composites=expand_composites)
    619

/usr/local/lib/python3.6/dist-packages/tensorflow/python/util/nest.py in <listcomp>(.0)
    615
    616   return pack_sequence_as(
--> 617       structure[0], [func(*x) for x in entries],
    618       expand_composites=expand_composites)
    619

/usr/local/lib/python3.6/dist-packages/tensorflow/python/keras/utils/tf_utils.py in _to_
single_numpy_or_python_type(t)
    517   def _to_single_numpy_or_python_type(t):
    518     if isinstance(t, ops.Tensor):
--> 519       x = t.numpy()
    520       return x.item() if np.ndim(x) == 0 else x
    521     return t  # Don't turn ragged or sparse tensors to NumPy.

/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/ops.py in numpy(self)
    959     """
    960     # TODO(slebedev): Consider avoiding a copy for non-CPU or remote tensors.
--> 961     maybe_arr = self._numpy()  # pylint: disable=protected-access
    962     return maybe_arr.copy() if isinstance(maybe_arr, np.ndarray) else maybe_arr
    963

/usr/local/lib/python3.6/dist-packages/tensorflow/python/framework/ops.py in _numpy(sel
f)
    925     # pylint: disable=protected-access
    926     try:
--> 927       return self._numpy_internal()
    928     except core._NotOkStatusException as e:
    929       six.raise_from(core._status_to_exception(e.code, e.message), None)

KeyboardInterrupt:
```

In [ ]:

```
# Fit with data augmentation
# Note: if you run this AFTER calling the previous model.fit(), it will CONTINUE trainin
```

```
batch_size = 32
data_generator = tf.keras.preprocessing.image.ImageDataGenerator(width_shift_range=0.1,
train_generator = data_generator.flow(x_train, y_train, batch_size)
steps_per_epoch = x_train.shape[0] // batch_size
r = model.fit(train_generator, validation_data=(x_test, y_test), steps_per_epoch=steps_
```

```
Epoch 1/50
1562/1562 [==============================] - 27s 17ms/step - loss: 0.9854 - accuracy: 0.
6597 - val_loss: 0.9380 - val_accuracy: 0.6898
Epoch 2/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.8444 - accuracy: 0.
7101 - val_loss: 0.8461 - val_accuracy: 0.7158
Epoch 3/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.7506 - accuracy: 0.
7444 - val_loss: 0.7562 - val_accuracy: 0.7485
Epoch 4/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.6825 - accuracy: 0.
7695 - val_loss: 0.6062 - val_accuracy: 0.7959
Epoch 5/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.6324 - accuracy: 0.
7856 - val_loss: 0.6161 - val_accuracy: 0.7971
Epoch 6/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.5944 - accuracy: 0.
7997 - val_loss: 0.6473 - val_accuracy: 0.7832
Epoch 7/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.5502 - accuracy: 0.
8109 - val_loss: 0.6116 - val_accuracy: 0.8007
Epoch 8/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.5210 - accuracy: 0.
8227 - val_loss: 0.6694 - val_accuracy: 0.7861
Epoch 9/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.4947 - accuracy: 0.
8300 - val_loss: 0.4850 - val_accuracy: 0.8358
Epoch 10/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.4690 - accuracy: 0.
8407 - val_loss: 0.5492 - val_accuracy: 0.8174
Epoch 11/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.4480 - accuracy: 0.
8479 - val_loss: 0.5357 - val_accuracy: 0.8212
Epoch 12/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.4283 - accuracy: 0.
8523 - val_loss: 0.5085 - val_accuracy: 0.8319
Epoch 13/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.4125 - accuracy: 0.
8577 - val_loss: 0.5201 - val_accuracy: 0.8308
Epoch 14/50
1562/1562 [==============================] - 26s 16ms/step - loss: 0.3929 - accuracy: 0.
8662 - val_loss: 0.4446 - val_accuracy: 0.8510
Epoch 15/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3779 - accuracy: 0.
8694 - val_loss: 0.4738 - val_accuracy: 0.8506
Epoch 16/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3706 - accuracy: 0.
8721 - val_loss: 0.4617 - val_accuracy: 0.8504
Epoch 17/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3470 - accuracy: 0.
8812 - val_loss: 0.4172 - val_accuracy: 0.8627
Epoch 18/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3405 - accuracy: 0.
8818 - val_loss: 0.4572 - val_accuracy: 0.8587
Epoch 19/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3312 - accuracy: 0.
8868 - val_loss: 0.4150 - val_accuracy: 0.8654
Epoch 20/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3203 - accuracy: 0.
```

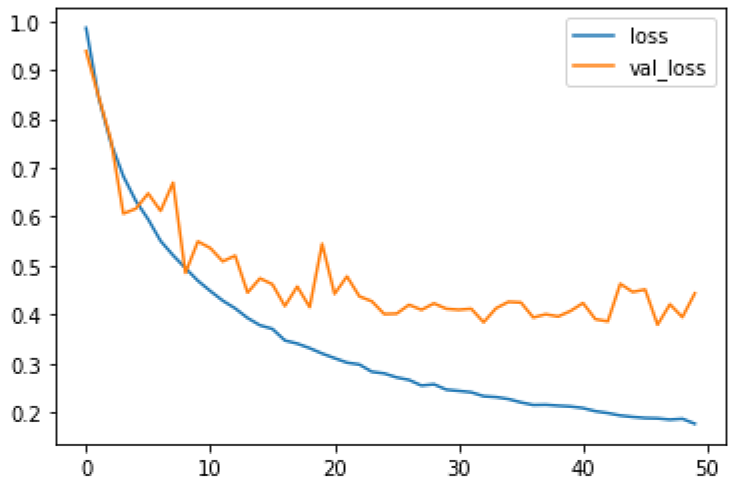
```
8880 - val_loss: 0.5443 - val_accuracy: 0.8273
Epoch 21/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3108 - accuracy: 0.
8919 - val_loss: 0.4421 - val_accuracy: 0.8605
Epoch 22/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.3017 - accuracy: 0.
8964 - val_loss: 0.4778 - val_accuracy: 0.8537
Epoch 23/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2978 - accuracy: 0.
8975 - val_loss: 0.4370 - val_accuracy: 0.8621
Epoch 24/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2830 - accuracy: 0.
9023 - val_loss: 0.4270 - val_accuracy: 0.8676
Epoch 25/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2796 - accuracy: 0.
9035 - val_loss: 0.4009 - val_accuracy: 0.8748
Epoch 26/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2714 - accuracy: 0.
9069 - val_loss: 0.4017 - val_accuracy: 0.8719
Epoch 27/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2663 - accuracy: 0.
9080 - val_loss: 0.4199 - val_accuracy: 0.8669
Epoch 28/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2547 - accuracy: 0.
9121 - val_loss: 0.4094 - val_accuracy: 0.8703
Epoch 29/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2574 - accuracy: 0.
9110 - val_loss: 0.4227 - val_accuracy: 0.8698
Epoch 30/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2464 - accuracy: 0.
9141 - val_loss: 0.4117 - val_accuracy: 0.8649
Epoch 31/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2439 - accuracy: 0.
9157 - val_loss: 0.4096 - val_accuracy: 0.8758
Epoch 32/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2411 - accuracy: 0.
9159 - val_loss: 0.4118 - val_accuracy: 0.8705
Epoch 33/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2330 - accuracy: 0.
9194 - val_loss: 0.3841 - val_accuracy: 0.8764
Epoch 34/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2312 - accuracy: 0.
9201 - val_loss: 0.4127 - val_accuracy: 0.8708
Epoch 35/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2272 - accuracy: 0.
9209 - val_loss: 0.4259 - val_accuracy: 0.8762
Epoch 36/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2204 - accuracy: 0.
9241 - val_loss: 0.4246 - val_accuracy: 0.8769
Epoch 37/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2150 - accuracy: 0.
9251 - val_loss: 0.3939 - val_accuracy: 0.8797
Epoch 38/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2156 - accuracy: 0.
9261 - val_loss: 0.4005 - val_accuracy: 0.8790
Epoch 39/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2135 - accuracy: 0.
9268 - val_loss: 0.3959 - val_accuracy: 0.8773
Epoch 40/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2121 - accuracy: 0.
9263 - val_loss: 0.4072 - val_accuracy: 0.8742
Epoch 41/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2087 - accuracy: 0.
9277 - val_loss: 0.4234 - val_accuracy: 0.8769
Epoch 42/50
```

```
1562/1562 [==============================] - 26s 17ms/step - loss: 0.2023 - accuracy: 0.
9310 - val_loss: 0.3904 - val_accuracy: 0.8812
Epoch 43/50
1562/1562 [==============================] - 26s 16ms/step - loss: 0.1986 - accuracy: 0.
9311 - val_loss: 0.3859 - val_accuracy: 0.8806
Epoch 44/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.1936 - accuracy: 0.
9341 - val_loss: 0.4627 - val_accuracy: 0.8703
Epoch 45/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.1907 - accuracy: 0.
9342 - val_loss: 0.4460 - val_accuracy: 0.8646
Epoch 46/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.1884 - accuracy: 0.
9341 - val_loss: 0.4511 - val_accuracy: 0.8658
Epoch 47/50
1562/1562 [==============================] - 26s 17ms/step - loss: 0.1877 - accuracy: 0.
9344 - val_loss: 0.3790 - val_accuracy: 0.8831
Epoch 48/50
1562/1562 [==============================] - 26s 16ms/step - loss: 0.1851 - accuracy: 0.
9366 - val_loss: 0.4208 - val_accuracy: 0.8770
Epoch 49/50
1562/1562 [==============================] - 26s 16ms/step - loss: 0.1869 - accuracy: 0.
9364 - val_loss: 0.3946 - val_accuracy: 0.8841
Epoch 50/50
1562/1562 [==============================] - 26s 16ms/step - loss: 0.1767 - accuracy: 0.
9397 - val_loss: 0.4432 - val_accuracy: 0.8781
```

In [ ]:

```python
# Plot loss per iteration
import matplotlib.pyplot as plt
plt.plot(r.history['loss'], label='loss')
plt.plot(r.history['val_loss'], label='val_loss')
plt.legend()
```

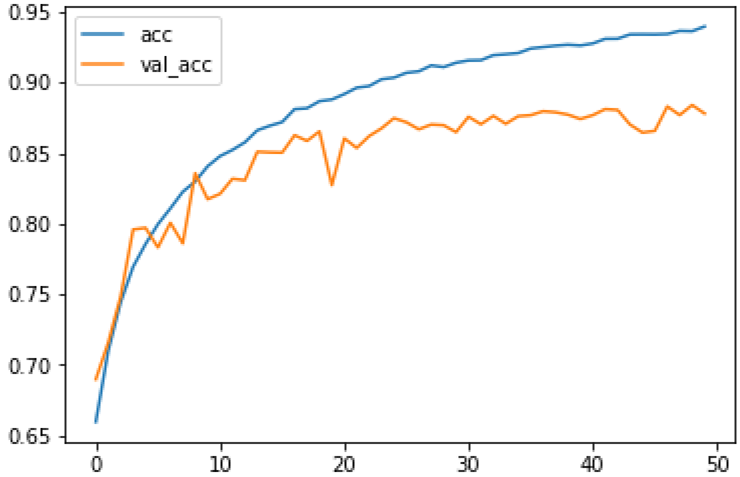
Out[ ]: <matplotlib.legend.Legend at 0x7f1d5a2856d8>



In [ ]:

```python
# Plot accuracy per iteration
plt.plot(r.history['accuracy'], label='acc')
plt.plot(r.history['val_accuracy'], label='val_acc')
plt.legend()
```

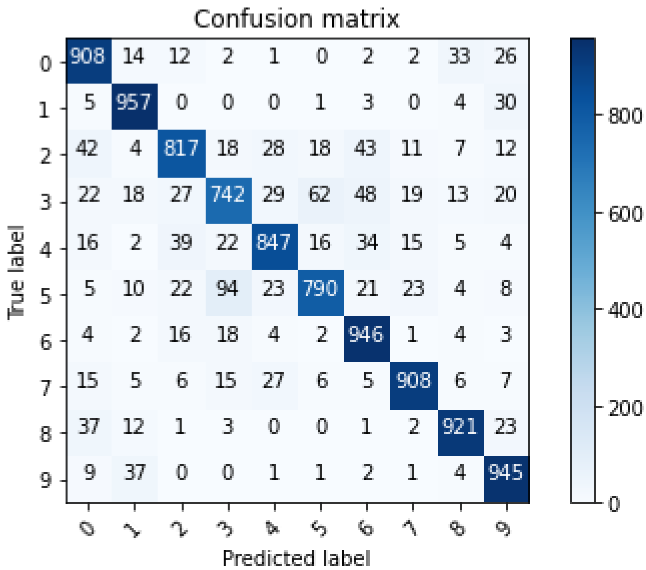
Out[ ]: <matplotlib.legend.Legend at 0x7f1d5a26ada0>



In [ ]:

```
# Plot confusion matrix
from sklearn.metrics import confusion_matrix
import itertools

def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
                          cmap=plt.cm.Blues):
  """
  This function prints and plots the confusion matrix.
  Normalization can be applied by setting `normalize=True`.
  """
  if normalize:
      cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
      print("Normalized confusion matrix")
  else:
      print('Confusion matrix, without normalization')

  print(cm)

  plt.imshow(cm, interpolation='nearest', cmap=cmap)
  plt.title(title)
  plt.colorbar()
  tick_marks = np.arange(len(classes))
  plt.xticks(tick_marks, classes, rotation=45)
  plt.yticks(tick_marks, classes)

  fmt = '.2f' if normalize else 'd'
  thresh = cm.max() / 2.
  for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
      plt.text(j, i, format(cm[i, j], fmt),
               horizontalalignment="center",
               color="white" if cm[i, j] > thresh else "black")

  plt.tight_layout()
  plt.ylabel('True label')
  plt.xlabel('Predicted label')
  plt.show()


p_test = model.predict(x_test).argmax(axis=1)
cm = confusion_matrix(y_test, p_test)
plot_confusion_matrix(cm, list(range(10)))
```

```
Confusion matrix, without normalization
[[908  14  12   2   1   0   2   2  33  26]
 [  5 957   0   0   0   1   3   0   4  30]
 [ 42   4 817  18  28  18  43  11   7  12]
 [ 22  18  27 742  29  62  48  19  13  20]
 [ 16   2  39  22 847  16  34  15   5   4]
 [  5  10  22  94  23 790  21  23   4   8]
 [  4   2  16  18   4   2 946   1   4   3]
 [ 15   5   6  15  27   6   5 908   6   7]
 [ 37  12   1   3   0   0   1   2 921  23]
 [  9  37   0   0   1   1   2   1   4 945]]
```

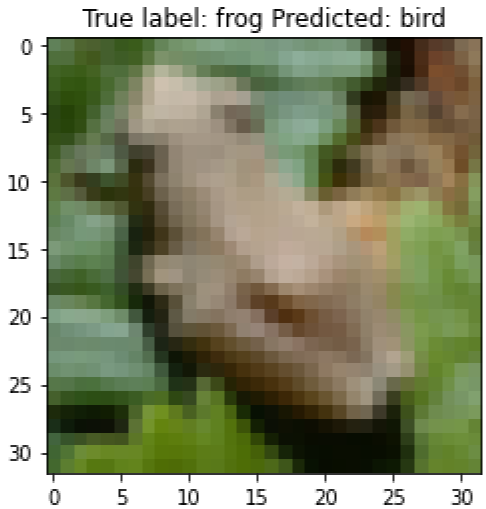


In [ ]:

```
# Label mapping
labels = '''airplane
automobile
bird
cat
deer
dog
frog
horse
ship
truck'''.split()
```

In [ ]:

```
# Show some misclassified examples
misclassified_idx = np.where(p_test != y_test)[0]
i = np.random.choice(misclassified_idx)
plt.imshow(x_test[i], cmap='gray')
plt.title("True label: %s Predicted: %s" % (labels[y_test[i]], labels[p_test[i]]));
```



In [ ]:

```python
# Now that the model is so large, it's useful to summarize it
model.summary()
```

```
Model: "model"
_________________________________________________________________
Layer (type)                Output Shape              Param #
=================================================================
input_1 (InputLayer)        [(None, 32, 32, 3)]       0
_________________________________________________________________
conv2d (Conv2D)             (None, 32, 32, 32)        896
_________________________________________________________________
batch_normalization (BatchNo (None, 32, 32, 32)       128
_________________________________________________________________
conv2d_1 (Conv2D)           (None, 32, 32, 32)        9248
_________________________________________________________________
batch_normalization_1 (Batch (None, 32, 32, 32)       128
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)       0
_________________________________________________________________
conv2d_2 (Conv2D)           (None, 16, 16, 64)        18496
_________________________________________________________________
batch_normalization_2 (Batch (None, 16, 16, 64)       256
_________________________________________________________________
conv2d_3 (Conv2D)           (None, 16, 16, 64)        36928
_________________________________________________________________
batch_normalization_3 (Batch (None, 16, 16, 64)       256
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 64)         0
_________________________________________________________________
conv2d_4 (Conv2D)           (None, 8, 8, 128)         73856
_________________________________________________________________
batch_normalization_4 (Batch (None, 8, 8, 128)        512
_________________________________________________________________
conv2d_5 (Conv2D)           (None, 8, 8, 128)         147584
_________________________________________________________________
batch_normalization_5 (Batch (None, 8, 8, 128)        512
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 4, 4, 128)        0
_________________________________________________________________
flatten (Flatten)           (None, 2048)              0
_________________________________________________________________
dropout (Dropout)           (None, 2048)              0
_________________________________________________________________
dense (Dense)               (None, 1024)              2098176
_________________________________________________________________
```

```
dropout_1 (Dropout)          (None, 1024)              0
_________________________________________________________________
dense_1 (Dense)              (None, 10)                10250
=================================================================
Total params: 2,397,226
Trainable params: 2,396,330
Non-trainable params: 896
_________________________________________________________________
```