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__)
```

```
     |████████████████████████████████| 348.9MB 70kB/s
     |████████████████████████████████| 3.1MB 33.3MB/s
     |████████████████████████████████| 501kB 41.2MB/s
2.0.0-beta1
```

In [ ]:
```
# More imports
from tensorflow.keras.layers import Input, SimpleRNN, GRU, LSTM, Dense, Flatten
from tensorflow.keras.models import Model
from tensorflow.keras.optimizers import SGD, Adam

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

In [ ]:
```
# Load in the data
mnist = tf.keras.datasets.mnist

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

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.
npz
11493376/11490434 [==============================] - 0s 0us/step
x_train.shape: (60000, 28, 28)
```

In [ ]:
```
# Build the model
i = Input(shape=x_train[0].shape)
x = LSTM(128)(i)
x = Dense(10, activation='softmax')(x)

model = Model(i, x)
```

In [ ]:
```
# Compile and train
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
r = model.fit(x_train, y_train, validation_data=(x_test, y_test), epochs=10)
```

```
WARNING: Logging before flag parsing goes to stderr.
W0803 17:03:38.451040 140542585788288 deprecation.py:323] From /usr/local/lib/python3.6/
dist-packages/tensorflow/python/ops/math_grad.py:1250: add_dispatch_support.<locals>.wra
pper (from tensorflow.python.ops.array_ops) is deprecated and will be removed in a futur
e version.
```

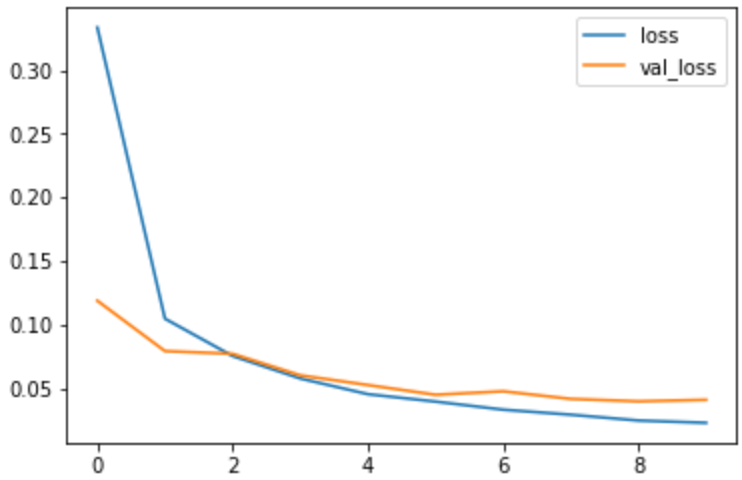
```
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
Train on 60000 samples, validate on 10000 samples
Epoch 1/10
60000/60000 [==============================] - 25s 411us/sample - loss: 0.3334 - accurac
y: 0.8929 - val_loss: 0.1187 - val_accuracy: 0.9629
Epoch 2/10
60000/60000 [==============================] - 21s 354us/sample - loss: 0.1046 - accurac
y: 0.9692 - val_loss: 0.0792 - val_accuracy: 0.9759
Epoch 3/10
60000/60000 [==============================] - 21s 357us/sample - loss: 0.0753 - accurac
y: 0.9774 - val_loss: 0.0770 - val_accuracy: 0.9756
Epoch 4/10
60000/60000 [==============================] - 22s 359us/sample - loss: 0.0576 - accurac
y: 0.9827 - val_loss: 0.0601 - val_accuracy: 0.9803
Epoch 5/10
60000/60000 [==============================] - 21s 358us/sample - loss: 0.0453 - accurac
y: 0.9862 - val_loss: 0.0525 - val_accuracy: 0.9833
Epoch 6/10
60000/60000 [==============================] - 21s 353us/sample - loss: 0.0395 - accurac
y: 0.9877 - val_loss: 0.0448 - val_accuracy: 0.9864
Epoch 7/10
60000/60000 [==============================] - 21s 352us/sample - loss: 0.0331 - accurac
y: 0.9897 - val_loss: 0.0476 - val_accuracy: 0.9857
Epoch 8/10
60000/60000 [==============================] - 21s 353us/sample - loss: 0.0292 - accurac
y: 0.9908 - val_loss: 0.0416 - val_accuracy: 0.9884
Epoch 9/10
60000/60000 [==============================] - 21s 357us/sample - loss: 0.0246 - accurac
y: 0.9923 - val_loss: 0.0397 - val_accuracy: 0.9887
Epoch 10/10
60000/60000 [==============================] - 21s 356us/sample - loss: 0.0228 - accurac
y: 0.9927 - val_loss: 0.0409 - val_accuracy: 0.9881
```

In [ ]:

```
# 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 0x7fd1e8624a58>
```

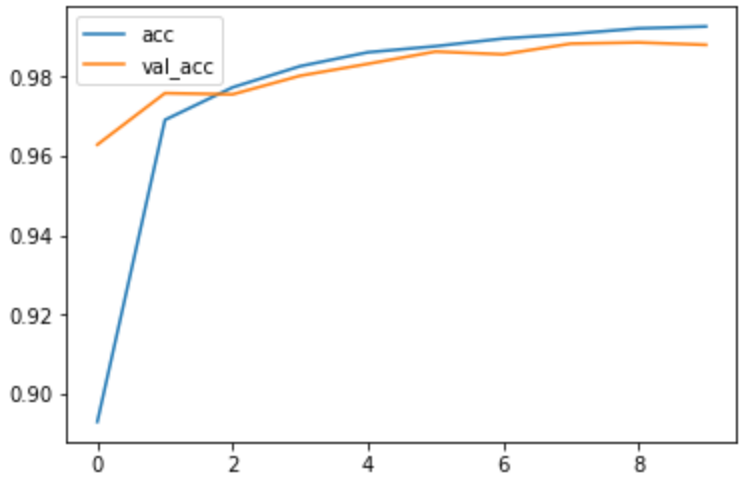


In [ ]:

```
# 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 0x7fd1e5dd0358>

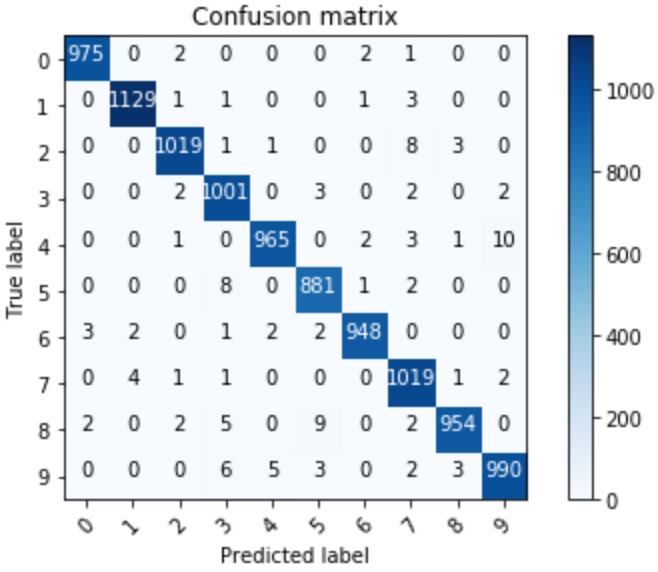


In [ ]:

```
# Plot confusion matrix
from sklearn.metrics import confusion_matrix
import numpy as np
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')
```

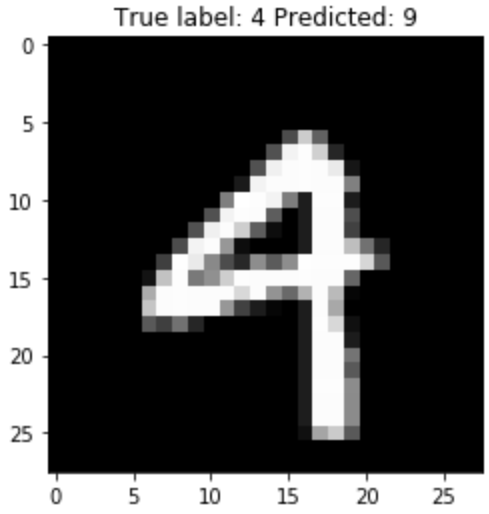
```
  plt.show()


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

# Do these results make sense?
# It's easy to confuse 9 <--> 4, 9 <--> 7, 2 <--> 7, etc.
```

```
Confusion matrix, without normalization
[[ 975    0    2    0    0    0    2    1    0    0]
 [   0 1129    1    1    0    0    1    3    0    0]
 [   0    0 1019    1    1    0    0    8    3    0]
 [   0    0    2 1001    0    3    0    2    0    2]
 [   0    0    1    0  965    0    2    3    1   10]
 [   0    0    0    8    0  881    1    2    0    0]
 [   3    2    0    1    2    2  948    0    0    0]
 [   0    4    1    1    0    0    0 1019    1    2]
 [   2    0    2    5    0    9    0    2  954    0]
 [   0    0    0    6    5    3    0    2    3  990]]
```



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" % (y_test[i], p_test[i]));
```


True label: 4 Predicted: 9
0
5
10
15
20
25
0
5
10
15
20
25