This assignment is **OPTIONAL**. If you complete it and submit it, it will take the place of your lowest programming assignment score.

In this assignment, you will use Keras, a popular deep learning framework, to train several different neural networks on the MNIST digit recognition dataset.

## 1 Step 1: Complete a Keras Tutorial

This tutorial will walk you through installing Keras and using it to train a neural network for digit recognition on the MNIST dataset. Please complete the entire tutorial to learn the basics of Keras:


**NOTE:** Getting Keras and the other software installed is half of the challenge! Depending on your system, it may take you some time to debug the proper installation commands or other details. I can’t necessarily help you with this.

## 2 Step 2: Train a Variety of Models

Next, use Keras to train several different models with the following architectures. All should have a softmax output layer with 10 nodes, corresponding to the 10 possible digit classes in MNIST. Use the commands from the tutorial as a starting point, but modify them as appropriate to create the following different models.

**Multi-layer perceptrons with a single hidden layer:**

- **model1**: Multi-layer perceptron with one layer of 16 hidden sigmoid units (no dropout).
- **model2**: Multi-layer perceptron with one layer of 128 hidden sigmoid units (no dropout).
- **model3**: Multi-layer perceptron with one layer of 128 hidden rectified linear units (ReLU) (no dropout).
- **model4**: Multi-layer perceptron with one layer of 128 hidden ReLUs (50% dropout).

**Convolutional neural networks:**

- **model5**: One 2D convolutional ReLU layer (as in the tutorial), one layer of 128 ReLUs (50% dropout).
• **model6**: One 2D convolutional ReLU layer (as in the tutorial), one max pooling layer (as in the tutorial) (25% dropout), one layer of 128 ReLUs (50% dropout).

• **model7**: Two 2D convolutional ReLU layers (as in the tutorial), one max pooling layer (as in the tutorial) (25% dropout), one layer of 128 ReLUs (50% dropout).

**model7** should be the same as the full tutorial model. After training your models, evaluate them on both the training and testing data.

### 3 Step 3: What To Submit

Please submit the following, through Canvas:

1. A Python script that trains all of these models. Please follow the naming convention above, naming the variable names for the different models `model1 through model7`.

2. A brief write-up (plain text or PDF) including:
   - The train and test set accuracy of each of the 7 models
   - One paragraph explaining what you learned about different neural network structures (in theory and/or practice) from playing around with Keras in general and this assignment in particular.

Have fun!