BU.330.760 Deep Learning with Unstructured Data

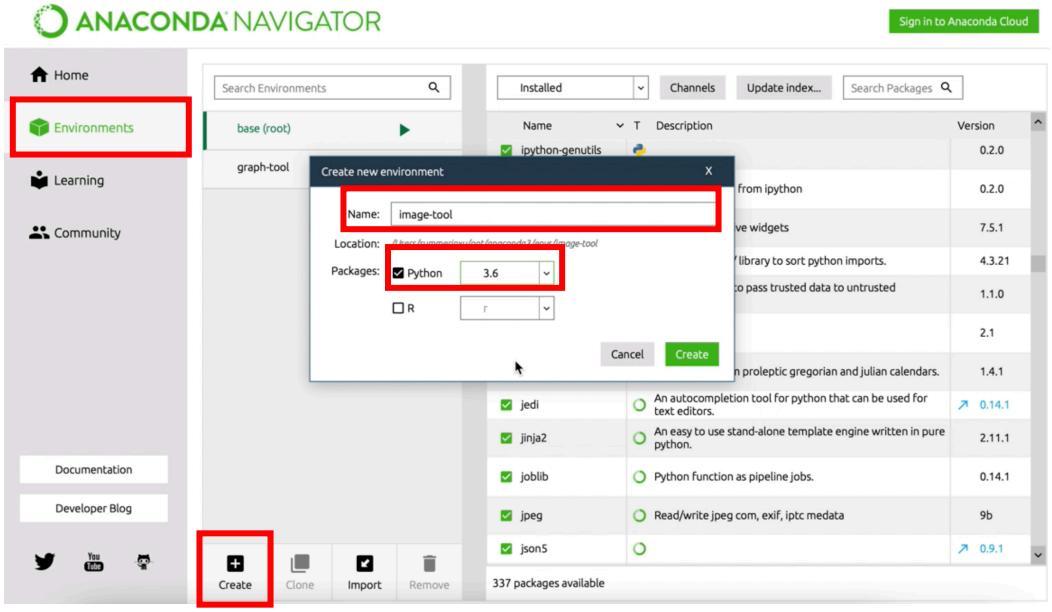
Lab 4. Keras and Deep Feedforward Network

Learning Goal: practice using Keras package to train a multilayer perceptron model on MNIST dataset
Required Skills: knowledge on feedforward network and Keras

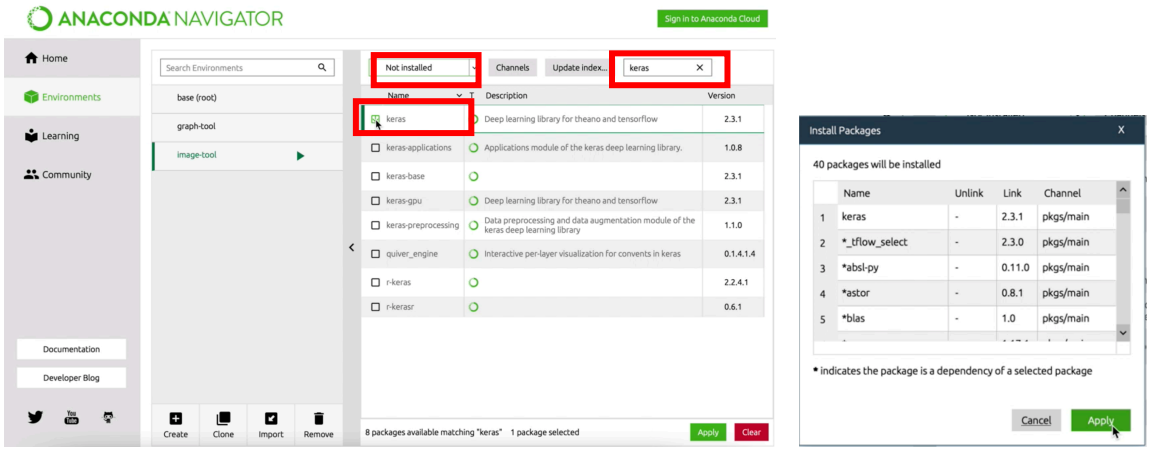
1. We will use Keras (https://keras.io) in lab 4, which is a high-level neural networks API, written in Python and capable of running on top of TensorFlow, CNTK, or Theano.
2. You can either install Keras package with conda in **Aanconda Navigator > JupyterLab > Launcher > Terminal**:

```
conda create -n image-tool keras
conda activate image-tool
conda install -c conda-forge matplotlib
conda install pillow
conda install nomkl
```

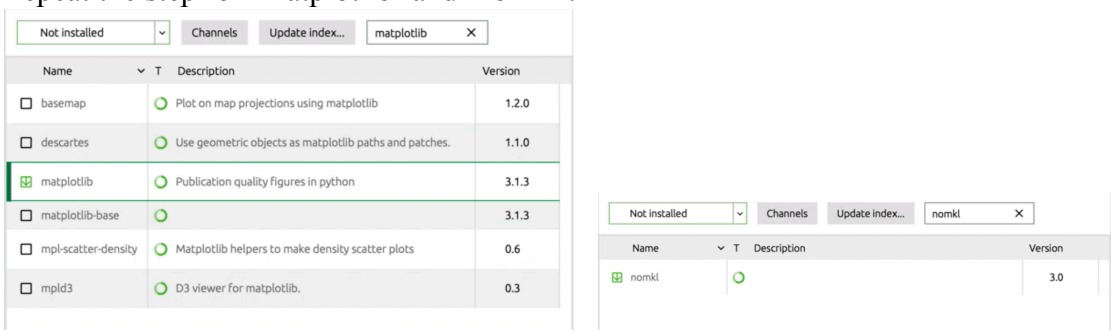
or you can install it using Anaconda user interface instead of command line. First launch Anaconda Navigator. Go to the **Environments** tab and click **Create**. Type in a new environment name such as 'image-tool'; we will have both Keras (for lab 4) and TensorFlow (for lab 5) in this environment. Make sure to select **Python 3.6** here. Then click **Create**, this may take few minutes.



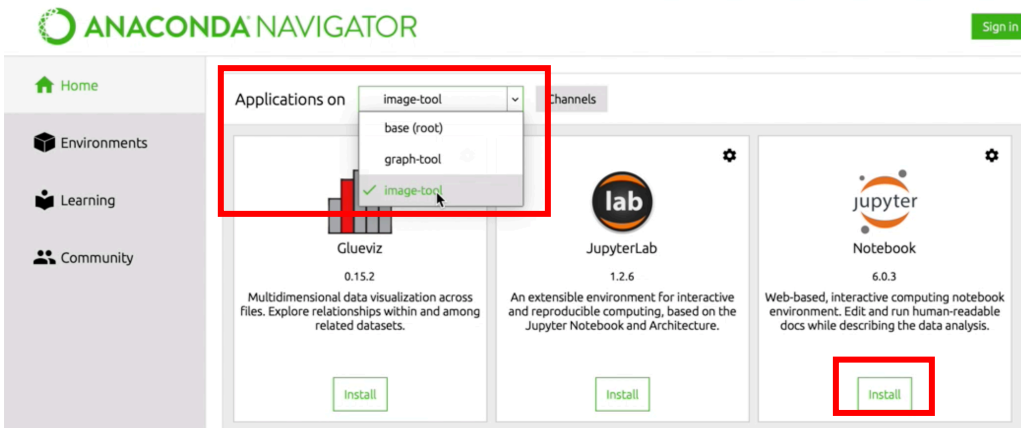
In your new 'image-tool' environment, select **Not installed**, and type in 'keras'. Then, click **keras** and **Apply**. A pop-up window will appear, go ahead and **Apply**. This may take several minutes.



Repeat the step for ‘matplotlib’ and ‘nomkl’.

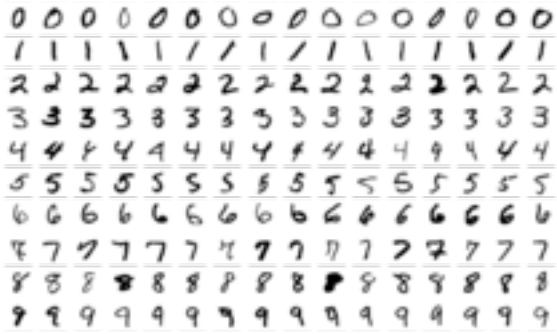


3. After installation, switch to the image-tool environment to use the package (as shown in the screenshot below). You may need to install Jupyter notebook under this environment.



4. If you prefer to use your own Python developer tools or platforms, please install Keras package according to instruction: https://keras.io/#installation, and other packages accordingly.
5. We will use the MNIST dataset for this lab. The MNIST database (Modified National Institute of Standards and Technology database) is a large database of handwritten digits that is commonly used for training various image processing systems. The testing dataset was taken from American high school students. The black and white images from NIST

were normalized to fit into a 28x28 pixel bounding box and anti-aliased, which introduced grayscale levels. See sample images below:



(https://en.wikipedia.org/wiki/MNIST_database)

6. In Jupyter notebook, or your own Python development environment, build the following scripts

    a. Import required packages.

```
import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.layers import Dense, Dropout
import matplotlib.pyplot as plt
from PIL import Image
```

    b. First, let's plot some MNIST instances. We will load the data, and create a grid of 3x3 images.

```
(x_train, y_train), (x_test, y_test) = mnist.load_data()
for i in range(0, 9):
    plt.subplot(330 + 1 + i)
    plt.imshow(Image.fromarray(x_train[i]))
plt.show()
```

    c. Since the dataset has digits 0-9, there will be 10 classes. We will use a batch size of 128, and 20 training epochs.

```
batch_size = 128
num_classes = 10
epochs = 20
```

    d. The database contains 60,000 training images and 10,000 testing images, each of 28x28 pixel. We will normalize from the vectors from 0-255 to range 0-1.

```
x_train = x_train.reshape(60000, 784)
x_test = x_test.reshape(10000, 784)
x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255
print(x_train.shape[0], 'train samples')
```

```
print(x_test.shape[0], 'test samples')
```

e. Then convert class vectors to binary class matrices.

```
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
```

f. We can build the model now.

```
model = Sequential()
model.add(Dense(512, activation='relu', input_shape=(784,)))
model.add(Dropout(0.2))
model.add(Dense(512, activation='relu'))
model.add(Dropout(0.2))
model.add(Dense(num_classes, activation='softmax'))
model.summary()
```

g. We will use cross-entropy for the loss function, and stochastic gradient descent as the optimization procedure.

```
model.compile(loss='categorical_crossentropy',
              optimizer='sgd',
             metrics=['accuracy'])
```

h. Now let's train the model, and test.

```
history = model.fit(x_train, y_train,
                    batch_size=batch_size,
                    epochs=epochs,
                    verbose=1,
                    validation_data=(x_test, y_test))
score = model.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

i. Finally, let's plot the accuracy curve as well as loss curve of the training process.

```
#Plot the Loss Curves
plt.figure(figsize=[8,6])
plt.plot(history.history['loss'],'r',linewidth=3.0)
plt.plot(history.history['val_loss'],'b',linewidth=3.0)
plt.legend(['Training loss', 'Validation Loss'],fontsize=18)
plt.xlabel('Epochs ',fontsize=16)
plt.ylabel('Loss',fontsize=16)
plt.title('Loss Curves',fontsize=16)
#Plot the Accuracy Curves
plt.figure(figsize=[8,6])
plt.plot(history.history['accuracy'],'r',linewidth=3.0)
plt.plot(history.history['val_accuracy'],'b',linewidth=3.0)
plt.legend(['Training Accuracy', 'Validation Accuracy'],fontsize=18)
plt.xlabel('Epochs ',fontsize=16)
plt.ylabel('Accuracy',fontsize=16)
plt.title('Accuracy Curves',fontsize=16)
```

7. Assignment question:

Draw the computation graph for the following function: $f(a, b, c, d, e) = \frac{1}{(1+(a^b+c^d)\times e)^2}$

Compute the gradient of the function with respect it to its inputs at (a, b, c, d, e) = (1, 1, 1, 1, 1) (refer to Lecture 3)

Submission:
Finish all the steps in the lab, save it to lab4.ipynb file with all the outputs.
Complete the assignment question. You can either use drawing and equations in word, or handwrite and then scan or take a picture using your phone. You can either save it as a pdf or an image, such as assignment4.pdf, assignment4.png or assignment4.jpg.
Your submission should include

1. lab4.ipynb, or lab4.py together with all the outputs.
2. assignment4.pdf, or assignment4.png, or assignment4.jpg.

Due: Feb 22nd 11:30am EST

Reference:

https://www.learnopencv.com/image-classification-using-feedforward-neural-network-in-keras/
IDS 576: Advanced Predictive Models and Applications for Business Analytics Assignment 1, Theja Tulabandhula, 2017, University of Illinois at Chicago
https://www.freecodecamp.org/news/install-tensorflow-and-keras-using-anaconda-navigator-without-command-line/