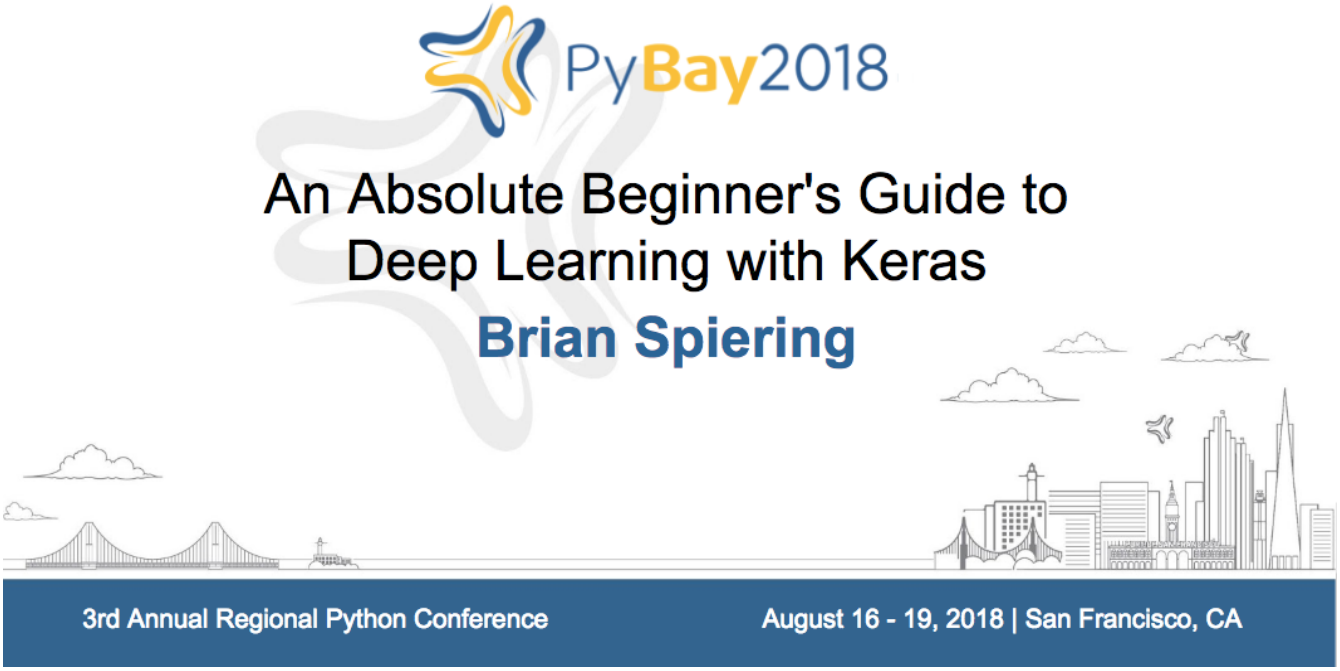


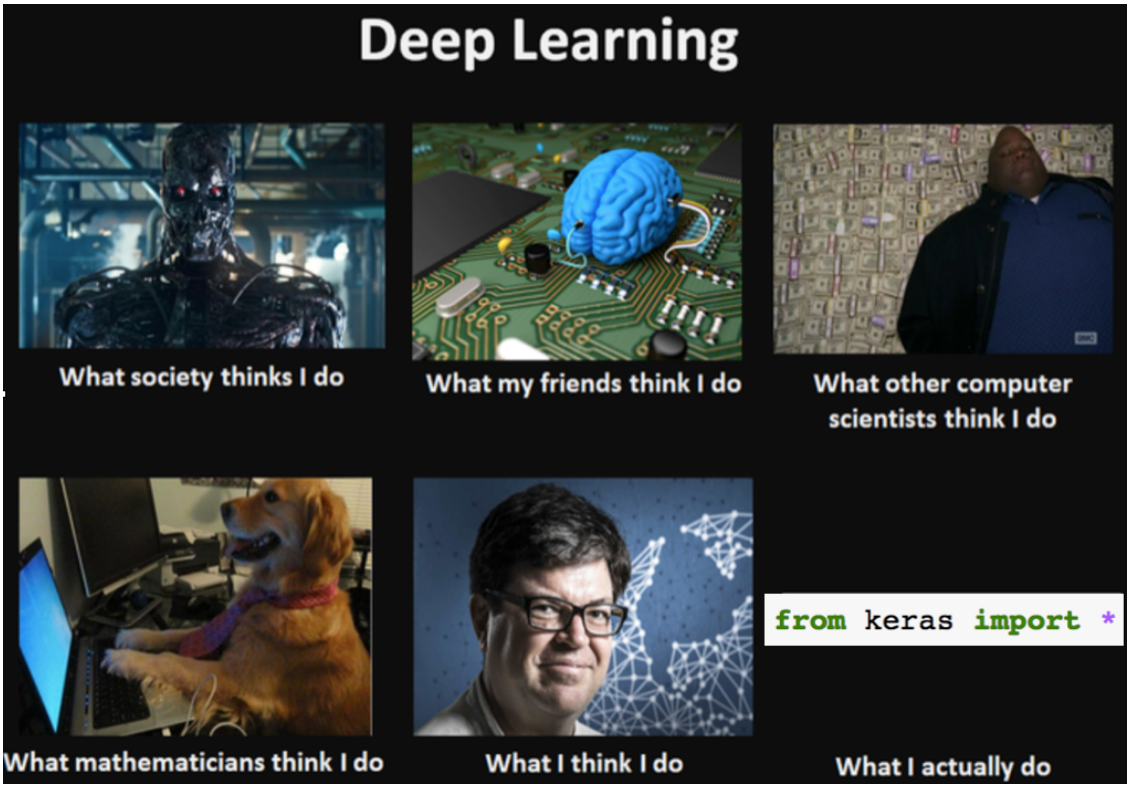
bit.ly/pybay-keras (http://bit.ly/pybay-keras)

What Do I Do?

Professor @

UNIVERSITY OF SAN FRANCISCO

Master of Science in Data Science



Keras - Neural Networks for humans

A high-level, intuitive API for Deep Learning.

Easy to define neural networks, then automatically handles execution.

A simple, modular interface which allows focus on learning and enables fast experimentation.

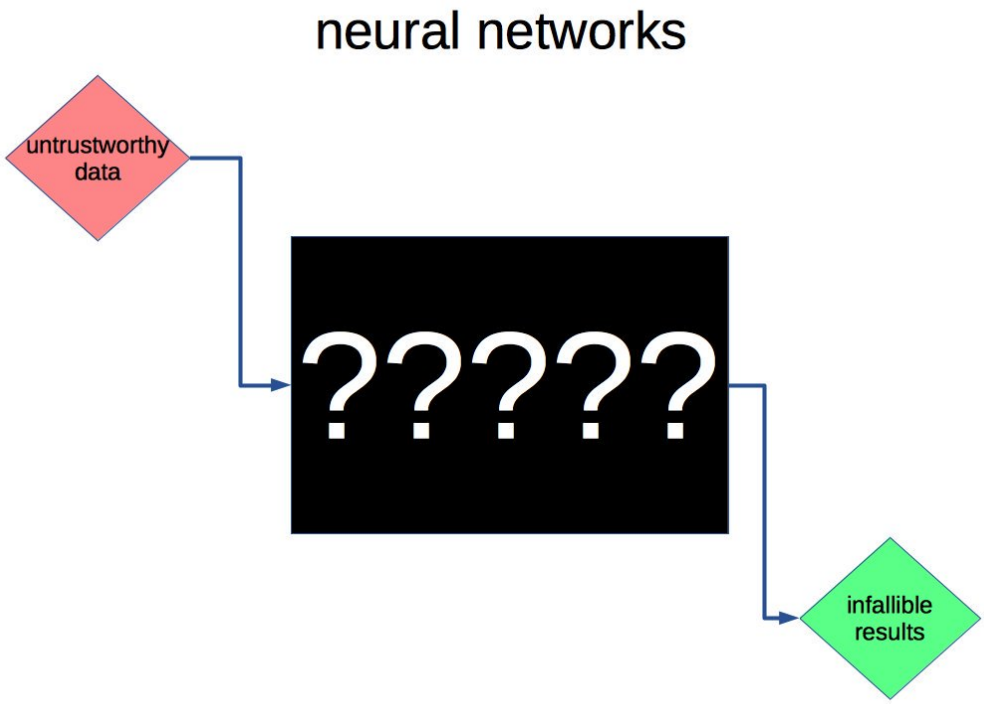
Goals

- **General introduction to Deep Learning**
- **Overview of Keras library**
- **An end-to-end example in Keras**

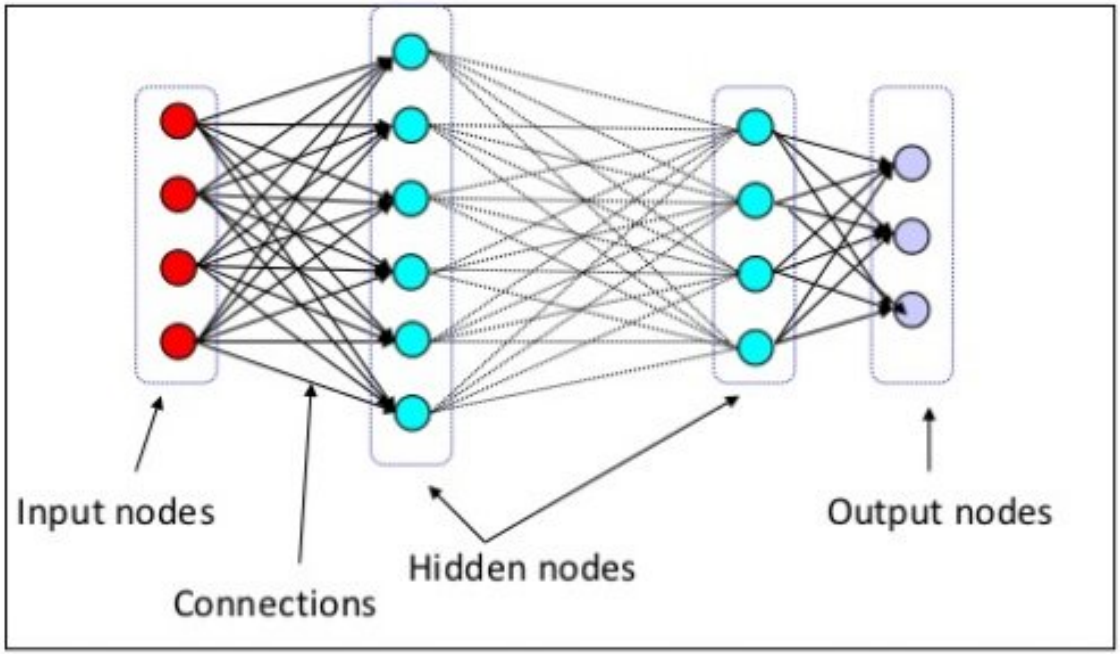
Anti-Goals

- **Understanding of Deep Learning**
- **Building neural networks from scratch**
- **A complete survey of keras library**

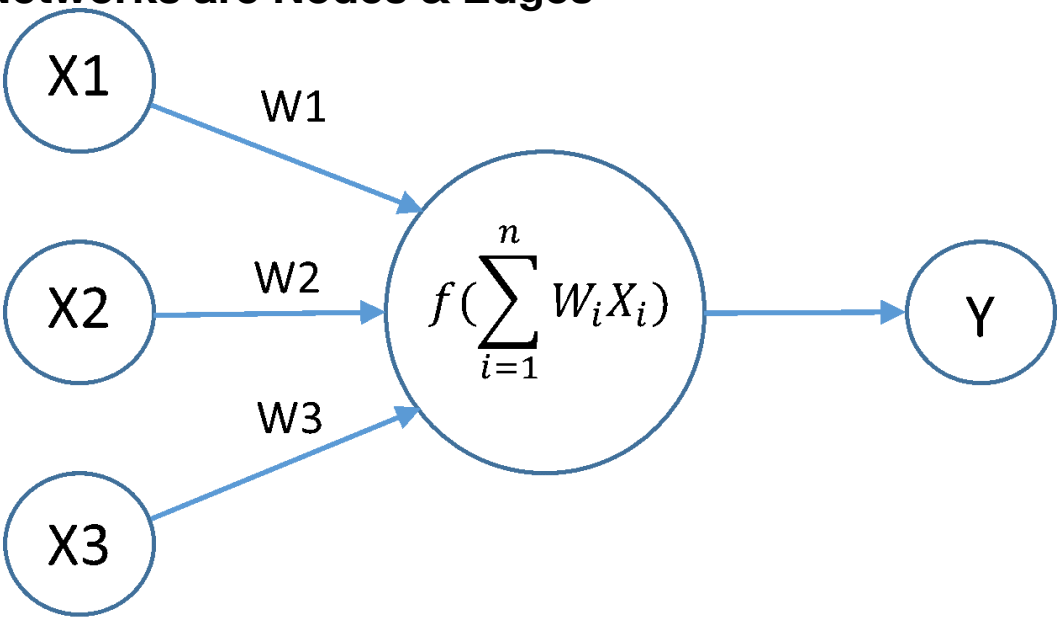
Deep Learning 101



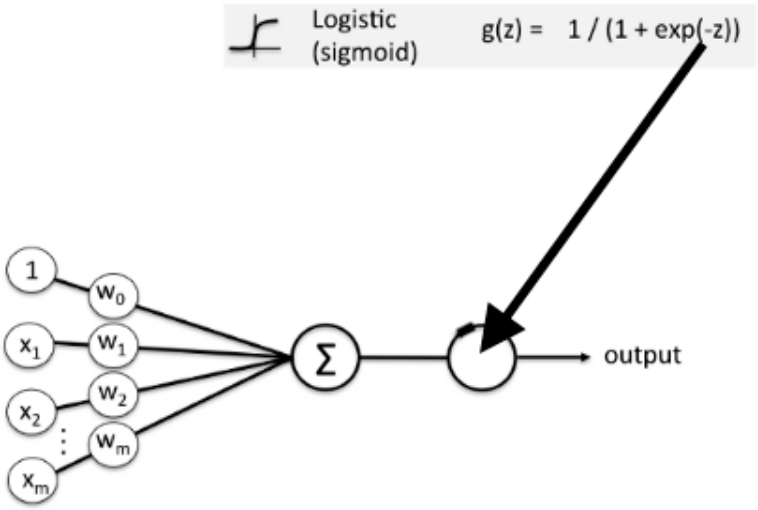
Deep Learning (DL) are Neural networks (NN) with >1 hidden layer



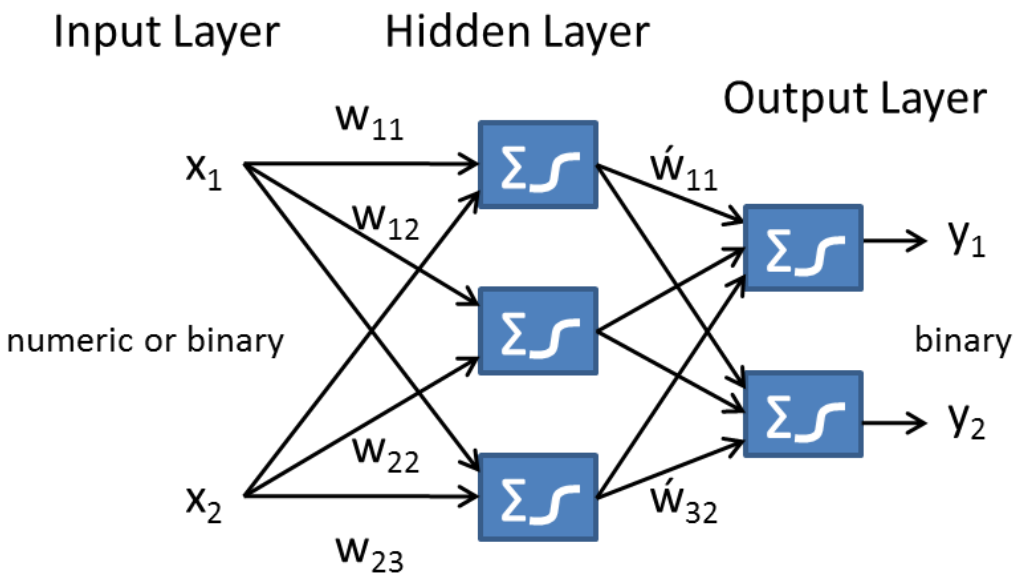
Neural Networks are Nodes & Edges



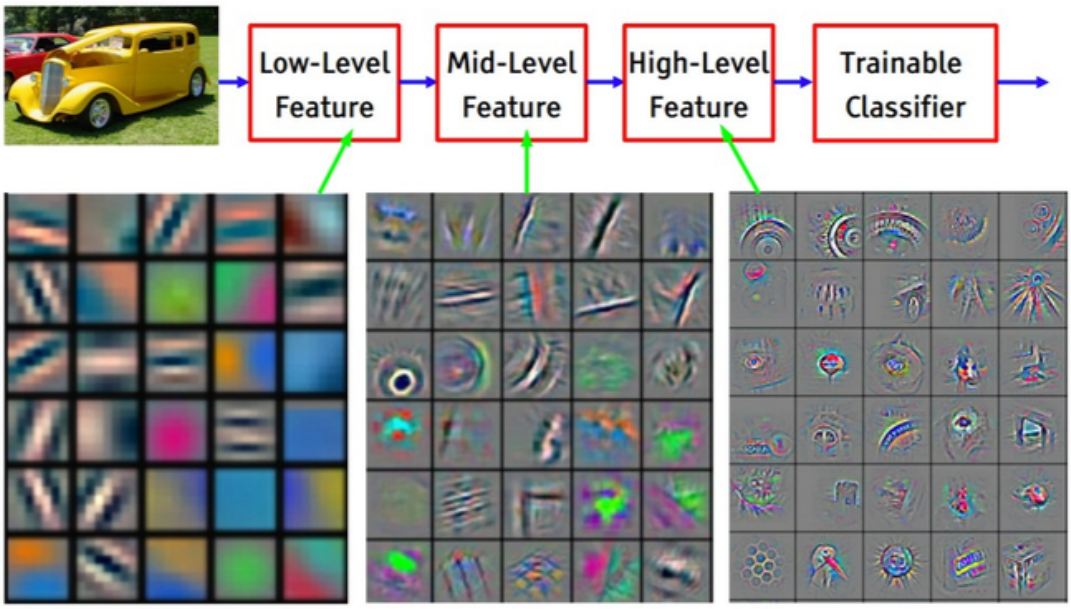
Nonlinear function allows learning of nonlinear relationships



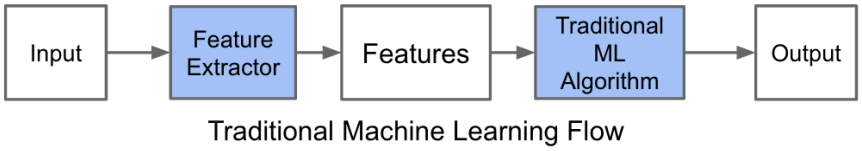
Groups of nodes all the way down



Deep Learning isn't magic, it is just very good at finding patterns



Deep Learning has fewer steps than traditional Machine Learning



Traditional Machine Learning Flow

Deep Learning Flow

If you want to follow along…

GitHub repo: bit.ly/pybay-keras (http://bit.ly/pybay-keras)

If you want to type along…

1. **Run a local Jupyter Notebook**
2. **Binder (https://mybinder.org/v2/gh/brianspiering/keras-intro/master): In-Browser Jupyter Notebook**
3. **Colaboratory (https://colab.research.google.com/): "Google Docs for Jupyter Notebooks"**

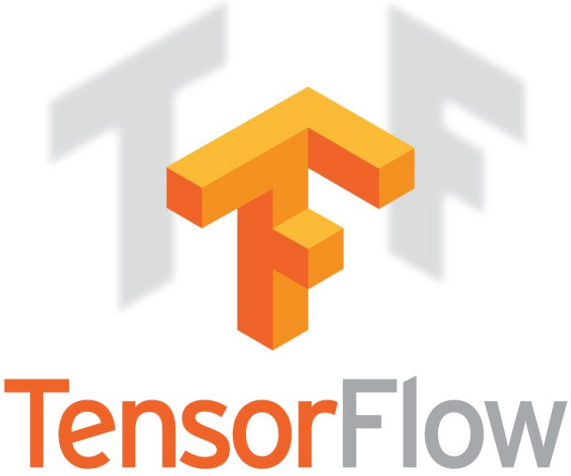
```
In [339]: reset -fs
```

```
In [340]: import keras
```

```
In [341]: # What is the backend / execution engine?
```

```
In [342]: keras.backend.backend()
```

```
Out[342]: 'tensorflow'
```



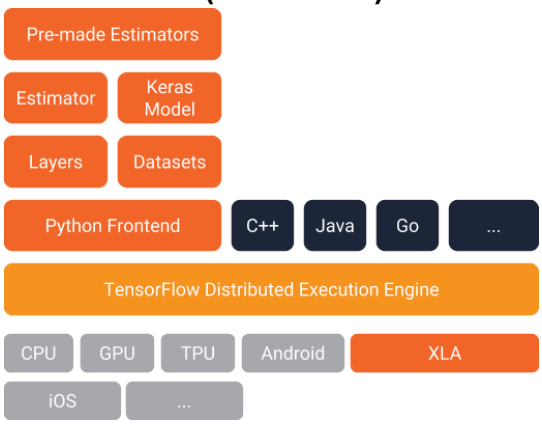
An open-source software library for Machine Intelligence

Numerical computation using data-flow graphs (DFG)

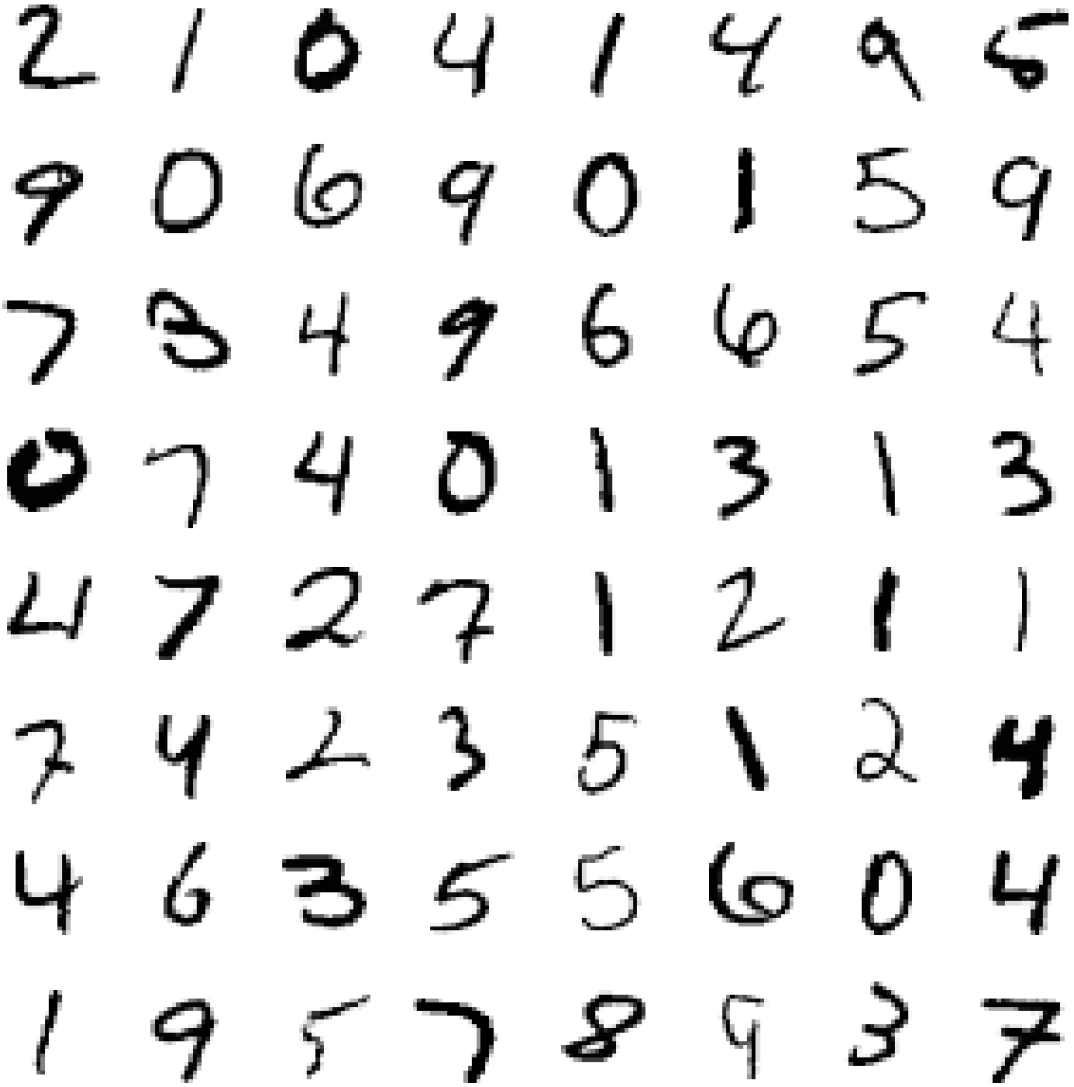
TensorFlow: A great backend

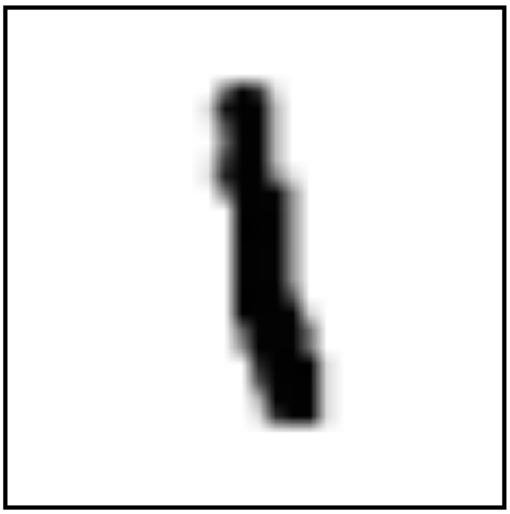
A very flexible architecture which allows you to do almost any numerical operation.

Then deploy the computation to CPUs or GPUs (one or more) across desktop, cloud, or mobile device.



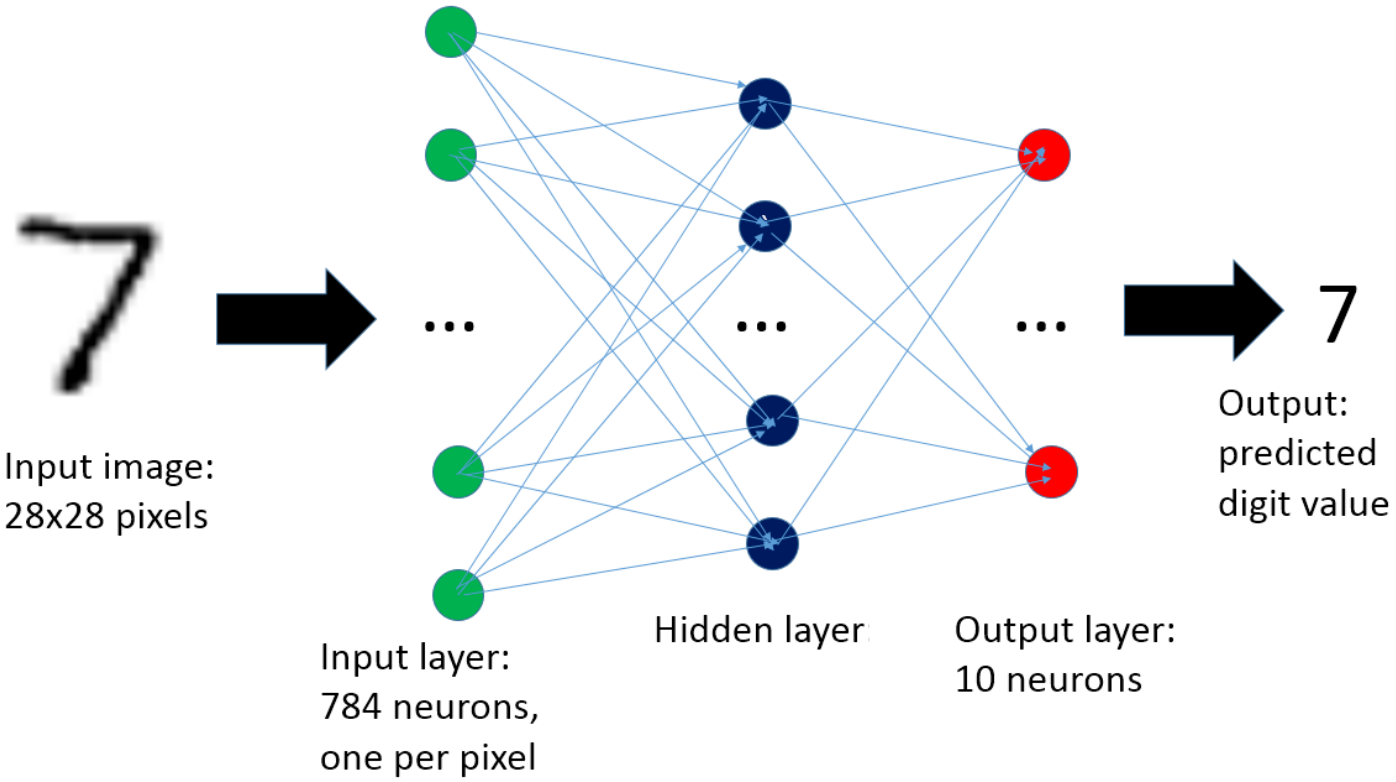
MNIST handwritten digit database:
The “Hello World!” of Computer Vision





$\simeq$

$$\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .6 & .8 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .7 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .7 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & .5 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .4 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & .7 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & .9 & 1 & .1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & .3 & 1 & .1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$



In [343]:
```
# Import data
```

In [344]:
```
from keras.datasets import mnist
```

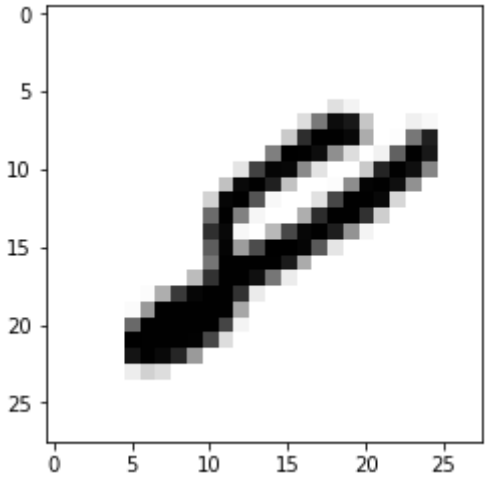
In [345]:
```
# Setup train and test splits
```

In [346]:
```
(x_train, y_train), (x_test, y_test) = mnist.load_data()
```

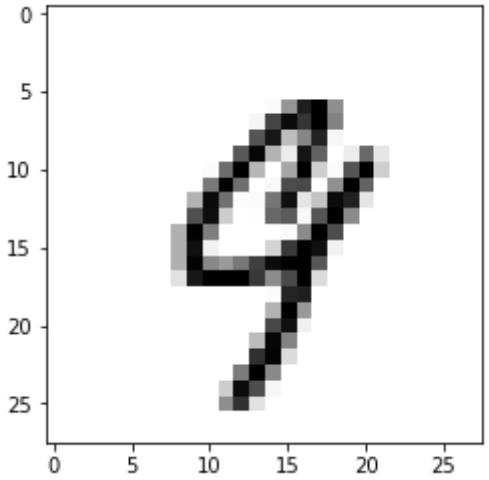
In [347]:
```
from random import randint
from matplotlib import pyplot

%matplotlib inline

# protip - visually inspect your data
i = randint(0, x_train.shape[0])
pyplot.imshow(x_train[i], cmap='gray_r');
```



In [348]:
```
i = 27_074
pyplot.imshow(x_train[i], cmap='gray_r');
```

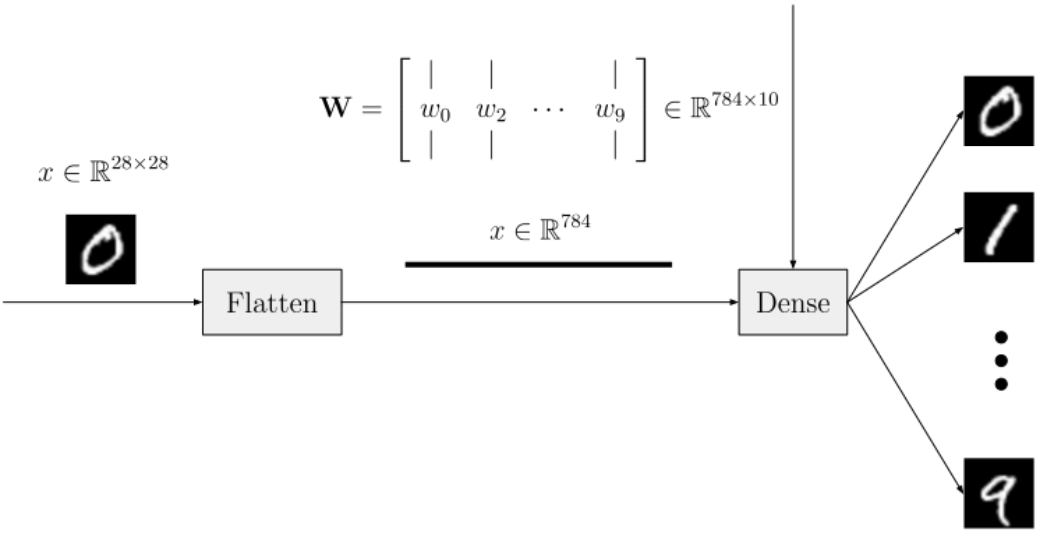


Is this thing a 4 or 9?

In [349]:
```
y_train[i]
```

Out[349]: 9

Munge data



Convert image matrix into vector to feed into first layer

In [350]:
```
# Munge Data
```

In [351]:
```
image_size = 784 # 28 x 28

x_train = x_train.reshape(x_train.shape[0], image_size) # Transform from
 matrix to vector
x_train = x_train.astype('float32') # Cast as 32 bit integers
x_train /= 255 # Normalize inputs from 0-255 to 0.0-1.0

x_test = x_test.reshape(x_test.shape[0], image_size) # Transform from ma
trix to vector
x_test = x_test.astype('float32') # Cast as 32 bit integers
x_test /= 255 # Normalize inputs from 0-255 to 0.0-1.0
```

In [352]:
```
# Convert class vectors to binary class matrices
```

In [353]:
```
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)
```

In [354]:
```
# Import the most common type of neural network
```

In [355]:
```
from keras.models import Sequential
```

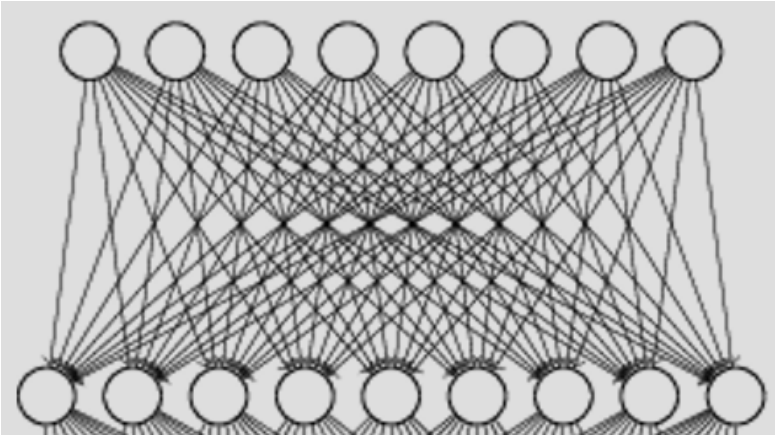
In [356]:
```
# Define model instance
```

In [357]:
```
model = Sequential()
```

In [358]:
```
# Import the most common type of network layer, fully interconnected
```

In [359]:
```
from keras.layers import Dense
```

RTFM - https://keras.io/layers/ (https://keras.io/layers/)



In [360]:
```
# Define input layer
```

In [361]:
```
layer_input = Dense(units=512,             # Number of nodes
                    activation='sigmoid', # The nonlinearity
                    input_shape=(image_size,))
model.add(layer_input)
```

In [362]:
```
# Define another layer
```

In [363]:
```
model.add(Dense(units=512, activation='sigmoid'))
```

In [364]:
```
# Define output layers
```

In [365]:
```
layer_output = Dense(units=10,              # Number of digits (0-9)
                     activation='softmax') # Convert neural activation t
o probability of category

model.add(layer_output)
```

In [366]:
```
# Print summary of model architecture
```

In [367]:
```
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_20 (Dense)             (None, 512)               401920
_________________________________________________________________
dense_21 (Dense)             (None, 512)               262656
_________________________________________________________________
dense_22 (Dense)             (None, 10)                5130
=================================================================
Total params: 669,706
Trainable params: 669,706
Non-trainable params: 0
_________________________________________________________________
```

In [368]:
```
# Add training paramters to architecture
```

In [369]:
```
# Yes - we compile the model to run it
model.compile(loss='categorical_crossentropy',
              optimizer='sgd',
              metrics=['accuracy'])
```

In [370]:
```
# Train the model to learn weights
```

In [371]:
```
training = model.fit(x_train,
                     y_train,
                     epochs=5, # Number of passes over complete dataset
                     verbose=True,
                     validation_split=0.1)
```

```
Train on 54000 samples, validate on 6000 samples
Epoch 1/5
54000/54000 [==============================] - 17s 312us/step - loss:
2.1620 - acc: 0.3160 - val_loss: 1.9285 - val_acc: 0.4772
Epoch 2/5
54000/54000 [==============================] - 15s 272us/step - loss:
1.5386 - acc: 0.6498 - val_loss: 1.1031 - val_acc: 0.7738
Epoch 3/5
54000/54000 [==============================] - 13s 245us/step - loss:
0.9209 - acc: 0.7743 - val_loss: 0.6921 - val_acc: 0.8255
Epoch 4/5
54000/54000 [==============================] - 15s 284us/step - loss:
0.6692 - acc: 0.8217 - val_loss: 0.5246 - val_acc: 0.8690
Epoch 5/5
54000/54000 [==============================] - 15s 283us/step - loss:
0.5523 - acc: 0.8482 - val_loss: 0.4430 - val_acc: 0.8845
```

In [372]:
```
# Let's see how well our model performs
```

In [373]:
```
loss, accuracy = model.evaluate(x_test,
                                y_test,
                                verbose=True)
print(f"Test loss: {loss:.3}")
print(f"Test accuracy: {accuracy:.3%}")
```

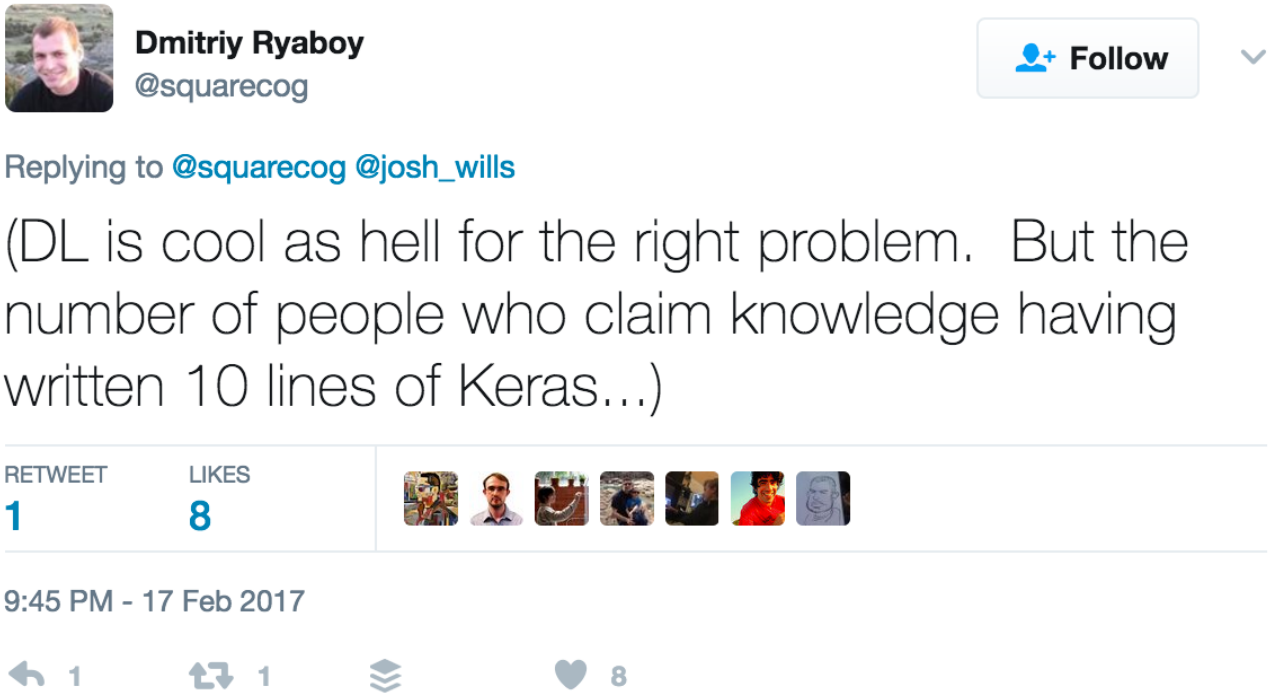
```
10000/10000 [==============================] - 1s 79us/step
Test loss: 0.494
Test accuracy: 86.230%
```

Keras' Other Features

- Common built-in functions (e.g., activation functions and optimitizers)
- Convolutional neural network (CNN or ConvNet)
- Recurrent neural network (RNN) & Long-short term memory (LSTM)
- Pre-trained models

Summary

- **Keras is designed for human beings, not computers.**
- **Easier to try out Deep Learning (focus on the what, not the how).**
- **Simple to define neural networks.**



Futher Study - Keras

- [Keras docs (https://keras.io/)](https://keras.io/)
- [Keras blog (https://blog.keras.io/)](https://blog.keras.io/)
- Keras courses
  - [edX (https://www.edx.org/course/deep-learning-fundamentals-with-keras)](https://www.edx.org/course/deep-learning-fundamentals-with-keras)
  - [Coursera (https://www.coursera.org/lecture/ai/keras-overview-7GfN9)](https://www.coursera.org/lecture/ai/keras-overview-7GfN9)

Futher Study - Deep Learning

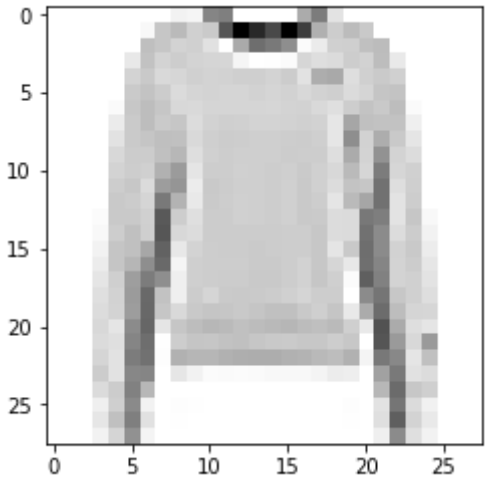
- **Prerequisites: Linear Algebra, Probability, Machine Learning**
- [fast.ai Course (http://www.fast.ai/)](http://www.fast.ai/)
- [Deep Learning Book (http://www.deeplearningbook.org/)](http://www.deeplearningbook.org/)

Bonus Material

In [389]:
```
from keras.datasets import fashion_mnist
```

In [390]:
```
# Setup train and test splits
(x_train, y_train), (x_test, y_test) = fashion_mnist.load_data()
```

In [391]:
```
pyplot.imshow(x_train[randint(0, x_train.shape[0])], cmap='gray_r');
```



In [392]:
```
# Define CNN model

# Redefine input dimensions to make sure conv works
img_rows, img_cols = 28, 28
x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
input_shape = (img_rows, img_cols, 1)
```

In [393]:
```
# Convert class vectors to binary class matrices
y_train = keras.utils.to_categorical(y_train, 10)
y_test = keras.utils.to_categorical(y_test, 10)
```

In [394]:
```
from keras.layers import Conv2D, Dense, Flatten, MaxPooling2D
```

In [398]:
```
# Define model
model = Sequential()
model.add(Conv2D(32,
         kernel_size=(3, 3),
         activation='relu',
         input_shape=input_shape))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dense(10, activation='softmax'))
```

In [401]:
```
model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_5 (Conv2D)            (None, 26, 26, 32)        320
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 24, 24, 64)        18496
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 12, 12, 64)        0
_________________________________________________________________
flatten_3 (Flatten)          (None, 9216)              0
_________________________________________________________________
dense_25 (Dense)             (None, 128)               1179776
_________________________________________________________________
dense_26 (Dense)             (None, 10)                1290
=================================================================
Total params: 1,199,882
Trainable params: 1,199,882
Non-trainable params: 0
_________________________________________________________________
```

In [402]:
```
model.compile(loss='categorical_crossentropy',
              optimizer='adam',a
              metrics=['accuracy'])
```

```
  File "<ipython-input-402-d99bd37e4570>", line 3
    metrics=['accuracy'])
           ^
SyntaxError: invalid syntax
```

In [403]:
```
# Define training
training = model.fit(x_train,
                     y_train,
                     epochs=1,
                     verbose=True,
                     validation_split=0.1)
```

```
Train on 54000 samples, validate on 6000 samples
Epoch 1/1
54000/54000 [==============================] - 171s 3ms/step - loss: 0.
4744 - acc: 0.8259 - val_loss: 0.4301 - val_acc: 0.8398
```

In [404]:
```
loss, accuracy = model.evaluate(x_test,
                                y_test,
                                verbose=True)
print(f"Test loss: {loss:.3}")
print(f"Test accuracy: {accuracy:.3%}")
```

```
10000/10000 [==============================] - 8s 826us/step
Test loss: 0.448
Test accuracy: 83.590%
```

What is `keras`?

Keras (κέρας) means horn in Greek.

It is a reference to a literary image from ancient Greek and Latin literature.

First found in the Odyssey, where dream spirits (Oneiroi, singular Oneiros) are divided between those who deceive men with false visions, who arrive to Earth through a gate of ivory, and those who announce a future that will come to pass, who arrive through a gate of horn.

It's a play on the words κέρας (horn) / κραίνω (fulfill), and ἐλέφας (ivory) / ἐλεφαίρομαι (deceive).

Source (https://keras.io/#why-this-name-keras)