Deep Learning

3007/7059 Artificial Intelligence

School of Computer Science
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MNIST LeNet Classifier

- Required packages:
  - Python version 3.5
  - numpy version 1.10 or later: http://www.numpy.org/
  - scipy version 0.16 or later: http://www.scipy.org/
  - matplotlib version 1.4 or later: http://matplotlib.org/
  - pandas version 0.16 or later: http://pandas.pydata.org
  - scikit-learn version 0.15 or later: http://scikit-learn.org
  - keras version 2.0 or later: http://keras.io
  - tensorflow version 1.0 or later: https://www.tensorflow.org
  - ipython/jupyter version 4.0 or later, with notebook support
- Optional packages:
  - pyyaml
  - hdf5 and h5py (required if you use model saving/loading functions in keras)
  - NVIDIA cuDNN if you have NVIDIA GPUs on your machines. https://developer.nvidia.com/rdp/cudnn-download
- Anaconda (from Continuum) has most of the packages above.

MNIST LeNet Classifier

- ./jupyter notebook
- Test your packages

In [1]:
```
import numpy as np
import scipy as sp
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import matplotlib
import IPython
import sklearn
import keras
```

```
Using TensorFlow backend.
```

In [2]:
```
print('numpy:', np.__version__)
print('scipy:', sp.__version__)
print('matplotlib:', matplotlib.__version__)
print('iPython:', IPython.__version__)
print('scikit-learn:', sklearn.__version__)
print('keras: ', keras.__version__)
import tensorflow as tf
print('Tensorflow: ', tf.__version__)
```

```
numpy: 1.13.3
scipy: 1.0.0
matplotlib: 2.1.0
iPython: 6.2.1
scikit-learn: 0.19.1
keras:  2.1.2
Tensorflow:  1.4.0
```

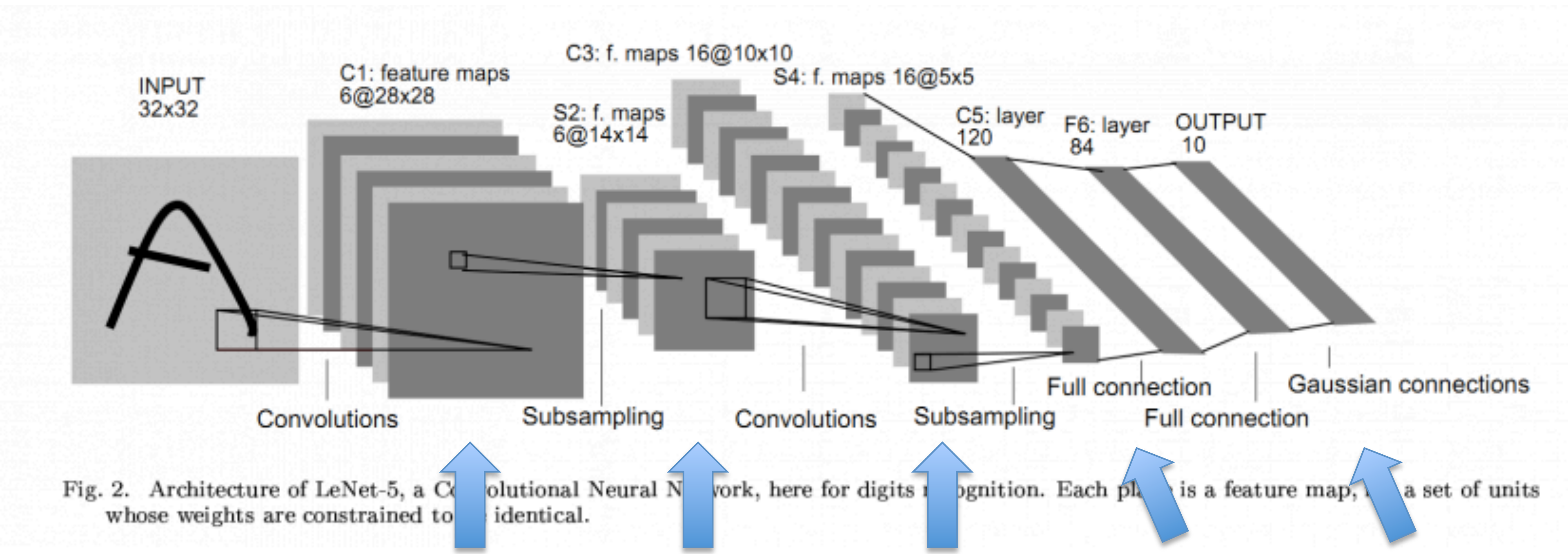
MNIST LeNet Classifier

- Load Keras packages for the CNN layers

```
In [3]: from keras.datasets import mnist
        from keras.models import Sequential
        from keras.layers import Dense, Flatten
        from keras.layers import Conv2D, MaxPooling2D
        from keras import backend as K
```

- mnist has the MNIST dataset
- Sequential model is a linear stack of layers
- Dense, Flatten, Conv2D and MaxPooling2D are the layer types we will use

MNIST LeNet Classifier



Conv2D (6 filters of size 5x5)

MaxPooling2D

Conv2D (16 filters of size 5x5)

MaxPooling2D + Flatten

3 Dense layers

1. Why feature maps change sizes during convolution? How can I avoid that?
2. How is the 2D convolution done with 6 channels of 14x14 inputs?

MNIST LeNet Classifier

- Training parameters
  - batch_size: number of images at each step of gradient descent
  - num_classes: number of MNIST classes (10)
  - epochs: number of times the whole training set is used for training
  - img_rows, img_cols: image size

In [4]:
```
# batch size for gradient descent
batch_size = 128
# number of MNIST classes
num_classes = 10
# number of epochs (1 epoch = amount of iterations that covers the whole training set)
epochs = 3 # try a larger number of epochs here (for example 10 or larger)
# input image dimensions
img_rows, img_cols = 28, 28
```

MNIST LeNet Classifier

- Loading the data, and adjusting image dimensions

```
In [5]: # the data, split between train and test sets
        (x_train, y_train), (x_test, y_test) = mnist.load_data()
```

```
In [6]: # adjust training image format
        if K.image_data_format() == 'channels_first':
            x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
            x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
            input_shape = (1, img_rows, img_cols)
        else:
            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)
```

MNIST LeNet Classifier

- Type casting input to be float32
- Normalizing gray values to be in [0,1]
- Verifying training and testing sets

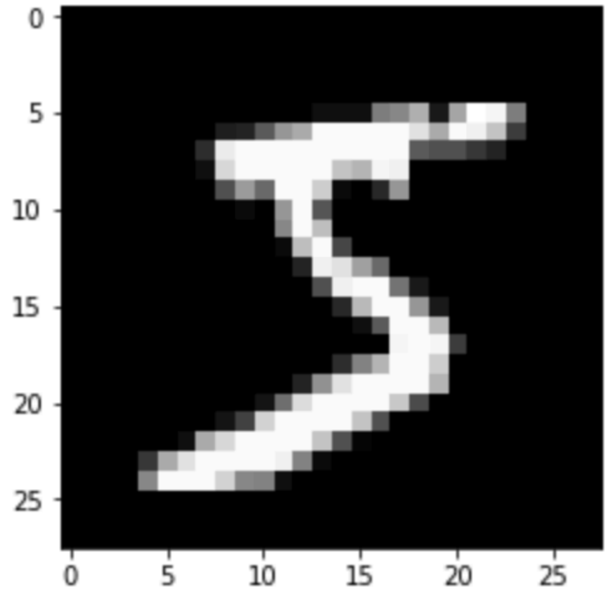
In [7]:
```
x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255
print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')
```

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
```

MNIST LeNet Classifier

- Visualizing the dataset

In [8]:
```
for i in range(10):
    first_image = x_train[i,:,:,0]
    first_image = np.array(first_image, dtype='float')
    pixels = first_image.reshape((28, 28))
    plt.imshow(pixels, cmap='gray')
    plt.show()
```



MNIST LeNet Classifier

- Convert labels to one-hot vectors

```
In [9]: # 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)
```

- Example
  - 4 -> [0 0 0 0 1 0 0 0 0 0]
  - 9 -> [0 0 0 0 0 0 0 0 0 1]

- Cross-entropy loss function – see explanation on the board.

MNIST LeNet Classifier

- Create Model

In [10]:
```
model = Sequential()
model.add(Conv2D(6, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Conv2D(16, (5, 5), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Flatten())
model.add(Dense(120, activation='relu'))
model.add(Dense(84, activation='relu'))
model.add(Dense(num_classes, activation='softmax'))
```

Note: softmax activation

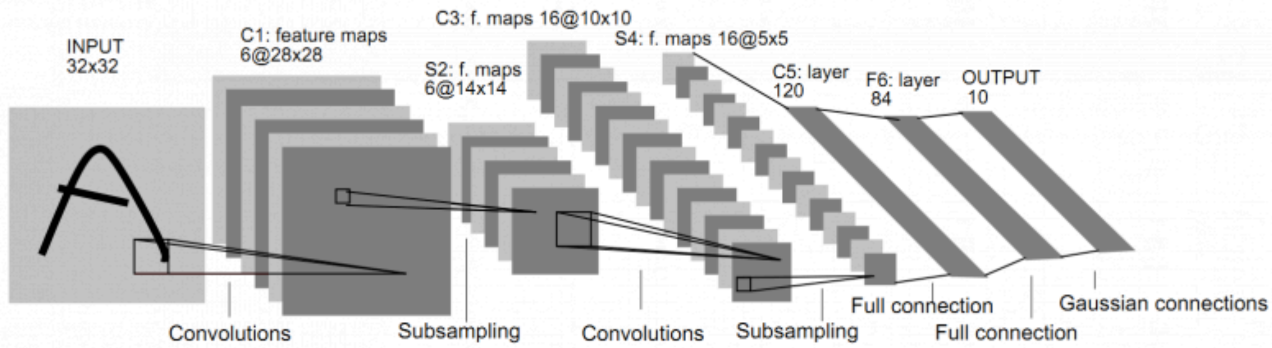


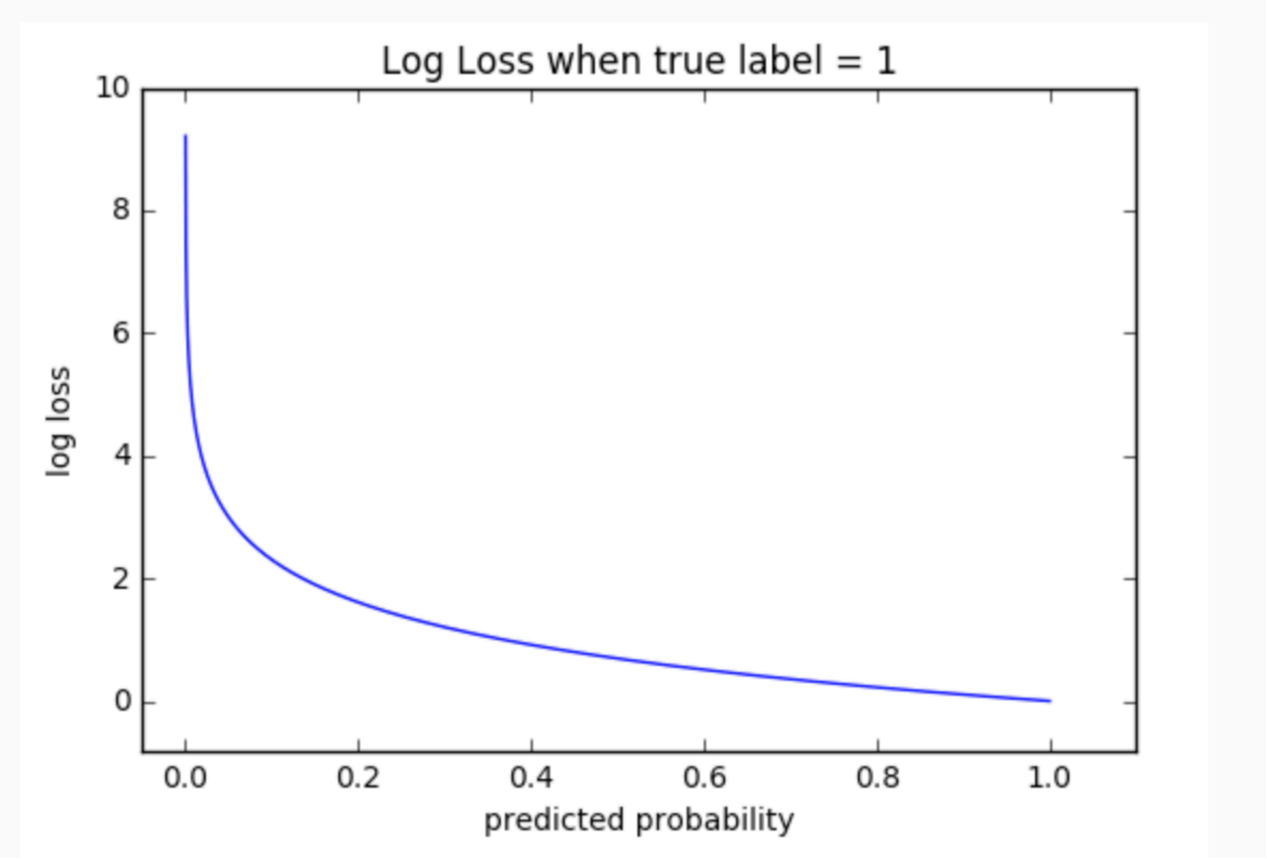
Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

MNIST LeNet Classifier

- Configuring the learning process:
  - An optimizer. This could be the string identifier of an existing optimizer (such as rmsprop or adagrad), or an instance of the Optimizer class. See: optimizers.
  - A loss function. This is the objective that the model will try to minimize. It can be the string identifier of an existing loss function (such as categorical_crossentropy or mse), or it can be an objective function. See: losses.
  - A list of metrics. For any classification problem you will want to set this to metrics=['accuracy']. A metric could be the string identifier of an existing metric or a custom metric function.

In [11]:
```
model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])
```

Cross entropy loss when true label is 1



MNIST LeNet Classifier

- Training… finally!

In [12]:
```
model.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/3
60000/60000 [==============================] - 16s 267us/step - loss: 0.3937 - acc: 0.8734 - val_loss: 0.1172 - val_a
cc: 0.9630
Epoch 2/3
60000/60000 [==============================] - 16s 261us/step - loss: 0.1030 - acc: 0.9677 - val_loss: 0.0770 - val_a
cc: 0.9757
Epoch 3/3
60000/60000 [==============================] - 16s 260us/step - loss: 0.0776 - acc: 0.9759 - val_loss: 0.0737 - val_a
cc: 0.9751
```

MNIST LeNet Classifier

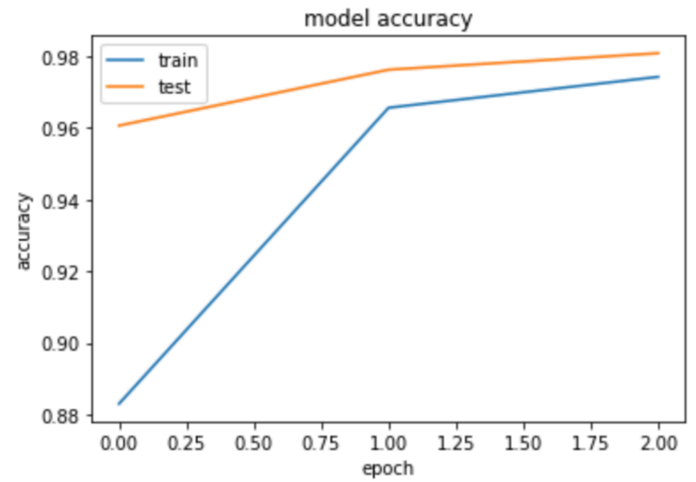
- Running the classifier

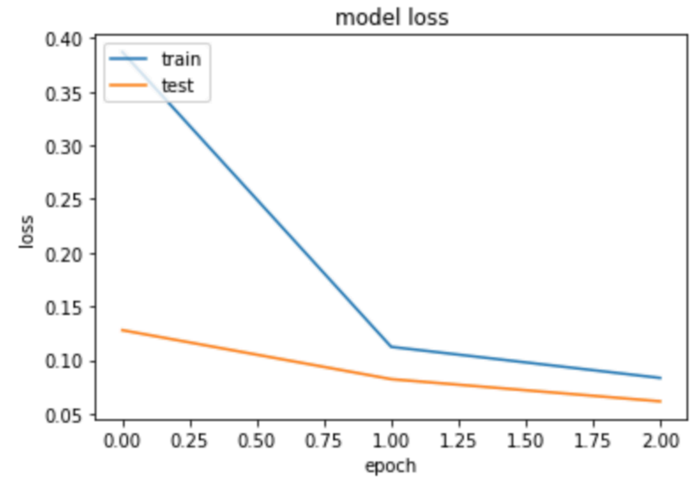
```
In [13]: score = model.evaluate(x_test, y_test, verbose=0)
         print('Test loss:', score[0])
         print('Test accuracy:', score[1])

Test loss: 0.0736543145942
Test accuracy: 0.9751
```

MNIST LeNet Classifier

- Plot graphs

In [15]:
```
# summarize history for accuracy
plt.plot(history.history['acc'])
plt.plot(history.history['val_acc'])
plt.title('model accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'test'], loc='upper left')
plt.show()
# summarize history for loss
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'test'], loc='upper left')
plt.show()
```





LSTMs

- Let's look at a couple of LSTM examples – just for fun, this is not going to be in your exam…