Young's Modulus Prediction

October 11, 2018

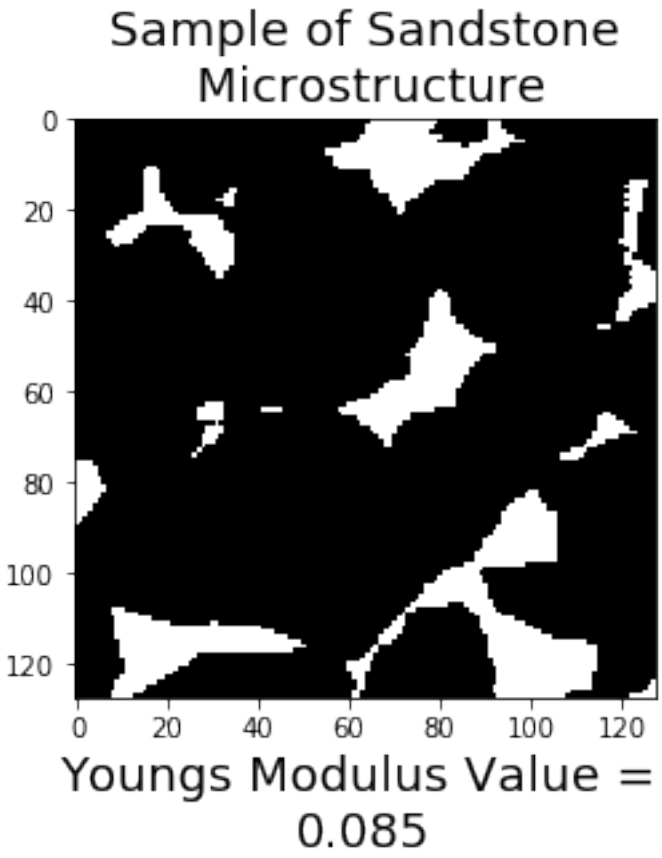
In [1]:
```
import numpy as np
import scipy.io as sio
from sklearn.metrics import mean_squared_error
from keras.models import Sequential, load_model
from keras.layers import Dense, Activation, Flatten
from keras.layers import Convolution2D, MaxPooling2D
from keras import backend as K
import matplotlib.pyplot as plt
np.random.seed(1337)  # for reproducibility
%matplotlib inline
```

```
Using TensorFlow backend.
```

In [2]:
```
# input image dimensions
img_rows, img_cols = 128, 128
# size of pooling area for max pooling
pool_size = (2, 2)
# convolution kernel size
kernel_size = (3, 3)

# Import the data
WB = np.array(sio.loadmat('sandstone_data.mat')['Data'])
Y_data = np.array(sio.loadmat('sandstone_data.mat')['L'])
# Normalize the data
X_data = np.reshape(WB,(len(WB),1,img_rows,img_cols))
Y_data = (Y_data-min(Y_data))/(max(Y_data)-min(Y_data))

# data splitting
X_train = X_data[:600]
Y_train = Y_data[:600]

X_val = X_data[600:700]
Y_val = Y_data[600:700]

X_test = X_data[700:]
Y_test = Y_data[700:]
```

```
# show image sample
axes = plt.gca()
plt.imshow(X_train[10].reshape(img_rows,img_cols),'gray')
axes.set_title('Sample of Sandstone\n Microstructure',fontsize=18)
axes.set_xlabel('Youngs Modulus Value = \n{:.2}'.format(Y_train[0][0]),fontsize=18)
```

Out[2]: Text(0.5,0,'Youngs Modulus Value = \n0.085')



In [3]:
```
# Adjust data shape for different Keras version
if K.image_dim_ordering() == 'th':
    X_train = X_train.reshape(X_train.shape[0], 1, img_rows, img_cols)
    X_val = X_val.reshape(X_val.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_val = X_val.reshape(X_val.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)
```

```
        # Tensorflow only take float32 data type
        X_train = X_train.astype('float32')
        X_val = X_val.astype('float32')
        X_test = X_test.astype('float32')

        # print out the data information
        print('X_train shape:', X_train.shape)
        print(X_train.shape[0], 'train samples')
        print(X_val.shape[0], 'validate samples')
        print(X_test.shape[0], 'test samples')
```

```
X_train shape: (600, 128, 128, 1)
600 train samples
100 validate samples
68 test samples
```

In [4]:
```
        # CNN Model
        model = Sequential()

        # block 1
        model.add(Convolution2D(24, (6, 6), padding='same', input_shape=input_shape))
        model.add(Activation('relu'))
        model.add(MaxPooling2D(pool_size=pool_size))

        # block 2
        model.add(Convolution2D(48, (3, 3), padding='same'))
        model.add(Activation('relu'))
        model.add(MaxPooling2D(pool_size=pool_size))

        # fully connected layers
        model.add(Flatten())
        model.add(Dense(100))
        model.add(Activation('relu'))
        model.add(Dense(1))
        model.add(Activation('sigmoid'))
        # model compile
        model.compile(loss='mse', optimizer='adam', metrics=['mae'])
        model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 128, 128, 24)      888
_________________________________________________________________
activation_1 (Activation)    (None, 128, 128, 24)      0
_________________________________________________________________
```

```
max_pooling2d_1 (MaxPooling2 (None, 64, 64, 24)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 64, 64, 48)        10416
_________________________________________________________________
activation_2 (Activation)    (None, 64, 64, 48)        0
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 32, 32, 48)        0
_________________________________________________________________
flatten_1 (Flatten)          (None, 49152)             0
_________________________________________________________________
dense_1 (Dense)              (None, 100)               4915300
_________________________________________________________________
activation_3 (Activation)    (None, 100)               0
_________________________________________________________________
dense_2 (Dense)              (None, 1)                 101
_________________________________________________________________
activation_4 (Activation)    (None, 1)                 0
=================================================================
Total params: 4,926,705
Trainable params: 4,926,705
Non-trainable params: 0
_________________________________________________________________
```

```
In [5]: # train the model
        from keras.callbacks import EarlyStopping
        early_stop = EarlyStopping(monitor='val_loss', min_delta=0, patience=0, verbose=0, mode
        model.fit(X_train, Y_train, batch_size=50, epochs=100, verbose=1, validation_data=(X_va
                  callbacks=[early_stop], initial_epoch=0)
```

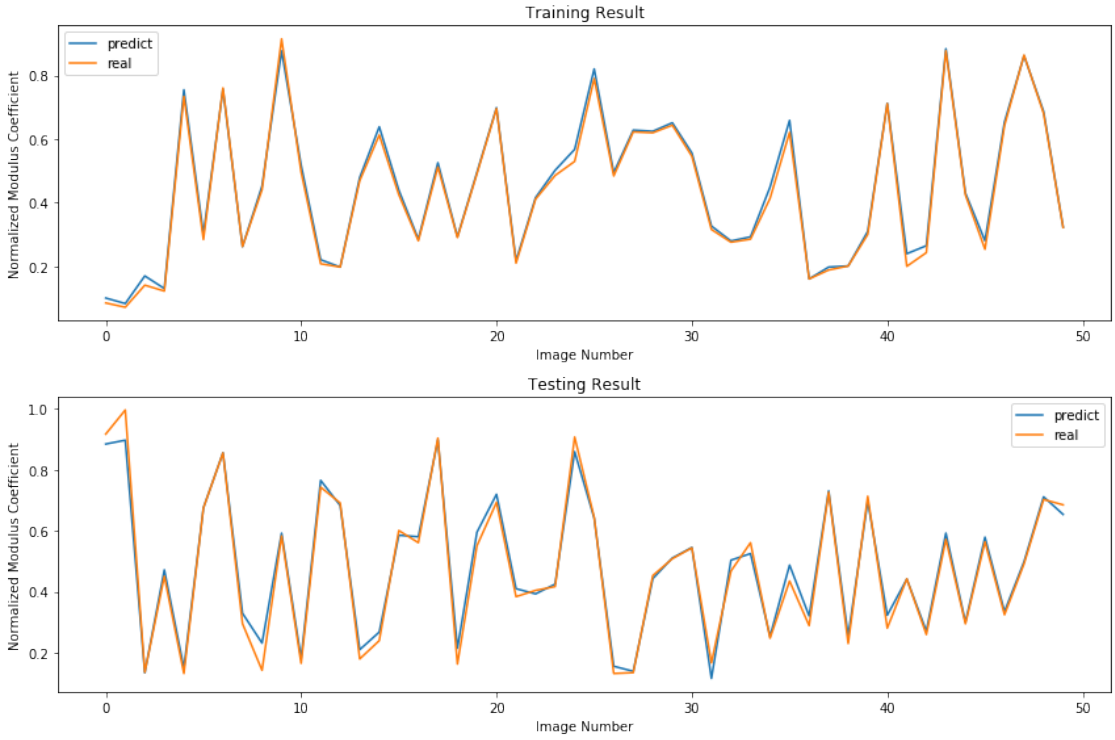
```
Train on 600 samples, validate on 100 samples
Epoch 1/100
600/600 [==============================] - 17s 29ms/step - loss: 0.1625 - mean_absolute_error:
Epoch 2/100
600/600 [==============================] - 16s 27ms/step - loss: 0.0537 - mean_absolute_error:
Epoch 3/100
600/600 [==============================] - 16s 27ms/step - loss: 0.0215 - mean_absolute_error:
Epoch 4/100
600/600 [==============================] - 15s 24ms/step - loss: 0.0051 - mean_absolute_error:
Epoch 5/100
600/600 [==============================] - 15s 25ms/step - loss: 0.0018 - mean_absolute_error:
Epoch 6/100
600/600 [==============================] - 15s 25ms/step - loss: 0.0011 - mean_absolute_error:
Epoch 7/100
600/600 [==============================] - 15s 25ms/step - loss: 6.6768e-04 - mean_absolute_er
Epoch 8/100
600/600 [==============================] - 15s 24ms/step - loss: 4.9390e-04 - mean_absolute_er
Epoch 9/100
```

```
600/600 [==============================] - 17s 28ms/step - loss: 4.1674e-04 - mean_absolute_er
Epoch 10/100
600/600 [==============================] - 16s 27ms/step - loss: 3.6740e-04 - mean_absolute_er
```

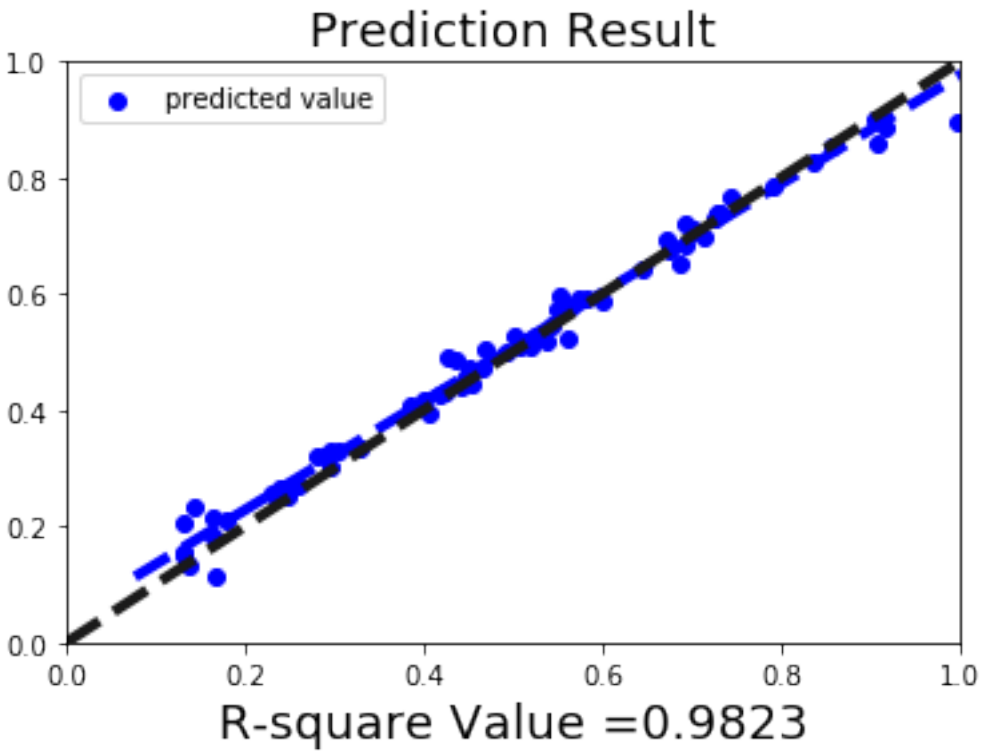
Out[5]: <keras.callbacks.History at 0x7f44d45edd68>

In [8]:
```
# the number of points to show as comparison
num_comp=50
x=np.arange(num_comp)

# define plot size
fig = plt.figure(figsize=(12,8))
ax1=fig.add_subplot(2,1,1)

# prediction value by training set
train_pred=model.predict(X_train)
print('training mse:', mean_squared_error(Y_train, train_pred))

ax1.plot(x,train_pred[0:num_comp], label='predict')
ax1.plot(x,Y_train[0:num_comp],label='real')
plt.legend()
ax1.set_title('Training Result')
ax1.set_xlabel('Image Number')
ax1.set_ylabel('Normalized Modulus Coefficient')


ax2=fig.add_subplot(2,1,2)

# prediction value by testing set
test_pred=model.predict(X_test)
print('testing mse:', mean_squared_error(Y_test, test_pred))

ax2.plot(x,test_pred[0:num_comp], label='predict')
ax2.plot(x,Y_test[0:num_comp],label='real')
plt.legend()
ax2.set_title('Testing Result')
ax2.set_xlabel('Image Number')
ax2.set_ylabel('Normalized Modulus Coefficient')

plt.tight_layout()
```

```
training mse: 0.0003691139357478827
testing mse: 0.0008954447495822719
```




```
In [9]: from sklearn.metrics import r2_score
        plt.scatter(Y_test.reshape(-1),test_pred,label='predicted value',color='blue')
        axes = plt.gca()
        m, b = np.polyfit(Y_test.reshape(-1), test_pred, 1)
        X_plot = np.linspace(axes.get_xlim()[0],axes.get_xlim()[1],100)
        plt.plot(X_plot, m*X_plot + b, '--',color='blue',linewidth=4)

        plt.plot([0, 1], [0, 1], ls="--", c=".1",linewidth=4)
        plt.legend()
        axes.set_title('Prediction Result',fontsize=18)
        axes.set_xlabel('R-square Value ={:.4}'.format(r2_score(Y_test.reshape(-1), test_pred.
        plt.ylim(0.0,1.0)
        plt.xlim(0.0,1.0)

Out[9]: (0.0, 1.0)
```


Prediction Result
predicted value
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
R-square Value =0.9823

In [ ]: