MNIST Hand-written digit classification

2019/3/22 성남-KAIST 인공지능 집중교육과정

Tip> shotcuts for Jupyter Notebook

- Shift + Enter : run cell and select below

Library

- Numpy: Fundamenta package for scientific computing with Python
- Tensorflow: An open source machine learning library for research and production
- Matplotlib: Python 2D plottin glibrary

```
from __future__ import print_function
from collections import namedtuple
from functools import partial

import numpy as np
import tensorflow as tf
import matplotlib.pyplot as plt
import time

from tensorflow.examples.tutorials.mnist import input_data
from tensorflow.python.training import moving_averages

tf.logging.set_verbosity(tf.logging.ERROR)
```

1. Prepare the data

[MNIST dataset]

The MNIST has a training set of 55,000 examples, a validation set of 5,000 examples and a test set of 10,000 examples.

```
mnist = input_data.read_data_sets('./data/', one_hot=True)
```

```
Extracting ./data/train-images-idx3-ubyte.gz
Extracting ./data/train-labels-idx1-ubyte.gz
Extracting ./data/t10k-images-idx3-ubyte.gz
Extracting ./data/t10k-labels-idx1-ubyte.gz
```

Load the training dataset

```
train_images = mnist.train.images
train_labels = mnist.train.labels
train_images = train_images.reshape([-1, 28, 28, 1])
```

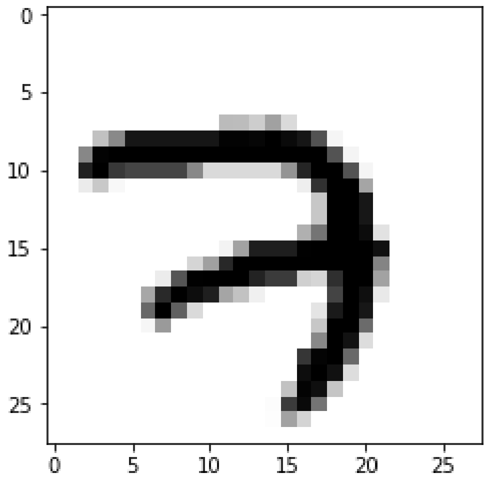
Load the validation sets

```
val_images = mnist.validation.images
val_labels = mnist.validation.labels
val_images = val_images.reshape([-1, 28, 28, 1])
```

Plot the 1st hand-written digit and its one-hot label

```
plt.imshow(train_images[0,:,:,0], cmap='Greys')
print("\nOne-hot labels for this image:")
print(train_labels[0])
```

```
One-hot labels for this image:
[0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
```



2. Build a graph

Set hyperparameters

- ***log_dir*** : Directory name to save models
- ***n_epochs*** : Maximun training epoch
- ***n_outputs*** : The number of classes for labels
- ***init_lr*** : Learning rate for gradient descent
- ***l2_lambda*** : regularization parameter
- ***batch_size*** : The number of images to update paramerters once

```
log_dir = 'logs/'
n_epochs = 20
n_outputs = 10
init_lr = 0.01
batch_size = 100
l2_lambda = 0.0001
```

Placeholder for learning rate, input images and labels

```
images = tf.placeholder(tf.float32, shape=(None, 28, 28, 1), name='images')
labels = tf.placeholder(tf.int32, shape=(None), name='labels')
```

DNN model

```
def DNN(images):

    ''' 1st hidden layer '''
    x =                             # fully-connected layer with 200 units
    x =                             # batch normalization
    x =                             # ReLU activation

    ''' 2nd hidden layer '''
    x =                             # fully-connected layer with 100 units
    x =                             # batch normalization
    x =                             # tanh activation

    return x
```

Build a model

```
global_step = tf.Variable(0, trainable=False)

## Reshape
inputs = tf.reshape(images, [-1, 28*28])

with tf.variable_scope('embed') as scope:
    feats = DNN(inputs)

## Logits
logits = tf.layers.dense(feats, n_outputs,
kernel_initializer=tf.uniform_unit_scaling_initializer(factor=2.0),

kernel_regularizer=tf.contrib.layers.l2_regularizer(l2_lambda))
```

```
## Evaluation
correct = tf.nn.in_top_k(logits, labels, 1)
accuracy = tf.reduce_mean(tf.cast(correct, tf.float32))

## SOFTMAX
preds = tf.nn.softmax(logits)

## Cost function
cent = tf.nn.softmax_cross_entropy_with_logits_v2(logits=logits, labels=labels)
cost_cls = tf.reduce_mean(cent, name='cent')
```

L2 regularization

```
reg_losses = tf.get_collection(tf.GraphKeys.REGULARIZATION_LOSSES)
cost = tf.add_n([cost_cls] + reg_losses)
```

Momentum optimizer

```
optimizer =                    # Momentum optimizer with momentum 0.9

```

3. Train a model

Create a session and initialize parameters

Tensorflow operations must be executed in the session.

```
## MAKE SESSION
sess = tf.Session()

## INITIALIZE SESSION
sess.run(tf.global_variables_initializer())
```

Updates parameters with back-propagation

```
start_time = time.time()

for epoch in range(n_epochs+1):
    for iteration in range(mnist.train.num_examples // batch_size):

        X_batch, y_batch = mnist.train.next_batch(batch_size)
```

```
        X_batch = X_batch.reshape([-1, 28, 28, 1])
        (_, loss, loss_cls, prediction) = sess.run([train_op, cost, cost_cls, preds],
                                           feed_dict={images: X_batch, labels:
y_batch})
        duration = time.time() - start_time
        sec_per_batch = float(duration)

    ## Training accuracy every one epoch
    acc_train = accuracy.eval(session=sess, feed_dict={images: X_batch, labels:
np.argmax(y_batch, axis=1)})
    if epoch % 1 == 0:
        print('  [*] TRAINING Iteration %d, Loss: %.4f, Acc: %.4f (duration: %.3fs)'
                     % (epoch, loss_cls, acc_train, sec_per_batch))

    ## Validation accuracy every 5 epochs
    if epoch % 5 == 0:
        acc_val = accuracy.eval(session=sess, feed_dict={images: val_images, labels:
np.argmax(val_labels, axis=1)})
        print('  [*] VALIDATION ACC: %.3f' % acc_val)

print('Optimization done.')
```

```
  [*] TRAINING Iteration 0, Loss: 0.1393, Acc: 0.9800 (duration: 1.447s)
  [*] VALIDATION ACC: 0.938
  [*] TRAINING Iteration 1, Loss: 0.1997, Acc: 0.9500 (duration: 2.545s)
  [*] TRAINING Iteration 2, Loss: 0.2013, Acc: 0.9400 (duration: 3.703s)
  [*] TRAINING Iteration 3, Loss: 0.1167, Acc: 0.9800 (duration: 4.800s)
  [*] TRAINING Iteration 4, Loss: 0.2359, Acc: 0.9400 (duration: 5.963s)
  [*] TRAINING Iteration 5, Loss: 0.1116, Acc: 0.9800 (duration: 7.151s)
  [*] VALIDATION ACC: 0.971
  [*] TRAINING Iteration 6, Loss: 0.0688, Acc: 0.9900 (duration: 8.391s)
  [*] TRAINING Iteration 7, Loss: 0.1584, Acc: 0.9600 (duration: 9.672s)
  [*] TRAINING Iteration 8, Loss: 0.0415, Acc: 0.9900 (duration: 10.971s)
  [*] TRAINING Iteration 9, Loss: 0.0663, Acc: 0.9900 (duration: 12.214s)
  [*] TRAINING Iteration 10, Loss: 0.1180, Acc: 0.9800 (duration: 13.503s)
  [*] VALIDATION ACC: 0.977
  [*] TRAINING Iteration 11, Loss: 0.0124, Acc: 1.0000 (duration: 14.739s)
  [*] TRAINING Iteration 12, Loss: 0.0318, Acc: 0.9900 (duration: 16.016s)
  [*] TRAINING Iteration 13, Loss: 0.0648, Acc: 0.9900 (duration: 17.268s)
  [*] TRAINING Iteration 14, Loss: 0.0342, Acc: 0.9900 (duration: 18.402s)
  [*] TRAINING Iteration 15, Loss: 0.0784, Acc: 0.9800 (duration: 19.591s)
  [*] VALIDATION ACC: 0.979
  [*] TRAINING Iteration 16, Loss: 0.0547, Acc: 0.9900 (duration: 20.768s)
  [*] TRAINING Iteration 17, Loss: 0.0197, Acc: 1.0000 (duration: 21.981s)
  [*] TRAINING Iteration 18, Loss: 0.0494, Acc: 0.9900 (duration: 23.131s)
  [*] TRAINING Iteration 19, Loss: 0.0271, Acc: 1.0000 (duration: 24.292s)
  [*] TRAINING Iteration 20, Loss: 0.0527, Acc: 0.9800 (duration: 25.515s)
  [*] VALIDATION ACC: 0.980
Optimization done.
```

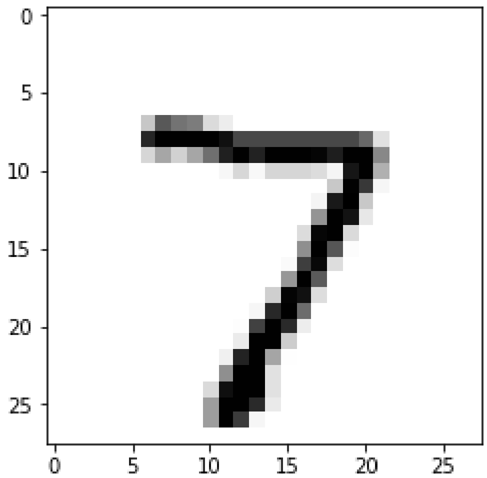
4. Test a model

Load the test images and labels

```
## READ MNIST INPUTS
test_images = mnist.test.images
test_labels = mnist.test.labels
test_images = test_images.reshape([-1, 28, 28, 1])

## Plot the 1st test image and label
plt.imshow(test_images[0,:,:,0], cmap='Greys')
print("\nOne-hot labels for this image:")
print(test_labels[0])
```

```
One-hot labels for this image:
[0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
```



Check the prediction for the first image

```
prediction = sess.run(preds, feed_dict={images:
test_images[0,:,:,0].reshape(1,28,28,1), labels: test_labels[0]})

print("The prediction of the network is: %d" % np.argmax(prediction))
```

```
The prediction of the network is: 7
```

Average the accuray for test set

```
test_acc = accuracy.eval(session=sess, feed_dict={images: test_images, labels: 
np.argmax(test_labels, axis=1)})
print('Acc: %.3f' % test_acc)
```

```
Acc: 0.979
```

The number of parameters

```
n_parameters = 0
for var in tf.trainable_variables():
    n_parameters += tf.size(var)
n_dnn = sess.run(n_parameters)
print("The number of parameters: %d" % n_dnn)
```

```
The number of parameters: 159410
```

```
sess.close()
tf.reset_default_graph()
```