Lab 1
TensorFlow Basics

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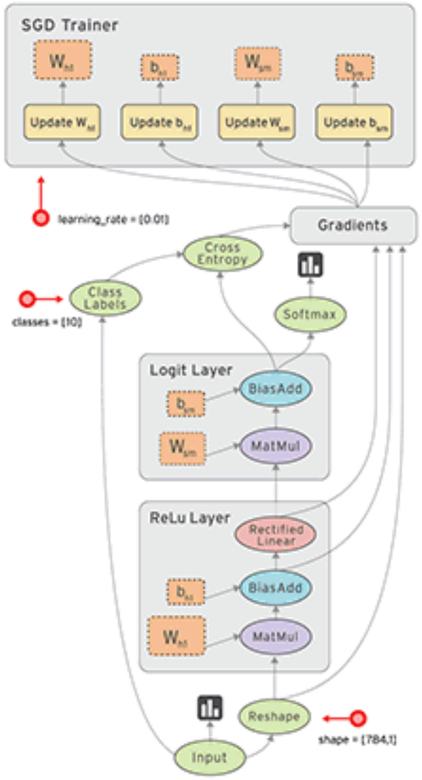
TensorFlow

- TensorFlow™ is an open source software library for numerical computation using data flow graphs.
- Python!

What is a Data Flow Graph?

- Nodes in the graph represent mathematical operations
- Edges represent the multidimensional data arrays (tensors) communicated between them.



https://www.tensorflow.org/

Installation

- install pip

```
# Ubuntu/Linux 64-bit
$ sudo apt-get install python-pip python-dev

# Mac OS X
$ sudo easy_install pip
```

- install TensorFlow

```
# Ubuntu/Linux 64-bit, CPU only:
$ sudo pip install --upgrade https://storage.googleapis.com/tensorflow/linux/cpu/te

# Ubuntu/Linux 64-bit, GPU enabled:
$ sudo pip install --upgrade https://storage.googleapis.com/tensorflow/linux/gpu/te

# Mac OS X, CPU only:
$ sudo easy_install --upgrade six
$ sudo pip install --upgrade https://storage.googleapis.com/tensorflow/mac/tensorfl
```

https://www.tensorflow.org/versions/r0.7/get_started/os_setup.html

Hello World!

```python
import tensorflow as tf

#Simple hello world using TensorFlow

# Create a Constant op
# The op is added as a node to the default graph.
#
# The value returned by the constructor represents the output
# of the Constant op.
hello = tf.constant('Hello, TensorFlow!')

# Start tf session
sess = tf.Session()

print sess.run(hello)
```

https://github.com/aymericdamien/TensorFlow-Examples/

Everything is operation!

```python
import tensorflow as tf

# Start tf session
sess = tf.Session()

# Basic constant operations
# The value returned by the constructor represents the output
# of the Constant op.
a = tf.constant(2)
b = tf.constant(3)

c = a+b

# Print out operation
print c

# Print out the result of operation
print sess.run(c)
```

Everything is operation!

```python
import tensorflow as tf

# Start tf session
sess = tf.Session()

# Basic constant operations
# The value returned by the constructor represents the output
# of the Constant op.
a = tf.constant(2)
b = tf.constant(3)

c = a+b

# Print out operation
print c

# Print out the result of operation
print sess.run(c)
```

```
Run 02-helloOp
/Library/Frameworks/Python.framework/Versions/2.7/bin/python2.7 /Users/hunkim/gitWorkspace/tFlow/01-Basics/02-helloOp.py
Tensor("add:0", shape=(), dtype=int32)
5
```

Basic operations

```
import tensorflow as tf

# Basic constant operations
# The value returned by the constructor represents the output
# of the Constant op.
a = tf.constant(2)
b = tf.constant(3)

# Launch the default graph.
with tf.Session() as sess:
    print "a=2, b=3"
    print "Addition with constants: %i" % sess.run(a+b)
    print "Multiplication with constants: %i" % sess.run(a*b)
```

output:

```
a=2, b=3
Addition with constants: 5
Multiplication with constants: 6
```

Placeholder

```
# Basic Operations with variable as graph input
# The value returned by the constructor represents the output
# of the Variable op. (define as input when running session)
# tf Graph input
a = tf.placeholder(tf.int16)
b = tf.placeholder(tf.int16)

# Define some operations
add = tf.add(a, b)
mul = tf.mul(a, b)

# Launch the default graph.
with tf.Session() as sess:
    # Run every operation with variable input
    print "Addition with variables: %i" % sess.run(add, feed_dict={a: 2, b: 3})
    print "Multiplication with variables: %i" % sess.run(mul, feed_dict={a: 2, b: 3})
```

output:

```
Addition with variables: 5
Multiplication with variables: 6
```

Lab 2

Linear Regression

Sung Kim <hunkim+ml@gmail.com>

Hypothesis and cost function

$$H(x) = Wx + b$$

$$cost(W, b) = \frac{1}{m} \sum_{i=1}^{m} (H(x^{(i)}) - y^{(i)})^2$$

```python
import tensorflow as tf

x_data = [1, 2, 3]
y_data = [1, 2, 3]

# Try to find values for W and b that compute y_data = W * x_data + b
# (We know that W should be 1 and b 0, but Tensorflow will
# figure that out for us.)
W = tf.Variable(tf.random_uniform([1], -1.0, 1.0))
b = tf.Variable(tf.random_uniform([1], -1.0, 1.0))

# Our hypothesis
hypothesis = W * x_data + b

# Simplified cost function
cost = tf.reduce_mean(tf.square(hypothesis - y_data))

# Minimize
a = tf.Variable(0.1) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train)
    if step % 20 == 0:
        print step, sess.run(cost), sess.run(W), sess.run(b)

# Learns best fit is W: [0.1], b: [0.3]
```

$$H(x) = Wx + b$$

$$cost(W, b) = \frac{1}{m} \sum_{i=1}^{m} (H(x^{(i)}) - y^{(i)})^2$$

Placeholder

```
# Basic Operations with variable as graph input
# The value returned by the constructor represents the output
# of the Variable op. (define as input when running session)
# tf Graph input
a = tf.placeholder(tf.int16)
b = tf.placeholder(tf.int16)

# Define some operations
add = tf.add(a, b)
mul = tf.mul(a, b)

# Launch the default graph.
with tf.Session() as sess:
    # Run every operation with variable input
    print "Addition with variables: %i" % sess.run(add, feed_dict={a: 2, b: 3})
    print "Multiplication with variables: %i" % sess.run(mul, feed_dict={a: 2, b: 3})
```

output:

```
Addition with variables: 5
Multiplication with variables: 6
```

```
x_data = [1., 2., 3.]
y_data = [1., 2., 3.]

# Try to find values for W and b that compute y_data = W * x_data + b
# (We know that W should be 1 and b 0, but Tensorflow will
# figure that out for us.)
W = tf.Variable(tf.random_uniform([1], -1.0, 1.0))
b = tf.Variable(tf.random_uniform([1], -1.0, 1.0))

X = tf.placeholder(tf.float32)
Y = tf.placeholder(tf.float32)

# Our hypothesis
hypothesis = W * X + b

# Simplified cost function
cost = tf.reduce_mean(tf.square(hypothesis - Y))

# Minimize
a = tf.Variable(0.1)
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train, feed_dict={X:x_data, Y:y_data})
    if step % 20 == 0:
        print step, sess.run(cost, feed_dict={X:x_data, Y:y_data}), sess.run(W), sess.run(b)
```

Placeholder

```
# Our hypothesis
hypothesis = W * X + b
...
# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train, feed_dict={X:x_data, Y:y_data})
    if step % 20 == 0:
        print step, sess.run(cost, feed_dict={X:x_data, Y:y_data}), sess.run(W), sess.run(b)

# Learns best fit is W: [1], b: [0]
print sess.run(hypothesis, feed_dict={X:5})
print sess.run(hypothesis, feed_dict={X:2.5})
```

Lab 3

Minimizing Cost

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Simplified hypothesis

$$H(x) = Wx$$

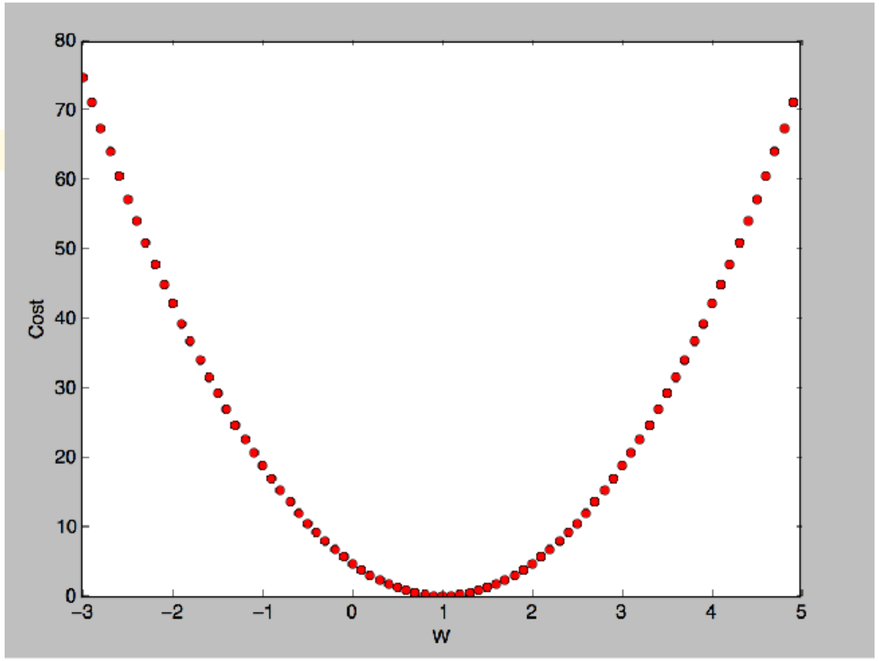
$$cost(W) = \frac{1}{m}\sum_{i=1}^{m}(Wx^{(i)} - y^{(i)})^2$$

```python
# tf Graph Input
X = [1., 2., 3.]
Y = [1., 2., 3.]
m = n_samples = len(X)

# Set model weights
W = tf.placeholder(tf.float32)

# Construct a linear model
hypothesis = tf.mul(X, W)

# Cost function
cost = tf.reduce_sum(tf.pow(hypothesis-Y, 2))/(m)

# Initializing the variables
init = tf.initialize_all_variables()

# For graphs
W_val = []
cost_val = []

# Launch the graph
sess = tf.Session()
sess.run(init)
for i in range(-30, 50):
    print i*0.1, sess.run(cost, feed_dict={W: i*0.1})
    W_val.append(i*0.1)
    cost_val.append(sess.run(cost, feed_dict={W: i*0.1}))

# Graphic display
plt.plot(W_val, cost_val, 'ro')
plt.ylabel('Cost')
plt.xlabel('W')
plt.show()
```

$$H(x) = Wx$$

$$cost(W) = \frac{1}{m}\sum_{i=1}^{m}(Wx^{(i)} - y^{(i)})^2$$

```python
# tf Graph Input
X = [1., 2., 3.]
Y = [1., 2., 3.]
m = n_samples = len(X)

# Set model weights
W = tf.placeholder(tf.float32)

# Construct a linear model
hypothesis = tf.mul(X, W)

# Cost function
cost = tf.reduce_sum(tf.pow(hypothesis-Y, 2))/(m)

# Initializing the variables
init = tf.initialize_all_variables()

# For graphs
W_val = []
cost_val = []

# Launch the graph
sess = tf.Session()
sess.run(init)
for i in range(-30, 50):
    print i*0.1, sess.run(cost, feed_dict={W: i*0.1})
    W_val.append(i*0.1)
    cost_val.append(sess.run(cost, feed_dict={W: i*0.1}))

# Graphic display
plt.plot(W_val, cost_val, 'ro')
plt.ylabel('Cost')
plt.xlabel('W')
plt.show()
```



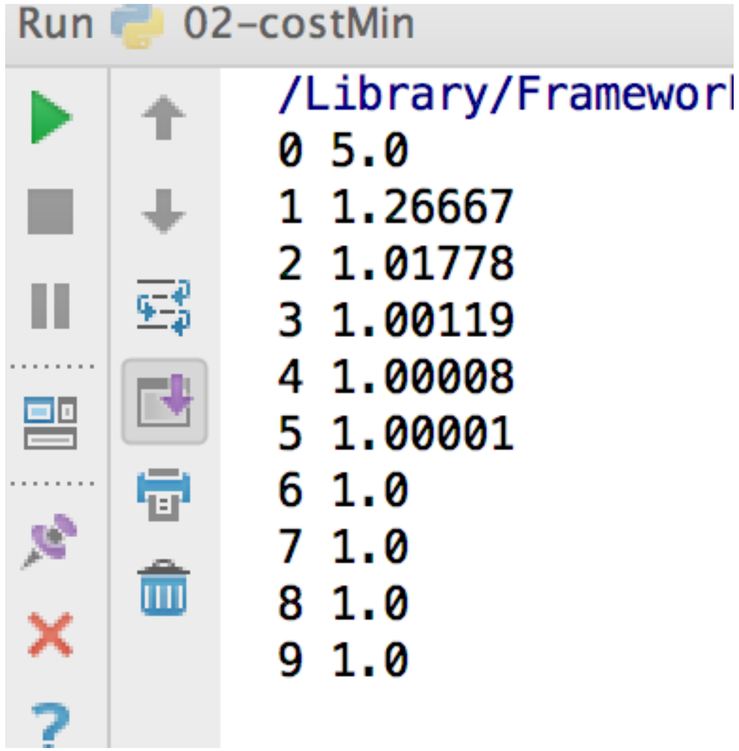
```
x_data = [1., 2., 3.]
y_data = [1., 2., 3.]

# Try to find values for W and b that compute y_data = W * x_data + b
# (We know that W should be 1 and b 0, but Tensorflow will
# figure that out for us.)
W = tf.Variable(tf.random_uniform([1], -10.0, 10.0))

X = tf.placeholder(tf.float32)
Y = tf.placeholder(tf.float32)

# Our hypothesis
hypothesis = W * X
```

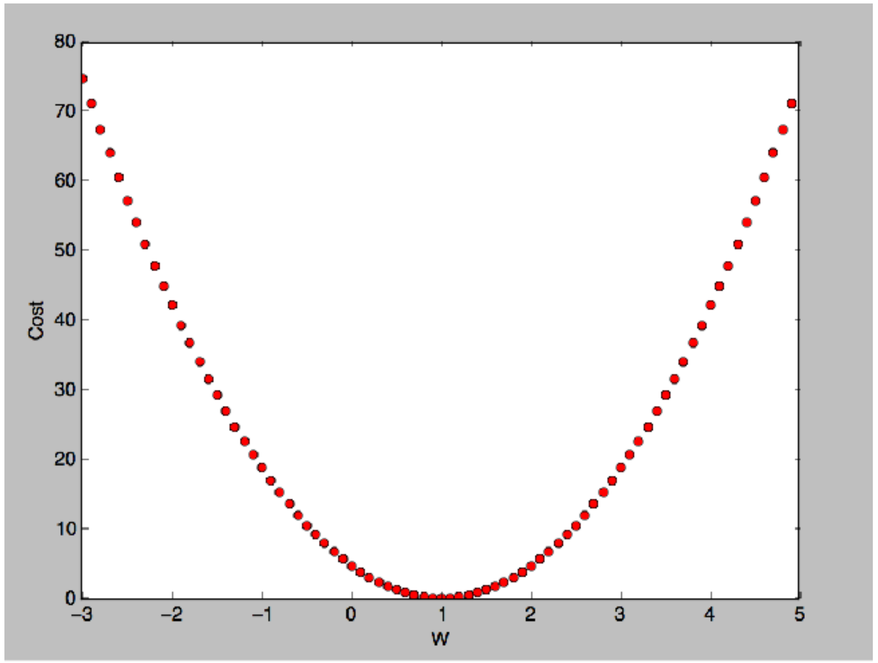
$$W := W - \alpha \frac{1}{m} \sum_{i=1}^{m} (W x^{(i)} - y^{(i)}) x^{(i)}$$

```
# Simplified cost function
cost = tf.reduce_mean(tf.square(hypothesis - Y))

# Minimize
descent = W - tf.mul(0.1, tf.reduce_mean(tf.mul((tf.mul(W, X) - Y), X)))
update = W.assign(descent)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(20):
    sess.run(update, feed_dict={X:x_data, Y:y_data})
    print step, sess.run(cost, feed_dict={X:x_data, Y:y_data}), sess.run(W)
```

```
# tf Graph Input
X = [1., 2., 3.]
Y = [1., 2., 3.]
m = n_samples = len(X)

# Set model weights
W = tf.Variable(0.)
# Construct a linear model
hypothesis = tf.mul(X, W)

# Cost function
cost = tf.reduce_sum(tf.pow(hypothesis-Y, 2))/(m)
optimizer = tf.train.GradientDescentOptimizer(0.1)
train = optimizer.minimize(cost)

# Initializing the variables
init = tf.initialize_all_variables()

# Launch the graph
sess = tf.Session()
sess.run(init)

# Set model weights
wOp = W.assign(5.)
sess.run(wOp)
for step in xrange(10):
    print step, sess.run(W)
    sess.run(train)
```

Output when W=5

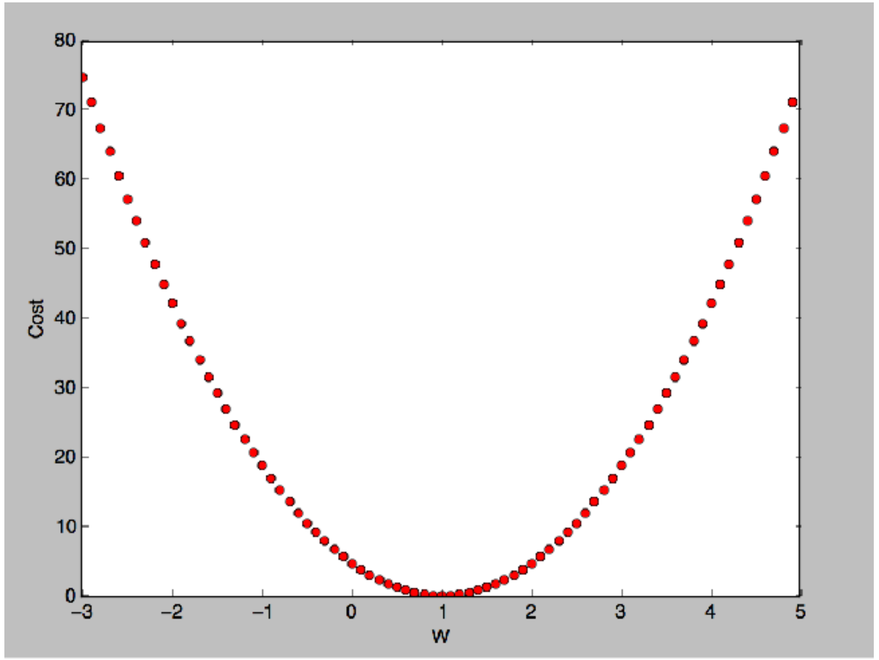




Output when W=-3

```
w0p = W.assign(-3.)
sess.run(init)
sess.run(w0p)
for step in xrange(10):
    print step, sess.run(W)
    sess.run(train)
```

```
Run 02-costMin
/Library/Framev
0 -3.0
1 0.733334
2 0.982222
3 0.998815
4 0.999921
5 0.999995
6 1.0
7 1.0
8 1.0
9 1.0
```



Lab 4

Multi-variable linear regression

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Multivariable example

$$H(x_1, x_2) = w_1 x_1 + w_2 x_2 + b$$

x1	x2	y
1	0	1
0	2	2
3	0	3
0	4	4
5	0	5

Multivariable example

$$H(x_1, x_2) = w_1 x_1 + w_2 x_2 + b$$

```
W1 = tf.Variable(tf.random_uniform([1], -1.0, 1.0))
W2 = tf.Variable(tf.random_uniform([1], -1.0, 1.0))

b = tf.Variable(tf.random_uniform([1], -1.0, 1.0))

# Our hypothesis
hypothesis = W1 * x1_data + W2 * x2_data + b
```

x1	x2	y
1	0	1
0	2	2
3	0	3
0	4	4
5	0	5

```
x1_data = [1, 0, 3, 0, 5]
x2_data = [0, 2, 0, 4, 0]
y_data = [1, 2, 3, 4, 5]
```

```
x1_data = [1, 0, 3, 0, 5]
x2_data = [0, 2, 0, 4, 0]
y_data = [1, 2, 3, 4, 5]

# Try to find values for W and b that compute y_data = W * x_data + b
# (We know that W should be 1 and b 0, but Tensorflow will
# figure that out for us.)
W1 = tf.Variable(tf.random_uniform([1], -1.0, 1.0))
W2 = tf.Variable(tf.random_uniform([1], -1.0, 1.0))

b = tf.Variable(tf.random_uniform([1], -1.0, 1.0))

# Our hypothesis
hypothesis = W1 * x1_data + W2 * x2_data + b

# Simplified cost function
cost = tf.reduce_mean(tf.square(hypothesis - y_data))

# Minimize
a = tf.Variable(0.1) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train)
    if step % 20 == 0:
        print step, sess.run(cost), sess.run(W1), sess.run(W2), sess.run(b)
```

Matrix

$$w_1x_1 + w_2x_2 + w_3x_3 + ... + w_nx_n$$

$$\begin{bmatrix} w1 & w2 & w3 \end{bmatrix} \times \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} w1 \times x1 + w2 \times x2 + w3 \times x3 \end{bmatrix}$$

Matrix

$$w_1x_1 + w_2x_2 + w_3x_3 + \ldots + w_nx_n$$

$$\begin{bmatrix} w1 & w2 & w3 \end{bmatrix} \times \begin{bmatrix} x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} w1 \times x1 + w2 \times x2 + w3 \times x3 \end{bmatrix}$$

```
x_data = [[0., 2., 0., 4., 0.],
          [1., 0., 3., 0., 5.]]
y_data = [1, 2, 3, 4, 5]

# Try to find values for W
W = tf.Variable(tf.random_uniform([1,2], -1.0, 1.0))
b = tf.Variable(tf.random_uniform([1], -1.0, 1.0))
```

```python
import tensorflow as tf
x_data = [[0., 2., 0., 4., 0.],
          [1., 0., 3., 0., 5.]]
y_data = [1, 2, 3, 4, 5]

# Try to find values for W
W = tf.Variable(tf.random_uniform([1,2], -1.0, 1.0))
b = tf.Variable(tf.random_uniform([1], -1.0, 1.0))

# Our hypothesis
hypothesis = tf.matmul(W, x_data) + b
# Simplified cost function
cost = tf.reduce_mean(tf.square(hypothesis - y_data))

# Minimize
a = tf.Variable(0.1) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train)
    if step % 20 == 0:
        print step, sess.run(cost), sess.run(W), sess.run(b)
```

Hypothesis

$$\begin{bmatrix} b & w1 & w2 & w3 \end{bmatrix} \times \begin{bmatrix} 1 \\ x1 \\ x2 \\ x3 \end{bmatrix} = \begin{bmatrix} b \times 1 + w1 \times x1 + w2 \times x2 + w3 \times x3 \end{bmatrix}$$

$$H(X) = WX$$

```
x_data = [[1, 1, 1, 1, 1],
          [0., 2., 0., 4., 0.],
          [1., 0., 3., 0., 5.]]
y_data = [1, 2, 3, 4, 5]

# Try to find values for W
W = tf.Variable(tf.random_uniform([1,3], -1.0, 1.0))

# Our hypothesis
# previous hypothesis with b, hypothesis = tf.matmul(W, x_data) + b
hypothesis = tf.matmul(W, x_data)
# Simplified cost function
cost = tf.reduce_mean(tf.square(hypothesis - y_data))

# Minimize
a = tf.Variable(0.1) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train)
    if step % 20 == 0:
        print step, sess.run(cost), sess.run(W)

# Learns best fit is W: [1 1 0]
```

Loading data from file

train.txt

```
#x0 x1 x2  y
1   1   0      1
1   0   2      2
1   3   0      3
1   0   4      4
1   5   0      5
```

```python
import tensorflow as tf
import numpy as np
# http://docs.scipy.org/doc/numpy-1.10.0/reference/generated/numpy.loadtxt.html
xy = np.loadtxt('train.txt', unpack=True, dtype='float32')
x_data = xy[0:-1]
y_data = xy[-1];
```

```python
import tensorflow as tf
import numpy as np
# http://docs.scipy.org/doc/numpy-1.10.0/reference/generated/numpy.loadtxt.html
xy = np.loadtxt('train.txt', unpack=True, dtype='float32')
x_data = xy[0:-1]
y_data = xy[-1];

print 'x', x_data
print 'y', y_data

W = tf.Variable(tf.random_uniform([1,len(x_data)], -5.0, 5.0))

# Our hypothesis
hypothesis = tf.matmul(W, x_data)
# Simplified cost function
cost = tf.reduce_mean(tf.square(hypothesis - y_data))

# Minimize
a = tf.Variable(0.1) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train)
    if step % 20 == 0:
        print step, sess.run(cost), sess.run(W)

# Learns best fit is W: [0.1], b: [0.3]
```

Lab 5

Logistic (regression) classifier

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Logistic Regression

$$H(X) = \frac{1}{1 + e^{-W^T X}}$$

$$c(W) = -\frac{1}{m} \sum ylog(H(x)) + (1 - y)log(1 - H(x))$$

$$W := W - \alpha \frac{\partial}{\partial W} cost(W)$$

```
xy = np.loadtxt('train.txt', unpack=True, dtype='float32')
x_data = xy[0:-1]
y_data = xy[-1];

X = tf.placeholder(tf.float32)
Y = tf.placeholder(tf.float32)

W = tf.Variable(tf.random_uniform([1,len(x_data)], -1.0, 1.0))

# Our hypothesis
h = tf.matmul(W, X)
hypothesis = tf.div(1., 1.+tf.exp(-h))
# cost function
cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesis))

# Minimize
a = tf.Variable(0.1) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()

# Launch the graph.
sess = tf.Session()
sess.run(init)

# Fit the line.
for step in xrange(2001):
    sess.run(train, feed_dict={X:x_data, Y:y_data})
    if step % 20 == 0:
        print step, sess.run(cost, feed_dict={X:x_data, Y:y_data}), sess.run(W)
```

$$H(X) = \frac{1}{1 + e^{-W^T X}}$$

$$W := W - \alpha \frac{\partial}{\partial W} cost(W)$$

$$cost(W) = -\frac{1}{m} \sum ylog(H(x)) + (1 - y)log(1 - H(x))$$

Training Data

```
#x0 x1 x2  y
1   2   1      0
1   3   2      0
1   3   4      0
1   5   5      1
1   7   5      1
1   2   5      1
```

```
# http://docs.scipy.org/doc/numpy-1.10.0/reference/generated/numpy.loadtxt.html
xy = np.loadtxt('train.txt', unpack=True, dtype='float32')
x_data = xy[0:-1]
y_data = xy[-1];
```

Ask to ML

Ask to ML

```
print '------------------------------------'
# study_hour attendance
print sess.run(hypothesis, feed_dict={X:[[1], [2], [2]]})>0.5
print sess.run(hypothesis, feed_dict={X:[[1], [5], [5]]})>0.5

print sess.run(hypothesis, feed_dict={X:[[1, 1], [4, 3], [3, 5]]})>0.5
```

output:

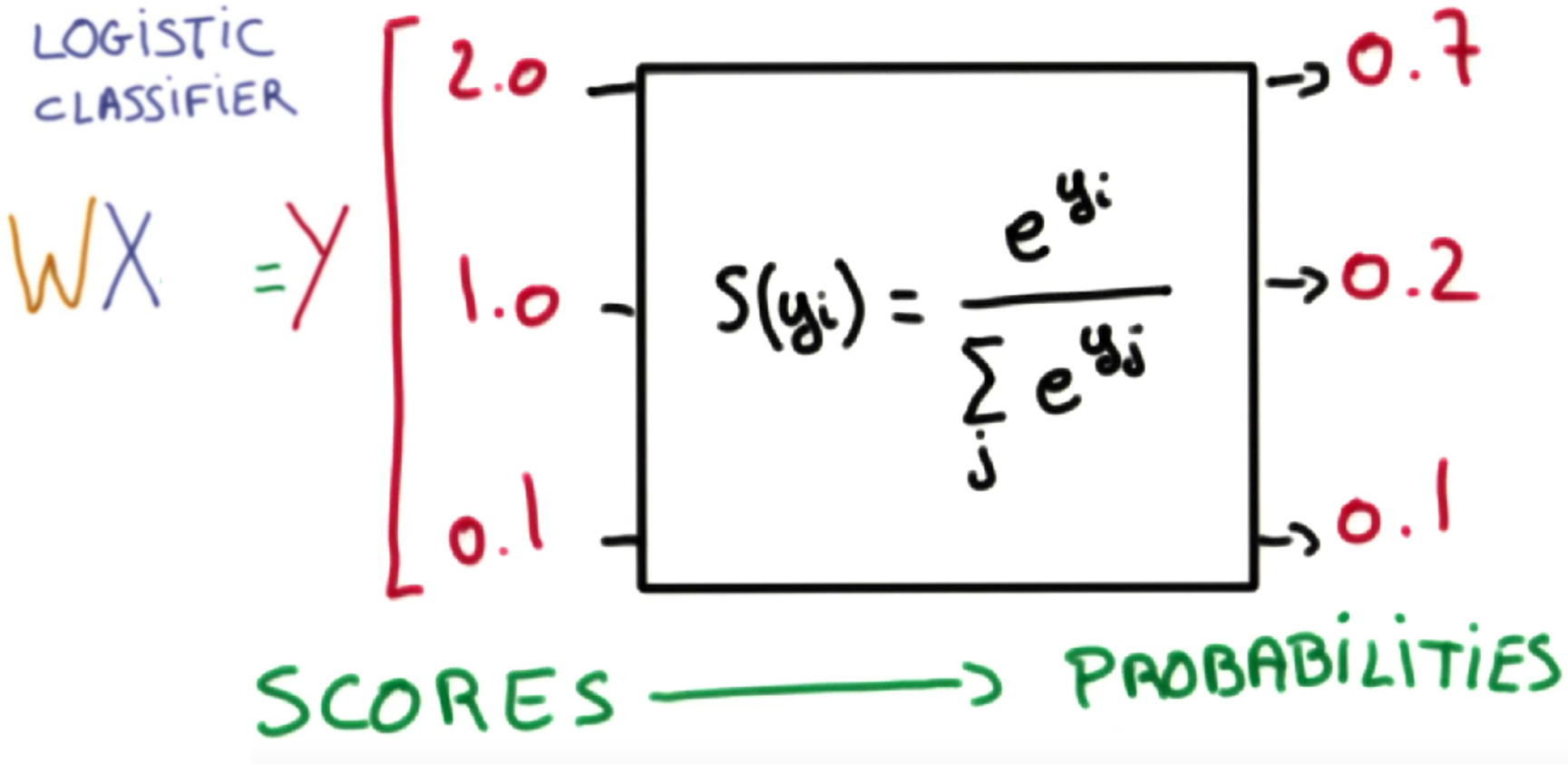
```
------------------------------------
[[False]]
[[ True]]
[[False  True]]
```

Lab 6

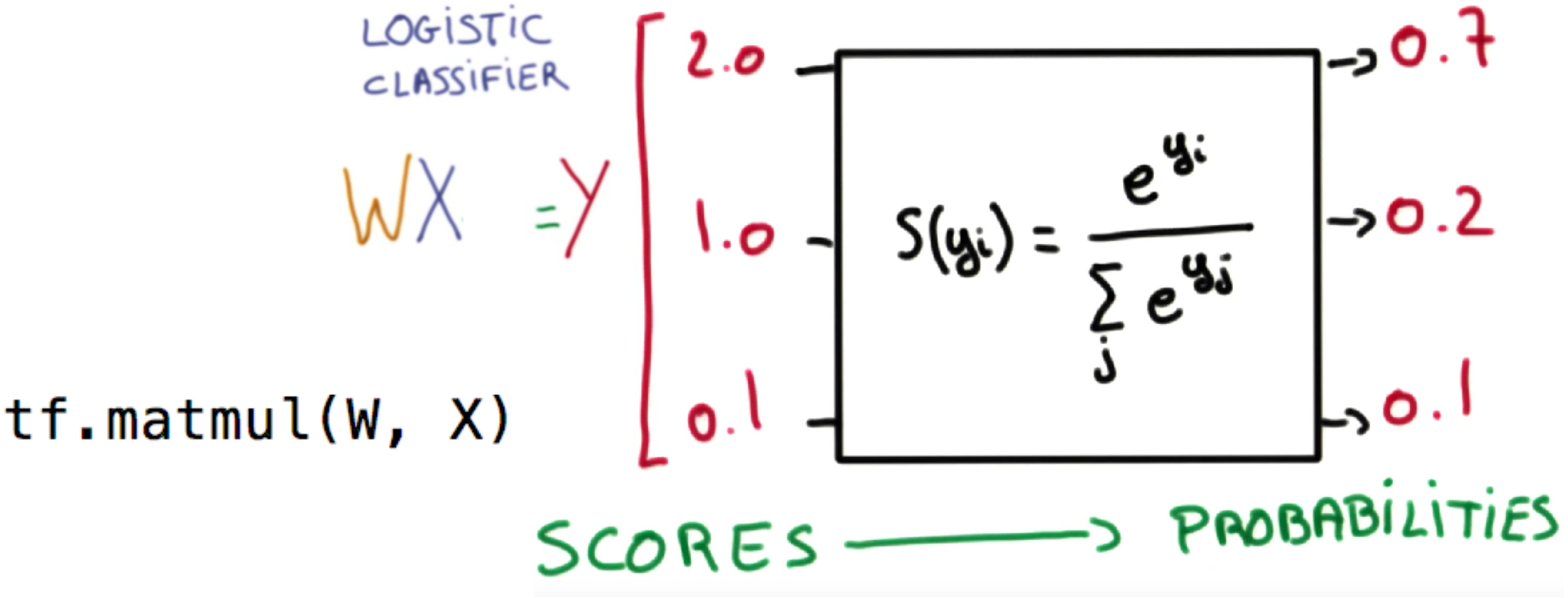
Softmax classifier

Sung Kim <hunkim+ml@gmail.com>

Softmax function



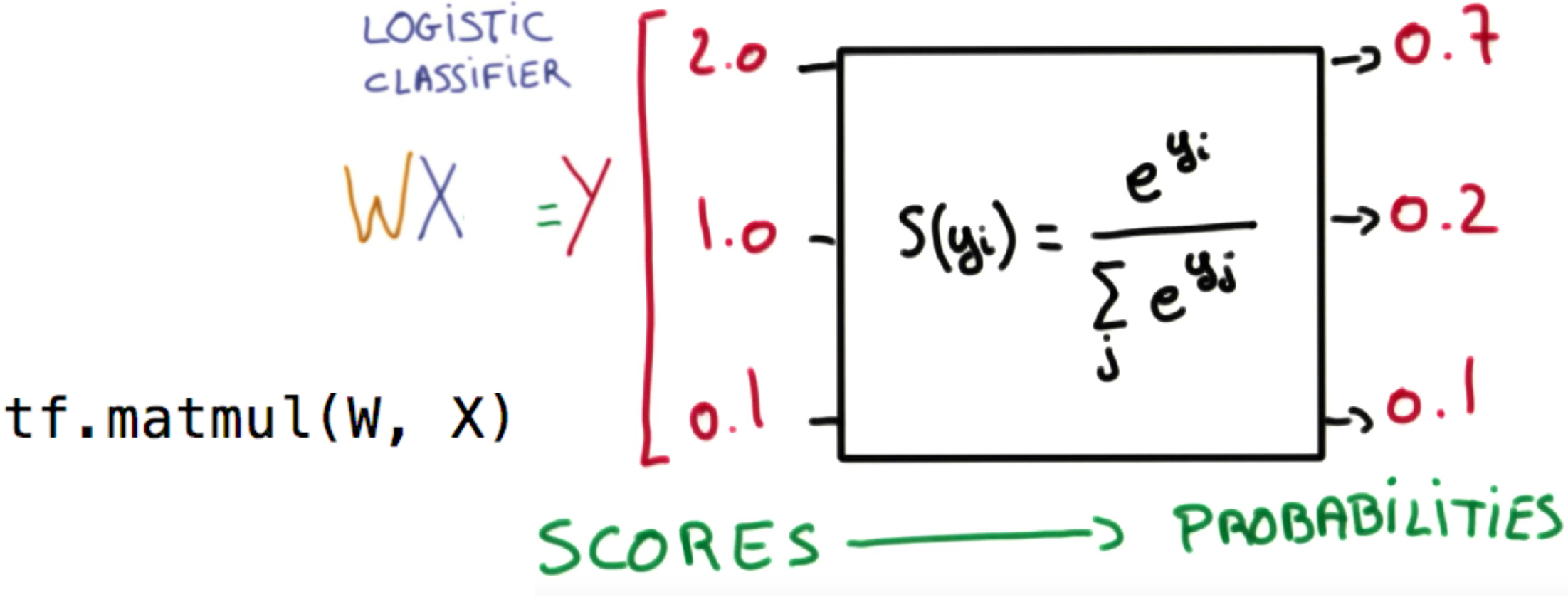
https://www.udacity.com/course/viewer#!/c-ud730/l-6370362152/m-6379811817




```
tf.matmul(W, X)
```

https://www.udacity.com/course/viewer#!/c-ud730/l-6370362152/m-6379811817

```
hypothesis = tf.nn.softmax(tf.matmul(W, X))
```



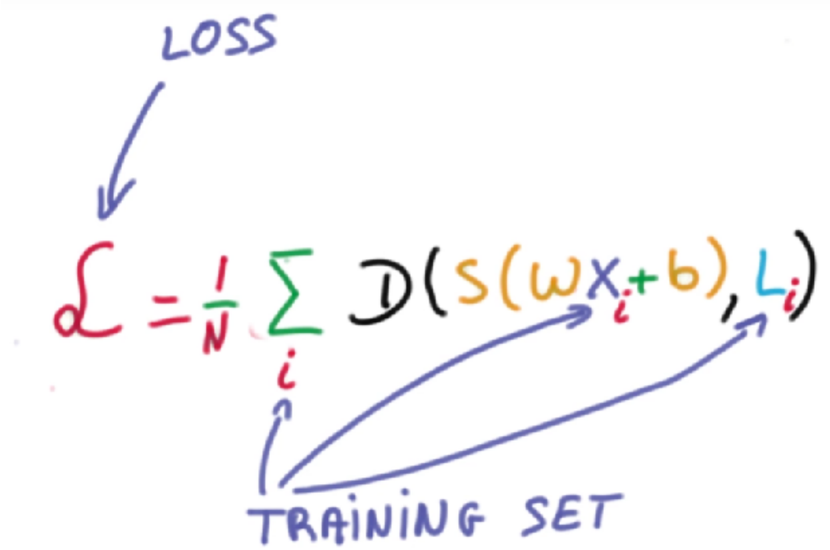
`tf.matmul(W, X)`

https://www.udacity.com/course/viewer#!/c-ud730/l-6370362152/m-6379811817

WX vs XW

```
# Construct model
# https://www.tensorflow.org/versions/r0.7/tutorials/mnist/beginners/inde
# First, we multiply x by W with the expression tf.matmul(x, W).
# This is flipped from when we multiplied them in our equation,
# where we had Wx, as a small trick to deal with x being
# a 2D tensor with multiple inputs.
#💡We then add b, and finally apply tf.nn.softmax.
hypothesis = tf.nn.softmax(tf.matmul(W, X)) # Softmax
```

Cost function




```
# Minimize error using cross entropy
learning_rate = 0.001

# Cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(Y*tf.log(hypothesis), reduction_indices=1))

# Gradient Descent
optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost)
```

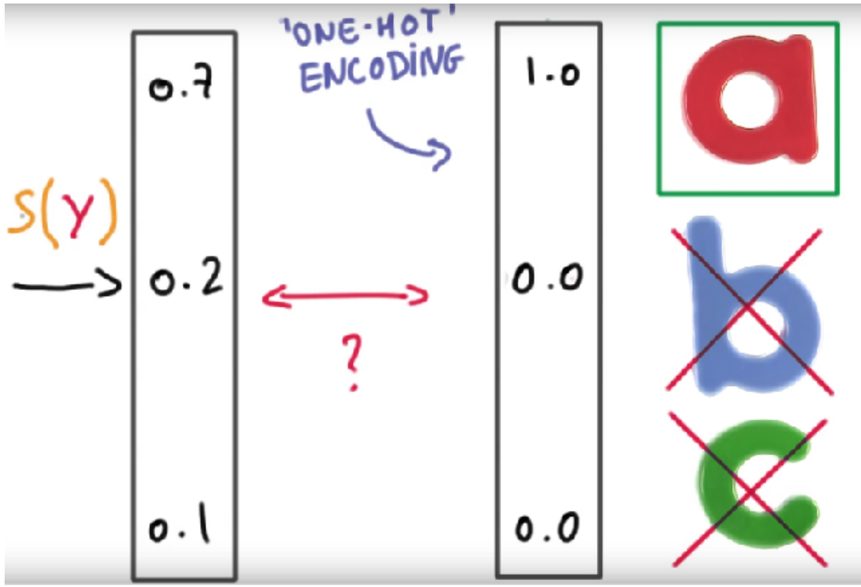
```
xy = np.loadtxt('train.txt', unpack=True, dtype='float32')
x_data = np.transpose(xy[0:3])
y_data = np.transpose(xy[3:])

# tf Graph Input
X = tf.placeholder("float", [None, 3]) # x1, x2 and 1 (for bias)
Y = tf.placeholder("float", [None, 3]) # A, B, C => 3 classes
# Set model weights
W = tf.Variable(tf.zeros([3, 3]))

# Construct model
hypothesis = tf.nn.softmax(tf.matmul(W, X)) # Softmax

# Minimize error using cross entropy
learning_rate = 0.001

# Cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(Y*tf.log(hypothesis), reduction_indices=1))

# Gradient Descent
optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost)

# Initializing the variables
init = tf.initialize_all_variables()

# Launch the graph
with tf.Session() as sess:
    sess.run(init)

    for step in xrange(2001):
        sess.run(optimizer, feed_dict={X:x_data, Y:y_data})
        if step % 200 == 0:
            print step, sess.run(cost, feed_dict={X:x_data, Y:y_data}), sess.run(W)
```

```
#x0 x1 x2  y [A B C]
1   2   1   0   0   1
1   3   2   0   0   1
1   3   4   0   0   1
1   5   5   0   1   0
1   7   5   0   1   0
1   2   5   0   1   0
1   6   6   1   0   0
1   7   7   1   0   0
```

Test & one-hot encoding

```
a = sess.run(hypothesis, feed_dict={X:[[1, 11, 7]]}
print a, sess.run(tf.arg_max(a, 1))

b = sess.run(hypothesis, feed_dict={X:[[1, 3, 4]]})
print b, sess.run(tf.arg_max(b, 1))

c = sess.run(hypothesis, feed_dict={X:[[1, 1, 0]]})
print c, sess.run(tf.arg_max(c, 1))

all = sess.run(hypothesis, feed_dict={X:[[1, 11, 7], [1, 3, 4], [1, 1, 0]]})
print all, sess.run(tf.arg_max(all, 1))
```

Test & one-hot encoding




```
a = sess.run(hypothesis, feed_dict={X:[[1, 11, 7]]}
print a, sess.run(tf.arg_max(a, 1))

b = sess.run(hypothesis, feed_dict={X:[[1, 3, 4]]})
print b, sess.run(tf.arg_max(b, 1))

c = sess.run(hypothesis, feed_dict={X:[[1, 1, 0]]})
print c, sess.run(tf.arg_max(c, 1))

all = sess.run(hypothesis, feed_dict={X:[[1, 11, 7], [1, 3, 4], [1, 1, 0]]})
print all, sess.run(tf.arg_max(all, 1))
```

Lab 7

Learning rate, Evaluation

Sung Kim <hunkim+ml@gmail.com>

Examples

- https://github.com/aymericdamien/TensorFlow-Examples

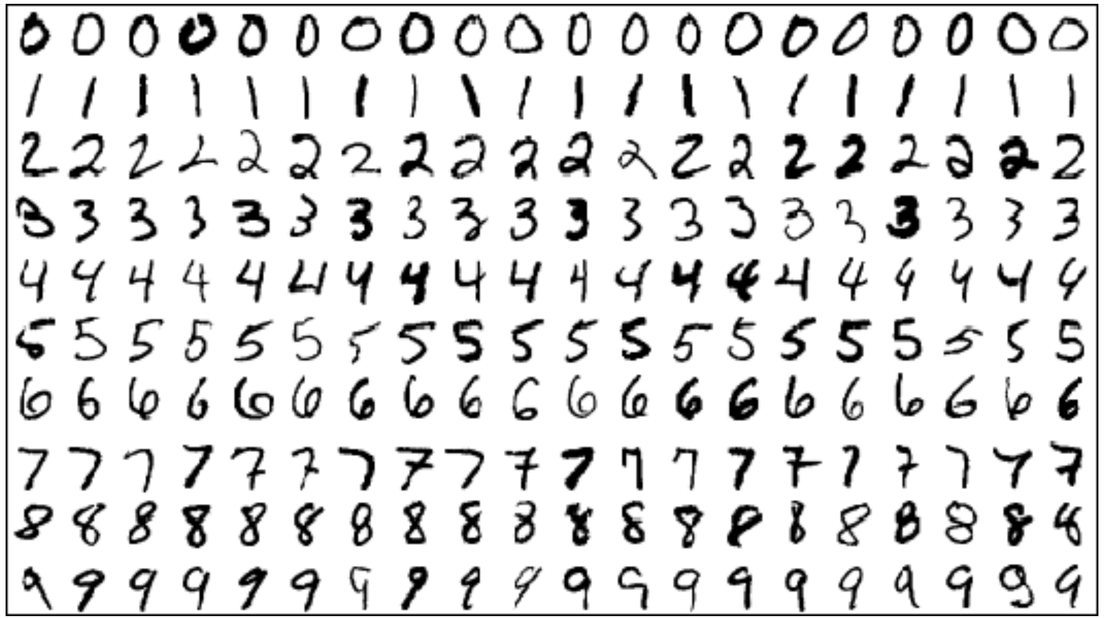
Learning rate

```
# Minimize error using cross entropy
learning_rate = 10.

# Cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(Y*tf.log(hypothesis), reduction_indices=1))

# Gradient Descent
optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost)

# Initializing the variables
init = tf.initialize_all_variables()

# Launch the graph
with tf.Session() as sess:
    sess.run(init)

    for step in xrange(2001):
        sess.run(optimizer, feed_dict={X:x_data, Y:y_data})
        if step % 200 == 0:
            print step, sess.run(cost, feed_dict={X:x_data, Y:y_data}), sess.run(W)
```

Learning rate

```
0 nan [[-0.83333319  0.4166666   0.41666645]
 [ 1.66666687  2.91666746 -4.58333397]
 [ 1.66666627  4.16666698 -5.83333397]]
200 nan [[ nan  nan  nan]
 [ nan  nan  nan]
 [ nan  nan  nan]]
400 nan [[ nan  nan  nan]
 [ nan  nan  nan]
 [ nan  nan  nan]]
```

MNIST Dataset



train-images-idx3-ubyte.gz: training set images (9912422 bytes)
train-labels-idx1-ubyte.gz: training set labels (28881 bytes)
t10k-images-idx3-ubyte.gz: test set images (1648877 bytes)
t10k-labels-idx1-ubyte.gz: test set labels (4542 bytes)

http://yann.lecun.com/exdb/mnist/

Reading data

```
"""Functions for downloading and reading MNIST data."""
import ...
SOURCE_URL = 'http://yann.lecun.com/exdb/mnist/'
def maybe_download(filename, work_directory):
  """Download the data from Yann's website, unless it's already here."""
  if not os.path.exists(work_directory):
    os.mkdir(work_directory)
  filepath = os.path.join(work_directory, filename)
  if not os.path.exists(filepath):
    filepath, _ = urllib.urlretrieve(SOURCE_URL + filename, filepath)
    statinfo = os.stat(filepath)
    print('Succesfully downloaded', filename, statinfo.st_size, 'bytes.')
  return filepath

def _read32(bytestream):
  dt = numpy.dtype(numpy.uint32).newbyteorder('>')
  return numpy.frombuffer(bytestream.read(4), dtype=dt)

def extract_images(filename):
  """Extract the images into a 4D uint8 numpy array [index, y, x, depth]."""
  print('Extracting', filename)
  with gzip.open(filename) as bytestream:
    magic = _read32(bytestream)
    if magic != 2051:
      raise ValueError(
          'Invalid magic number %d in MNIST image file: %s' %
          (magic, filename))
    num_images = _read32(bytestream)
    rows = _read32(bytestream)
    cols = _read32(bytestream)
    buf = bytestream.read(rows * cols * num_images)
    data = numpy.frombuffer(buf, dtype=numpy.uint8)
```

Reading data and set variables

```
# tf Graph Input
x = tf.placeholder("float", [None, 784]) # mnist data image of shape 28*28=784
y = tf.placeholder("float", [None, 10]) # 0-9 digits recognition => 10 classes

# Create model

# Set model weights
W = tf.Variable(tf.zeros([784, 10]))
b = tf.Variable(tf.zeros([10]))
```

Activation (hypothesis) and cost

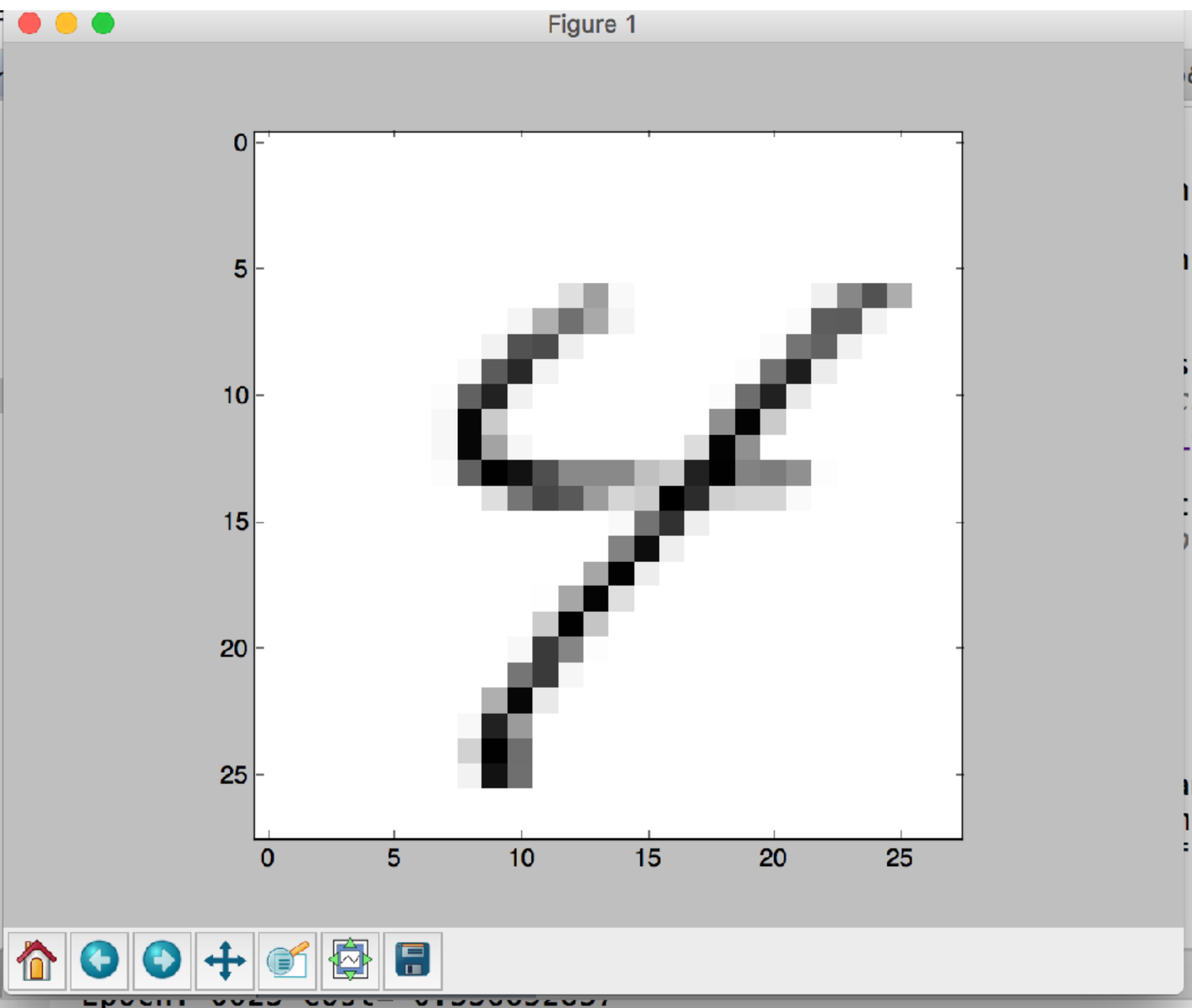
```
# Construct model
activation = tf.nn.softmax(tf.matmul(x, W) + b) # Softmax

# Minimize error using cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(y*tf.log(activation), reduction_indices=1))
optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost) # Gra
```

Training batch

```
# Training cycle
for epoch in range(training_epochs):
    avg_cost = 0.
    total_batch = int(mnist.train.num_examples/batch_size)
    # Loop over all batches
    for i in range(total_batch):
        batch_xs, batch_ys = mnist.train.next_batch(batch_size)
        # Fit training using batch data
        sess.run(optimizer, feed_dict={x: batch_xs, y: batch_ys})
        # Compute average loss
        avg_cost += sess.run(cost, feed_dict={x: batch_xs, y: batch_ys})/total_batch
    # Display logs per epoch step
    if epoch % display_step == 0:
        print "Epoch:", '%04d' % (epoch+1), "cost=", "{:.9f}".format(avg_cost)

print "Optimization Finished!"
```

Predict & Show

```
# Get one and predict
r = randint(0, mnist.test.num_examples -1)
print "Label: ", sess.run(tf.argmax(mnist.test.labels[r:r+1], 1))
print "Prediction: ", sess.run(tf.argmax(activation,1), {x: mnist.test.images[r:r+1]})

# Show the img
plt.imshow(mnist.test.images[r:r+1].reshape(28, 28), cmap='Greys', interpolation='nearest')
plt.show()
```




```
Epoch: 0024 cost= 0.334489702
Epoch: 0025 cost= 0.332481820
Optimization Finished!
Label:  [4]
Prediction:  [4]
```

```
02-mnist-show
&Tips/01-lettergrade.py
03-mnist-eval.py
02-mnist-show.py

s):

.num_examples/batch_size)

t.train.next_batch(batch_size)
h data
dict={x: batch_xs, y: batch_ys})

, feed_dict={x: batch_xs, y: batch_ys})/total_batch

(epoch+1), "cost=", "{:.9f}".format(avg_cost)

mples -1)
ax(mnist.test.labels[r:r+1], 1))
.argmax(activation,1), {x: mnist.test.images[r:r+1]})
```

Evaluation

```
print "Optimization Finished!"

# Test model
correct_prediction = tf.equal(tf.argmax(activation, 1), tf.argmax(y, 1))
# Calculate accuracy
accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
print "Accuracy:", accuracy.eval({x: mnist.test.images, y: mnist.test.labels})
```

Evaluation

```
print "Optimization Finished!"

# Test model
correct_prediction = tf.equal(tf.argmax(activation, 1), tf.argmax(y, 1))
# Calculate accuracy
accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
print "Accuracy:", accuracy.eval({x: mnist.test.images, y: mnist.test.labels})
```

```
.
Epoch: 0015 cost= 0.361379657
Epoch: 0016 cost= 0.357280465
Epoch: 0017 cost= 0.353490356
Epoch: 0018 cost= 0.350175499
Epoch: 0019 cost= 0.347017571
Epoch: 0020 cost= 0.344151569
Epoch: 0021 cost= 0.341454394
Epoch: 0022 cost= 0.339011900
Epoch: 0023 cost= 0.336664148
Epoch: 0024 cost= 0.334490953
Epoch: 0025 cost= 0.332419457
Optimization Finished!
Accuracy: 0.9146
```

Lab 9-1
NN for XOR

Sung Kim <hunkim+ml@gmail.com>

Data set

```
# XOR
# x1 x2   y
0    0      0
0    1      1
1    0      1
1    1      0
```

XOR with logistic regression?

```
# http://docs.scipy.org/doc/numpy-1.10.0/reference/generated/numpy.loadtxt.html
xy = np.loadtxt('train.txt', unpack=True)
x_data = xy[0:-1]
y_data = xy[-1]

X = tf.placeholder(tf.float32)
Y = tf.placeholder(tf.float32)

W = tf.Variable(tf.random_uniform([1,len(x_data)], -1.0, 1.0))

# Our hypothesis
h = tf.matmul(W, X)
hypothesis = tf.div(1., 1.+tf.exp(-h))
# cost function
cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesis))

# Minimize
a = tf.Variable(0.01) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()
```

XOR with logistic regression?

```
# Launch the graph.
with tf.Session() as sess:
    sess.run(init)

    # Fit the line.
    for step in xrange(1000):
        sess.run(train, feed_dict={X:x_data, Y:y_data})
        if step % 200 == 0:
            print step, sess.run(cost, feed_dict={X:x_data, Y:y_data}), sess.run(W)

    # Test model
    correct_prediction = tf.equal(tf.floor(hypothesis+0.5), Y)
    # Calculate accuracy
    accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
    print sess.run([hypothesis, tf.floor(hypothesis+0.5), correct_prediction, accuracy], feed_dict={X:x_data, Y:y_data})
    print "Accuracy:", accuracy.eval({X:x_data, Y:y_data})
```

Does not work!

```
print sess.run([hypothesis, tf.floor(hypothesis+0.5), correct_prediction, accuracy], feed_dict={X:x_data, Y:y_data})
print "Accuracy:", accuracy.eval({X:x_data, Y:y_data})
```

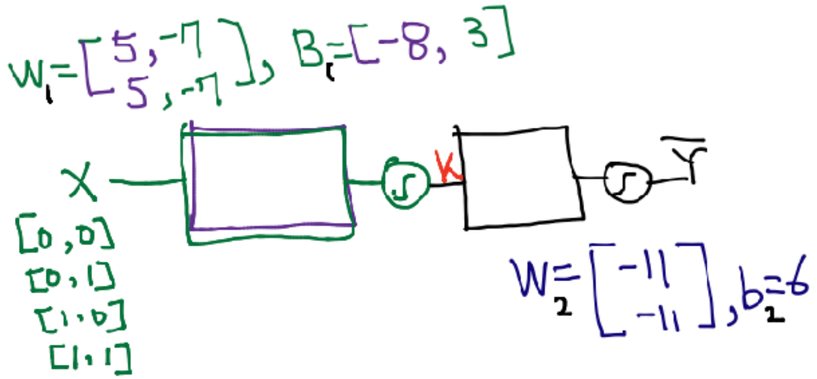
```
0 0.707739 [[-0.5306738   0.10871095]]
200 0.702072 [[-0.42843163  0.13686776]]
400 0.698917 [[-0.35024348  0.14920615]]
600 0.697075 [[-0.28977284  0.15132181]]
800 0.695938 [[-0.24237214  0.14709207]]
[array([[ 0.5       ,  0.53474092,  0.44896561,  0.48359016]], dtype=float32), array([[ 1.,  1.,  0.,  0.]]
Accuracy: 0.5
```

NN

```
# http://docs.scipy.org/doc/numpy-1.10.0/reference/generated/numpy.loadtxt.html
xy = np.loadtxt('train.txt', unpack=True)
x_data = xy[0:-1]
y_data = xy[-1]

X = tf.placeholder(tf.float32)
Y = tf.placeholder(tf.float32)

W = tf.Variable(tf.random_uniform([1,len(x_data)], -1.0, 1.0))

# Our hypothesis
h = tf.matmul(W, X)
hypothesis = tf.div(1., 1.+tf.exp(-h))
# cost function
cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesis))

# Minimize
a = tf.Variable(0.01) # Learning rate, alpha
optimizer = tf.train.GradientDescentOptimizer(a)
train = optimizer.minimize(cost)

# Before starting, initialize the variables.  We will 'run' this first.
init = tf.initialize_all_variables()
```

```
W1 = tf.Variable(tf.random_uniform([2, 2], -1.0, 1.0))
W2 = tf.Variable(tf.random_uniform([2, 1], -1.0, 1.0))

b1 = tf.Variable(tf.zeros([2]), name="Bias1")
b2 = tf.Variable(tf.zeros([1]), name="Bias2")

# Our hypothesis
L2 = tf.sigmoid(tf.matmul(X, W1) + b1)
hypothesis = tf.sigmoid(tf.matmul(L2, W2) + b2)
```

NN for XOR




```
W1 = tf.Variable(tf.random_uniform([2, 2], -1.0, 1.0))
W2 = tf.Variable(tf.random_uniform([2, 1], -1.0, 1.0))

b1 = tf.Variable(tf.zeros([2]), name="Bias1")
b2 = tf.Variable(tf.zeros([1]), name="Bias2")

# Our hypothesis
L2 = tf.sigmoid(tf.matmul(X, W1) + b1)
hypothesis = tf.sigmoid(tf.matmul(L2, W2) + b2)
```

NN for XOR

```
198000 cost 0.00878375
    predict [[ 0.01067145]
 [ 0.99207062]
 [ 0.99207932]
 [ 0.00845705]]
    W1, B1 [array([[ 6.84843874,  5.02159739],
       [ 6.83831406,  5.0197401 ]], dtype=float32), array([-5.00321722], dtype=float32)]
    W2, B2 [array([[ 10.83042145],
       [-11.59721661]], dtype=float32), array([-5.00321722], dtype=float32)]
[array([[ 0.],
       [ 1.],
       [ 1.],
       [ 0.]], dtype=float32), array([[ True],
       [ True],
       [ True],
       [ True]], dtype=bool)]
Accuracy: 1.0
```

Wide NN for XOR

```
W1 = tf.Variable(tf.random_uniform([2, 10], -1.0, 1.0))
W2 = tf.Variable(tf.random_uniform([10, 1], -1.0, 1.0))

b1 = tf.Variable(tf.zeros([10]), name="Bias1")
b2 = tf.Variable(tf.zeros([1]), name="Bias2")

# Our hypothesis
L2 = tf.sigmoid(tf.matmul(X, W1) + b1)
hypothesis = tf.sigmoid(tf.matmul(L2, W2) + b2)
```

Wide NN for XOR

```
198000 cost 0.00357563
    predict [[ 0.00214934]
 [ 0.99605185]
 [ 0.99672902]
 [ 0.00490645]]
    W1, B1 [array([[-1.64474547,  0.8943826 ,  0.28936383, -0.56383854,  3.85756803,
        -2.07212377,  1.19432867, -1.34555447,  6.40112543,  6.01214457],
       [-1.12384748,  0.70554543,  1.48841226, -0.80537623, -5.49986124,
         4.09881163,  0.32355428, -0.79951024, -4.84555626,  6.11010885]], dtype=float32), array([-0.45977819], dtype=float32)]
    W2, B2 [array([[ 2.93114686],
       [-1.35010254],
       [-1.59123349],
       [ 1.30858362],
       [ 7.05565166],
       [-4.19236469],
       [-1.34470844],
       [ 2.38127279],
       [-9.47126675],
       [ 9.30797291]], dtype=float32), array([-0.45977819], dtype=float32)]
[array([[ 0.],
       [ 1.],
       [ 1.],
       [ 0.]], dtype=float32), array([[ True],
       [ True],
       [ True],
       [ True]], dtype=bool)]
Accuracy: 1.0
```

Deep NN for XOR

```
W1 = tf.Variable(tf.random_uniform([2, 5], -1.0, 1.0))
W2 = tf.Variable(tf.random_uniform([5, 4], -1.0, 1.0))
W3 = tf.Variable(tf.random_uniform([4, 1], -1.0, 1.0))

b1 = tf.Variable(tf.zeros([5]), name="Bias1")
b2 = tf.Variable(tf.zeros([4]), name="Bias2")
b3 = tf.Variable(tf.zeros([1]), name="Bias2")

# Our hypothesis
L2 = tf.sigmoid(tf.matmul(X, W1) + b1)
L3 = tf.sigmoid(tf.matmul(L2, W2) + b2)
hypothesis = tf.sigmoid(tf.matmul(L3, W3) + b3)
```

Deep NN for XOR

```
198000 cost 0.00111391
    predict [[  5.58296102e-04]
 [  9.98885453e-01]
 [  9.98768628e-01]
 [  1.54864462e-03]]
    W1, B1 [array([[ 5.39242172,  2.17747116,  5.26371241, -0.18648638, -0.05985435],
       [ 4.86114264, -4.64419937, -3.61568236, -1.43215752, -2.03103042]], dtype=float32), array([ 0.
    W2, B2 [array([[-2.3721838 , -3.82411337,  2.479671  ,  1.95326269],
       [-2.15816069, -3.55406022,  2.87128544,  2.1189158 ],
       [ 2.92693424,  4.71013832, -3.4270494 , -2.09762478],
       [-0.03848177, -0.86011964,  1.32942307,  0.62142414],
       [-1.01190925, -1.92403996,  0.65061325, -0.27596042]], dtype=float32), array([ 0.70831299,  1.
[array([[ 0.],
       [ 1.],
       [ 1.],
       [ 0.]], dtype=float32), array([[ True],
       [ True],
       [ True],
       [ True]], dtype=bool)]
Accuracy: 1.0
```

Let's go deep & wide!

```
W1 = tf.Variable(tf.random_uniform([2, 5], -1.0, 1.0))
W2 = tf.Variable(tf.random_uniform([5, 4], -1.0, 1.0))
W3 = tf.Variable(tf.random_uniform([4, 1], -1.0, 1.0))

b1 = tf.Variable(tf.zeros([5]), name="Bias1")
b2 = tf.Variable(tf.zeros([4]), name="Bias2")
b3 = tf.Variable(tf.zeros([1]), name="Bias2")

# Our hypothesis
L2 = tf.sigmoid(tf.matmul(X, W1) + b1)
L3 = tf.sigmoid(tf.matmul(L2, W2) + b2)
hypothesis = tf.sigmoid(tf.matmul(L3, W3) + b3)
```

Lab 9-2

Tensorboard

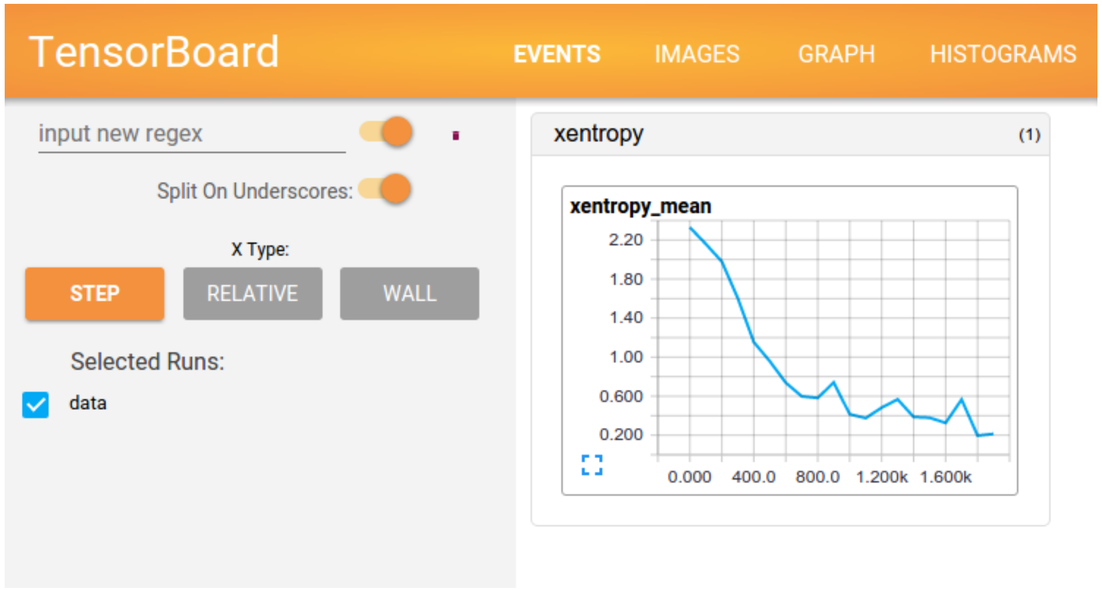
Sung Kim <hunkim+ml@gmail.com>

Visualizing your Deep learning using TensorBoard (TensorFlow)

Sung Kim <hunkim+ml@gmail.com>

TensorBoard: TF logging/debugging tool

- Visualize your TF graph
- Plot quantitative metrics
- Show additional data

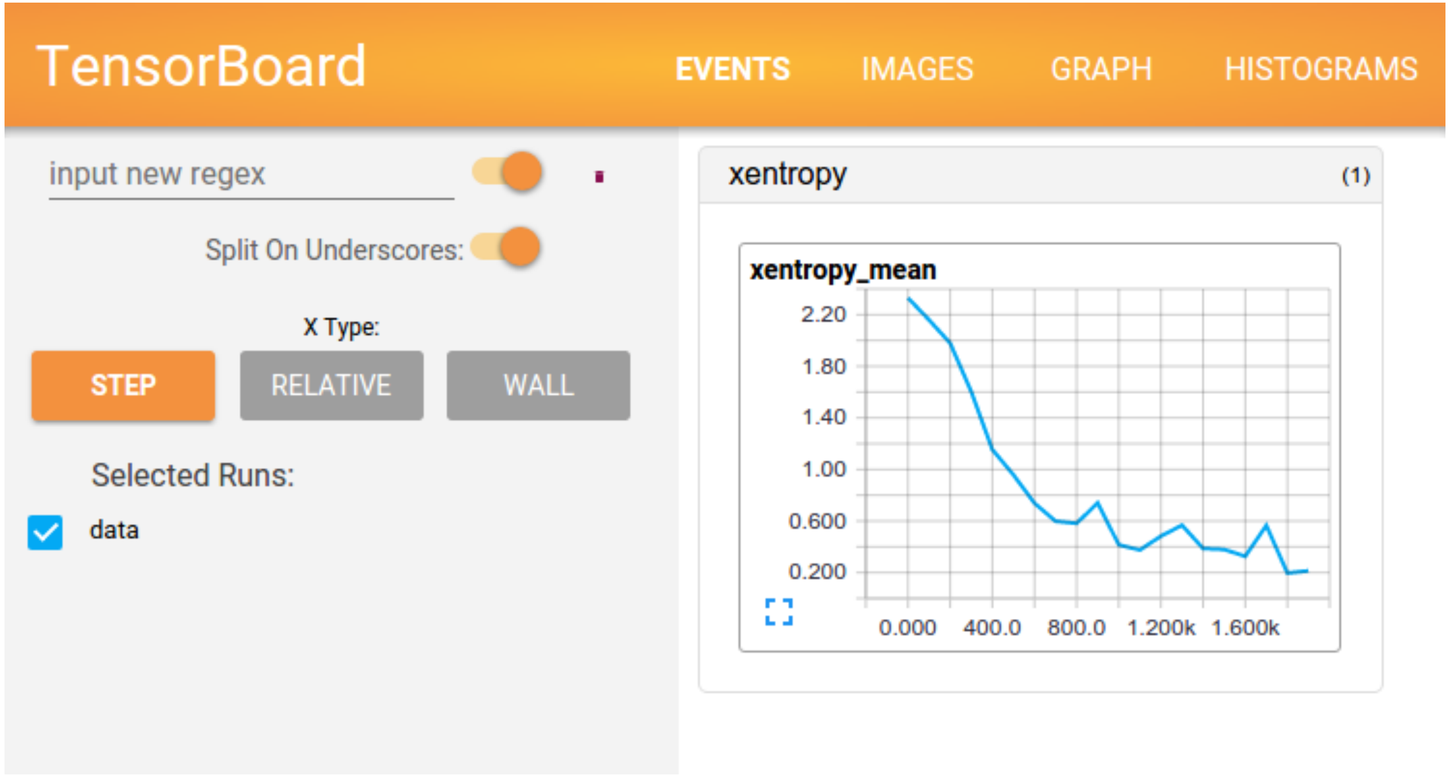


https://www.tensorflow.org/versions/r0.7/how_tos/summaries_and_tensorboard/index.html

Old fashion: print, print, print

```
2000 [0.69364417, array([[ 0.50981331,  0.50592244],
       [ 0.37054271,  0.37088916],
       [ 0.6810087 ,  0.38607275],
       [ 0.54717511,  0.26581794]], dtype=float32), array([[ 0.50861073],
       [ 0.51602864],
       [ 0.4826754 ],
       [ 0.49036184]], dtype=float32), array([[ 0.71915275, -0.48754135],
       [-0.56914777, -0.55209494]], dtype=float32), array([[-0.44138899],
       [ 0.23536676]], dtype=float32), array([ 0.03925836,  0.02369077], dtype=float32), array([ 0.14039496], dtype=float32)]
4000 [0.69332385, array([[ 0.52235132,  0.50927138],
       [ 0.38598102,  0.37814924],
       [ 0.69650716,  0.39592981],
       [ 0.56881481,  0.27748841]], dtype=float32), array([[ 0.50748861],
       [ 0.51554251],
       [ 0.48338425],
       [ 0.49113813]], dtype=float32), array([[ 0.74125487, -0.45954311],
       [-0.55370271, -0.53450096]], dtype=float32), array([[-0.42565805],
       [ 0.19686614]], dtype=float32), array([ 0.08946501,  0.03708982], dtype=float32), array([ 0.15204136], dtype=float32)]
6000 [0.69306737, array([[ 0.53439337,  0.51197231],
       [ 0.39961013,  0.38383543],
       [ 0.71191686,  0.40380618],
       [ 0.58899951,  0.2868301 ]], dtype=float32), array([[ 0.50660294],
       [ 0.51538038],
```

New way!


TensorBoard
EVENTS
IMAGES
GRAPH
HISTOGRAMS
input new regex
Split On Underscores:
X Type:
STEP
RELATIVE
WALL
Selected Runs:
data
xentropy
(1)
xentropy_mean
2.20
1.80
1.40
1.00
0.600
0.200
0.000
400.0
800.0
1.200k
1.600k

5 steps of using tensorboard

- From TF graph, decide which node you want to annotate
  - with tf.name_scope("test") as scope:
  - tf.histogram_summary("weights", W), tf.scalar_summary(“accuracy", accuracy)
- Merge all summaries
  - merged = tf.merge_all_summaries()
- Create writer
  - writer = tf.train.SummaryWriter("/tmp/mnist_logs", sess.graph_def)
- Run summary merge and add_summary
  - summary = sess.run(merged, …); writer.add_summary(summary);
- Launch Tensorboard
  - tensorboard --logdir=/tmp/mnist_logs

Name variables

```
X = tf.placeholder(tf.float32, name = 'X-input')
Y = tf.placeholder(tf.float32, name = 'Y-input')

W1 = tf.Variable(tf.random_uniform([2, 2], -1.0, 1.0), name = "Weight1")
W2 = tf.Variable(tf.random_uniform([2, 1], -1.0, 1.0), name = "Weight2")

b1 = tf.Variable(tf.zeros([2]), name="Bias1")
b2 = tf.Variable(tf.zeros([1]), name="Bias2")
```

Add scope for better graph hierarch

```
# Our hypothesis
with tf.name_scope("layer2") as scope:
    L2 = tf.sigmoid(tf.matmul(X, W1) + b1)

with tf.name_scope("layer3") as scope:
    hypothesis = tf.sigmoid(tf.matmul(L2, W2) + b2)

# cost function
with tf.name_scope("cost") as scope:
    cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesis))
    cost_summ = tf.scalar_summary("cost", cost)

# Minimize
with tf.name_scope("train") as scope:
    optimizer = tf.train.GradientDescentOptimizer(0.01) # Learning rate, alpha
    train = optimizer.minimize(cost)
```

Add histogram

```
w1_hist = tf.histogram_summary("weights1", W1)
w2_hist = tf.histogram_summary("weights2", W2)

b1_hist = tf.histogram_summary("biases1", b1)
b2_hist = tf.histogram_summary("biases2", b2)

y_hist = tf.histogram_summary("y", Y)
```

Add scalar variables

```
# cost function
with tf.name_scope("cost") as scope:
    cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesis))
    cost_summ = tf.scalar_summary("cost", cost)
```

Merge summaries and create writer after creating session

```
# Launch the graph.
with tf.Session() as sess:

    #tensorboard --logdir=./logs/xor_logs
    merged = tf.merge_all_summaries()
    writer = tf.train.SummaryWriter("./logs/xor_logs", sess.graph_def)
```

Run merged summary and write (add summary)

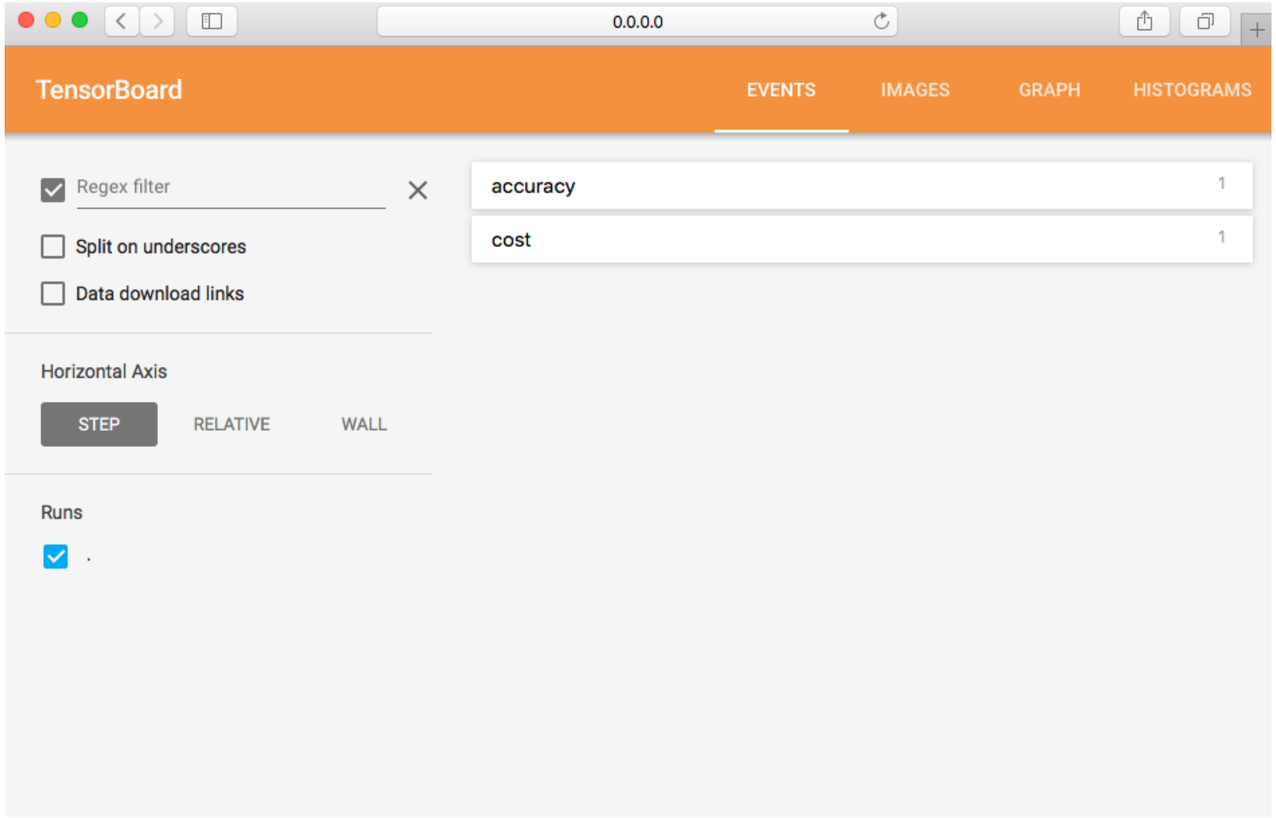
```
# Fit the line.
for step in xrange(200000):
    summary, _ = sess.run([merged, train], feed_dict={X:x_data, Y:y_data})
    writer.add_summary(summary, step)
```

```
# Fit the line.
for step in xrange(200000):
    sess.run(train, feed_dict={X:x_data, Y:y_data})
    if step % 2000 == 0:
        summary = sess.run(merged, feed_dict={X:x_data, Y:y_data})
        writer.add_summary(summary, step)
```

[merged, train]

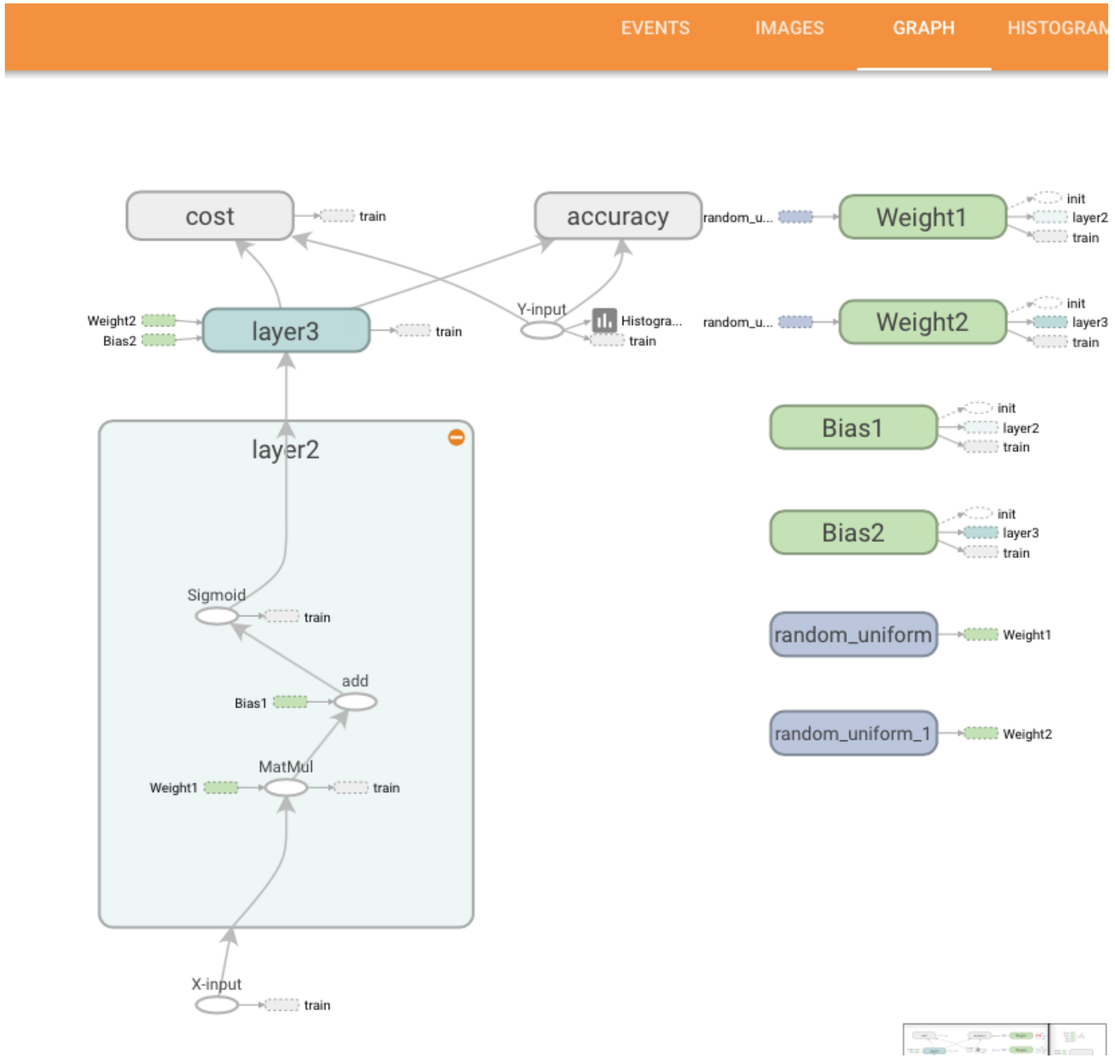
Launch tensorboard

- tensorboard —logdir=/tmp/mnist_logs
- (You can navigate to http://0.0.0.0:6006)



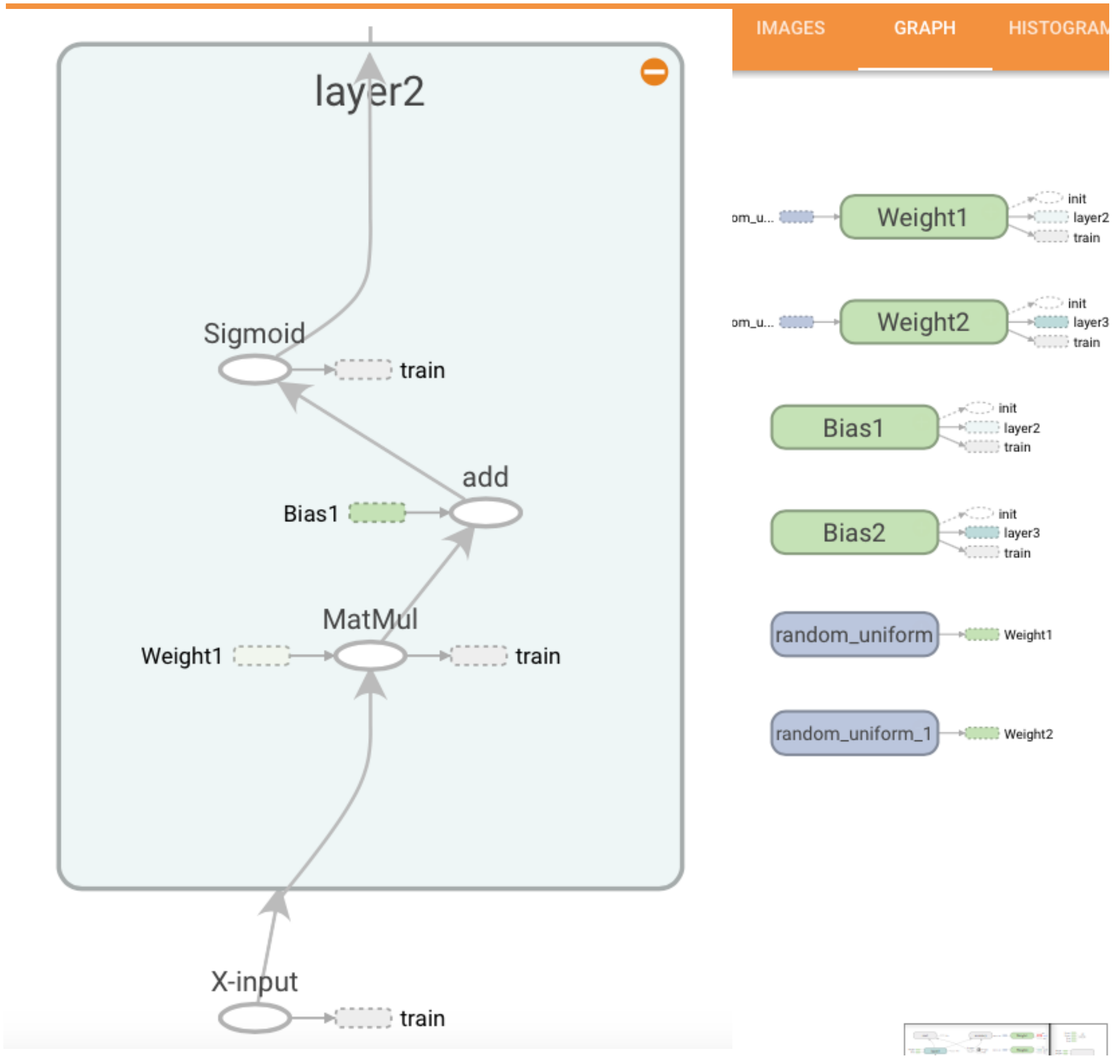
Add scope for better graph hierarch

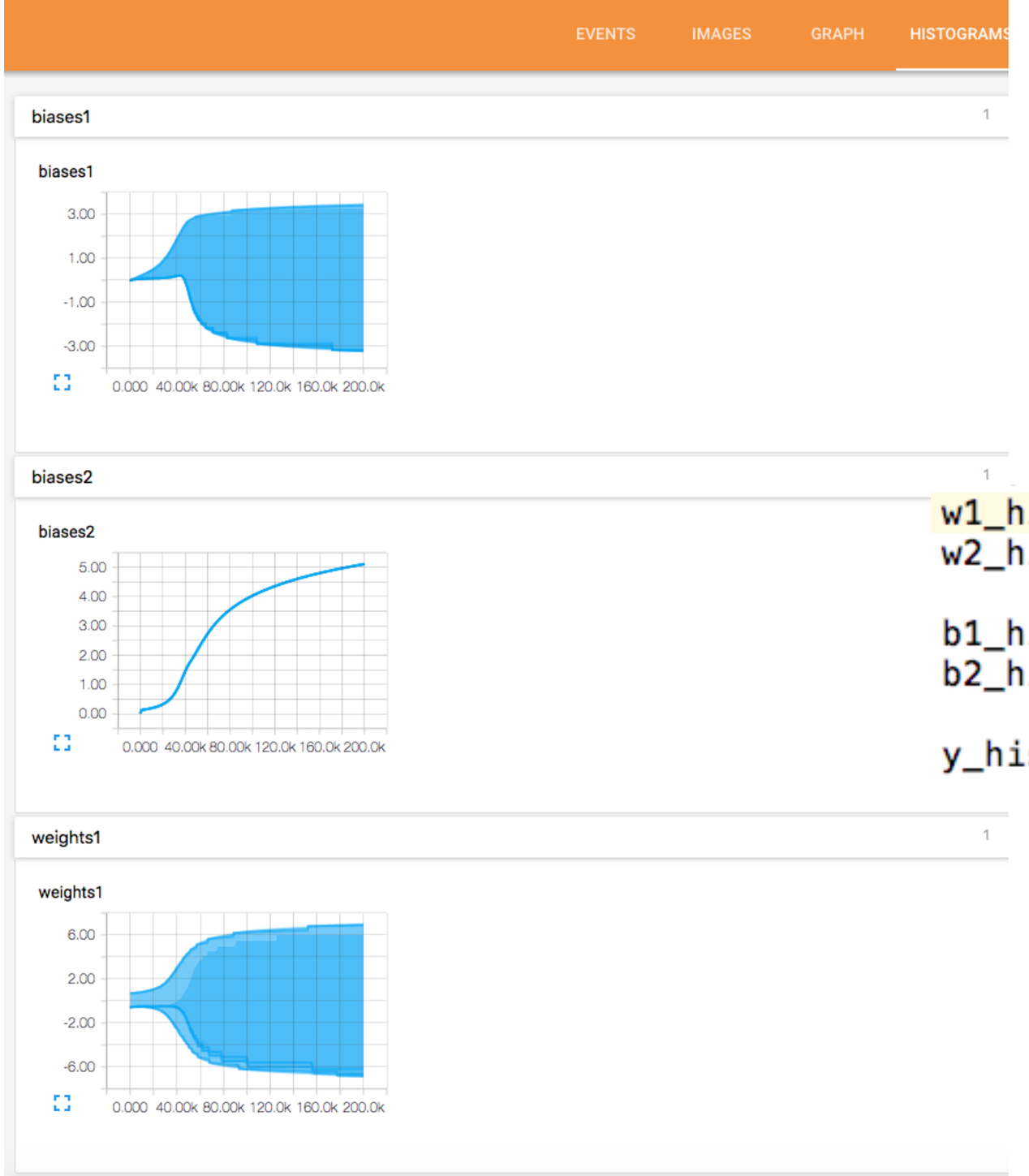
```python
# Our hypothesis
with tf.name_scope("layer2") as scope:
    L2 = tf.sigmoid(tf.matmul(X, W1) + b1)

with tf.name_scope("layer3") as scope:
    hypothesis = tf.sigmoid(tf.matmul(L2, W2) + b2)

# cost function
with tf.name_scope("cost") as scope:
    cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesis))
    cost_summ = tf.scalar_summary("cost", cost)

# Minimize
with tf.name_scope("train") as scope:
    optimizer = tf.train.GradientDescentOptimizer(0.01) # Learning rate, alpha
    train = optimizer.minimize(cost)
```



Add scope for better graph hierarch

```python
# Our hypothesis
with tf.name_scope("layer2") as scope:
    L2 = tf.sigmoid(tf.matmul(X, W1) + b1)

with tf.name_scope("layer3") as scope:
    hypothesis = tf.sigmoid(tf.matmul(L2, W2) + b2)

# cost function
with tf.name_scope("cost") as scope:
    cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesis))
    cost_summ = tf.scalar_summary("cost", cost)

# Minimize
with tf.name_scope("train") as scope:
    optimizer = tf.train.GradientDescentOptimizer(0.01) # Learning rate, alpha
    train = optimizer.minimize(cost)
```





Add histogram

```
w1_hist = tf.histogram_summary("weights1", W1)
w2_hist = tf.histogram_summary("weights2", W2)

b1_hist = tf.histogram_summary("biases1", b1)
b2_hist = tf.histogram_summary("biases2", b2)

y_hist = tf.histogram_summary("y", Y)
```

Add scalar variables


```python
# cost function
with tf.name_scope("cost") as scope:
    cost = -tf.reduce_mean(Y*tf.log(hypothesis) + (1-Y)*tf.log(1-hypothesi
    cost_summ = tf.scalar_summary("cost", cost)
```

5 steps of using tensorboard

- From TF graph, decide which node you want to annotate
  - with tf.name_scope("test") as scope:
  - tf.histogram_summary("weights", W), tf.scalar_summary(“accuracy", accuracy)
- Merge all summaries
  - merged = tf.merge_all_summaries()
- Create writer
  - writer = tf.train.SummaryWriter("/tmp/mnist_logs", sess.graph_def)
- Run summary merge and add_summary
  - summary = sess.run(merged, …); writer.add_summary(summary);
- Launch Tensorboard
  - tensorboard --logdir=/tmp/mnist_logs

Lab 10

NN, ReLu, Xavier, Dropout, and Adam

Sung Kim <hunkim+ml@gmail.com>
http://hunkim.github.io/ml/

Examples

- https://github.com/aymericdamien/TensorFlow-Examples

Softmax classifier for MNIST

```
# tf Graph Input
x = tf.placeholder("float", [None, 784]) # mnist data image of shape 28*28=784
y = tf.placeholder("float", [None, 10]) # 0-9 digits recognition => 10 classes

# Create model

# Set model weights
W = tf.Variable(tf.zeros([784, 10]))
b = tf.Variable(tf.zeros([10]))

# Construct model
activation = tf.nn.softmax(tf.matmul(x, W) + b) # Softmax

# Minimize error using cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(y*tf.log(activation), reduction_indices=1)) # Cross entropy
optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost) # Gradient Descent

# Initializing the variables
init = tf.initialize_all_variables()

# Launch the graph
with tf.Session() as sess:
    sess.run(init)

    # Training cycle
    for epoch in range(training_epochs):
        avg_cost = 0.
        total_batch = int(mnist.train.num_examples/batch_size)
        # Loop over all batches
        for i in range(total_batch):
            batch_xs, batch_ys = mnist.train.next_batch(batch_size)
            # Fit training using batch data
            sess.run(optimizer, feed_dict={x: batch_xs, y: batch_ys})
            # Compute average loss
            avg_cost += sess.run(cost, feed_dict={x: batch_xs, y: batch_ys})/total_batch
        # Display logs per epoch step
        if epoch % display_step == 0:
            print "Epoch:", '%04d' % (epoch+1), "cost=", "{:.9f}".format(avg_cost)

    print "Optimization Finished!"

    # Test model
    correct_prediction = tf.equal(tf.argmax(activation, 1), tf.argmax(y, 1))
    # Calculate accuracy
    accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
    print "Accuracy:", accuracy.eval({x: mnist.test.images, y: mnist.test.labels})
```

softmax classifier

Epoch: 0001 cost= 1.174406660
Epoch: 0002 cost= 0.661967539
Epoch: 0003 cost= 0.550489192
Epoch: 0004 cost= 0.496657414
Epoch: 0005 cost= 0.463665792
Epoch: 0006 cost= 0.440912077
Epoch: 0007 cost= 0.423909424
Epoch: 0008 cost= 0.410630655
Epoch: 0009 cost= 0.399893884
Epoch: 0010 cost= 0.390907963
Epoch: 0011 cost= 0.383317497
Epoch: 0012 cost= 0.376792131
Epoch: 0013 cost= 0.371025368
Epoch: 0014 cost= 0.365951805
Epoch: 0015 cost= 0.361361689
Epoch: 0016 cost= 0.357238019
Epoch: 0017 cost= 0.353540161
Epoch: 0018 cost= 0.350144092
Epoch: 0019 cost= 0.347053342
Epoch: 0020 cost= 0.344076798
Epoch: 0021 cost= 0.341447881
Epoch: 0022 cost= 0.339008725
Epoch: 0023 cost= 0.336701365
Epoch: 0024 cost= 0.334450486
Epoch: 0025 cost= 0.332461696
Optimization Finished!
Accuracy: 0.9139

Neural Nets (NN) for MNIST

```
# Parameters
learning_rate = 0.001
training_epochs = 15
batch_size = 100
display_step = 1

# tf Graph input
X = tf.placeholder("float", [None, 784]) # MNIST data input (img shape: 28*28)
Y = tf.placeholder("float", [None, 10])  # MNIST total classes (0-9 digits)

# Store layers weight & bias
W1 = tf.Variable(tf.random_normal([784, 256]))
W2 = tf.Variable(tf.random_normal([256, 256]))
W3 = tf.Variable(tf.random_normal([256, 10]))

B1 = tf.Variable(tf.random_normal([256]))
B2 = tf.Variable(tf.random_normal([256]))
B3 = tf.Variable(tf.random_normal([10]))

# Construct model
L1 = tf.nn.relu(tf.add(tf.matmul(X, W1), B1))
L2 = tf.nn.relu(tf.add(tf.matmul(L1, W2), B2)) #Hidden layer with RELU activation
hypothesis = tf.add(tf.matmul(L2, W3), B3) # No need to use softmax here

# Define loss and optimizer
cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(hypothesis, Y)) # Softmax loss
optimizer = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost) # Adam Optimizer
```

Neural Nets (NN) for MNIST

```
# Initializing the variables
init = tf.initialize_all_variables()

# Launch the graph
with tf.Session() as sess:
    sess.run(init)

    # Training cycle
    for epoch in range(training_epochs):
        avg_cost = 0.
        total_batch = int(mnist.train.num_examples/batch_size)
        # Loop over all batches
        for i in range(total_batch):
            batch_xs, batch_ys = mnist.train.next_batch(batch_size)
            # Fit training using batch data
            sess.run(optimizer, feed_dict={X: batch_xs, Y: batch_ys})
            # Compute average loss
            avg_cost += sess.run(cost, feed_dict={X: batch_xs, Y: batch_ys})/total_batch
        # Display logs per epoch step
        if epoch % display_step == 0:
            print "Epoch:", '%04d' % (epoch+1), "cost=", "{:.9f}".format(avg_cost)

    print "Optimization Finished!"

    # Test model
    correct_prediction = tf.equal(tf.argmax(hypothesis, 1), tf.argmax(Y, 1))
    # Calculate accuracy
    accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
    print "Accuracy:", accuracy.eval({X: mnist.test.images, Y: mnist.test.labels})
```

softmax classifier

Epoch: 0001 cost= 1.174406660
Epoch: 0002 cost= 0.661967539
Epoch: 0003 cost= 0.550489192
Epoch: 0004 cost= 0.496657414
Epoch: 0005 cost= 0.463665792
Epoch: 0006 cost= 0.440912077
Epoch: 0007 cost= 0.423909424
Epoch: 0008 cost= 0.410630655
Epoch: 0009 cost= 0.399893884
Epoch: 0010 cost= 0.390907963
Epoch: 0011 cost= 0.383317497
Epoch: 0012 cost= 0.376792131
Epoch: 0013 cost= 0.371025368
Epoch: 0014 cost= 0.365951805
Epoch: 0015 cost= 0.361361689
Epoch: 0016 cost= 0.357238019
Epoch: 0017 cost= 0.353540161
Epoch: 0018 cost= 0.350144092
Epoch: 0019 cost= 0.347053342
Epoch: 0020 cost= 0.344076798
Epoch: 0021 cost= 0.341447881
Epoch: 0022 cost= 0.339008725
Epoch: 0023 cost= 0.336701365
Epoch: 0024 cost= 0.334450486
Epoch: 0025 cost= 0.332461696
Optimization Finished!
Accuracy: 0.9139

NN

Epoch: 0001 cost= 153.374492868
Epoch: 0002 cost= 41.126819546
Epoch: 0003 cost= 25.309642092
Epoch: 0004 cost= 17.206465834
Epoch: 0005 cost= 12.155490249
Epoch: 0006 cost= 8.755095852
Epoch: 0007 cost= 6.392030562
Epoch: 0008 cost= 4.629136964
Epoch: 0009 cost= 3.347306573
Epoch: 0010 cost= 2.372126589
Epoch: 0011 cost= 1.667233310
Epoch: 0012 cost= 1.202339336
Epoch: 0013 cost= 0.837206638
Epoch: 0014 cost= 0.593220934
Epoch: 0015 cost= 0.431912481
Optimization Finished!
Accuracy: 0.9446

Xavier initialization

```python
def xavier_init(n_inputs, n_outputs, uniform=True):
  """Set the parameter initialization using the method described.
  This method is designed to keep the scale of the gradients roughly the same
  in all layers.
  Xavier Glorot and Yoshua Bengio (2010):
           Understanding the difficulty of training deep feedforward neural
           networks. International conference on artificial intelligence and
           statistics.
  Args:
    n_inputs: The number of input nodes into each output.
    n_outputs: The number of output nodes for each input.
    uniform: If true use a uniform distribution, otherwise use a normal.
  Returns:
    An initializer.
  """
  if uniform:
    # 6 was used in the paper.
    init_range = tf.sqrt(6.0 / (n_inputs + n_outputs))
    return tf.random_uniform_initializer(-init_range, init_range)
  else:
    # 3 gives us approximately the same limits as above since this repicks
    # values greater than 2 standard deviations from the mean.
    stddev = tf.sqrt(3.0 / (n_inputs + n_outputs))
    return tf.truncated_normal_initializer(stddev=stddev)
```

```python
# Store layers weight & bias
W1 = tf.get_variable("W1", shape=[784, 256], initializer=xavier_init(784,256))
W2 = tf.get_variable("W2", shape=[256, 256], initializer=xavier_init(256,256))
W3 = tf.get_variable("W3", shape=[256, 10], initializer=xavier_init(256,10))
```

http://stackoverflow.com/questions/33640581/how-to-do-xavier-initialization-on-tensorflow

NN

Epoch: 0001 cost= 153.374492868
Epoch: 0002 cost= 41.126819546
Epoch: 0003 cost= 25.309642092
Epoch: 0004 cost= 17.206465834
Epoch: 0005 cost= 12.155490249
Epoch: 0006 cost= 8.755095852
Epoch: 0007 cost= 6.392030562
Epoch: 0008 cost= 4.629136964
Epoch: 0009 cost= 3.347306573
Epoch: 0010 cost= 2.372126589
Epoch: 0011 cost= 1.667233310
Epoch: 0012 cost= 1.202339336
Epoch: 0013 cost= 0.837206638
Epoch: 0014 cost= 0.593220934
Epoch: 0015 cost= 0.431912481
Optimization Finished!
Accuracy: 0.9446

NN with xavier initialization

Epoch: 0001 cost= 0.330929694
Epoch: 0002 cost= 0.110038888
Epoch: 0003 cost= 0.067369296
Epoch: 0004 cost= 0.045064388
Epoch: 0005 cost= 0.031090851
Epoch: 0006 cost= 0.022001974
Epoch: 0007 cost= 0.016603567
Epoch: 0008 cost= 0.011094349
Epoch: 0009 cost= 0.008923969
Epoch: 0010 cost= 0.007312808
Epoch: 0011 cost= 0.006277084
Epoch: 0012 cost= 0.004857574
Epoch: 0013 cost= 0.004891470
Epoch: 0014 cost= 0.004491583
Epoch: 0015 cost= 0.003429245
Optimization Finished!
Accuracy: 0.9779

More deep & dropout

```
# Construct model
dropout_rate = tf.placeholder("float")
_L1 = tf.nn.relu(tf.add(tf.matmul(X, W1), B1)) #Hidden layer with RELU activation
L1 = tf.nn.dropout(_L1, dropout_rate)
_L2 = tf.nn.relu(tf.add(tf.matmul(L1, W2), B2)) #Hidden layer with RELU activation
L2 = tf.nn.dropout(_L2, dropout_rate)
_L3 = tf.nn.relu(tf.add(tf.matmul(L2, W3), B3)) #Hidden layer with RELU activation
L3 = tf.nn.dropout(_L3, dropout_rate)
_L4 = tf.nn.relu(tf.add(tf.matmul(L3, W4), B4)) #Hidden layer with RELU activation
L4 = tf.nn.dropout(_L4, dropout_rate)

hypothesis = tf.add(tf.matmul(L4, W5), B5) # No need to use softmax here
```

```
for i in range(total_batch):
    batch_xs, batch_ys = mnist.train.next_batch(batch_size)
    # Fit training using batch data
    sess.run(optimizer, feed_dict={X: batch_xs, Y: batch_ys, dropout_rate: 0.7})
```

```
# Test model
correct_prediction = tf.equal(tf.argmax(hypothesis, 1), tf.argmax(Y, 1))
# Calculate accuracy
accuracy = tf.reduce_mean(tf.cast(correct_prediction, "float"))
print "Accuracy:", accuracy.eval({X: mnist.test.images, Y: mnist.test.labels, dropout_rate: 1})
```

NN deep + dropout

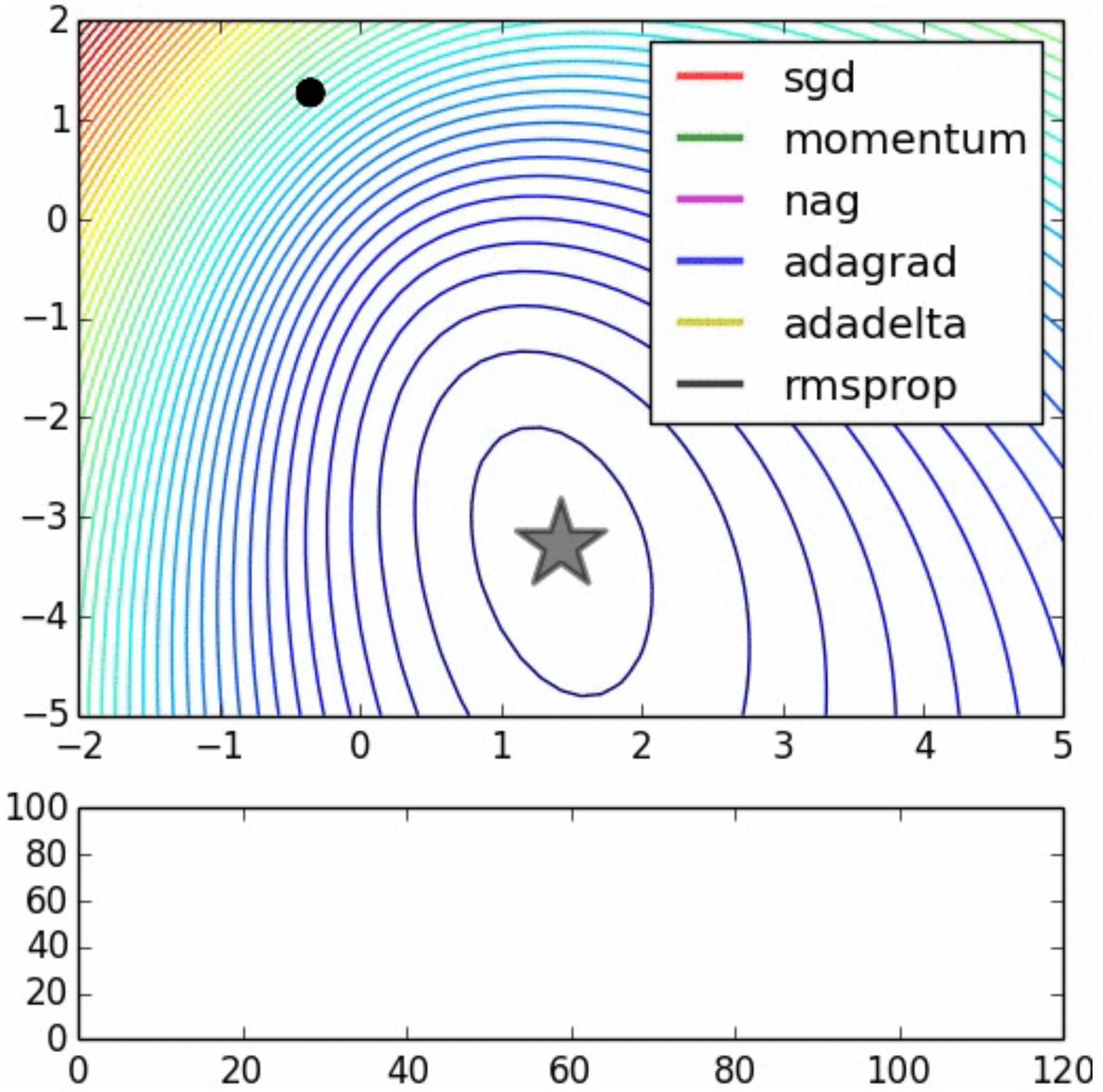
Epoch: 0001 cost= 0.584449715
Epoch: 0002 cost= 0.215399251
Epoch: 0003 cost= 0.160561109
Epoch: 0004 cost= 0.132314345
Epoch: 0005 cost= 0.114490116
Epoch: 0006 cost= 0.103506013
Epoch: 0007 cost= 0.095571726
Epoch: 0008 cost= 0.084172901
Epoch: 0009 cost= 0.079563179
Epoch: 0010 cost= 0.073859323
Epoch: 0011 cost= 0.071492671
Epoch: 0012 cost= 0.066446339
Epoch: 0013 cost= 0.061337474
Epoch: 0014 cost= 0.058591939
Epoch: 0015 cost= 0.055077895
Optimization Finished!
Accuracy: 0.9803

NN with xavier initialization

Epoch: 0001 cost= 0.330929694
Epoch: 0002 cost= 0.110038888
Epoch: 0003 cost= 0.067369296
Epoch: 0004 cost= 0.045064388
Epoch: 0005 cost= 0.031090851
Epoch: 0006 cost= 0.022001974
Epoch: 0007 cost= 0.016603567
Epoch: 0008 cost= 0.011094349
Epoch: 0009 cost= 0.008923969
Epoch: 0010 cost= 0.007312808
Epoch: 0011 cost= 0.006277084
Epoch: 0012 cost= 0.004857574
Epoch: 0013 cost= 0.004891470
Epoch: 0014 cost= 0.004491583
Epoch: 0015 cost= 0.003429245
Optimization Finished!
Accuracy: 0.9779

Optimizer

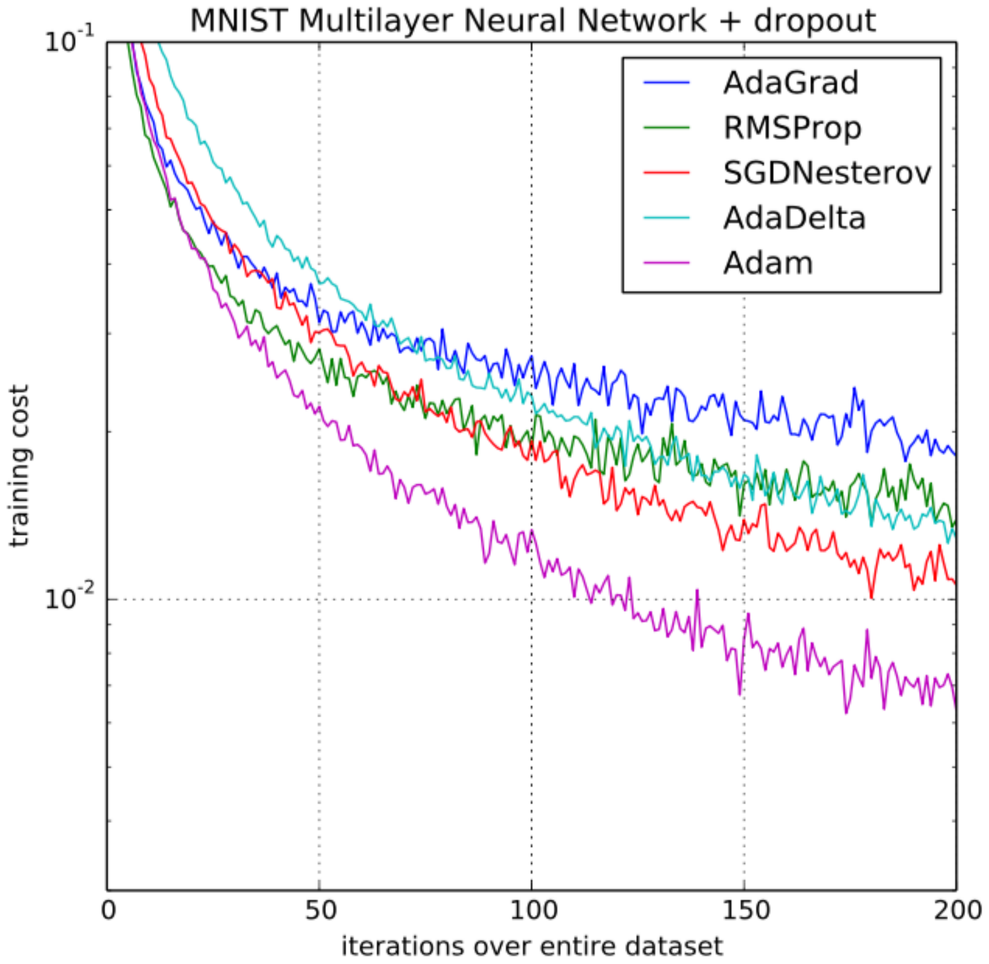
```
# Construct model
activation = tf.nn.softmax(tf.matmul(x, W) + b) # Softmax

# Minimize error using cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(y*tf.log(activation), reduction_indices=1)) # Cross entropy
optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost) # Gradient Descent
```



http://www.denizyuret.com/2015/03/alec-radfords-animations-for.html

ADAM: a method for stochastic optimization

[Kingma et al. 2015]



Use Adam Optimizer

```
# Construct model
activation = tf.nn.softmax(tf.matmul(x, W) + b) # Softmax

# Minimize error using cross entropy
cost = tf.reduce_mean(-tf.reduce_sum(y*tf.log(activation), reduction_indices=1)) # Cross entropy
optimizer = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost) # Gradient Descent
```

```
hypothesis = tf.add(tf.matmul(L4, W5), B5) # No need to use softmax here

# Define loss and optimizer
cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(hypothesis, Y)) # Softmax loss
optimizer = tf.train.AdamOptimizer(learning_rate=learning_rate).minimize(cost) # Adam Optimizer
```

Lab summary

- Softmax VS Neural Nets for MNIST, 91.4% and 94.4%
- Xavier initialization: 97.8%
- Deep Neural Nets and Dropout: 98%
- Adam optimizer

Lab 11
CNN

Sung Kim <hunkim+ml@gmail.com>
http://hunkim.github.io/ml/

TensorFlow-Tutorials

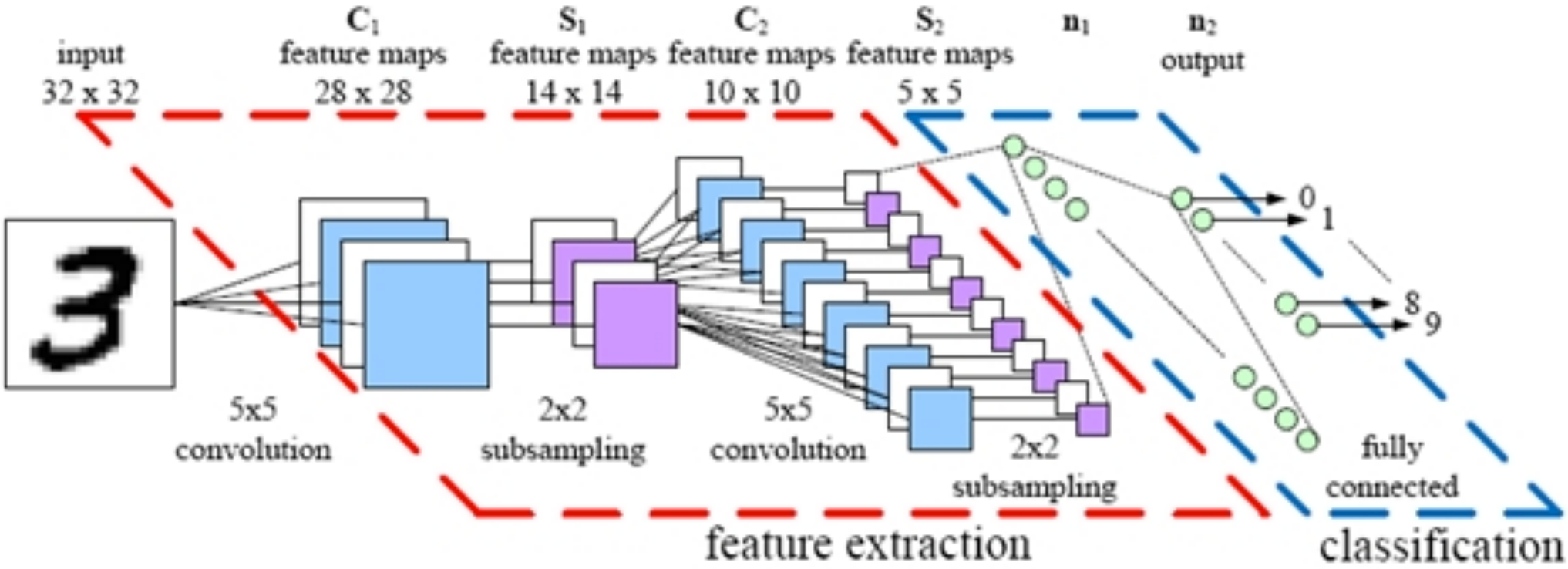
Introduction to deep learning based on Google's TensorFlow framework. These tutorials are direct ports of Newmu's Theano Tutorials

Topics

- Simple Multiplication
- Linear Regression
- Logistic Regression
- Feedforward Neural Network (Multilayer Perceptron)
- Deep Feedforward Neural Network (Multilayer Perceptron with 2 Hidden Layers O.o)
- Convolutional Neural Network
- Denoising Autoencoder
- LSTM

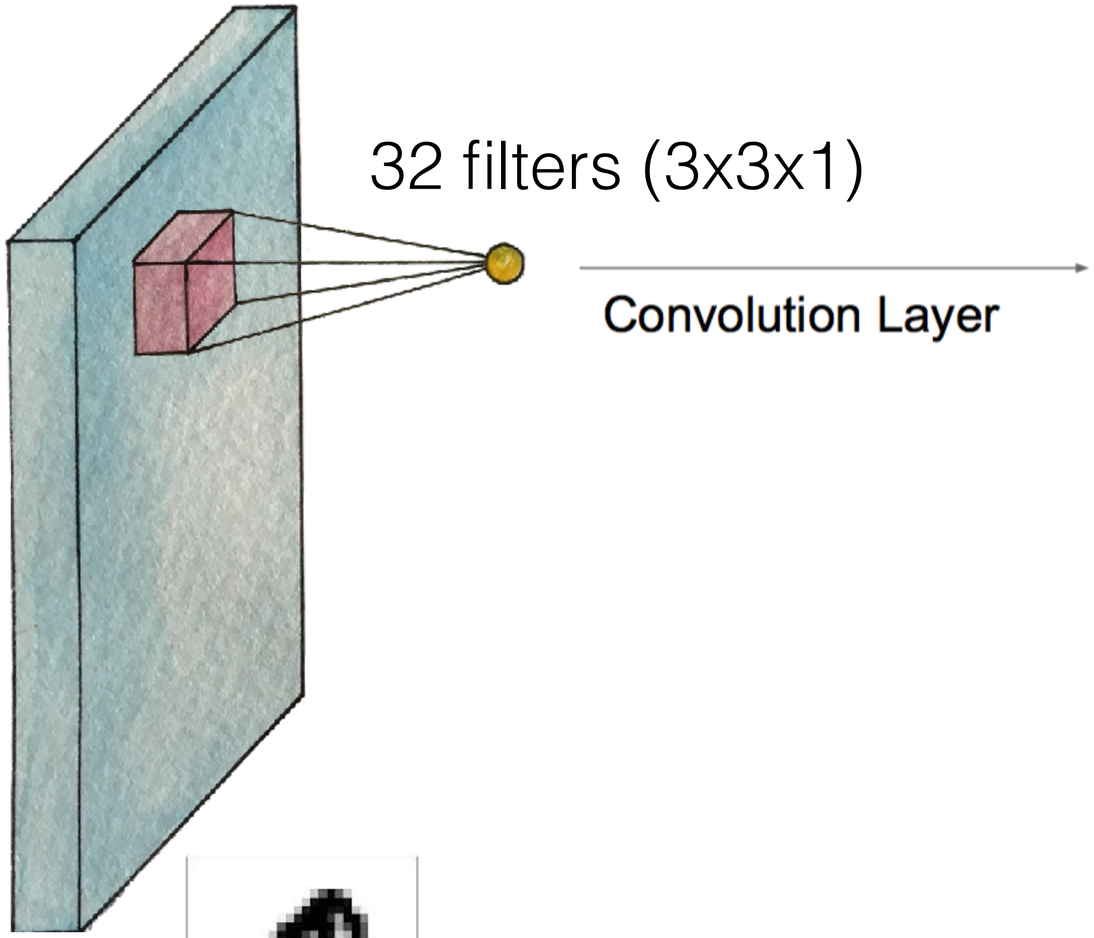
https://github.com/nlintz/TensorFlow-Tutorials

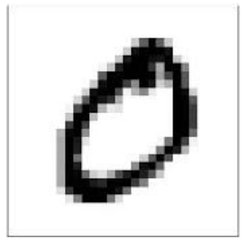
CNN



http://parse.ele.tue.nl/cluster/2/CNNArchitecture.jpg

Convolutional layers



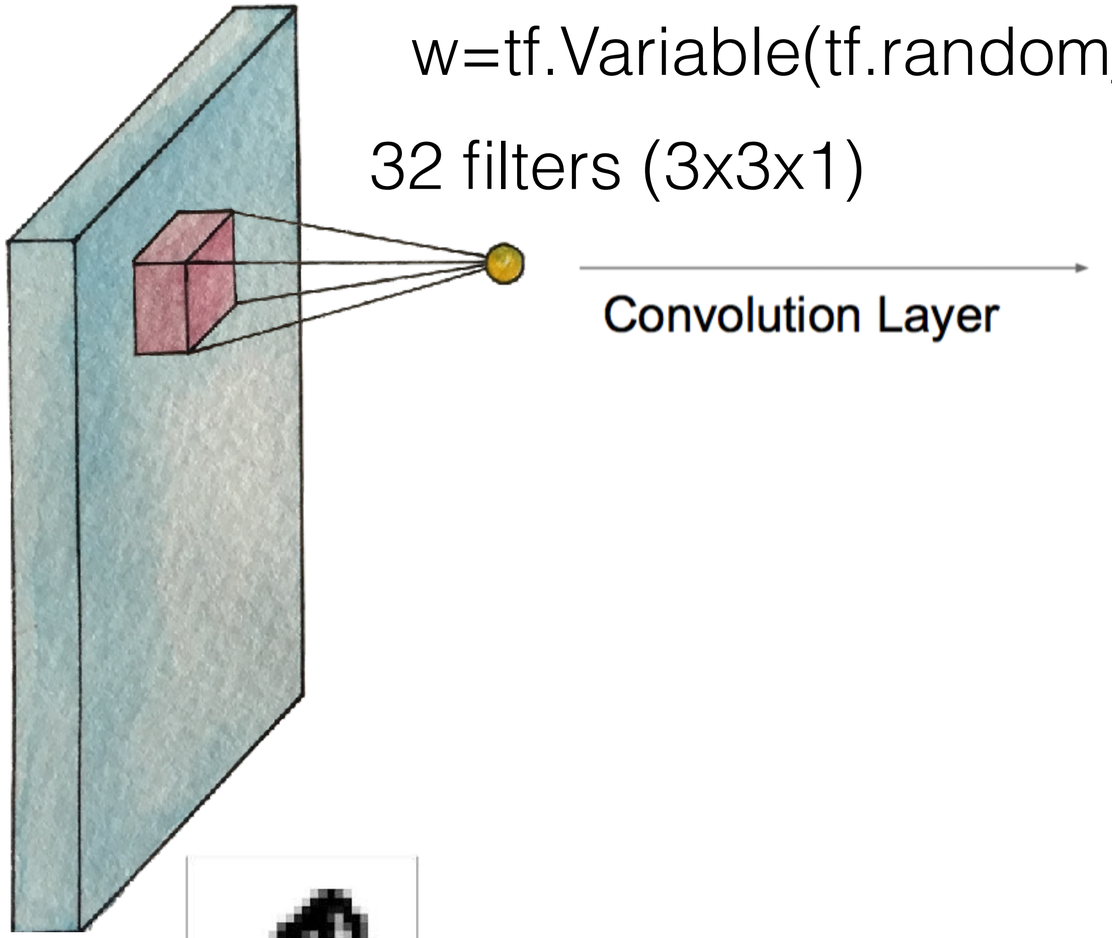


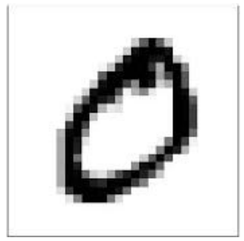
MNIST 28x28x1 image

Convolutional layers

w=tf.Variable(tf.random_normal([3,3,1,32], stddev=0.01))

32 filters (3x3x1)



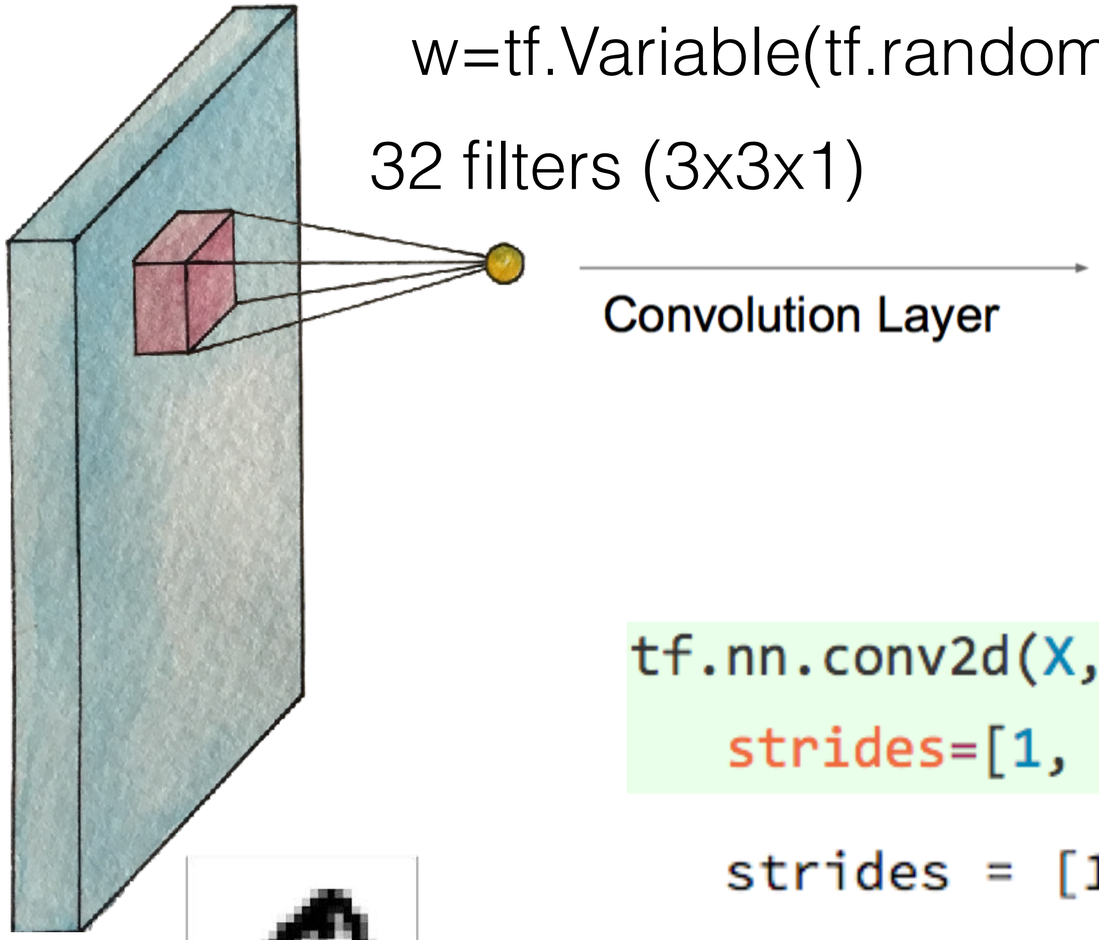


28x28x1 image

Convolutional layers

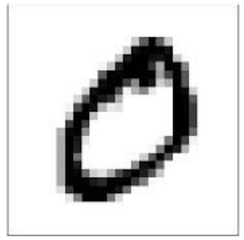
w=tf.Variable(tf.random_normal([3,3,1,32], stddev=0.01))

32 filters (3x3x1)



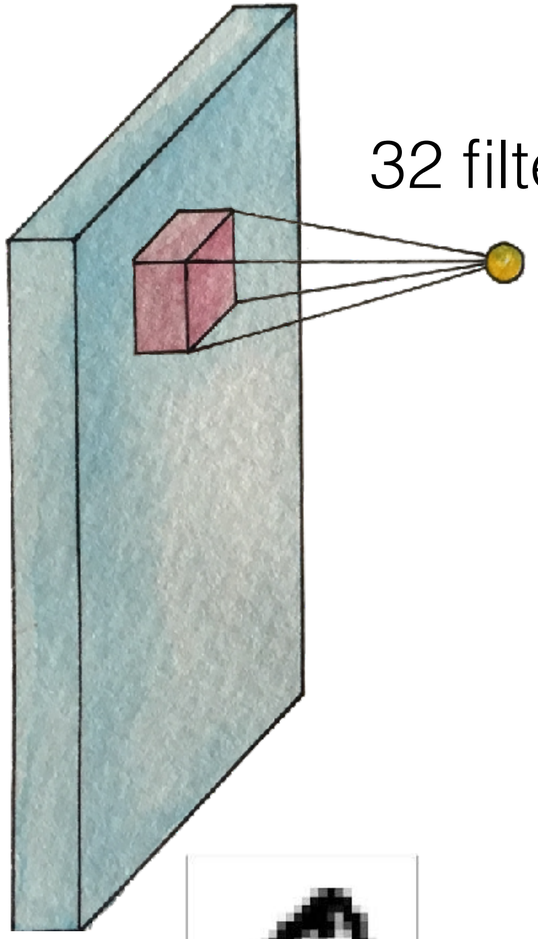

```
tf.nn.conv2d(X, w,
    strides=[1, 1, 1, 1], padding='SAME')
```

```
strides = [1, stride, stride, 1].
```



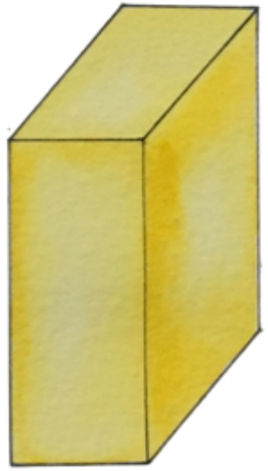
28x28x1 image

Convolutional layers



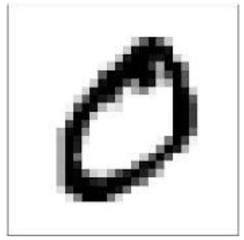
32 filters (3x3x1)

Convolution Layer



activation maps
(?, ?, 32)

```
tf.nn.conv2d(X, w,
    strides=[1, 1, 1, 1], padding='SAME')
```

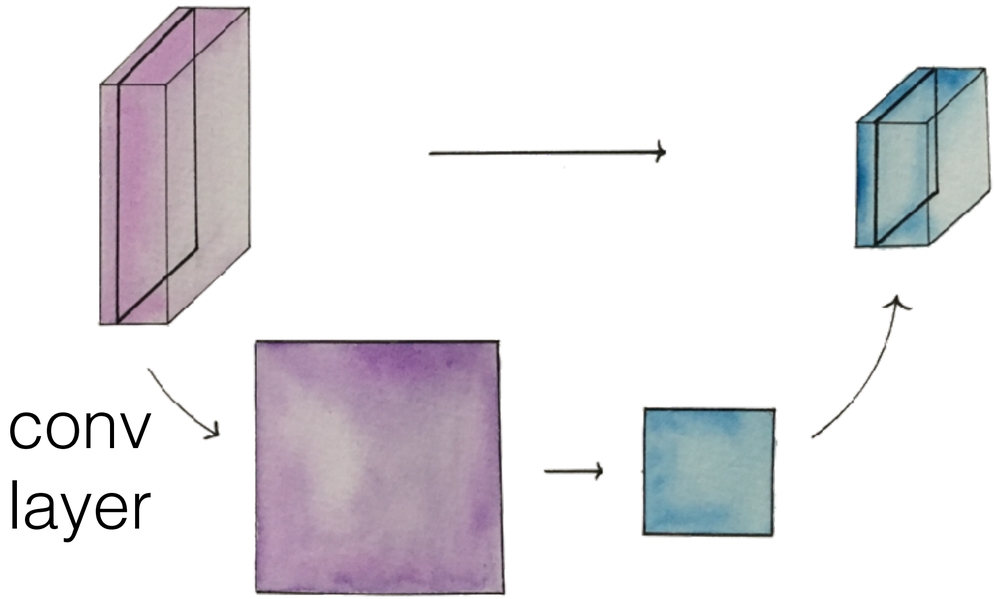


28x28x1 image

ReLU

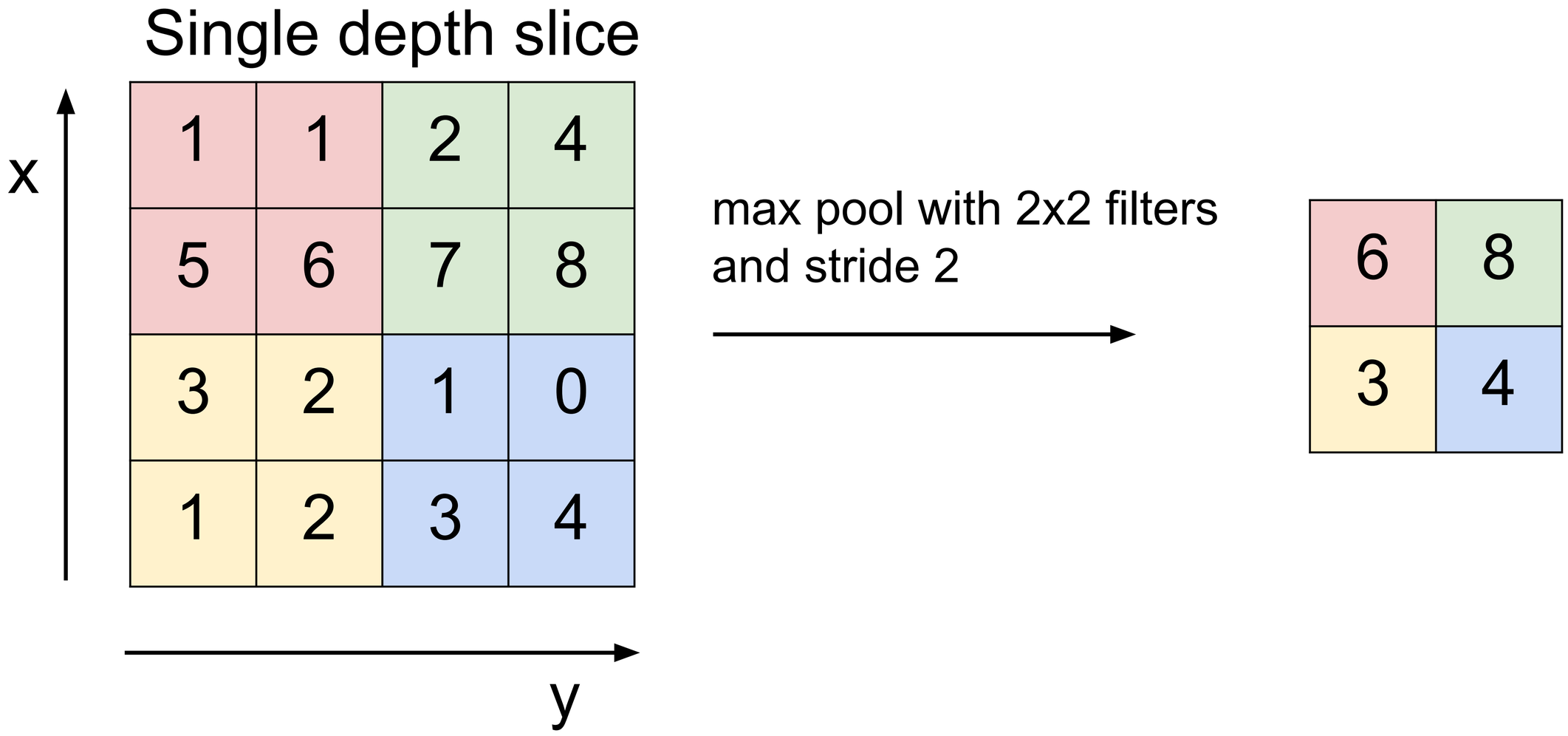
```
l = tf.nn.conv2d(X, w, [1, 1, 1, 1], 'SAME')

l1a = tf.nn.relu(tf.nn.conv2d(X, w, [1, 1, 1, 1], 'SAME'))
```

Pooling layer (sampling)

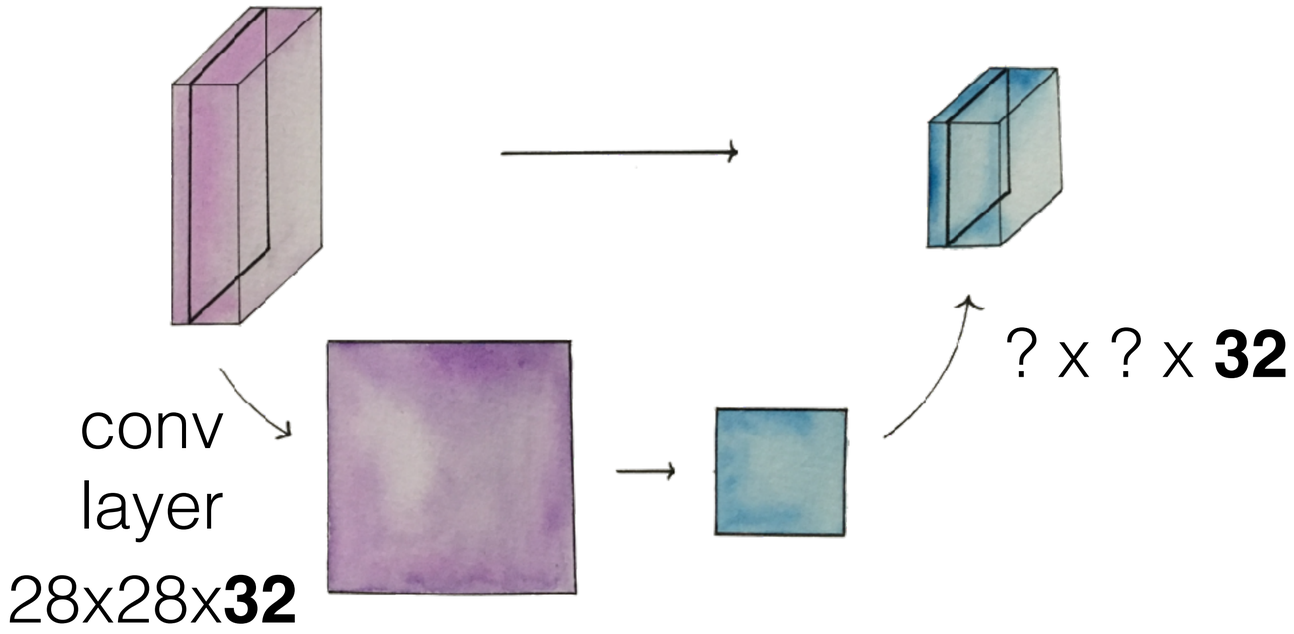



```
l1 = tf.nn.max_pool(c1, ksize=[1, 2, 2, 1],
                    strides=[1, 2, 2, 1], padding='SAME')
```

MAX POOLING


Single depth slice
x
y
1 1 2 4
5 6 7 8
3 2 1 0
1 2 3 4
max pool with 2x2 filters
and stride 2
6 8
3 4

Pooling layer (sampling)




```
l1 = tf.nn.max_pool(c1, ksize=[1, 2, 2, 1],
                    strides=[1, 2, 2, 1], padding='SAME')
```

Shape not sure? Print tensor

```
l1a = tf.nn.relu(tf.nn.conv2d(X, w, [1, 1, 1, 1], 'SAME'))
print l1a
```

Tensor("Conv2D:0", shape=(?, 28, 28, 32), dtype=float32)

```
l1 = tf.nn.max_pool(l1a, ksize=[1, 2, 2, 1],
                    strides=[1, 2, 2, 1], padding='SAME')
print l1
```

Tensor("MaxPool:0", shape=(?, 14, 14, 32), dtype=float32)

X = trX.reshape(-1, 28, 28, 1)

```
w = init_weights([3, 3, 1, 32])       # 3x3x1 conv, 32 outputs
w2 = init_weights([3, 3, 32, 64])     # 3x3x32 conv, 64 outputs
w3 = init_weights([3, 3, 64, 128])    # 3x3x32 conv, 128 outputs
```

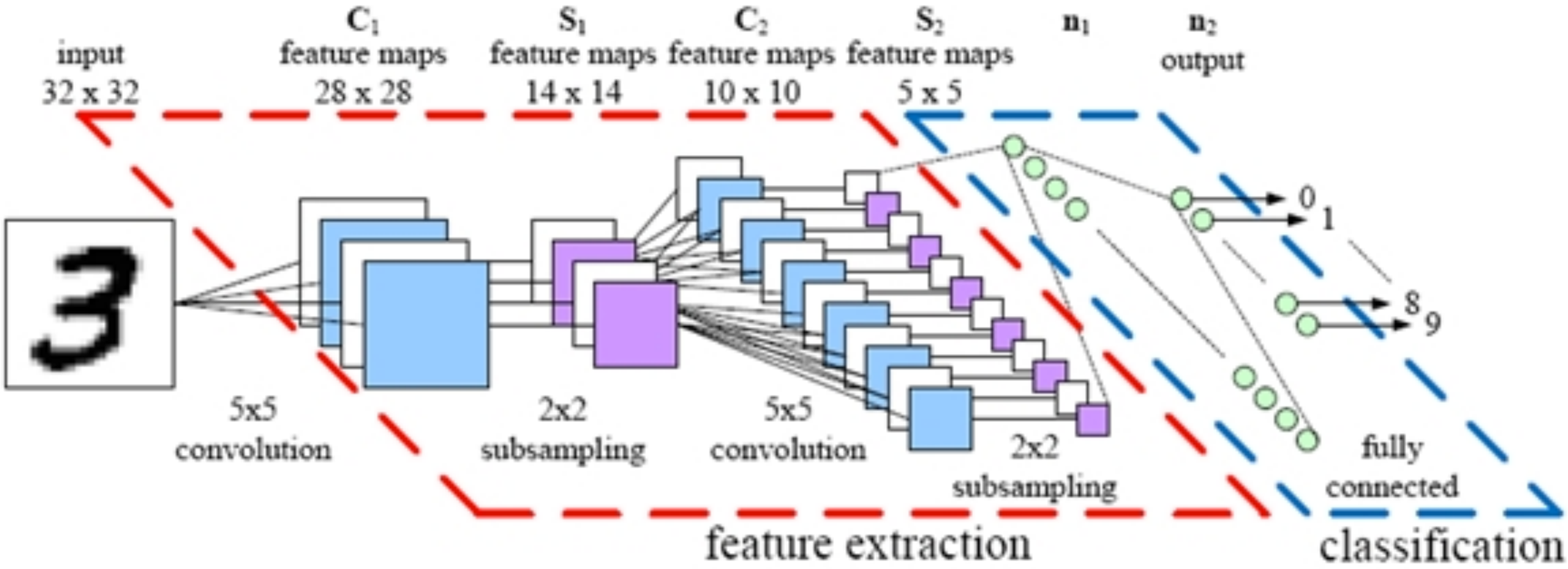
```
l1a = tf.nn.relu(tf.nn.conv2d(X, w,                           # l1a shape=(?, 28, 28, 32)
                    strides=[1, 1, 1, 1], padding='SAME'))
l1 = tf.nn.max_pool(l1a, ksize=[1, 2, 2, 1],                  # l1 shape=(?, 14, 14, 32)
                    strides=[1, 2, 2, 1], padding='SAME')


l2a = tf.nn.relu(tf.nn.conv2d(l1, w2,                         # l2a shape=(?, 14, 14, 64)
                    strides=[1, 1, 1, 1], padding='SAME'))
l2 = tf.nn.max_pool(l2a, ksize=[1, 2, 2, 1],                  # l2 shape=(?, 7, 7, 64)
                    strides=[1, 2, 2, 1], padding='SAME')


l3a = tf.nn.relu(tf.nn.conv2d(l2, w3,                         # l3a shape=(?, 7, 7, 128)
                    strides=[1, 1, 1, 1], padding='SAME'))
l3 = tf.nn.max_pool(l3a, ksize=[1, 2, 2, 1],                  # l3 shape=(?, 4, 4, 128)
                    strides=[1, 2, 2, 1], padding='SAME')
```

dropout

X = trX.reshape(-1, 28, 28, 1)

```
l1a = tf.nn.relu(tf.nn.conv2d(X, w,                     # l1a shape=(?, 28, 28, 32)
                    strides=[1, 1, 1, 1], padding='SAME'))
l1 = tf.nn.max_pool(l1a, ksize=[1, 2, 2, 1],            # l1 shape=(?, 14, 14, 32)
                    strides=[1, 2, 2, 1], padding='SAME')
l1 = tf.nn.dropout(l1, p_keep_conv)

l2a = tf.nn.relu(tf.nn.conv2d(l1, w2,                   # l2a shape=(?, 14, 14, 64)
                    strides=[1, 1, 1, 1], padding='SAME'))
l2 = tf.nn.max_pool(l2a, ksize=[1, 2, 2, 1],            # l2 shape=(?, 7, 7, 64)
                    strides=[1, 2, 2, 1], padding='SAME')
l2 = tf.nn.dropout(l2, p_keep_conv)

l3a = tf.nn.relu(tf.nn.conv2d(l2, w3,                   # l3a shape=(?, 7, 7, 128)
                    strides=[1, 1, 1, 1], padding='SAME'))
l3 = tf.nn.max_pool(l3a, ksize=[1, 2, 2, 1],            # l3 shape=(?, 4, 4, 128)
                    strides=[1, 2, 2, 1], padding='SAME')
```

CNN



http://parse.ele.tue.nl/cluster/2/CNNArchitecture.jpg

Fully connected net

```
w4 = init_weights([128 * 4 * 4, 625]) # FC 128 * 4 * 4 inputs, 625 outputs
w_o = init_weights([625, 10])         # FC 625 inputs, 10 outputs (labels)

l3 = tf.nn.max_pool(l3a, ksize=[1, 2, 2, 1],              # l3 shape=(?, 4, 4, 128)
                    strides=[1, 2, 2, 1], padding='SAME')
l3 = tf.reshape(l3, [-1, w4.get_shape().as_list()[0]])    # reshape to (?, 2048)
l3 = tf.nn.dropout(l3, p_keep_conv)

l4 = tf.nn.relu(tf.matmul(l3, w4))
l4 = tf.nn.dropout(l4, p_keep_hidden)

pyx = tf.matmul(l4, w_o)
```

cost and optimization

```
cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(py_x, Y))
train_op = tf.train.RMSPropOptimizer(0.001, 0.9).minimize(cost)
predict_op = tf.argmax(py_x, 1)
```

```
tf.train.RMSPropOptimizer.__init__(learning_rate, decay=0.9,
momentum=0.0, epsilon=1e-10, use_locking=False,
name='RMSProp')
```

Construct a new RMSProp optimizer.

Args:

- `learning_rate`: A Tensor or a floating point value. The learning rate.
- `decay`: Discounting factor for the history/coming gradient

https://www.tensorflow.org/versions/r0.8/api_docs/python/train.html#RMSPropOptimizer

Other TF optimizers

```
cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(py_x, Y))
train_op = tf.train.RMSPropOptimizer(0.001, 0.9).minimize(cost)
predict_op = tf.argmax(py_x, 1)
```

- class tf.train.GradientDescentOptimizer
- class tf.train.AdadeltaOptimizer
- class tf.train.AdagradOptimizer
- class tf.train.MomentumOptimizer
- class tf.train.AdamOptimizer
- class tf.train.FtrlOptimizer
- class tf.train.RMSPropOptimizer

https://www.tensorflow.org/versions/r0.8/api_docs/python/train.html#RMSPropOptimizer

Train and testing

```
# Launch the graph in a session
with tf.Session() as sess:
    # you need to initialize all variables
    tf.initialize_all_variables().run()

    for i in range(100):
        for start, end in zip(range(0, len(trX), 128), range(128, len(trX), 128)):
            sess.run(train_op, feed_dict={X: trX[start:end], Y: trY[start:end],
                                          p_keep_conv: 0.8, p_keep_hidden: 0.5})

        test_indices = np.arange(len(teX)) # Get A Test Batch
        np.random.shuffle(test_indices)
        test_indices = test_indices[0:256]

        print i, np.mean(np.argmax(teY[test_indices], axis=1) ==
                         sess.run(predict_op, feed_dict={X: teX[test_indices],
                                                         Y: teY[test_indices],
                                                         p_keep_conv: 1.0,
                                                         p_keep_hidden: 1.0}))
```

Train and testing

0	128
128	256
256	384
384	512

```
# Launch the graph in a session
with tf.Session() as sess:
    # you need to initialize all variables
    tf.initialize_all_variables().run()

    for i in range(100):
        for start, end in zip(range(0, len(trX), 128), range(128, len(trX), 128)):
            sess.run(train_op, feed_dict={X: trX[start:end], Y: trY[start:end],
                                          p_keep_conv: 0.8, p_keep_hidden: 0.5})

        test_indices = np.arange(len(teX)) # Get A Test Batch
        np.random.shuffle(test_indices)
        test_indices = test_indices[0:256]

        print i, np.mean(np.argmax(teY[test_indices], axis=1) ==
                         sess.run(predict_op, feed_dict={X: teX[test_indices],
                                                         Y: teY[test_indices],
                                                         p_keep_conv: 1.0,
                                                         p_keep_hidden: 1.0}))
```

Train and testing

```
# Launch the graph in a session
with tf.Session() as sess:
    # you need to initialize all variables
    tf.initialize_all_variables().run()

    for i in range(100):
        for start, end in zip(range(0, len(trX), 128), range(128, len(trX
            sess.run(train_op, feed_dict={X: trX[start:end], Y: trY[start
                                          p_keep_conv: 0.8, p_keep_hidden

        test_indices = np.arange(len(teX)) # Get A Test Batch
        np.random.shuffle(test_indices)
        test_indices = test_indices[0:256]

        print i, np.mean(np.argmax(teY[test_indices], axis=1) ==
                         sess.run(predict_op, feed_dict={X: teX[test_indices],
                                                         Y: teY[test_indices],
                                                         p_keep_conv: 1.0,
                                                         p_keep_hidden: 1.0}))
```

```
0 0.98046875
1 0.97265625
2 0.984375
3 0.9765625
4 0.9921875
5 0.9921875
6 0.9921875
```

https://github.com/nlintz/TensorFlow-Tutorials

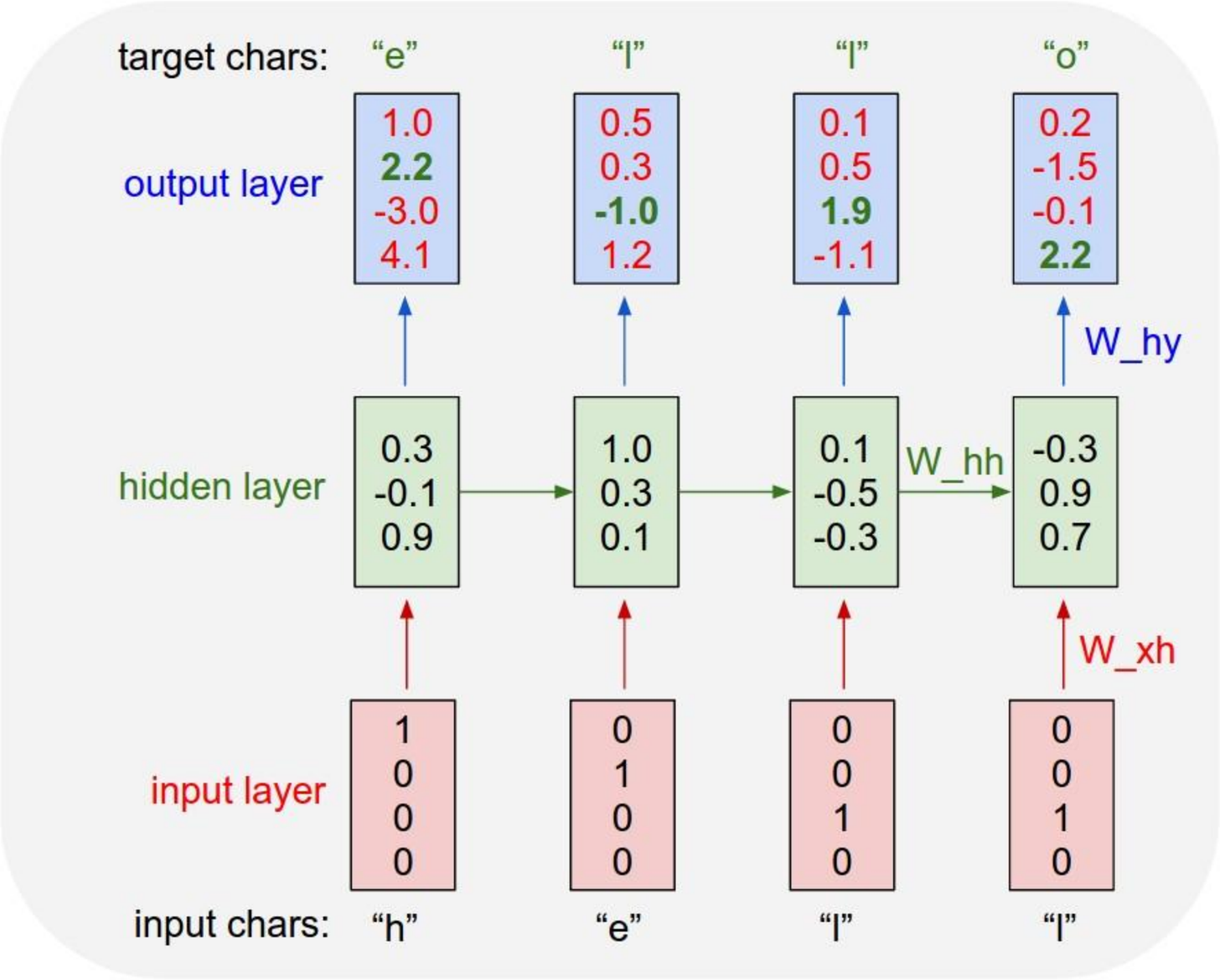
Lab 12
RNN

Sung Kim <hunkim+ml@gmail.com>
http://hunkim.github.io/ml/

Character-level language model example

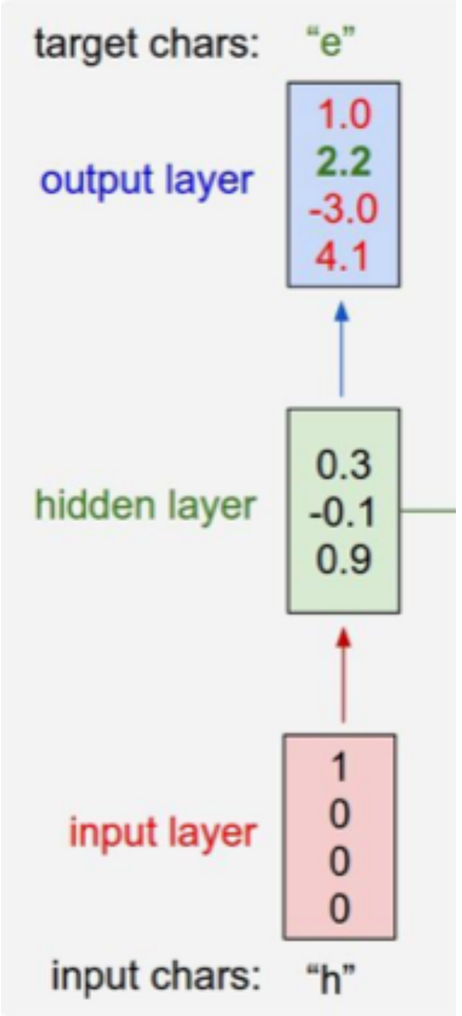
Vocabulary:
[h,e,l,o]

Example training sequence:
“hello”



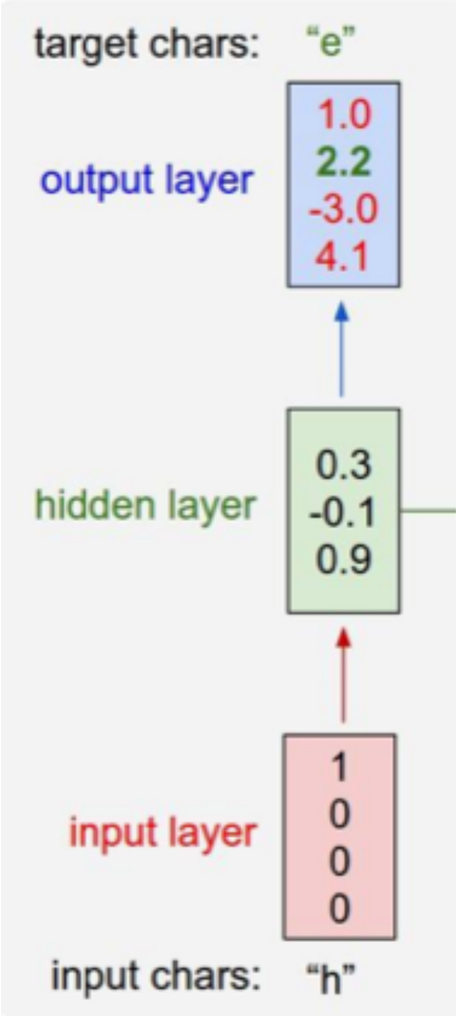
Creating rnn cell

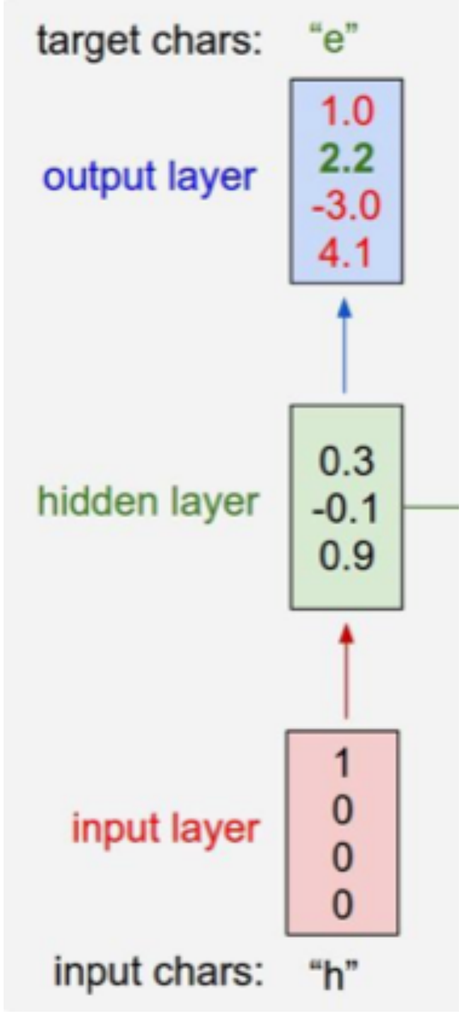
```
# RNN model
rnn_cell = rnn_cell.BasicRNNCell(rnn_size)
```



Creating rnn cell

```
# RNN model
rnn_cell = rnn_cell.BasicRNNCell(rnn_size)


rnn_cell = rnn_cell. BasicLSTMCell(rnn_size)
rnn_cell = rnn_cell. GRUCell(rnn_size)
```



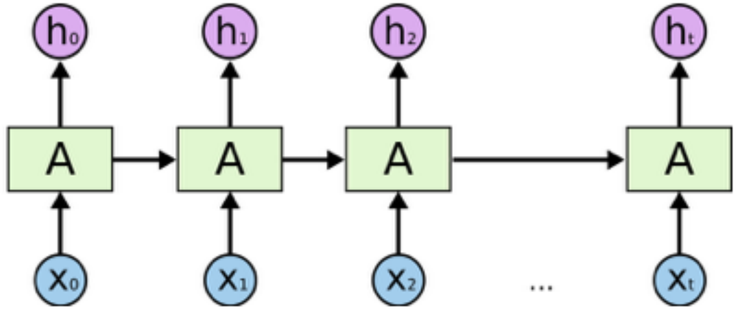


RNN in TensorFlow

```
# RNN model
rnn_cell = rnn_cell.BasicRNNCell(4)
```

```
outputs, state = rnn.rnn(rnn_cell, X_split, state)
```

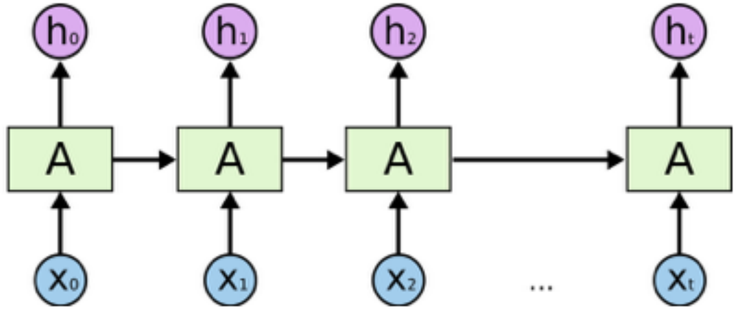
outputs, state = rnn.rnn(rnn_cell, **X_split**, state)



[<tf.Tensor 'split:0' shape=(1, 4) dtype=float32>,
<tf.Tensor 'split:1' shape=(1, 4) dtype=float32>,
<tf.Tensor 'split:2' shape=(1, 4) dtype=float32>,
<tf.Tensor 'split:3' shape=(1, 4) dtype=float32>]

outputs, state = rnn.rnn(rnn_cell, **X_split**, state)

[<tf.Tensor 'RNN/BasicRNNCell/Tanh:0' shape=(1, 4) dtype=float32>,
<tf.Tensor 'RNN/BasicRNNCell_1/Tanh:0' shape=(1, 4) dtype=float32>,
<tf.Tensor 'RNN/BasicRNNCell_2/Tanh:0' shape=(1, 4) dtype=float32>,
<tf.Tensor 'RNN/BasicRNNCell_3/Tanh:0' shape=(1, 4) dtype=float32>]



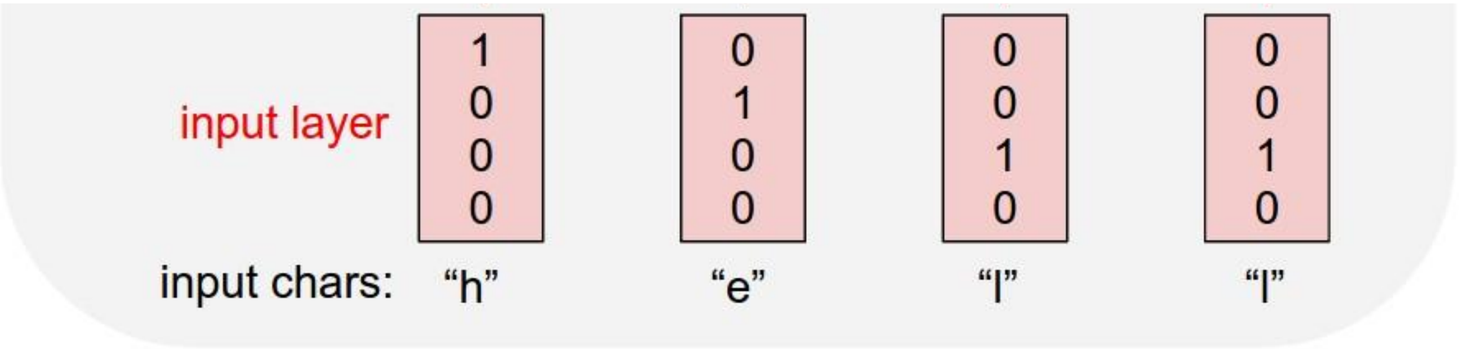
[<tf.Tensor 'split:0' shape=(1, 4) dtype=float32>,
<tf.Tensor 'split:1' shape=(1, 4) dtype=float32>,
<tf.Tensor 'split:2' shape=(1, 4) dtype=float32>,
<tf.Tensor 'split:3' shape=(1, 4) dtype=float32>]

Character-level language model example

Vocabulary:
[h,e,l,o]

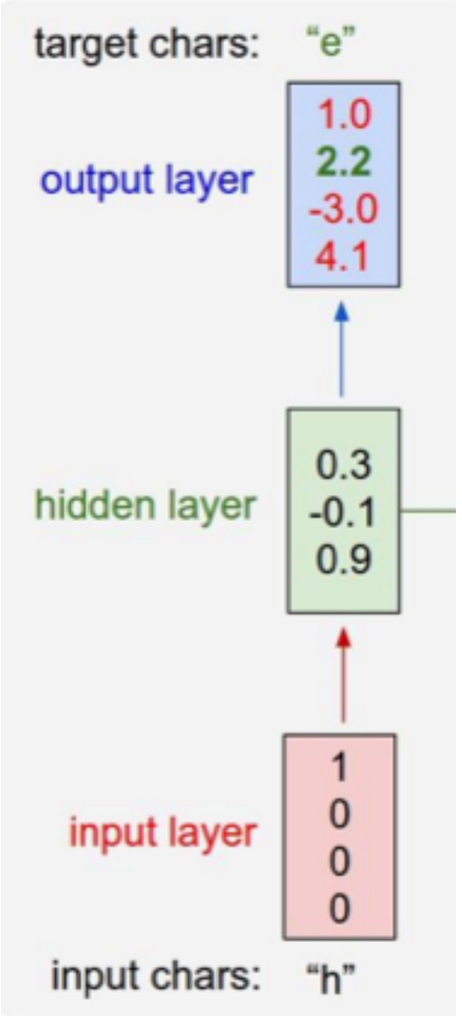
Example training sequence:
“hello”

```
x_data = np.array([ [1,0,0,0],  # h
                    [0,1,0,0],  # e
                    [0,0,1,0],  # l
                    [0,0,1,0]],  # l
                  dtype='f')
```



RNN in TensorFlow

```
# RNN model
rnn_cell = rnn_cell.BasicRNNCell(rnn_size)
state = tf.zeros([batch_size, rnn_cell.state_size])
X_split = tf.split(0, time_step_size, x_data)
outputs, state = rnn.rnn(rnn_cell, X_split, state)
```



Cost

```
# logits: list of 2D Tensors of shape [batch_size x num_decoder_symbols].
# targets: list of 1D batch-sized int32 Tensors of the same length as logits.
# weights: list of 1D batch-sized float-Tensors of the same length as logits.
logits = tf.reshape(tf.concat(1, outputs), [-1, rnn_size])
targets = tf.reshape(sample[1:], [-1])
weights = tf.ones([time_step_size * batch_size])

loss = tf.nn.seq2seq.sequence_loss_by_example([logits], [targets], [weights])
cost = tf.reduce_sum(loss) / batch_size
train_op = tf.train.RMSPropOptimizer(0.01, 0.9).minimize(cost)
```

Train & Prediction

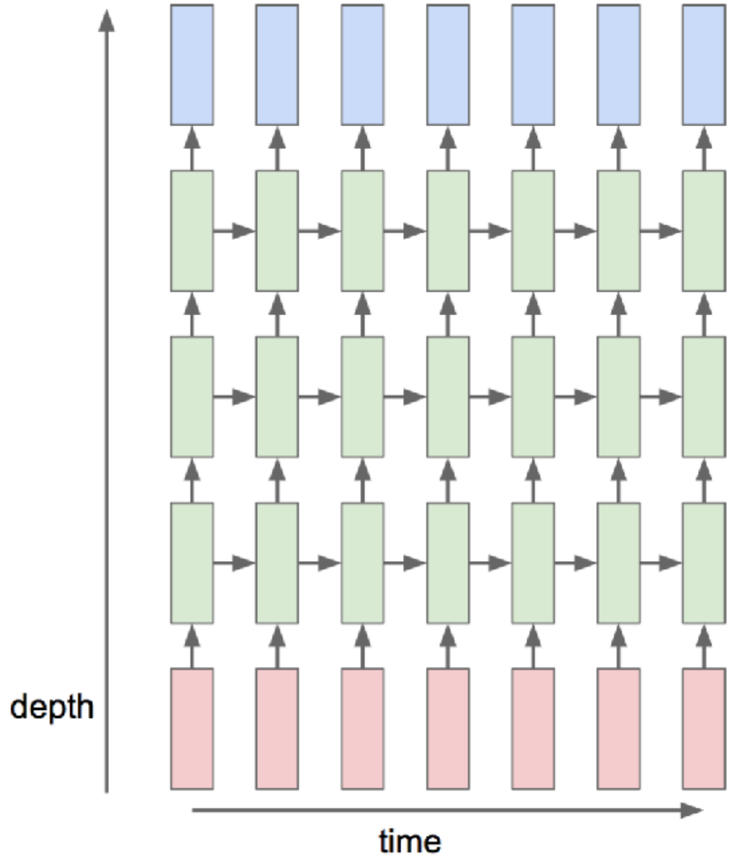
```
# Launch the graph in a session
with tf.Session() as sess:
    # you need to initialize all variables
    tf.initialize_all_variables().run()
    for i in range(100):
        sess.run(train_op)
        result = sess.run(tf.arg_max(logits, 1))
        print (result, [char_rdic[t] for t in result])
```

```
import tensorflow as tf
from tensorflow.models.rnn import rnn, rnn_cell
import numpy as np

char_rdic = ['h','e','l','o']  # id -> char
char_dic = {w: i for i, w in enumerate(char_rdic)}  # char -> id
x_data = np.array([ [1,0,0,0],  # h
                    [0,1,0,0],  # e
                    [0,0,1,0],  # l
                    [0,0,1,0]],  # l
                     dtype='f')

sample = [char_dic[c] for c in "hello"] # to index

# Configuration
char_vocab_size = len(char_dic)
rnn_size = char_vocab_size  # 1 hot coding (one of 4)
time_step_size = 4  # 'hell' -> predict 'ello'
batch_size = 1      # one sample

# RNN model
rnn_cell = rnn_cell.BasicRNNCell(rnn_size)
state = tf.zeros([batch_size, rnn_cell.state_size])
X_split = tf.split(0, time_step_size, x_data)
outputs, state = rnn.rnn(rnn_cell, X_split, state)

# logits: list of 2D Tensors of shape [batch_size x num_decoder_symbols].
# targets: list of 1D batch-sized int32 Tensors of the same length as logits.
# weights: list of 1D batch-sized float-Tensors of the same length as logits.
logits = tf.reshape(tf.concat(1, outputs), [-1, rnn_size])
targets = tf.reshape(sample[1:], [-1])
weights = tf.ones([time_step_size * batch_size])

loss = tf.nn.seq2seq.sequence_loss_by_example([logits], [targets], [weights])
cost = tf.reduce_sum(loss) / batch_size
train_op = tf.train.RMSPropOptimizer(0.01, 0.9).minimize(cost)

# Launch the graph in a session
with tf.Session() as sess:
    # you need to initialize all variables
    tf.initialize_all_variables().run()
    for i in range(100):
        sess.run(train_op)
        result = sess.run(tf.arg_max(logits, 1))
        print (result, [char_rdic[t] for t in result])
```

Output

```
result = sess.run(tf.arg_max(logits, 1))
print (result, [char_rdic[t] for t in result])
```

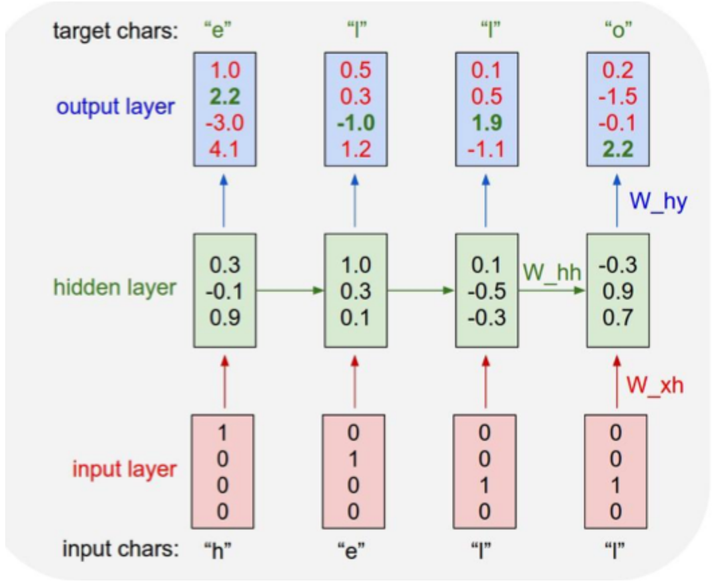
```
(array([2, 0, 2, 1]), ['l', 'h', 'l', 'e'])
(array([2, 0, 2, 1]), ['l', 'h', 'l', 'e'])
(array([2, 0, 2, 1]), ['l', 'h', 'l', 'e'])
(array([2, 0, 2, 1]), ['l', 'h', 'l', 'e'])
(array([2, 0, 2, 1]), ['l', 'h', 'l', 'e'])
(array([2, 0, 2, 1]), ['l', 'h', 'l', 'e'])
(array([2, 2, 2, 3]), ['l', 'l', 'l', 'o'])
(array([2, 2, 2, 3]), ['l', 'l', 'l', 'o'])
(array([1, 2, 2, 3]), ['e', 'l', 'l', 'o'])
(array([1, 2, 2, 3]), ['e', 'l', 'l', 'o'])
(array([1, 2, 2, 3]), ['e', 'l', 'l', 'o'])
```



one_cell = rnn_cell.BasicRNNCell(**rnn_size**)

rnn_cell = rnn_cell.MultiRNNCell([one_cell] * **depth**)

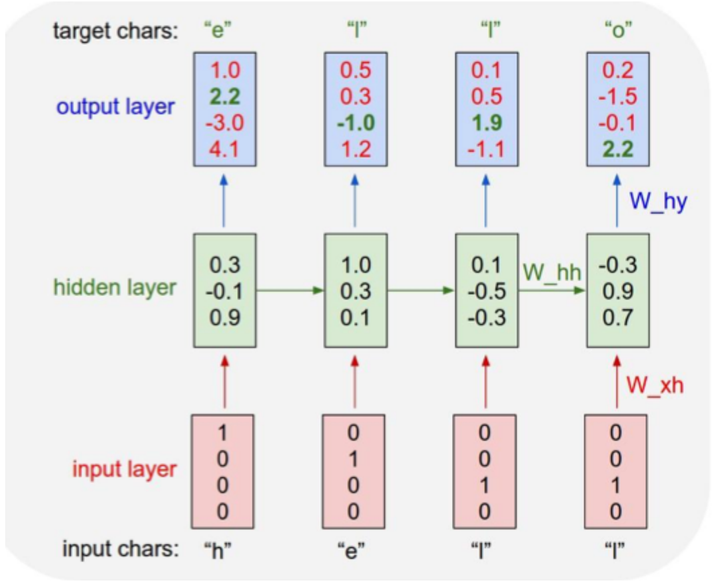
char-rnn



Shakespeare

It looks like we can learn to spell English words. But how about if there is more structure and style in the data? To examine this I downloaded all the works of Shakespeare and concatenated them into a single (4.4MB) file. We can now afford to train a larger network, in this case lets try a 3-layer RNN with 512 hidden nodes on each layer. After we train the network for a few hours we obtain samples such as:

```
PANDARUS:
Alas, I think he shall be come approached and the day
When little srain would be attain'd into being never fed,
And who is but a chain and subjects of his death,
I should not sleep.

Second Senator:
They are away this miseries, produced upon my soul,
Breaking and strongly should be buried, when I perish
The earth and thoughts of many states.

DUKE VINCENTIO:
Well, your wit is in the care of side and that.

Second Lord:
They would be ruled after this chamber, and
my fair nues begun out of the fact, to be conveyed,
Whose noble souls I'll have the heart of the wars.

Clown:
Come, sir, I will make did behold your worship.

VIOLA:
I'll drink it.
```

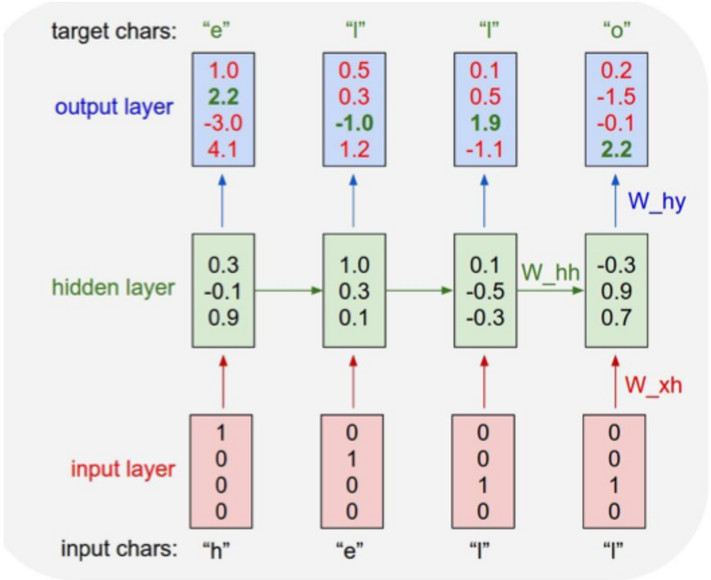


Linux Source Code

I wanted to push structured data to its limit, so for the final challenge I decided to use code. In particular, I took all the source and header files found in the Linux repo on Github, concatenated all of them in a single giant file (474MB of C code) (I was originally going to train only on the kernel but that by itself is only ~16MB). Then I trained several as-large-as-fits-on-my-GPU 3-layer LSTMs over a period of a few days. These models have about 10 million parameters, which is still on the lower end for RNN models. The results are superfun:

```
/*
 * Increment the size file of the new incorrect UI_FILTER group information
 * of the size generatively.
 */
static int indicate_policy(void)
{
  int error;
  if (fd == MARN_EPT) {
    /*
     * The kernel blank will coeld it to userspace.
     */
    if (ss->segment < mem_total)
      unblock_graph_and_set_blocked();
    else
      ret = 1;
    goto bail;
  }
  segaddr = in_SB(in.addr);
  selector = seg / 16;
  setup_works = true;
  for (i = 0; i < blocks; i++) {
    seq = buf[i++];
    bpf = bd->bd.next + i * search;
    if (fd) {
      current = blocked;
    }
  }
  rw->name = "Getjbbregs";
  bprm_self_clearl(&iv->version);
  regs->new = blocks[(BPF_STATS << info->historidac)] | PFMR_CLOBATHINC_SECONDS << 12;
  return segtable;
}
```

char/word rnn (char/word level n to n model)



https://github.com/sherjilozair/char-rnn-tensorflow

https://github.com/hunkim/word-rnn-tensorflow

bot.wpoem.com

신춘문예 2017 후보 시봇 (v0.003) 다시쓰기

괜찮은 행이 있으면 선택해주세요. 선택된 행들은 자동저장후 학습됩니다.

- [ ] 앞서 돌아보면 까치는 하늘 끝에서
- [ ] 초승달되도 자꾸만 안고 동안고지
- [ ] 글고양이 또통할 때마다
- [ ] 달빛 주랍지
- [ ] 풀벌빛 대하여 씨고 바라보아드는

이 봇은 무엇인가?

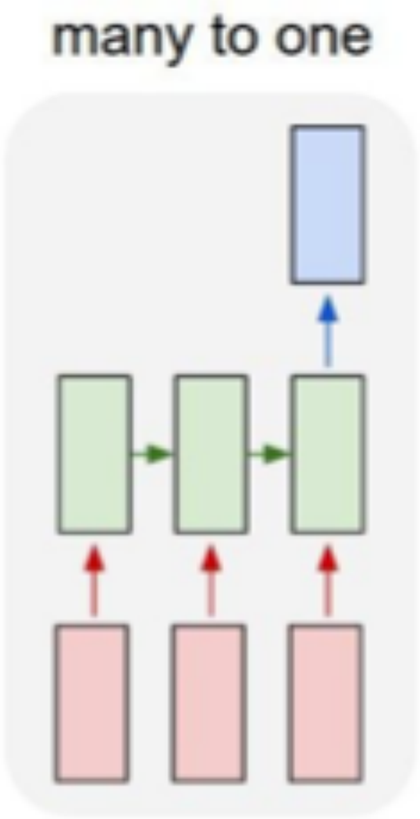
이 봇은 딥러닝을 기반으로 기존의 시에서 배워 새로운 시를 만들어 내는 프로그램입니다. 지금은 매우 엉성하지만 일년간 학습하여 2017년 신촌문예 작품을 제출하는 것을 목표로 하고 있습니다.

참여하기

- 우선 시를 보고 마음에 드는 행이 있으면 체크박스를 선택해 주시면 이 행을 추가학습에 사용합니다.
- 여러분들의 시를 아래 "시 알려주기" 입력을 통해 로봇에게 학습시켜주세요.
- 시봇 알고리즘에 기여하고 싶으시면 https://github.com/DeepLearningProjects/poem-bot 에 참여하시면 됩니다.
  - 지금은 매우 단순한 문자 RNN 학습방법입니다. 추후 단어 레벨이나 attention 등을 추가 할 예정입니다.
- 딥러닝에 대해 자세히 알고 싶으시면 https://hunkim.github.io/ml/ 을 참고 하시면 됩니다.

(10자 이상) 시 알려주기 이거 학습해봐!

Many to one



https://github.com/nlintz/TensorFlow-Tutorials/blob/master/7_lstm.py

RNN applications

- Language Modeling
- Speech Recognition
- Machine Translation
- Conversation Modeling/Question Answering
- Image/Video Captioning
- Image/Music/Dance Generation

http://jiwonkim.org/awesome-rnn/

TensorFlow GPU @AWS

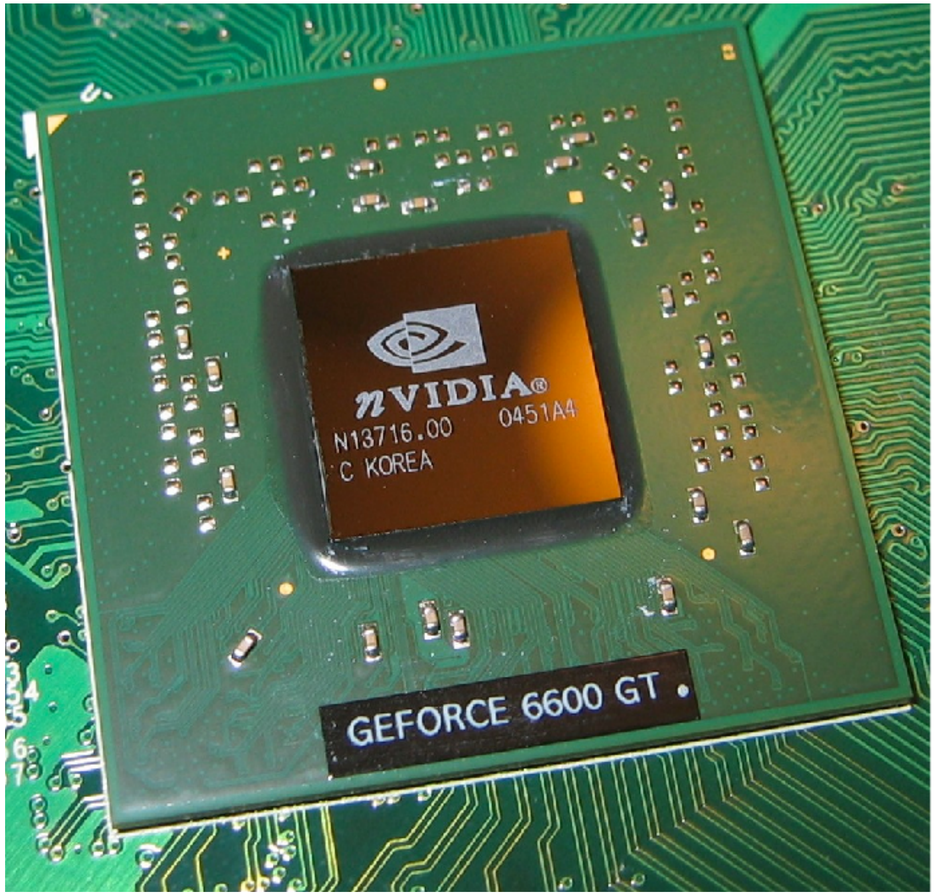
Sung Kim <hunkim+ml@gmail.com>
http://hunkim.github.io/ml/

Deep Network

- Takes a long time for training
  - Many forward/backward propagation and weight updates
  - Many metrics multiplications
- Very quick for testing and use in practice
  - One simple forward propagation

GPU

- A graphics processing unit (GPU), also occasionally called visual processing unit (VPU), is a specialized electronic circuit designed to rapidly manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display.



GPU version

# Ubuntu/Linux 64-bit, GPU enabled, Python 2.7
# Requires CUDA toolkit 7.5 and CuDNN v4. For other versions, see "Install from sources" below.
$ export TF_BINARY_URL=https://storage.googleapis.com/tensorflow/linux/gpu/tensorflow-0.9.0rc0-cp27-none-linux_x86_64.whl

Python 2
$ sudo pip install --upgrade $TF_BINARY_URL

http://solutionsreview.com/cloud-platforms/microsoft-beats-aws-google-on-cloud-storage-benchmark-test

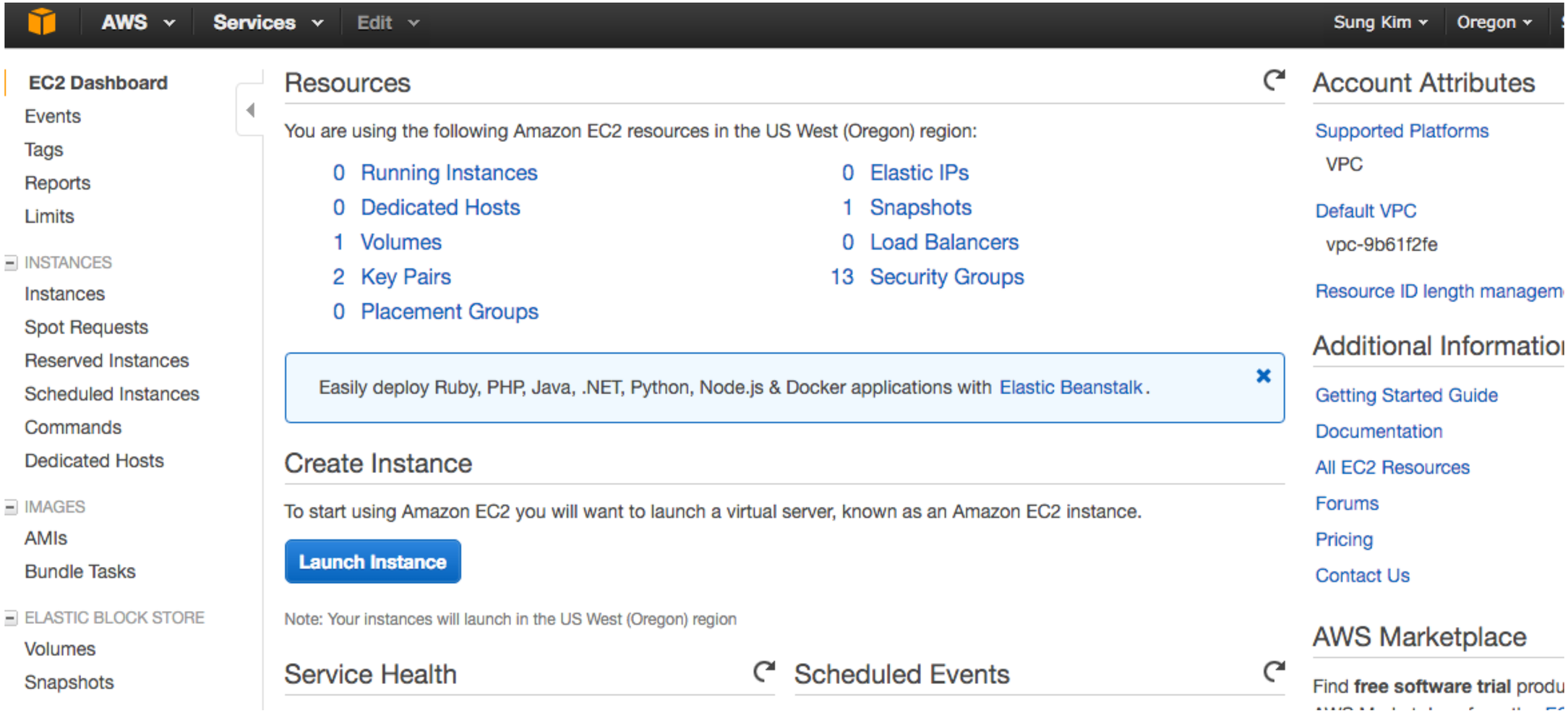

amazon
web services™

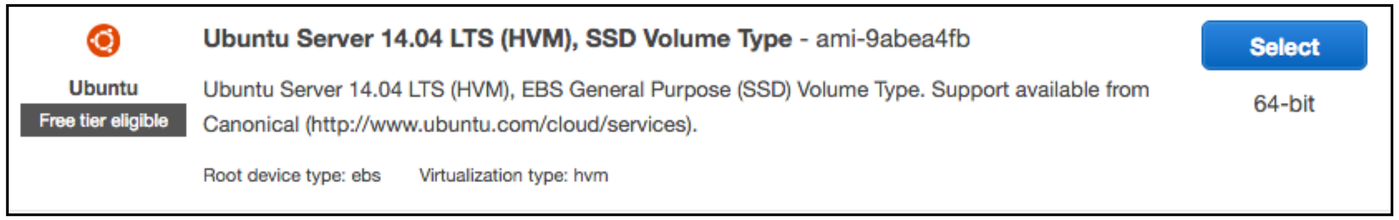
AWS GPU price in Oregon

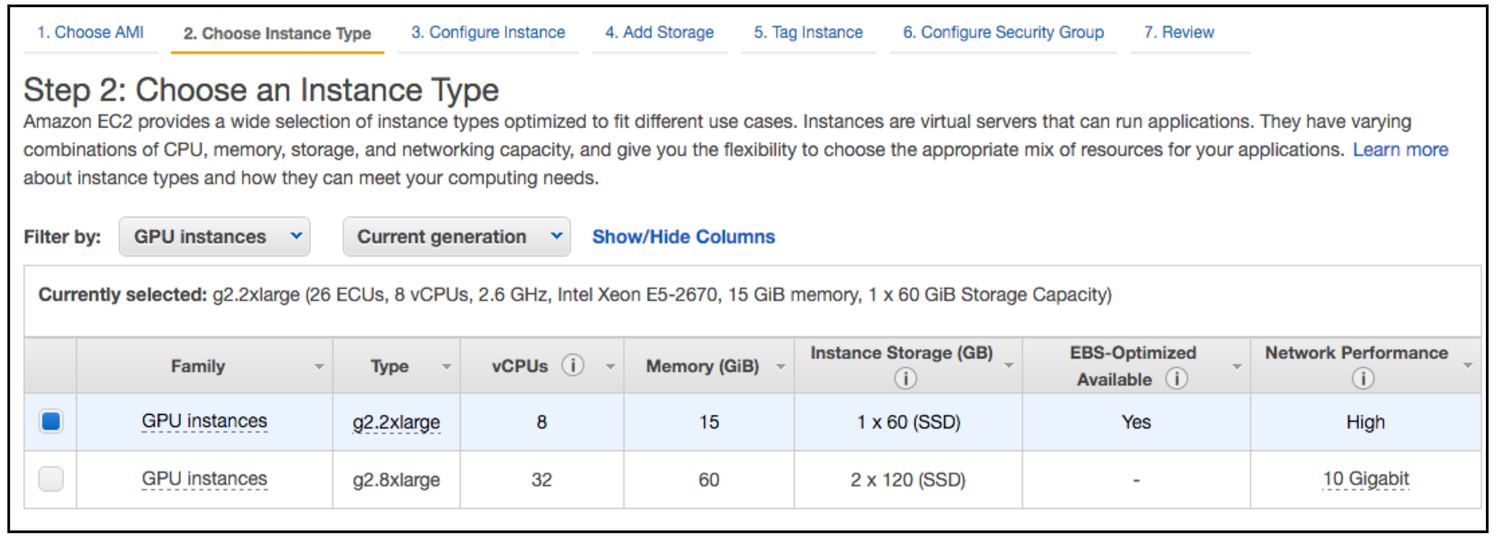
GPU Instances - Current Generation

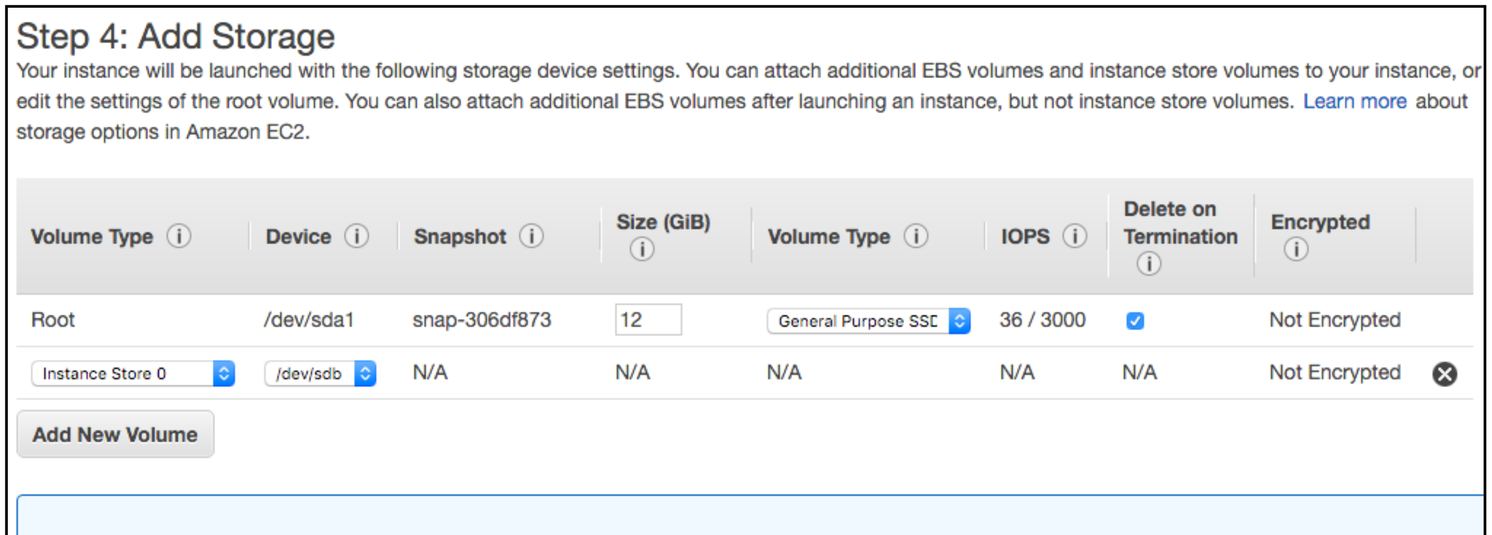
g2.2xlarge	8	26	15	60 SSD	$0.65 per Hour
g2.8xlarge	32	104	60	2 x 120 SSD	$2.6 per Hour

EC2 Console: Oregon



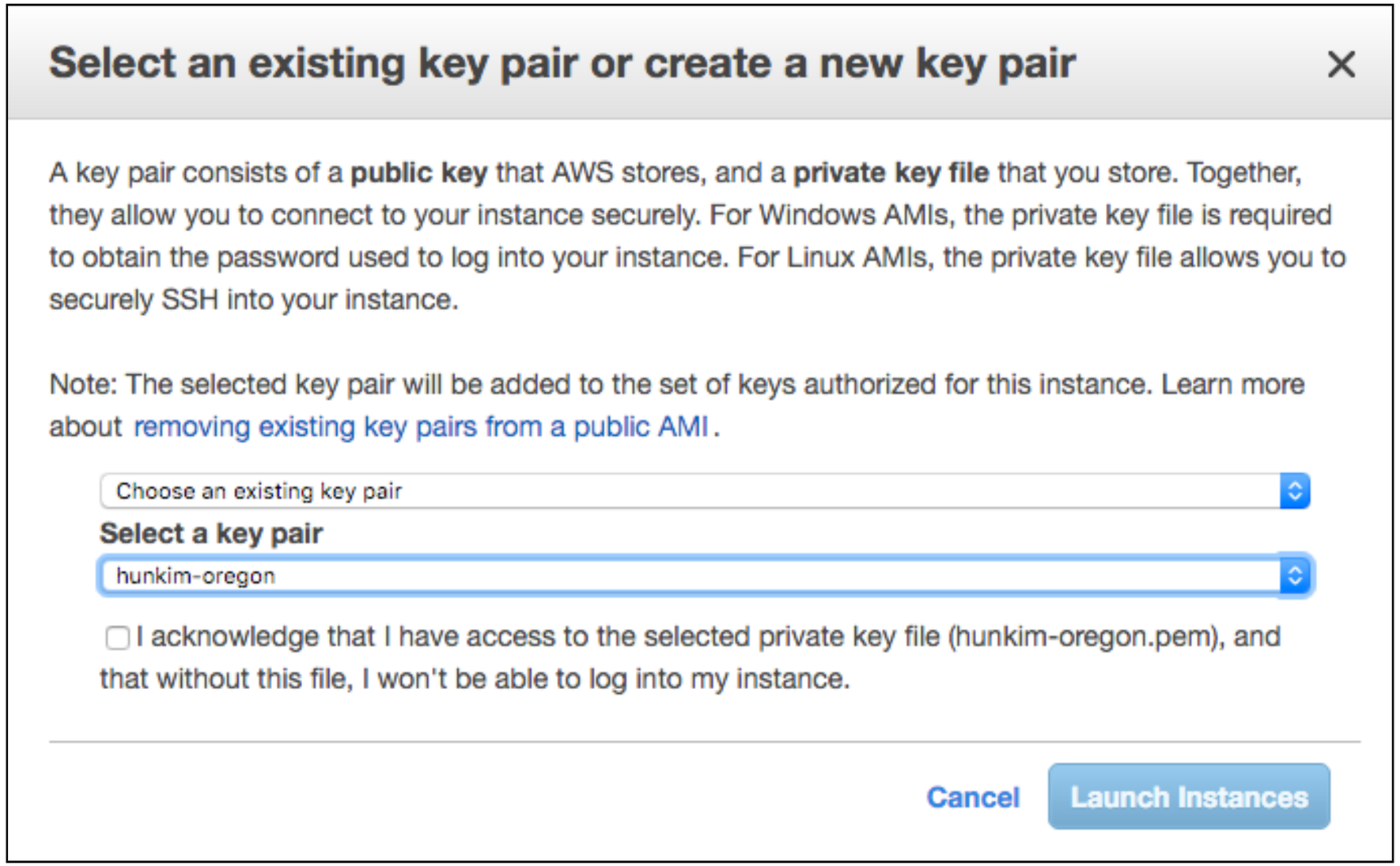




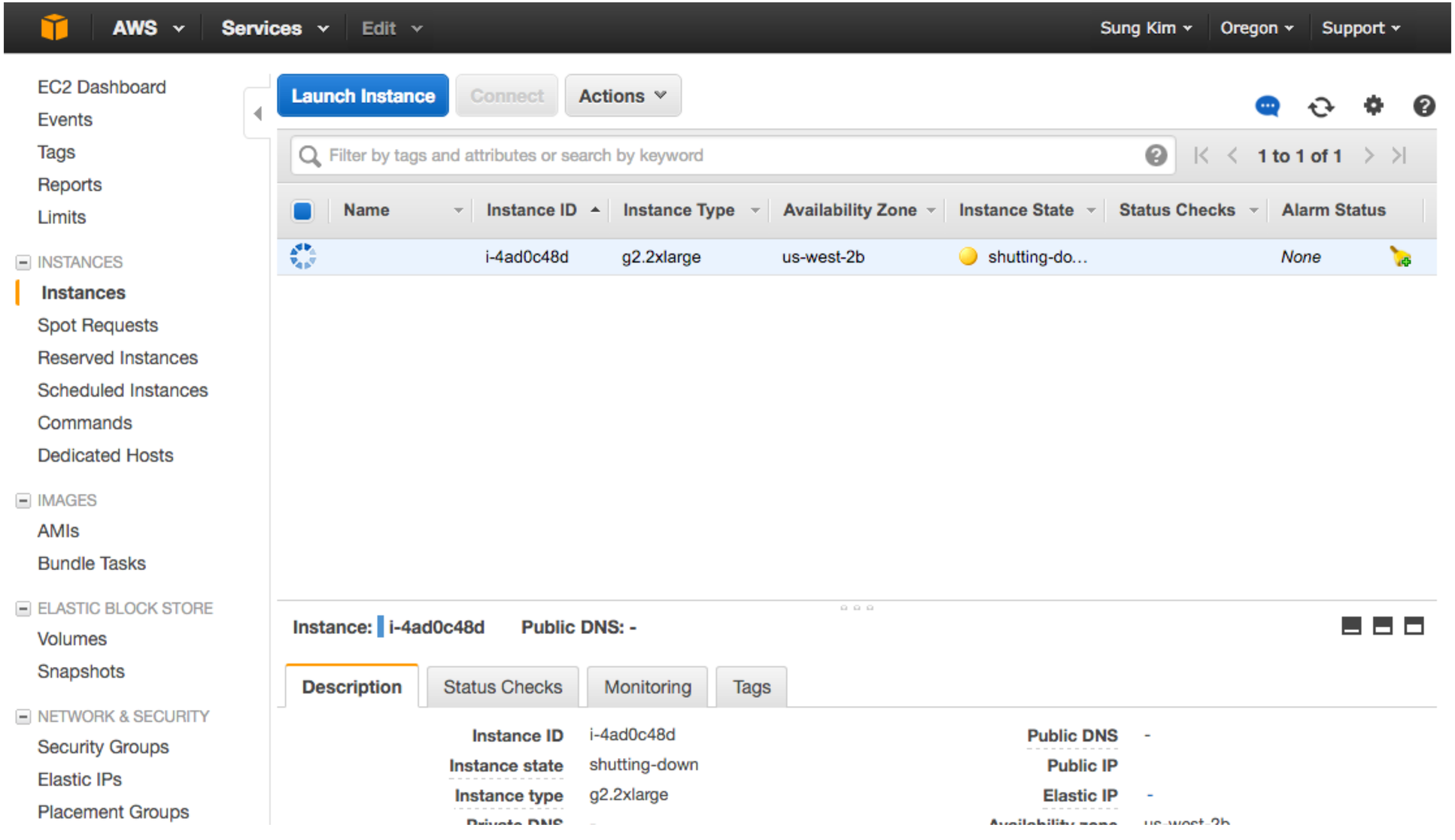


ubuntu,
GPU,
12G or more

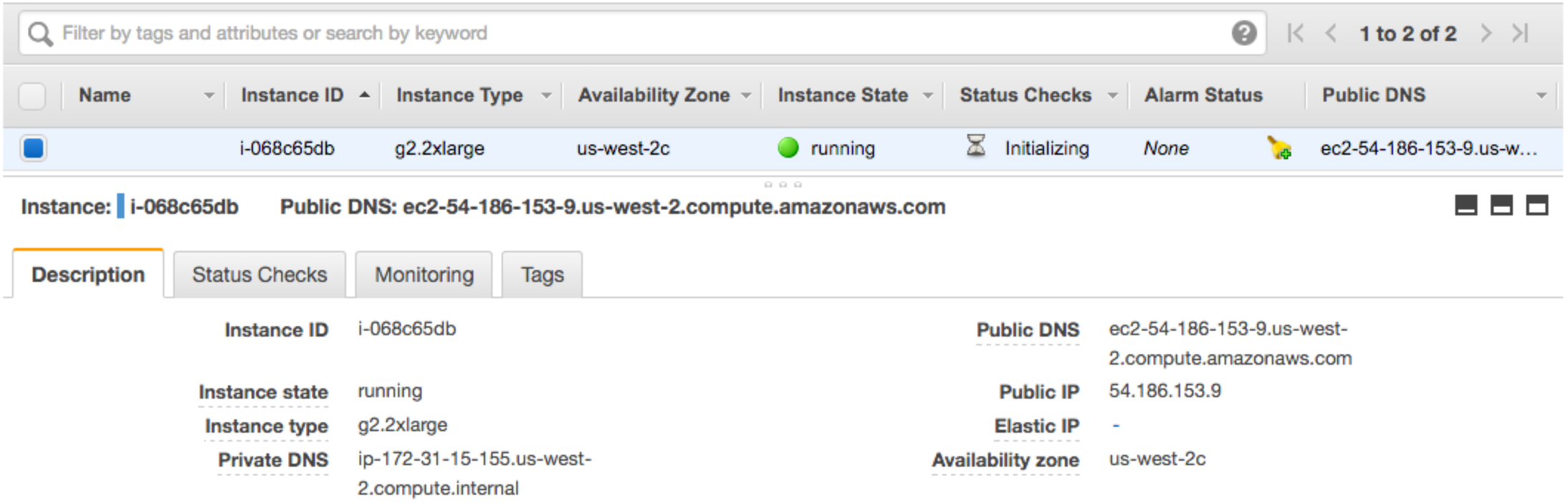
key to access the server



EC2: Create an instance



It's ready to ssh!



Requires CUDA and CuDNN

# Ubuntu/Linux 64-bit, GPU enabled, Python 2.7
# Requires **CUDA toolkit 7.5 and CuDNN v4**. For other versions, see "Install from sources" below.
$ export TF_BINARY_URL=https://storage.googleapis.com/tensorflow/linux/gpu/tensorflow-0.9.0rc0-cp27-none-linux_x86_64.whl

Python 2
$ sudo pip install --upgrade $TF_BINARY_URL

CUDA

http://tleyden.github.io/blog/2015/11/22/cuda-7-dot-5-on-aws-gpu-instance-running-ubuntu-14-dot-04/

cuDNN

Optional: cuDNN

One can apply for the developer program here https://developer.nvidia.com/cudnn. When approved, download cuDNN for Linux (either v4 RC or v3 is fine), upload the cuDNN package from the local computer to the instance, and install cuDNN:

```
tar -zxf cudnn-7.0-linux-x64-v4.0-rc.tgz #or cudnn-7.0-linux-x64-v3.0
cd cuda
sudo cp lib64/* /usr/local/cuda/lib64/
sudo cp include/cudnn.h /usr/local/cuda/include/
```

https://no2147483647.wordpress.com/2016/01/16/setup-amazon-aws-gpu-instance-with-mxnet

16 commends

1 wget http://developer.download.nvidia.com/…/cuda-repo-ubuntu1404…
2 sudo dpkg -i cuda-repo-ubuntu1404_7.5-18_amd64.deb
3 sudo apt-get update
4 sudo apt-get upgrade -y
5 sudo apt-get install -y opencl-headers build-essential protobuf-compiler libprotoc-dev libboost-all-dev libleveldb-dev hdf5-tools libhdf5-serial-dev libopencv-core-dev libopencv-highgui-dev libsnappy-dev libsnappy1 libatlas-base-dev cmake libstdc++6-4.8-dbg libgoogle-glog0 libgoogle-glog-dev libgflags-dev liblmdb-dev git python-pip gfortran
6 sudo apt-get clean
7 sudo apt-get install -y linux-image-extra-`uname -r` linux-headers-`uname -r` linux-image-`uname -r`
8 sudo apt-get install -y cuda
9 nvidia-smi
10 sudo apt-get install python-pip python-dev
11 sudo pip install --upgrade https://storage.googleapis.com/…/tensorflow-0.8.0rc0-cp27-n…
12 git clone https://github.com/nlintz/TensorFlow-Tutorials
13 cd TensorFlow-Tutorials/
14 vi ~/.profile # add PATH, LD PATH
15 source ~/.profile
16 python 06_autoencoder.py

Add Path

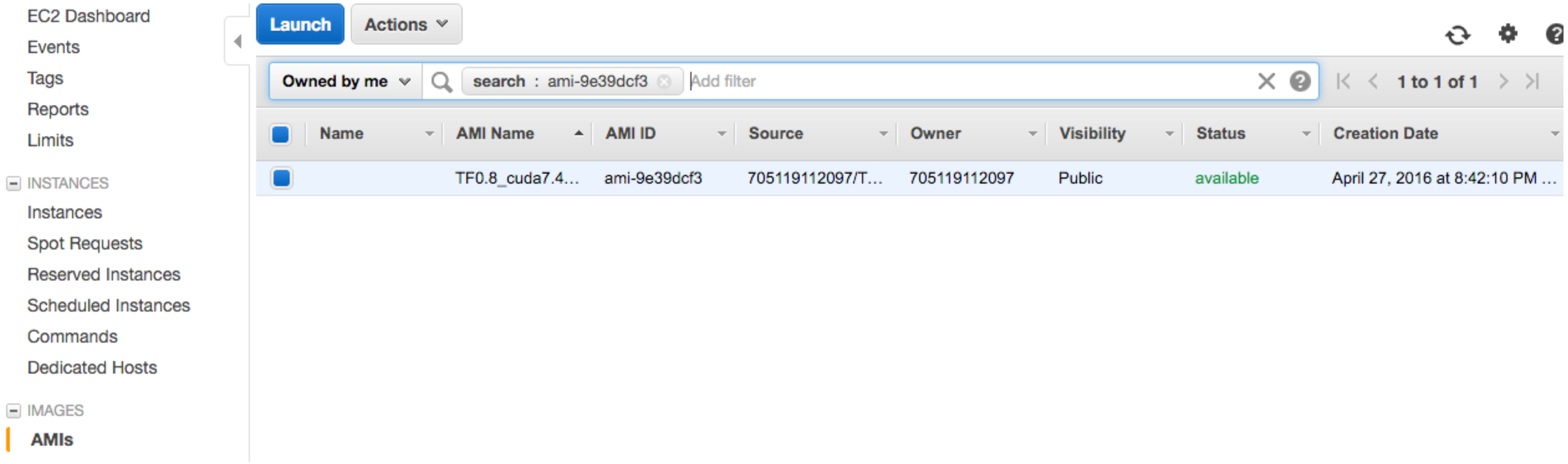
- export PATH=/usr/local/cuda/bin:$PATH
- export LD_LIBRARY_PATH=/usr/local/cuda/lib64:$LD_LIBRARY_PATH

Requires CUDA and CuDNN

# Ubuntu/Linux 64-bit, GPU enabled, Python 2.7
# Requires **CUDA toolkit 7.5 and CuDNN v4**. For other versions, see "Install from sources" below.
$ export TF_BINARY_URL=https://storage.googleapis.com/tensorflow/linux/gpu/tensorflow-0.9.0rc0-cp27-none-linux_x86_64.whl

Python 2
$ sudo pip install --upgrade $TF_BINARY_URL

Reuse ami-9e39dcf3 (N.Virginia)
ami-38f60658 (oregon)



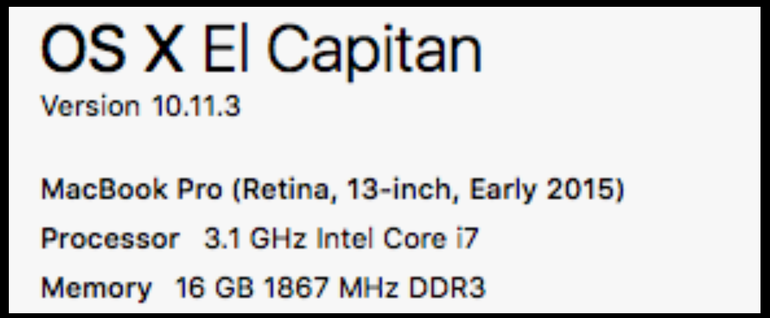
Perhaps, it will be unavailable when later CUDA versions are out.

Creating TensorFlow device (/gpu:0)

```
05] successfully opened CUDA library libcublas.so locally
9] Couldn't open CUDA library libcudnn.so. LD_LIBRARY_PATH: /usr/local/cuda/lib64:
c:1562] Unable to load cuDNN DSO
05] successfully opened CUDA library libcufft.so locally
05] successfully opened CUDA library libcuda.so.1 locally
05] successfully opened CUDA library libcurand.so locally
-ubyte.gz')
cationWarning: converting an array with ndim > 0 to an index will result in an error in the
e]
.py:42: VisibleDeprecationWarning: converting an array with ndim > 0 to an index will result
, 1)
-ubyte.gz')
ubyte.gz')
ubyte.gz')
xecutor.cc:900] successful NUMA node read from SysFS had negative value (-1), but there must
t.cc:102] Found device 0 with properties:

7



t.cc:126] DMA: 0
t.cc:136] 0:   Y
ice.cc:755] Creating TensorFlow device (/gpu:0) -> (device: 0, name: GRID K520, pci bus id:
locator.cc:244] PoolAllocator: After 1704 get requests, put_count=1321 evicted_count=1000 ev
locator.cc:256] Raising pool_size_limit_ from 100 to 110
locator.cc:244] PoolAllocator: After 1704 get requests, put_count=1812 evicted_count=1000 ev
locator.cc:256] Raising pool_size_limit_ from 256 to 281
```

```
482/6750 (epoch 3), train_loss = 7.503, time/batch = 0.237
483/6750 (epoch 3), train_loss = 7.612, time/batch = 0.239
484/6750 (epoch 3), train_loss = 7.473, time/batch = 0.248
485/6750 (epoch 3), train_loss = 7.603, time/batch = 0.241
486/6750 (epoch 3), train_loss = 7.519, time/batch = 0.248
487/6750 (epoch 3), train_loss = 7.526, time/batch = 0.238
488/6750 (epoch 3), train_loss = 7.356, time/batch = 0.243
489/6750 (epoch 3), train_loss = 7.550, time/batch = 0.239
490/6750 (epoch 3), train_loss = 7.440, time/batch = 0.243
491/6750 (epoch 3), train_loss = 7.514, time/batch = 0.240
492/6750 (epoch 3), train_loss = 7.514, time/batch = 0.242
493/6750 (epoch 3), train_loss = 7.467, time/batch = 0.245
494/6750 (epoch 3), train_loss = 7.351, time/batch = 0.239
495/6750 (epoch 3), train_loss = 7.553, time/batch = 0.245
496/6750 (epoch 3), train_loss = 7.373, time/batch = 0.240
497/6750 (epoch 3), train_loss = 7.493, time/batch = 0.242
498/6750 (epoch 3), train_loss = 7.445, time/batch = 0.243
499/6750 (epoch 3), train_loss = 7.432, time/batch = 0.240
500/6750 (epoch 3), train_loss = 7.476, time/batch = 0.246
501/6750 (epoch 3), train_loss = 7.463, time/batch = 0.238
502/6750 (epoch 3), train_loss = 7.477, time/batch = 0.241
503/6750 (epoch 3), train_loss = 7.495, time/batch = 0.244
504/6750 (epoch 3), train_loss = 7.543, time/batch = 0.240
505/6750 (epoch 3), train_loss = 7.550, time/batch = 0.241
506/6750 (epoch 3), train_loss = 7.567, time/batch = 0.242
507/6750 (epoch 3), train_loss = 7.415, time/batch = 0.247
508/6750 (epoch 3), train_loss = 7.414, time/batch = 0.236
509/6750 (epoch 3), train_loss = 7.540, time/batch = 0.242
510/6750 (epoch 3), train_loss = 7.402, time/batch = 0.245
511/6750 (epoch 3), train_loss = 7.548, time/batch = 0.241
512/6750 (epoch 3), train_loss = 7.385, time/batch = 0.242
513/6750 (epoch 3), train_loss = 7.563, time/batch = 0.238
514/6750 (epoch 3), train_loss = 7.488, time/batch = 0.241
515/6750 (epoch 3), train_loss = 7.504, time/batch = 0.245
516/6750 (epoch 3), train_loss = 7.546, time/batch = 0.243
517/6750 (epoch 3), train_loss = 7.521, time/batch = 0.244
518/6750 (epoch 3), train_loss = 7.384, time/batch = 0.246
519/6750 (epoch 3), train_loss = 7.402, time/batch = 0.242
520/6750 (epoch 3), train_loss = 7.552, time/batch = 0.244
521/6750 (epoch 3), train_loss = 7.499, time/batch = 0.250
522/6750 (epoch 3), train_loss = 7.342, time/batch = 0.239
523/6750 (epoch 3), train_loss = 7.378, time/batch = 0.237
524/6750 (epoch 3), train_loss = 7.391, time/batch = 0.242
525/6750 (epoch 3), train_loss = 7.348, time/batch = 0.242
526/6750 (epoch 3), train_loss = 7.270, time/batch = 0.242
527/6750 (epoch 3), train_loss = 7.381, time/batch = 0.244
```

```
model saved to save/model.ckpt
1/6750 (epoch 0), train_loss = 11.127, time/batch = 4.697
2/6750 (epoch 0), train_loss = 11.176, time/batch = 4.430
3/6750 (epoch 0), train_loss = 10.946, time/batch = 4.604
4/6750 (epoch 0), train_loss = 10.616, time/batch = 4.483
5/6750 (epoch 0), train_loss = 10.207, time/batch = 5.354
6/6750 (epoch 0), train_loss = 9.723, time/batch = 5.674
7/6750 (epoch 0), train_loss = 9.449, time/batch = 5.972
8/6750 (epoch 0), train_loss = 9.089, time/batch = 5.785
9/6750 (epoch 0), train_loss = 8.861, time/batch = 5.518
10/6750 (epoch 0), train_loss = 8.797, time/batch = 5.856
11/6750 (epoch 0), train_loss = 8.688, time/batch = 5.795
12/6750 (epoch 0), train_loss = 8.814, time/batch = 5.803
13/6750 (epoch 0), train_loss = 8.728, time/batch = 5.595
14/6750 (epoch 0), train_loss = 8.938, time/batch = 5.586
15/6750 (epoch 0), train_loss = 8.657, time/batch = 5.529
16/6750 (epoch 0), train_loss = 8.736, time/batch = 5.536
17/6750 (epoch 0), train_loss = 8.643, time/batch = 5.690
18/6750 (epoch 0), train_loss = 8.985, time/batch = 5.828
19/6750 (epoch 0), train_loss = 8.792, time/batch = 5.504
20/6750 (epoch 0), train_loss = 8.882, time/batch = 5.555
21/6750 (epoch 0), train_loss = 8.750, time/batch = 5.437
22/6750 (epoch 0), train_loss = 8.872, time/batch = 5.597
```



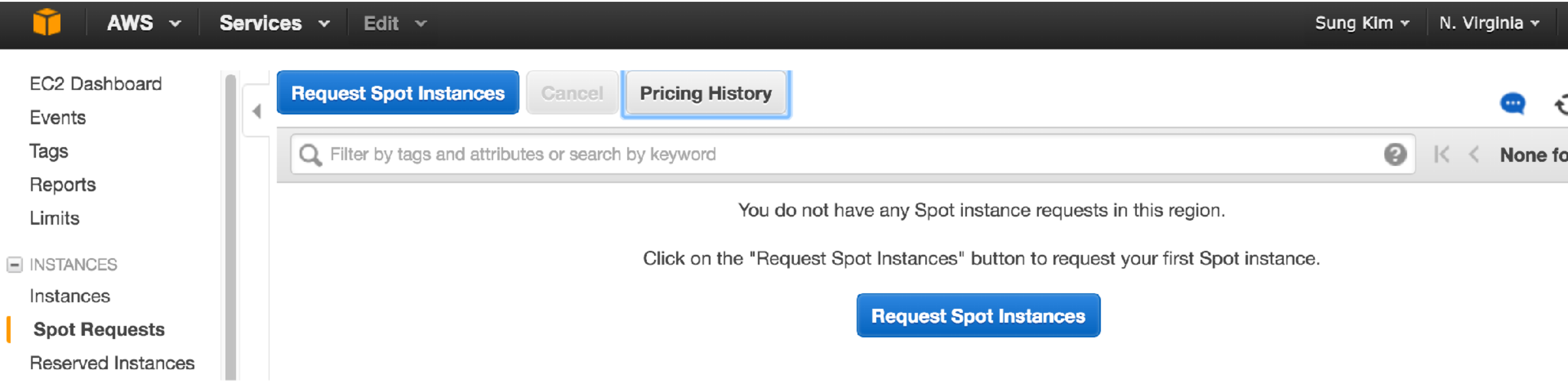
AWS GPU price in Oregon

GPU Instances - Current Generation					
g2.2xlarge	8	26	15	60 SSD	$0.65 per Hour
g2.8xlarge	32	104	60	2 x 120 SSD	$2.6 per Hour

Amazon Elastic Compute Cloud running Linux/UNIX		
$0.650 per On Demand Linux g2.2xlarge Instance Hour	17 Hrs	$11.05
$2.6 per On Demand Linux g2.8xlarge Instance Hour	1 Hrs	$2.60
Total:		**$13.65**

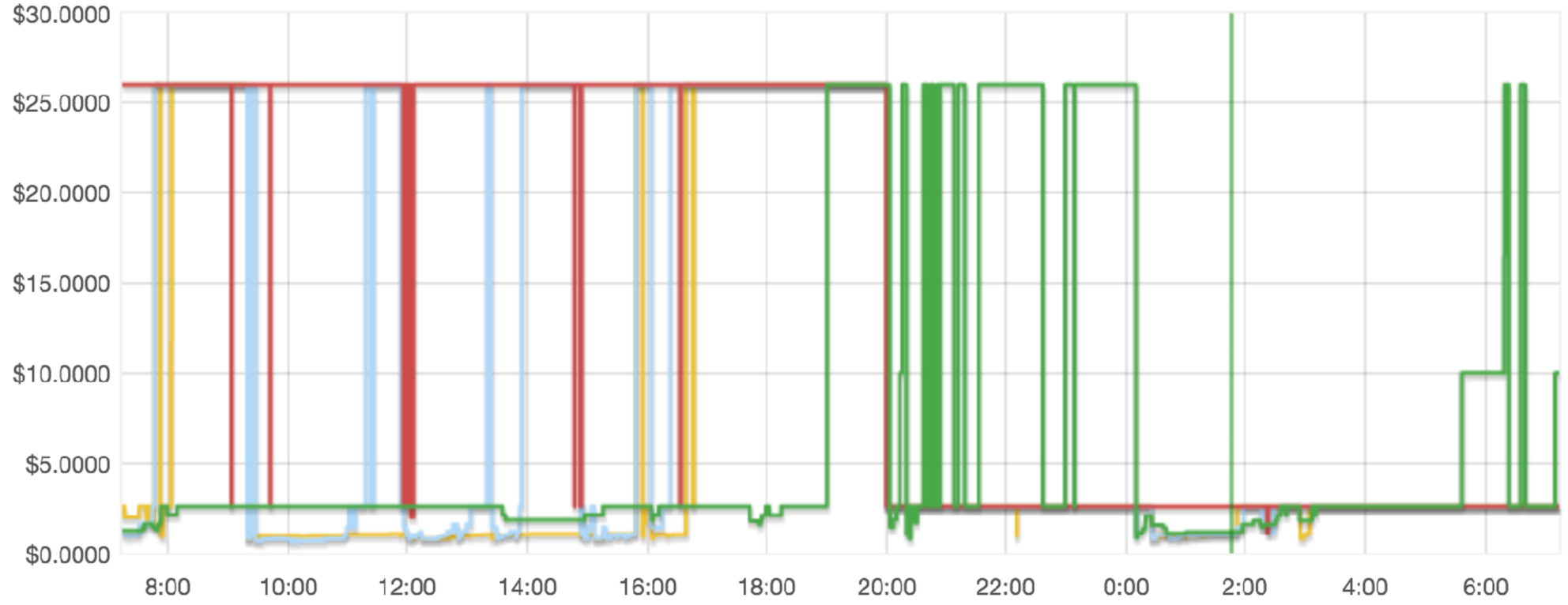
2.6 * 24 * 30 = 1,872 USD

Spot instances



Spot Instance Pricing History

Product : **Linux/UNIX** Instance type: **g2.8xlarge** Date range : **1 day** Availability zone: **All zones**



Availability zone	Price
us-east-1a	$1.0485
us-east-1c	$1.0200
us-east-1d	$2.6001

AWS

EC2 Dashboa
Events
Tags
Reports
Limits

INSTANCES
Instances
Spot Reques
Reserved Inst

N. Virginia

None fo

Price bidding

Step 3: Configure Instance Details

Configure the instance to suit your requirements. You can launch multiple instances from the same AMI, request Spot instances to take advantage of the lower pricing, assign an access management role to the instance, and more.

Number of instances 1 Launch into Auto Scaling Group

Purchasing option Request Spot instances

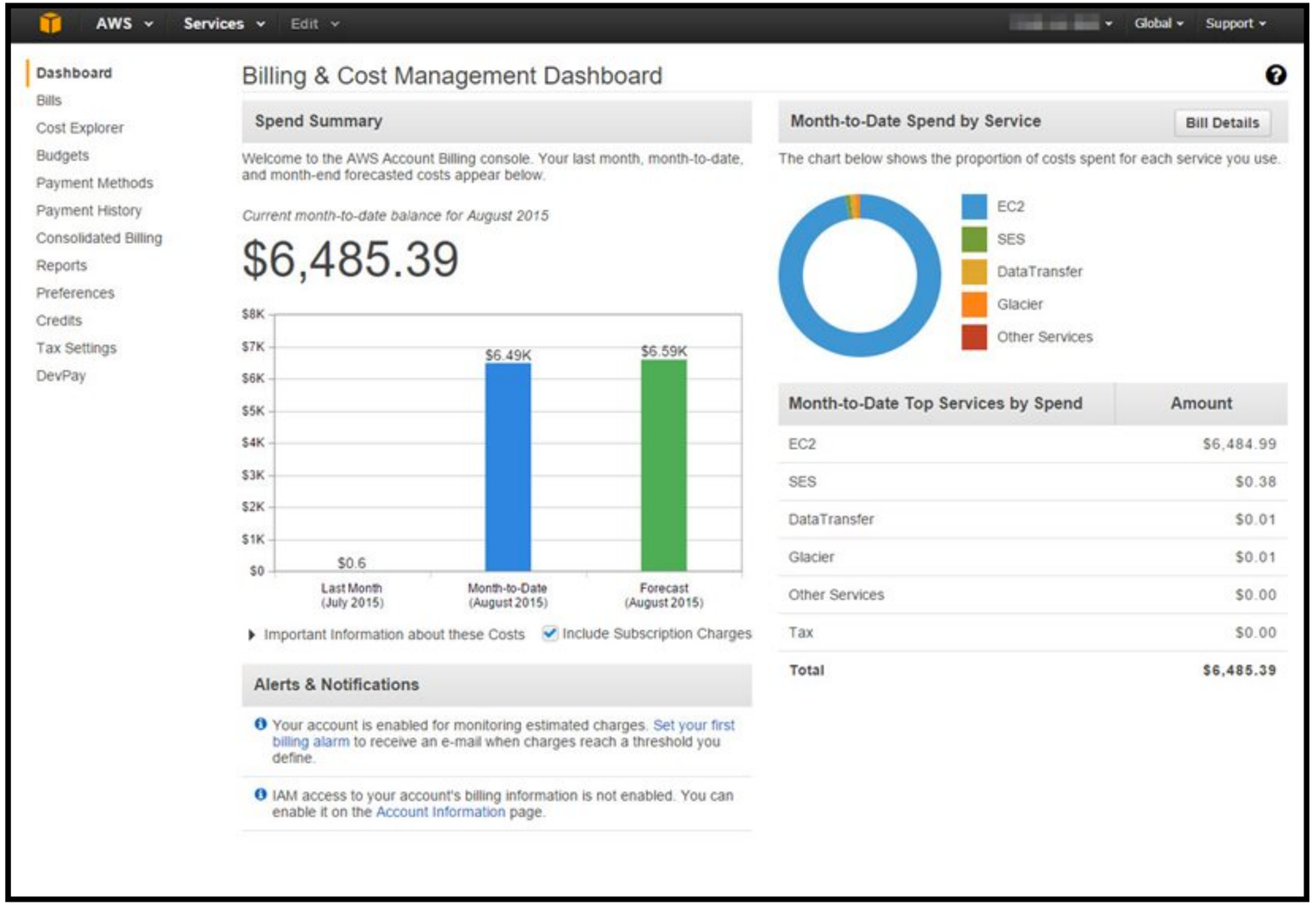
Current price

us-east-1a	0.2428
us-east-1c	0.1442
us-east-1d	0.153
us-east-1e	6.500

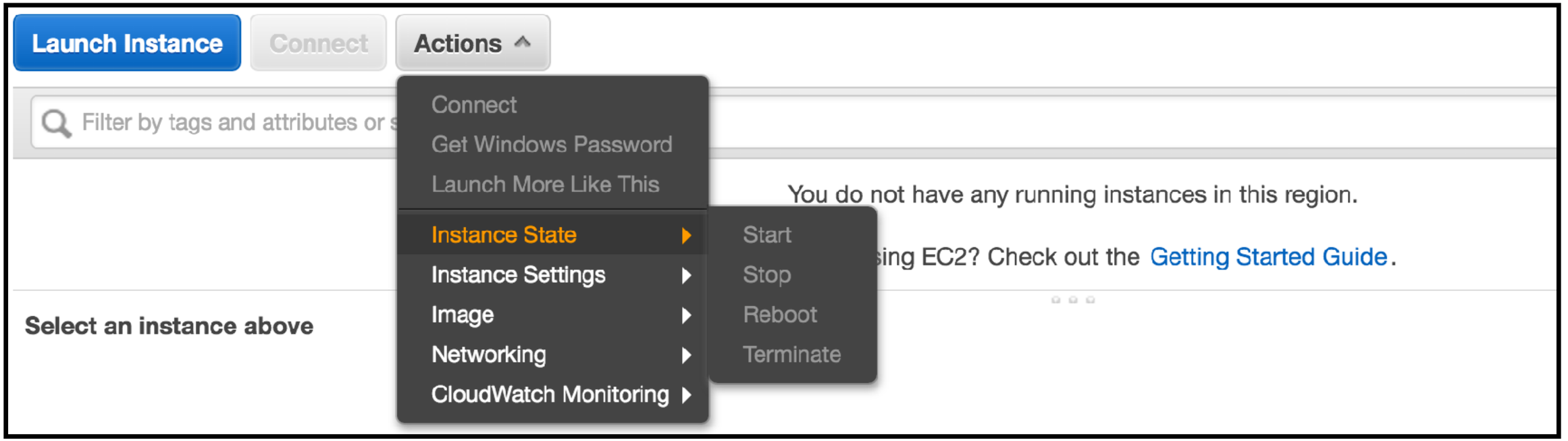
Maximum price $ (e.g. 0.045 = 4.5 cents/hour)

Launch group (Optional)

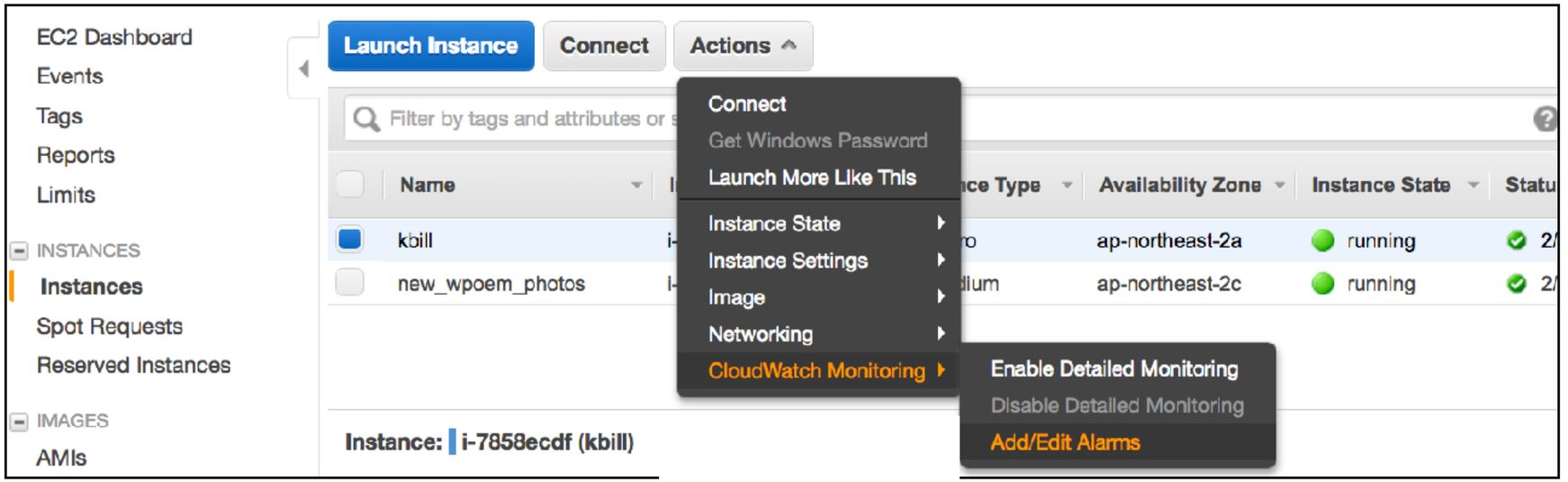
bill, bill, bill!

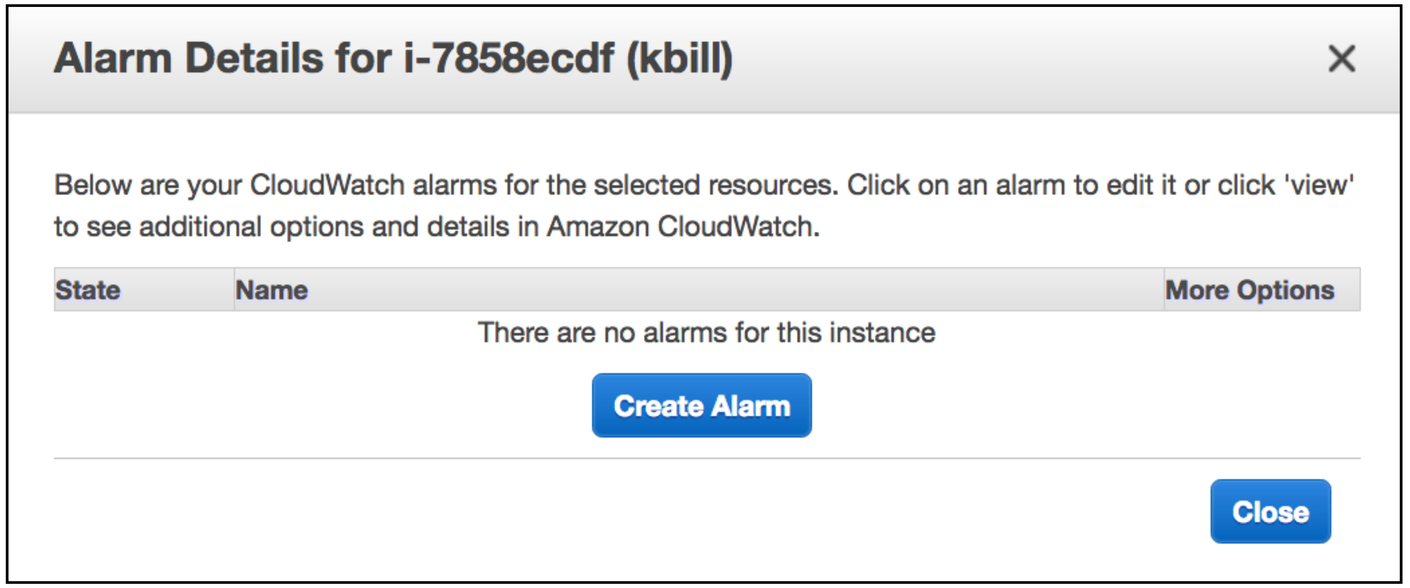


Check, stop, and terminate



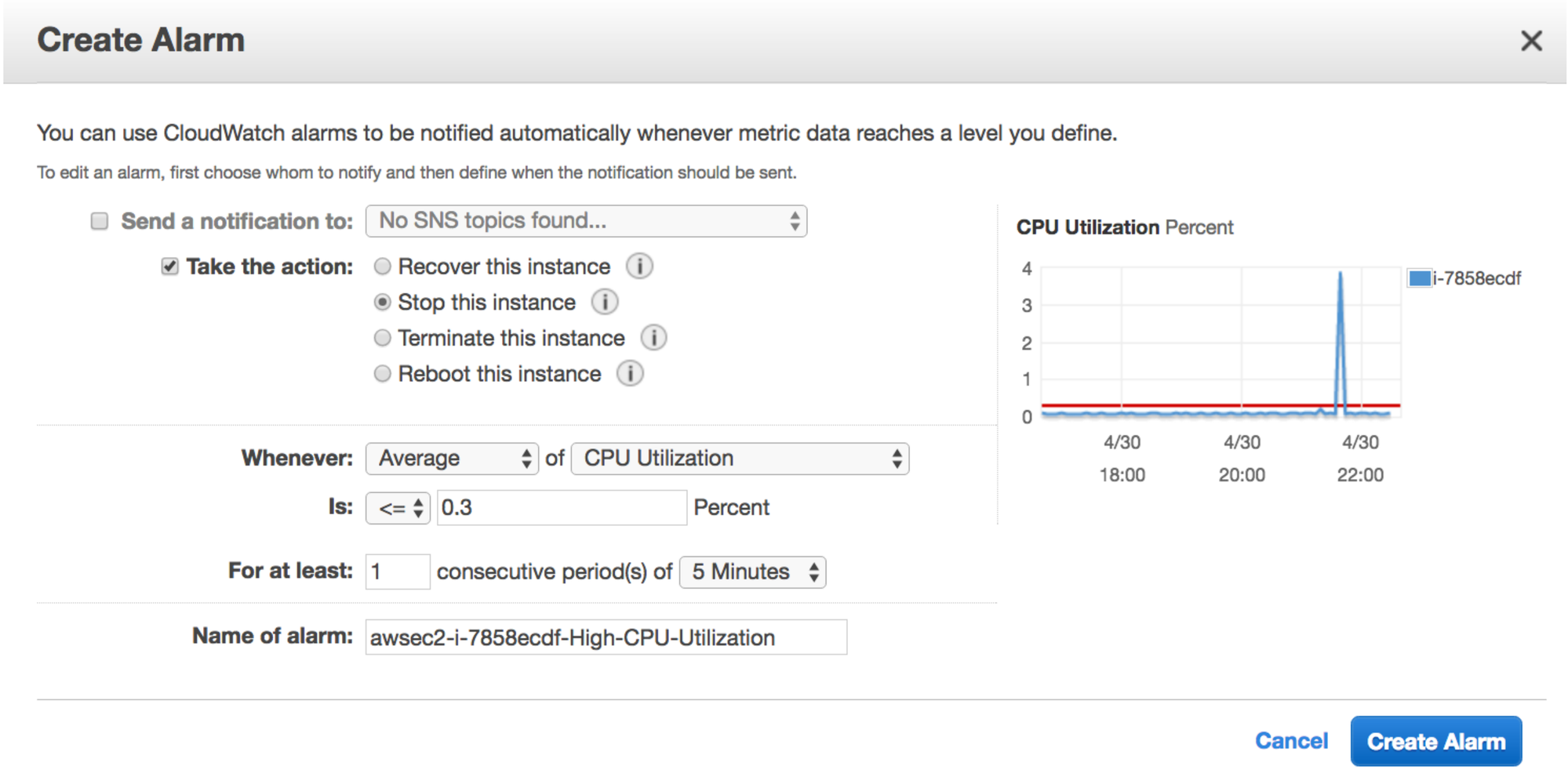
Cloud Watch





http://docs.aws.amazon.com/AmazonCloudWatch/latest/DeveloperGuide/UsingAlarmActions.html#AddingStopActions

Stop when CPU utilization <= 0.3



Shutdown after training

```
$ screen

$ sudo -i
# python train.py; shutdown -h now
```

Deep learning for Everyone
Season 2 coming soon!

Sung Kim <hunkim+ml@gmail.com>
http://hunkim.github.io/ml/

TensorFlow GPU @AWS Spot Instances without losing data

+ *100 USD credit*

Sung Kim <hunkim+ml@gmail.com>
http://hunkim.github.io/ml/

Consulted Channy Yun and DoHyun Jung

GPU

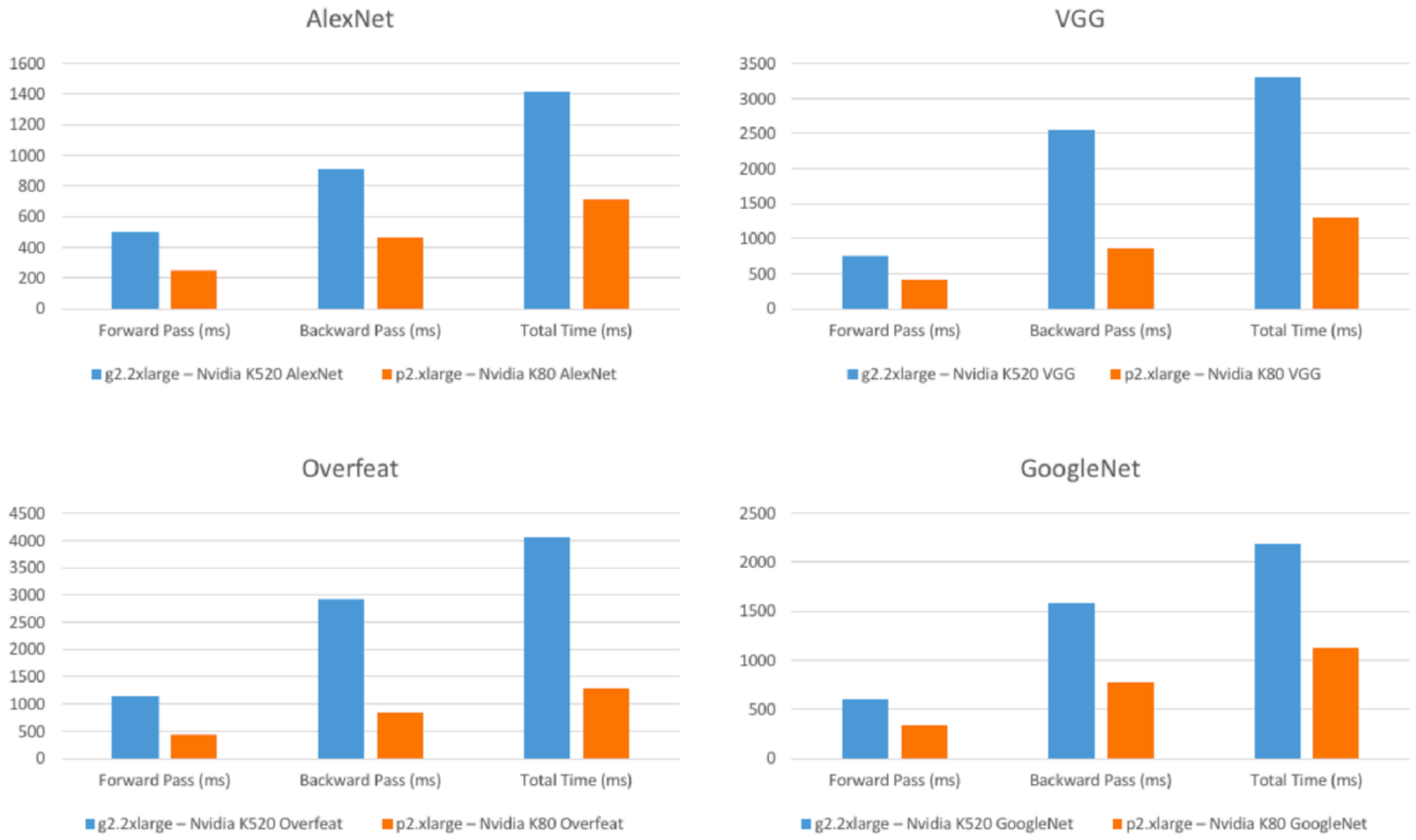
- A graphics processing unit (GPU), also occasionally called visual processing unit (VPU), is a specialized electronic circuit designed to rapidly manipulate and alter memory to accelerate the creation of images in a frame buffer intended for output to a display.

AWS G2 and P2 Instances

Model	GPUs	vCPU	Mem (GiB)	SSD Storage (GB)	GPU Memory
g2.2xlarge	1	8	15	1 x 60	4G (8G)
g2.8xlarge	4	32	60	2 x 120	4G (32G)

Instance Name	GPU Count	vCPU Count	Memory	Parallel Processing Cores	GPU Memory	Network Performance
p2.xlarge	1	4	61 GiB	2,496	12 GiB	High
p2.8xlarge	8	32	488 GiB	19,968	96 GiB	10 Gigabit
p2.16xlarge	16	64	732 GiB	39,936	192 GiB	20 Gigabit

AWS G2 and P2 Instances



TensorFlow GPU Performance: AlexNet, VGG, Overfeat, GoogleNet

http://www.bitfusion.io/2016/11/03/quick-comparison-of-tensorflow-gpu-performance-on-aws-p2-and-g2-instances/

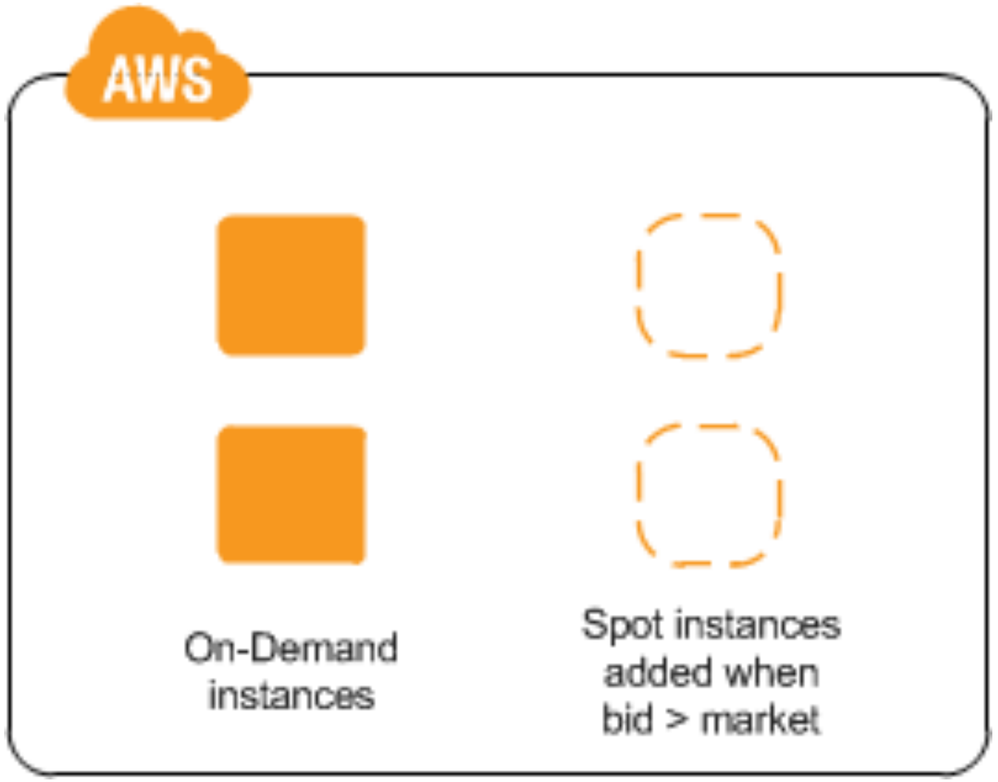
US EAST (N.Virginia) On-Demand Price

	vCPU	ECU	Memory (GiB)	Instance Storage (GB)	Linux/UNIX Usage
GPU Instances - Current Generation					
p2.xlarge	4	12	61	EBS Only	$0.9 per Hour
p2.8xlarge	32	94	488	EBS Only	$7.2 per Hour
p2.16xlarge	64	188	732	EBS Only	$14.4 per Hour
g2.2xlarge	8	26	15	60 SSD	$0.65 per Hour
g2.8xlarge	32	104	60	2 x 120 SSD	$2.6 per Hour

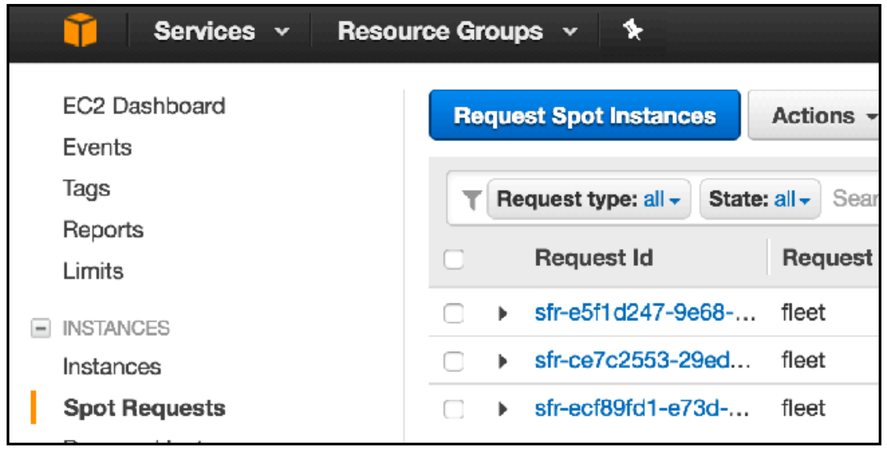
US EAST (N.Virginia) Spot Instance Price

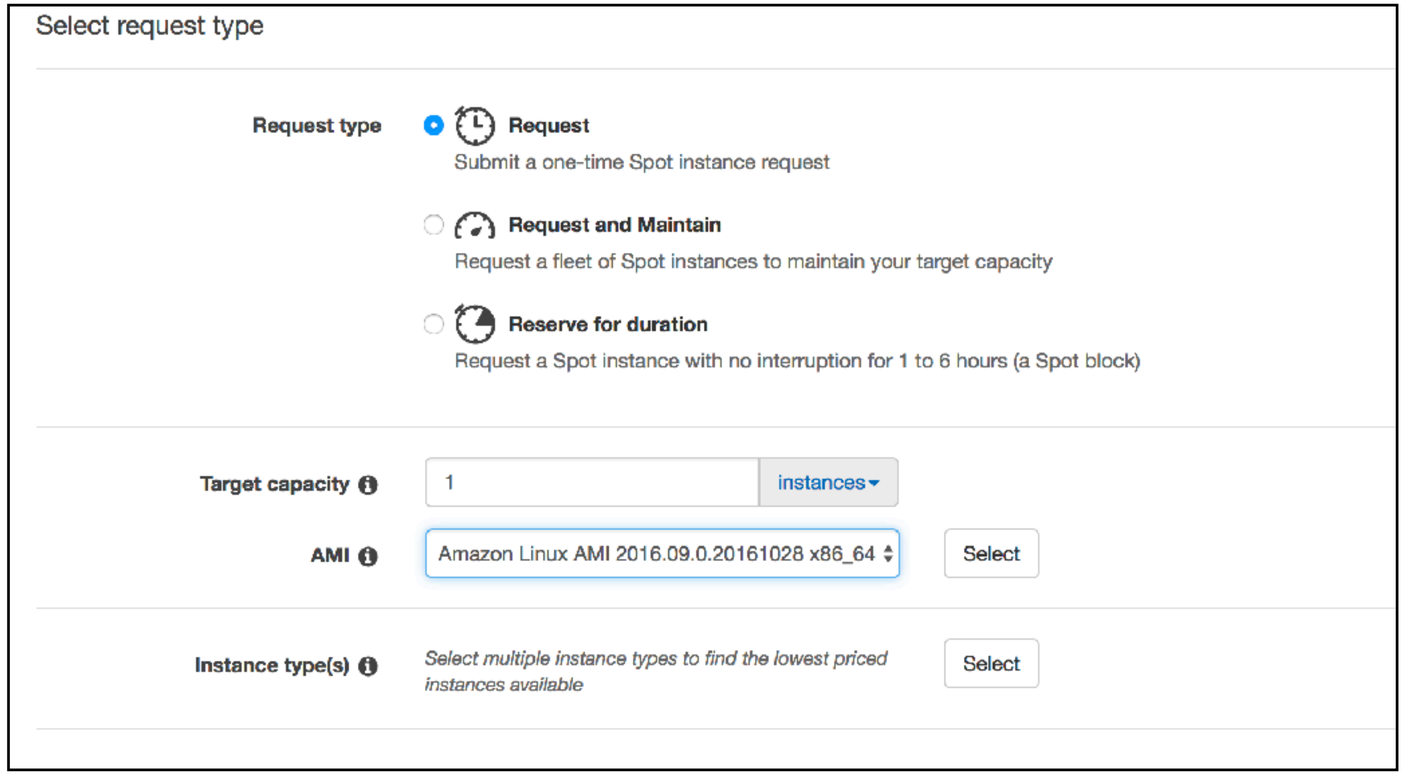
g2.2xlarge	$0.1564 per Hour	VS 0.6
g2.8xlarge	$1.966 per Hour	VS 2.8
p2.xlarge	$0.243 per Hour	VS 0.9
p2.8xlarge	$3.583 per Hour	VS 7.2

On-Demand VS Spot Instances



Request spot instances and save $





Request spot instances and save $

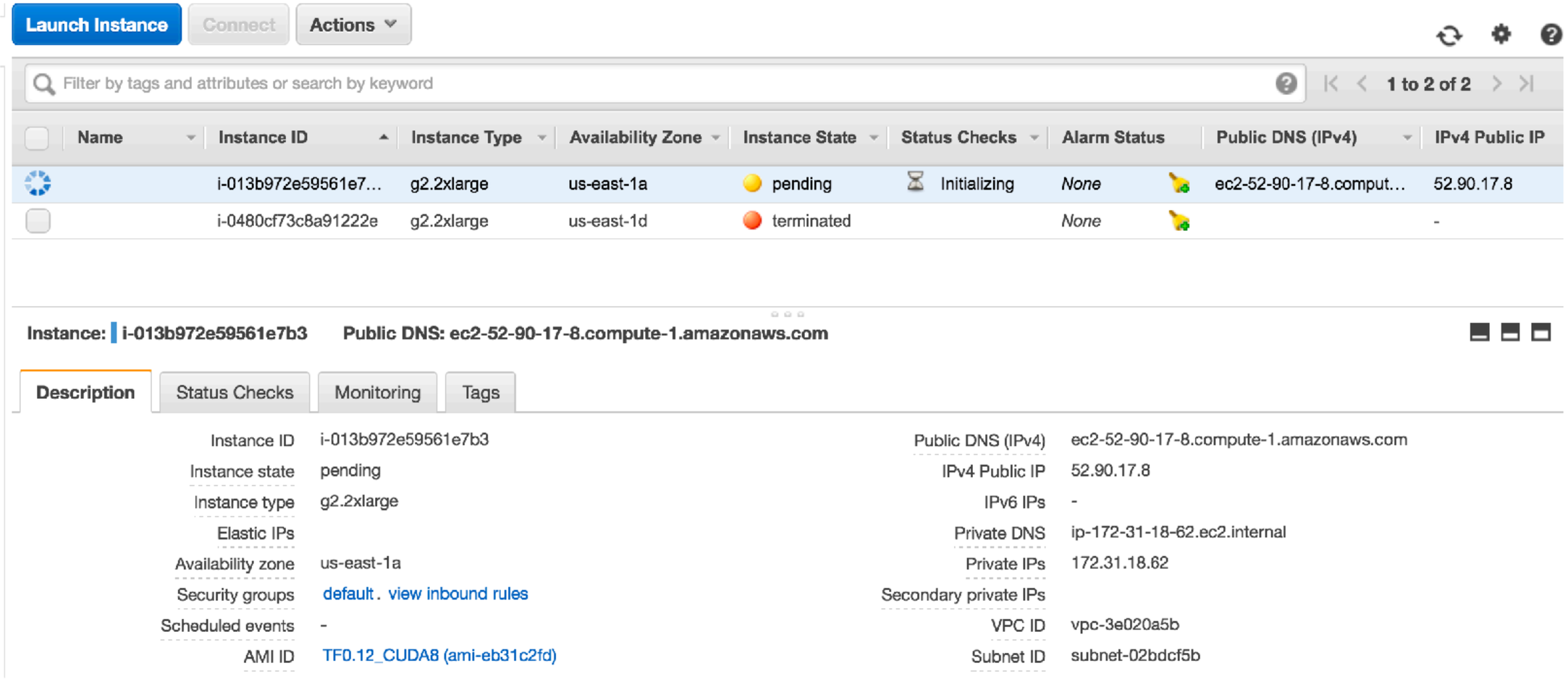
Select instance types

Supports dedicated tenancy

Pricing History | Spot Bid Advisor

Instance type	vCPUs	Memory (GiB)	Storage (GB)	Network	Current spot price	Spot savings
GPU compute	1	(Any)	(Any)	Any network		
p2.xlarge	4	61	EBS only	High	$0.1162	87%
p2.8xlarge	32	488	EBS only	10 Gigabit	$1.3821	81%
p2.16xlarge	64	732	EBS only	20 Gigabit	$4.5648	68%

Request spot instances ready (takes 2~3 min)



Work with screen

- ssh
- screen: open a new screen
  - python train.py; ..; echo “Done” | mail -s “Finished” hunkim@gmail.com
  - Ctrl-a d (to exit screen)
- screen -r: attach the screen

batch.ly
AWS COST
REDUCTION.
AUTOMATED.

AWS Spot Instance

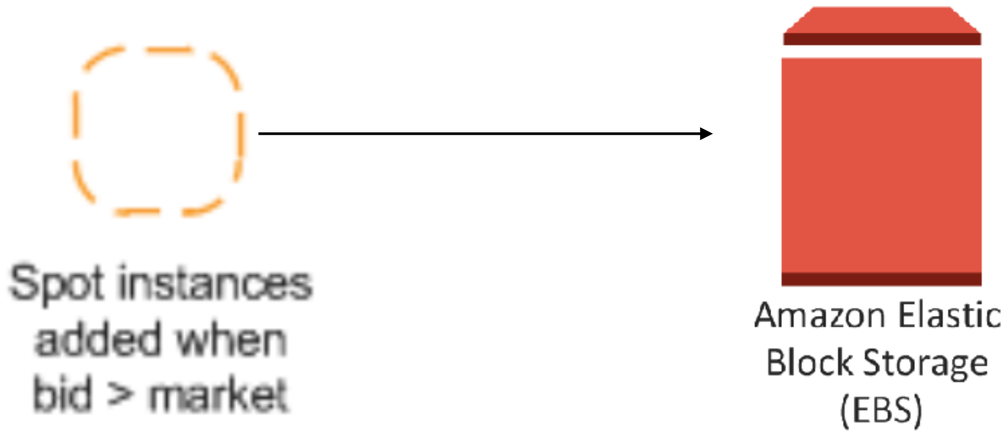
TERMINATION NOTICES

But spot instances can be terminated by AWS!

Solution: Spot Instance + EBS Volume

Automatic termination after finishing job! (save $)

Solution: Spot Instance + EBS Volume (do not delete on termination)



Automatic termination after finishing job! (save $)

Don’t delete the volume!

Spot instance launch wizard

Step 1: Find instance types
Step 2: Configure
Step 3: Review

Configure storage

Instance store ⓘ ☐ Attach at launch

EBS volumes ⓘ

Device ⓘ	Snapshot	Size (GiB)	Volume Type	IOPS	Delete ⓘ	
Root: /dev/xvda	snap-fe8a3c04	8	General Purpose (SSD)		☐	ⓘ

No additional EBS volumes configured

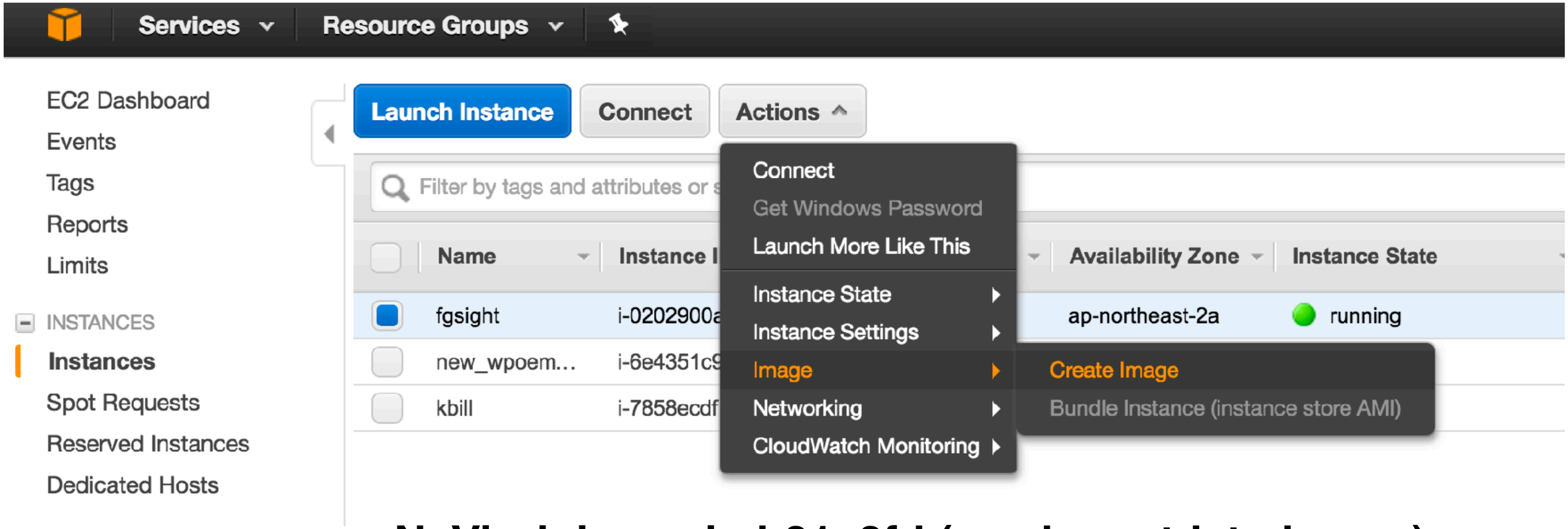
Add new volume

EBS-optimized ⓘ ☐ Launch EBS-optimized instances

Workflow

- Create a spot instance (from an AMI)
  - ***Do not delete the main disk on termination***
- Run TF tasks; sudo shutdown now
  - run (in screen) and save results on the volume
  - terminate the instance (save $)
- Create a (1) snapshot and (2) AMI from the leftover volume
- Create a new spot using the AMI
  - Delete old AMIs

0. Create AMI - TF/Cuda

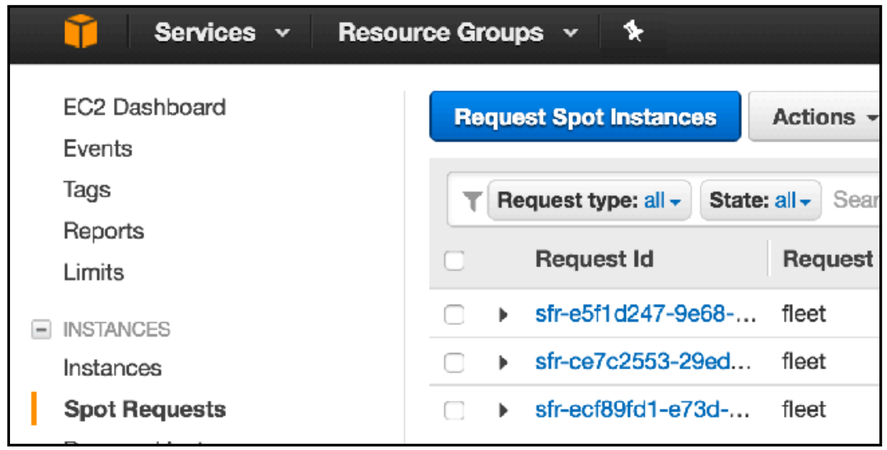


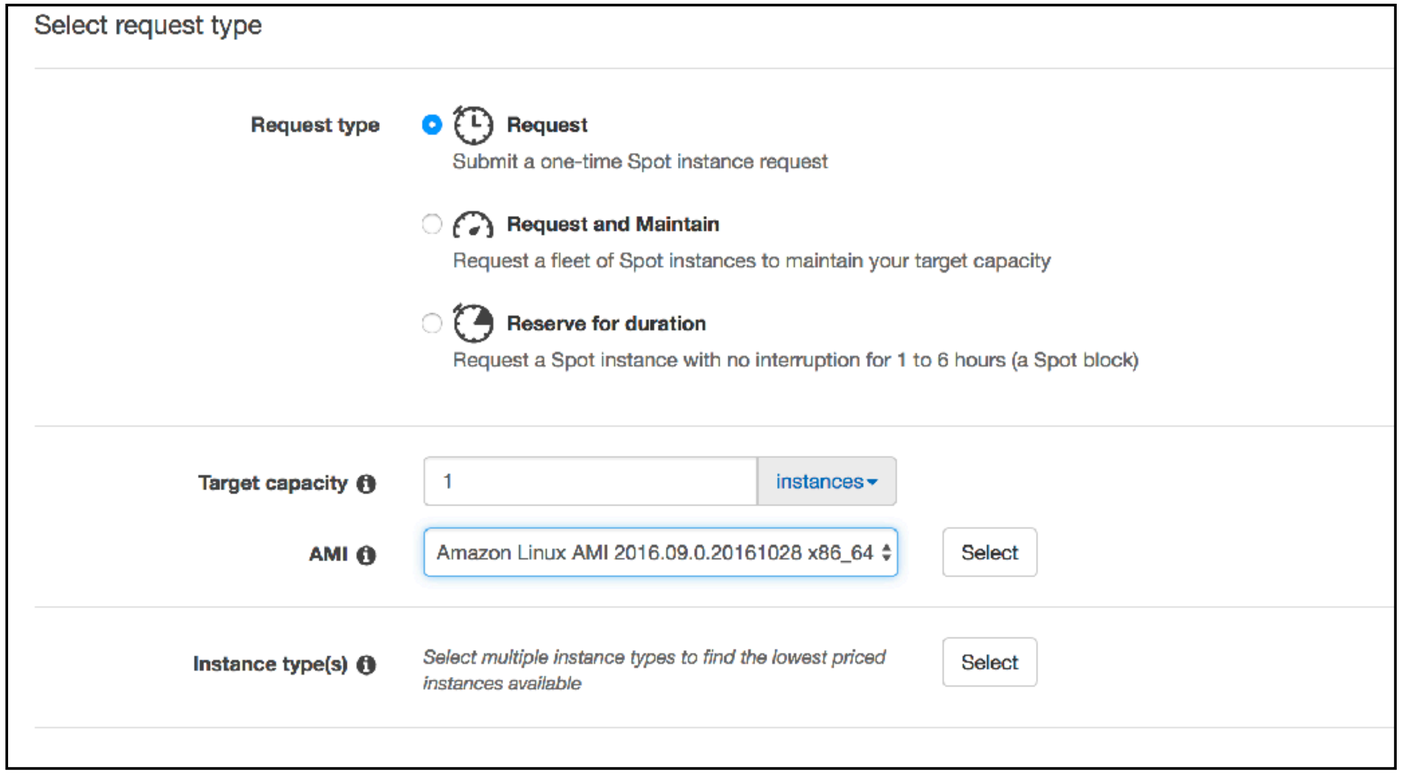
N. Virginia: ami-eb31c2fd (maybe outdated soon)

https://github.com/ritchieng/tensorflow-aws-ami

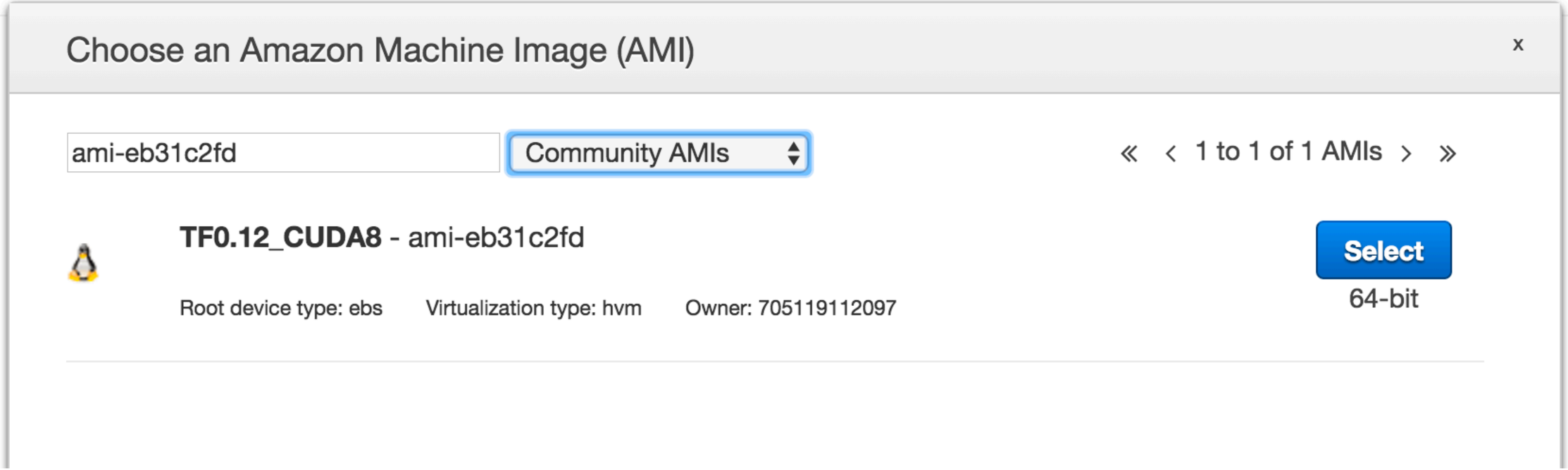
http://expressionflow.com/2016/10/09/installing-tensorflow-on-an-aws-ec2-p2-gpu-instance

1. Request spot instances using AMI

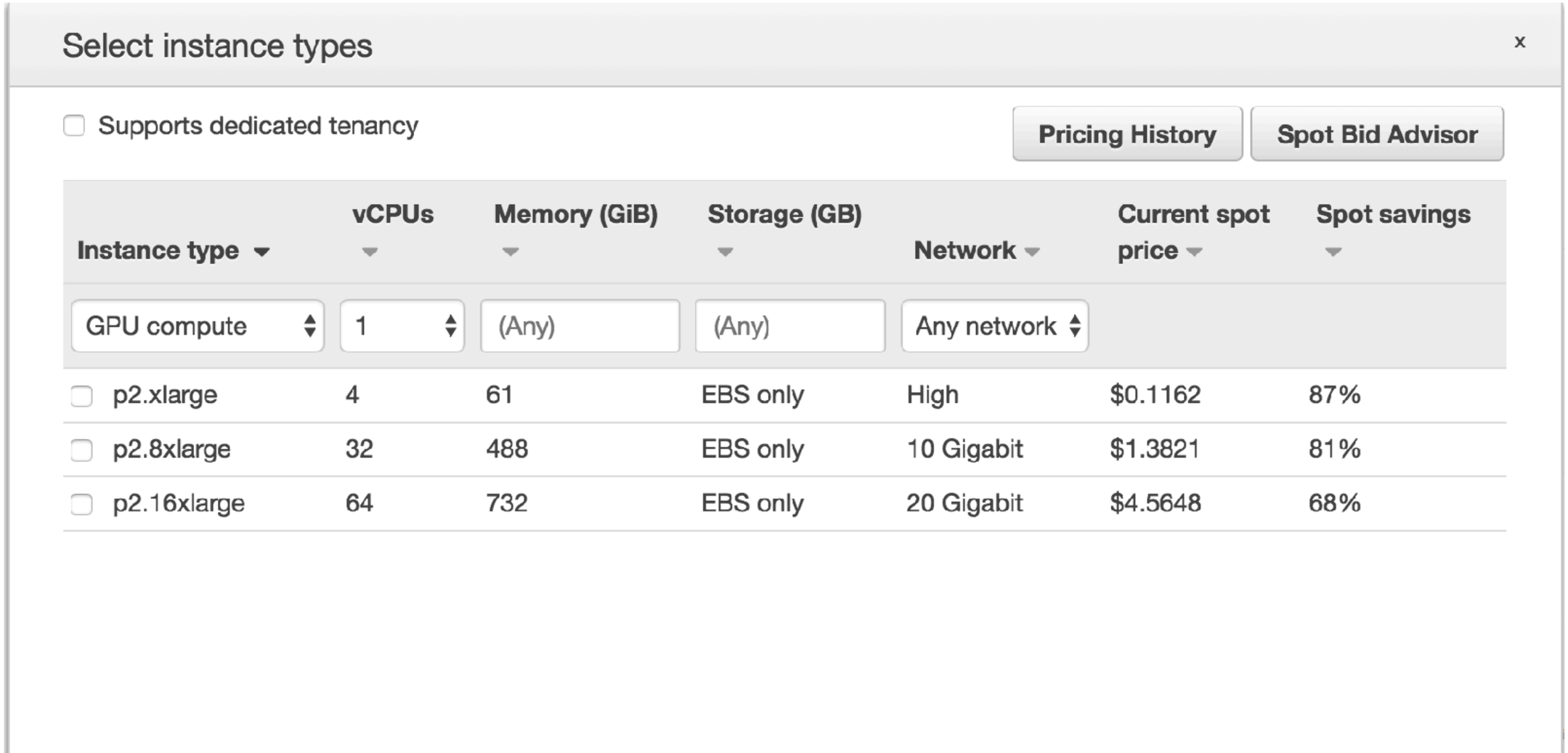




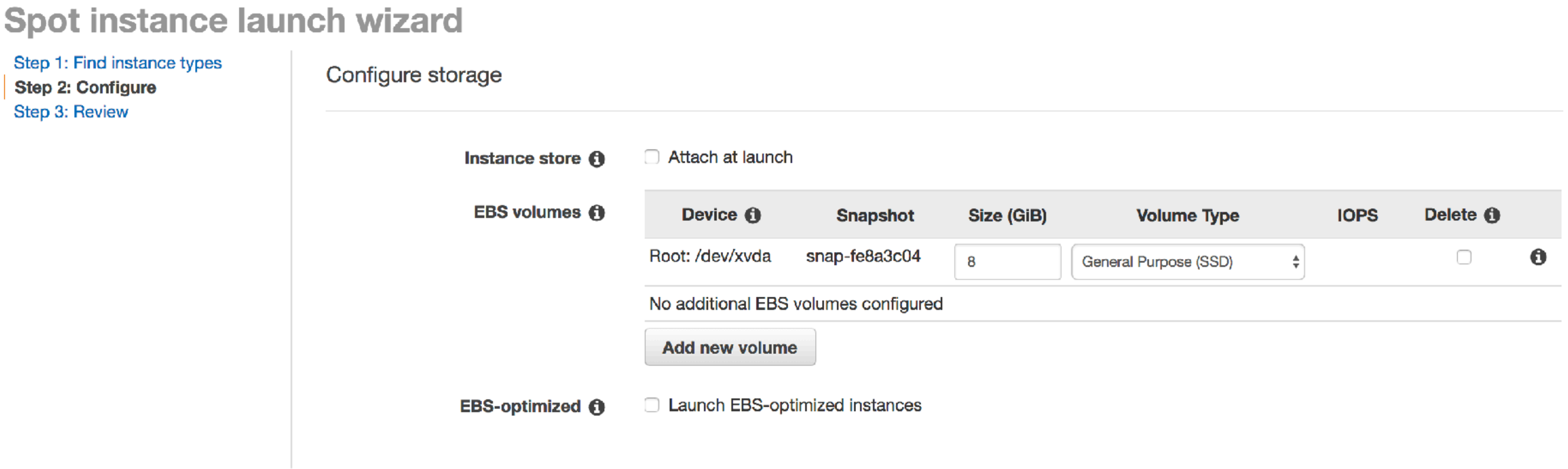
1. Request spot instances using AMI



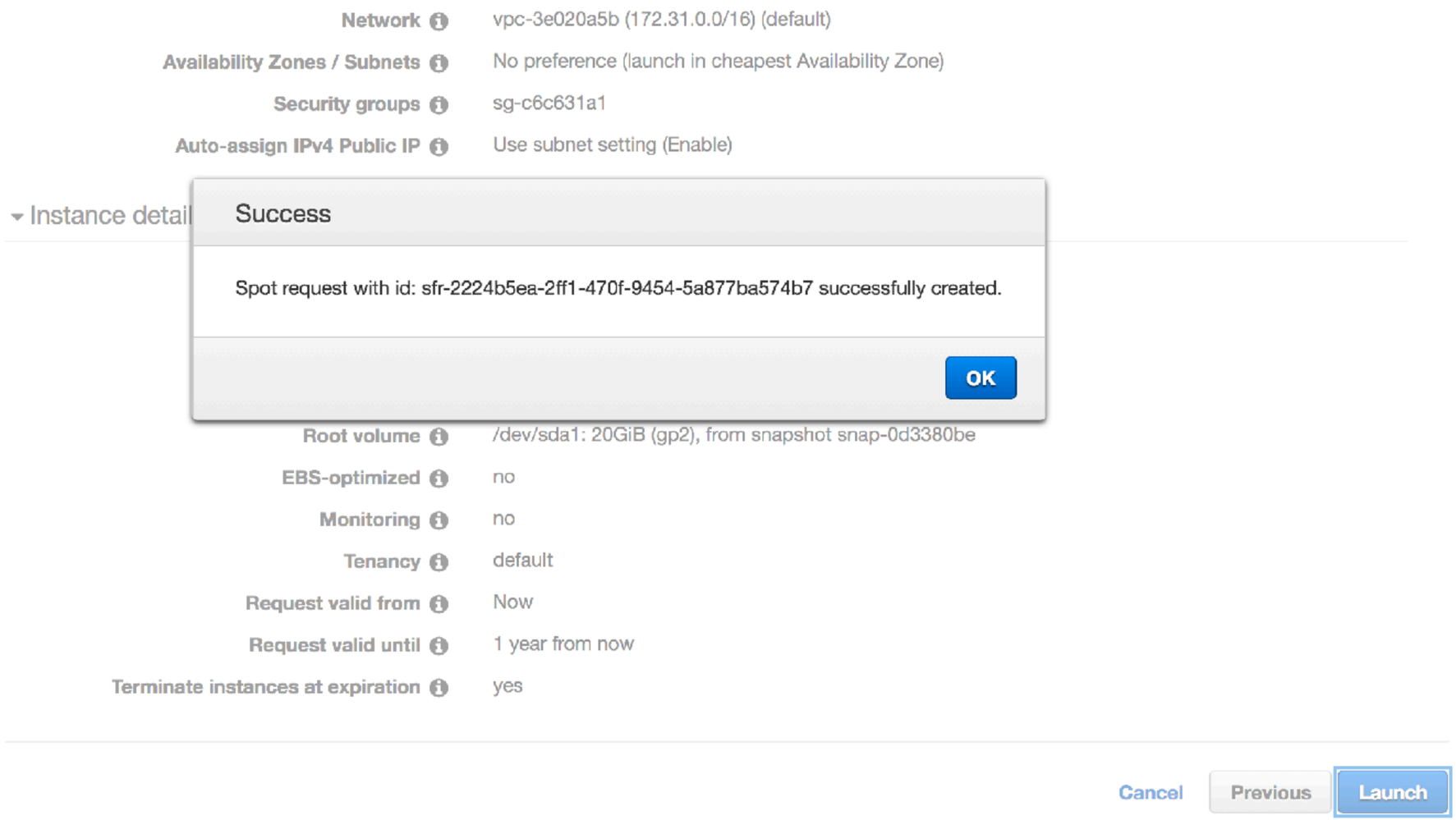
1. Request spot instances: check price



1. Request spot instances: Don't delete the volume!



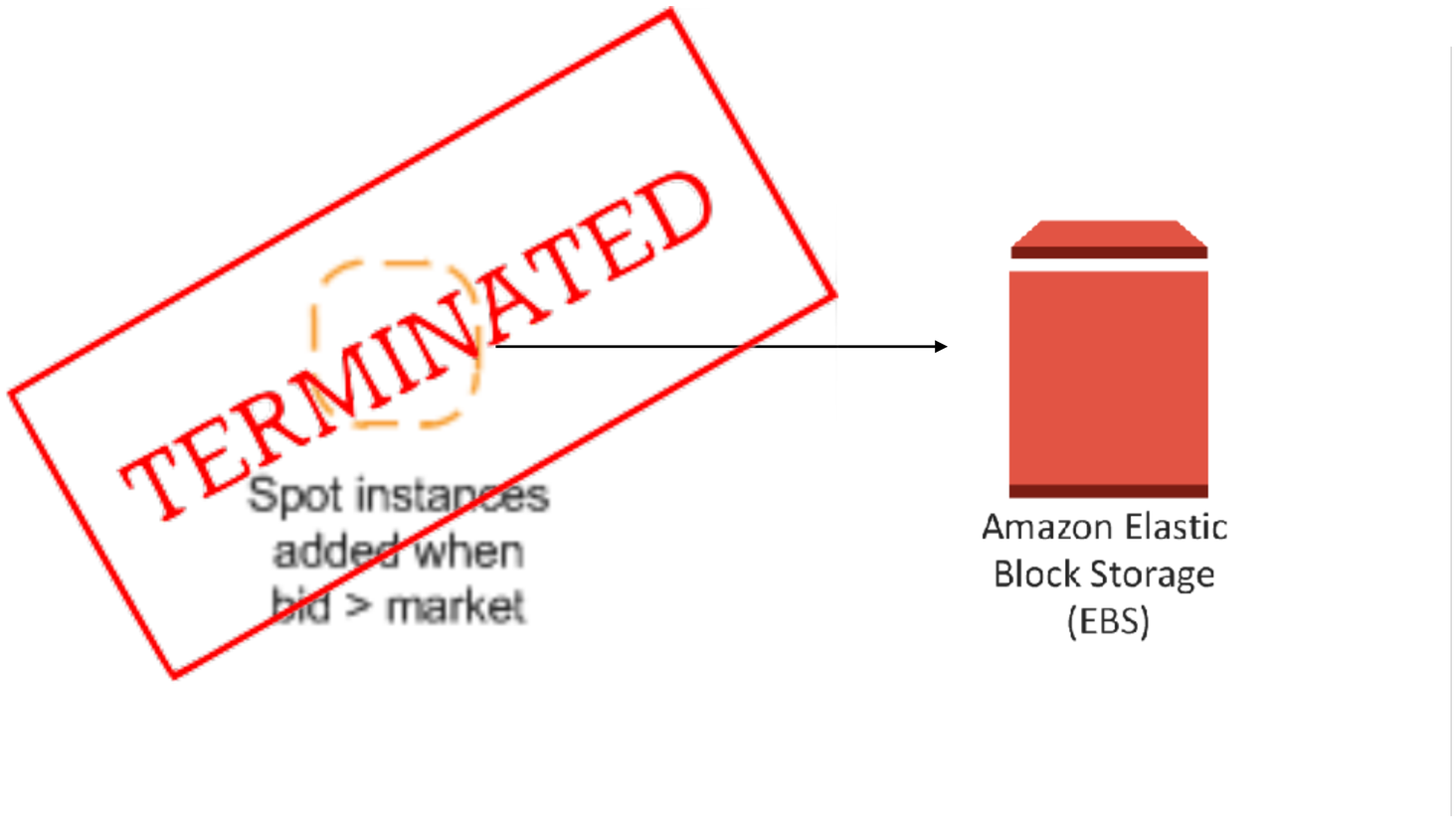
1. Request spot instances: Success



2. Run TF (with screen) and enjoy!

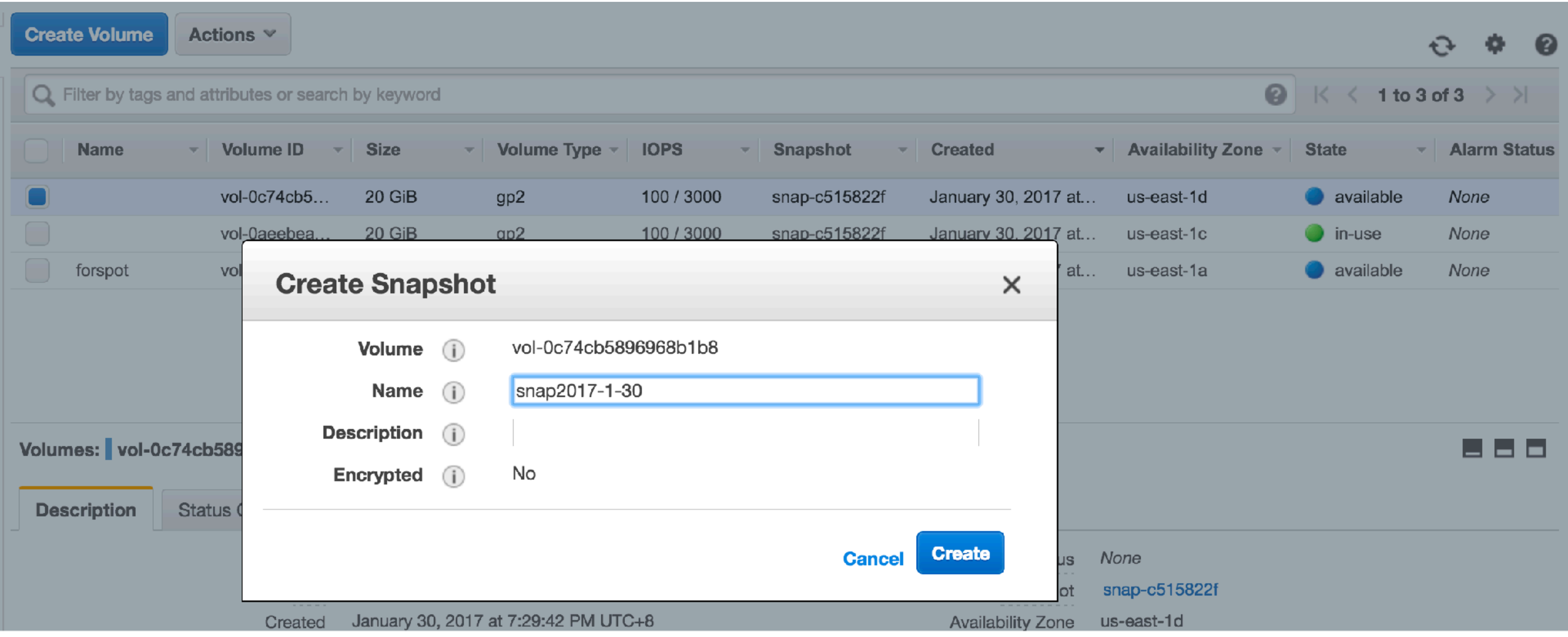
- screen
  - Start job: python3 ….py; **sudo shutdown now**
  - python3 main.py --maxLength=80 | tee out.log; sudo shutdown now
  - Ctrl-a d (exit the screen, but Job is going)
- Checking progress: screen -r
  - Ctrl-a d (exit the screen)
- When the job is done, the instances will be terminated (save $)
- But the results will be in the volume

3. Spot Instance termination + EBS Volume

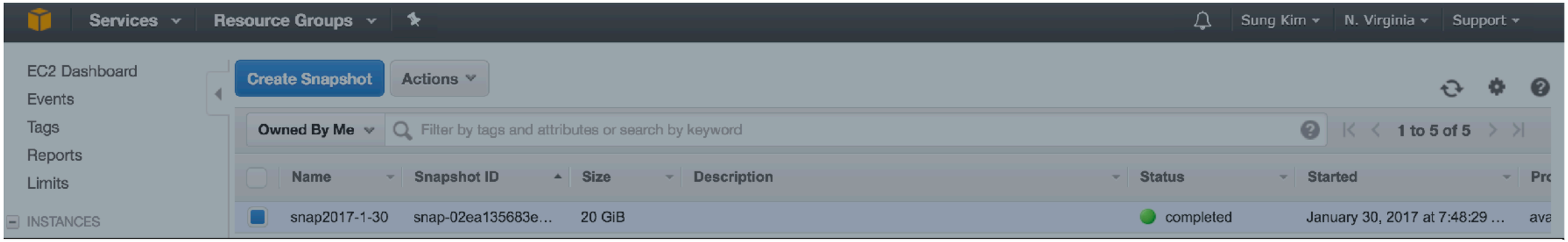


Automatic termination after finishing job! (save $)

4. Create snapshot from the volume



5.Create AMI from the snapshot



Create Image from EBS Snapshot

Name	AMI-2017-1-20	Description	
Architecture	x86_64	Virtualization type	Paravirtual
Root device name	/dev/sda1	Kernel ID	Use default
RAM disk ID	Use default		

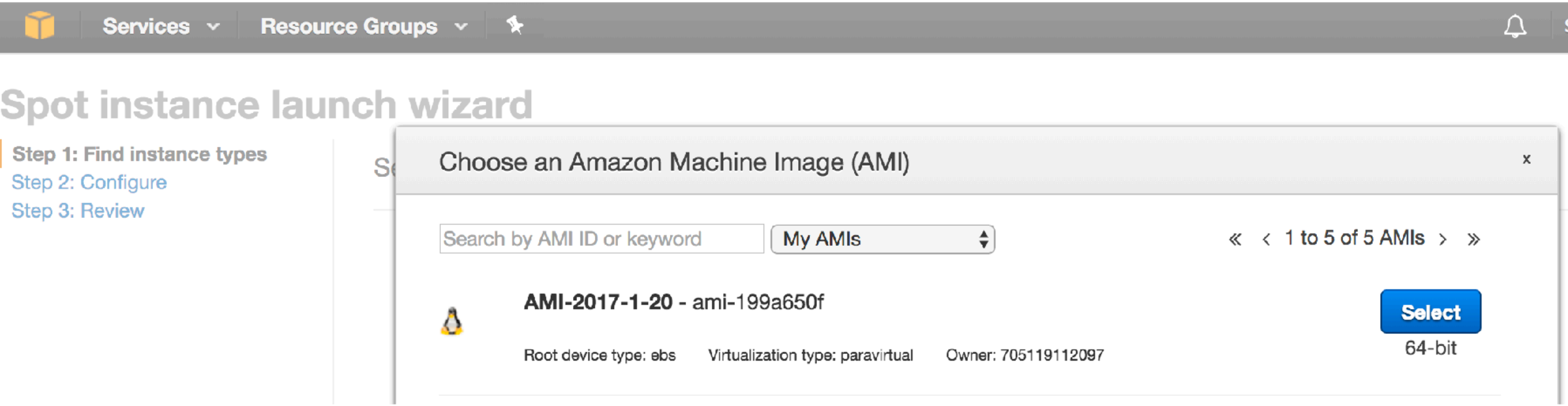
Block Device Mappings

Volume Type	Device	Snapshot	Size (GiB)	Volume Type	IOPS	Throughput (MB/s)	Delete on Termination	Encrypted
Root	/dev/sda1	snap-02ea135683e1fb71d	20	General Purpose SSD (GP2)	100 / 3000	N/A	☑	Not Encrypted

Add New Volume

Cancel Create

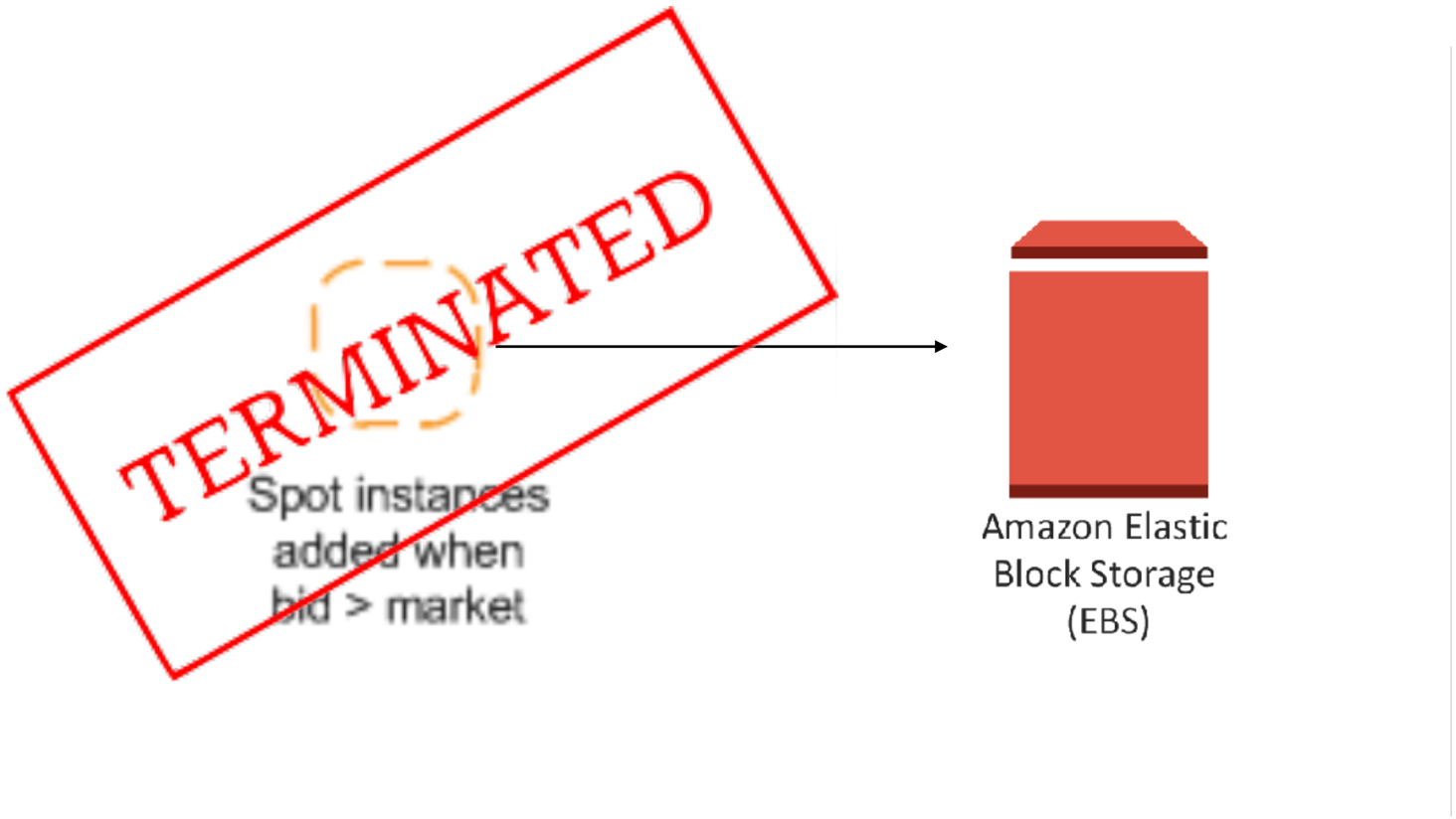
6. Create new spot instance using the AMI



GPU, GPU, GPU

```
Total memory: 11.17GiB
Free memory: 11.11GiB
I tensorflow/core/common_runtime/gpu/gpu_device.cc:906] DMA: 0 1 2 3 4 5 6 7
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 0:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 1:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 2:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 3:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 4:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 5:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 6:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:916] 7:   Y Y Y Y Y Y Y Y
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:0) -> (device: 0, name: Tesla K80, pci bus id: 0000:00:17.0)
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:1) -> (device: 1, name: Tesla K80, pci bus id: 0000:00:18.0)
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:2) -> (device: 2, name: Tesla K80, pci bus id: 0000:00:19.0)
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:3) -> (device: 3, name: Tesla K80, pci bus id: 0000:00:1a.0)
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:4) -> (device: 4, name: Tesla K80, pci bus id: 0000:00:1b.0)
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:5) -> (device: 5, name: Tesla K80, pci bus id: 0000:00:1c.0)
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:6) -> (device: 6, name: Tesla K80, pci bus id: 0000:00:1d.0)
I tensorflow/core/common_runtime/gpu/gpu_device.cc:975] Creating TensorFlow device (/gpu:7) -> (device: 7, name: Tesla K80, pci bus id: 0000:00:1e.0)
```

Solution: Spot Instance + EBS Volume



Automatic termination after finishing job! (save $)

TensorFlow-KR 회원을 위한 AWS 크레딧 제공!

http://bit.ly/awskr-feedback

딥러닝 연구및 학습
AWS 100달러 무료 크레딧 제공

등록하시면 패키지를 받으실 수 있는 URL 및 AWS 학습 정보를 이메일로 보내드립니다!