# TensorFlow Tutorial

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# Deep Learning Libraries

- Caffe : Python, Matlab, C++
- CNTK : Python, C++

- Theano : Python
- Torch : Lua
- Keras : Python and Theano
- Lasagne : Python and Theano
- TensorFlow : Python, C++
- etc.

# Deep Learning Libraries

- Caffe
- CNTK

Configuration File

- Theano
- Torch
- Keras
- Lasagne
- TensorFlow
- etc.

Programmatic generation

# TensorFlow

- TensorFlow provides large number of inbuilt functions for doing operations on tensors and automatically computer their derivatives
- Developed by *Google* as part of *Google Brain* project
- Large number of inbuilt functions available and keep getting update
- Pretty good documentations available and getting update
- Large number of users : You can get lots of code in github
- Better support for distributed system

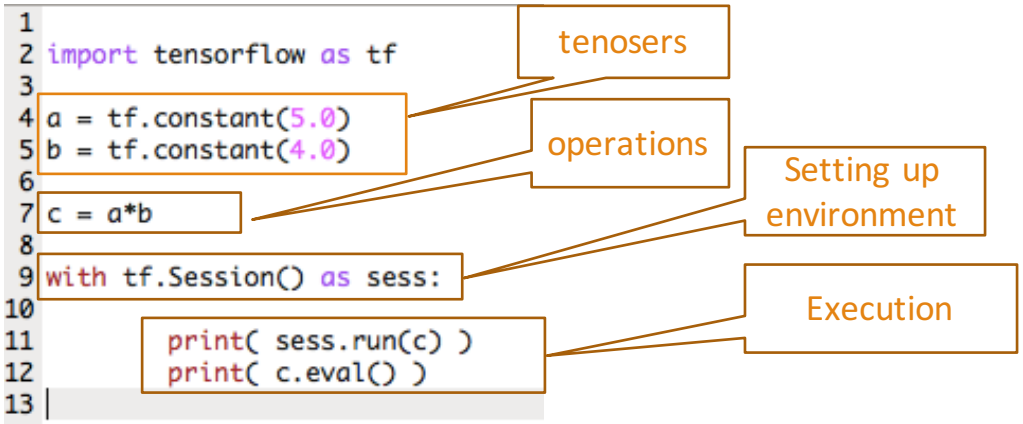
# Summing two matrices

```
>>> import numpy as np
>>> x = np.zeros((3,2))
>>> y = np.ones((3,2))
>>> z = x + y
>>> z
array([[ 1.,  1.],
       [ 1.,  1.],
       [ 1.,  1.]])
...
```

```
>>> import tensorflow as tf
>>> x = tf.zeros((3,2))
>>> y = tf.ones((3,2))
>>> z = x + y
>>> tf.InteractiveSession()
<tensorflow.python.client.session.InteractiveSession object at 0x11352aa90>
>>> z.eval()
array([[ 1.,  1.],
       [ 1.,  1.],
       [ 1.,  1.]], dtype=float32)
>>>
```

# Flow of Writing Codes

1. Create tensors
2. Write operations for tensors
3. Setting up environment for those operations to execute
4. Execute operations in given environment



# Tensors in TensorFlow

1. **Constant tensor :**
2. **Variable tensor** : initialize with init_op, restoring with save file, assign() works

```
1  import tensorflow as tf
2  import numpy as np
3
4  W1 = tf.convert_to_tensor(np.random.rand(4,3) )
5  W2 = tf.Variable(tf.ones((3,5), dtype='float64', name = 'weights') )
6
7  A = tf.matmul(W1, W2)
8
9  with tf.Session() as sess:
10         print (sess.run(W1) )
11
12         sess.run( tf.initialize_all_variables() )
13
14         print (sess.run(W2) )
15
16         print (sess.run(A))
17
18
```

Constant tensor

Variable tensor

Initialize all variable tensor

# Place Holder

- Kind of a Variable or dummy node in computation graph
- We can write sequence of operations with place holder
- Real assignment happens when we call run()
- Syntax :

```
X = tf.placeholder(tf.float32, [3, None], name='X' )

X = tf.placeholder(tf.float32, [None, 3], name='X' )

X = tf.placeholder(tf.float32, [None, None], name='X' )
```

# Fetching and Feeding

```
1  import tensorflow as tf
2  import numpy as np
3
4  X = tf.placeholder(tf.float32, [None, 3], name='X' )
5
6  W = tf.Variable( tf.random_uniform( [3,2], -1.0, +1.0) , name = 'W' )
7
8  z1 = tf.matmul(X, W)
9  z2 = tf.nn.sigmoid(z1)
10
11 with tf.Session() as sess:
12         sess.run( tf.initialize_all_variables() )
13         a, b = sess.run([z1,z2], {X:np.ones((4,3))} )
14         print a
15         print b
```

Feed data into computation graph

Fetch values from computation graph

# Important Operations

```
8
9
10          # Concatenation
11 emb0 = tf.constant( np.random.rand(3,4) )        # 3X4
12 emb1 = tf.constant( np.random.rand(3,3) )        # 3X3
13 X = tf.concat(1, [emb0, emb2])                   # 3X7
14
15          # Operations wrt one index
16 X = tf.constant( np.ones((3,4)) )                # 3X4
17 y = tf.reduce_sum( X, 1 )                        # Output: [4,4,4]
18 z = tf.reduce_max(X, 1)                          # Output: [1,1,1]
19 a = tf.reduce_mean(X, 1)                         # Output: [1,1,1]
20 b = tf.argmax(X, 1)                              # Output: [0,0,0]
21
22
23          # Reshape the tensor
24 x = tf.constant( np.random.rand(3,4,5) )        # 3X4X5
25 y = tf.reshape( x, [3,20] )                      # 3X20
26 z = tf.reshape( y, [-1] )                       # 60
27 a = tf.reshape( z, [-1, 5, 2] )                 # 6X5X2
28 b = tf.expand_dims(a, -1)                       # 6X5X2X1
29 c = tf.squeeze(b)                               # 6X5X2
30
31
```

# Part-2

## IMPLEMENTATIONS

# Multi Layer Neural Network (1)

```
1  import tensorflow as tf
2
3  i_dim = 10
4  h1_dim = 5
5  num_classes = 3
6  #Symbolic or Place holder for input and output
7  X = tf.placeholder(tf.float32, [None, i_dim], name='input')                    # 100 X 10
8  input_y = tf.placeholder(tf.float32, [None, num_classes], name="input_y")      # 100 X 3
9  #Initialize parameters
10 W1 = tf.get_variable('W_1', shape = [i_dim, h1_dim], initializer = tf.random_normal_initializer() )     # 10 X 5
11 b1 = tf.Variable(tf.constant(0.1, shape=[h1_dim]), name="b1")                                           # 5
12 W2 = tf.get_variable('W_2', shape = [h1_dim, num_classes], initializer = tf.random_normal_initializer() )       # 5X3
13 b2 = tf.Variable(tf.constant(0.1, shape=[num_classes]), name="b2")                                      # 3
14
15 #First layer operations
16 H1 = tf.nn.xw_plus_b(X, W1, b1, name="H2")      # 100 X 5
17 Z1 = tf.sigmoid(H1)                             # 100 X 5
18 #Second layer operations
19 H2 = tf.nn.xw_plus_b(H1, W2, b2, name="H2")     # 100 X 3
20 #Loss function
21 losses = tf.nn.softmax_cross_entropy_with_logits(H2, input_y)   # 100
22 loss = tf.reduce_mean(losses) + 0.001 * (tf.nn.l2_loss(W1) + tf.nn.l2_loss(W2) )               # 1
23 #Predicitons of the batch
24 predictions = tf.argmax(H2, 1, name="predictions")
25 #Accuracy of correct prediction in batch
26 correct_predictions = tf.equal(predictions, tf.argmax(input_y, 1) )
27 accuracy = tf.reduce_mean(tf.cast(correct_predictions, "float"), name="accuracy")
28 #Optimization
29 optimizer = tf.train.AdamOptimizer(1e-2)
30 grads_and_vars = optimizer.compute_gradients(loss)
31 global_step = tf.Variable(0, name="global_step", trainable=False)
32 train_op = optimizer.apply_gradients(grads_and_vars, global_step = global_step)
33
34 with tf.Session() as sess :
35
36         sess.run(tf.initialize_all_variables())
37         # Create Dataset
38         D = np.asarray( np.random.rand(1000, 10), dtype='float32')
39         Y = np.asarray ( np.zeros((1000, 3)), dtype='float32' )
40         for i in range(1000) :
41                 k = np.random.randint(3)
42                 Y[i][k] = 1.0
43         X_train = D[0:800]; Y_train = Y[0:800]
44         X_test = D[800:] ; Y_test = Y[800:]
45         # Training
```

Create Tensors

Define Operations

Environment Setup

Execution

# Multi Layer Neural Network (2)

nnEx.py

```
import tensorflow as tf

i_dim = 10
h1_dim = 5
num_classes = 3
#Symbolic or Place holder for input and output
X = tf.placeholder(tf.float32, [None, i_dim], name='input')                  # 100 X 10
input_y = tf.placeholder(tf.float32, [None, num_classes], name="input_y")    # 100 X 3
#Initialize parameters
W1 = tf.get_variable('W_1', shape = [i_dim, h1_dim], initializer = tf.random_normal_initializer() )    # 10 X 5
b1 = tf.Variable(tf.constant(0.1, shape=[h1_dim]), name="b1")                                          # 5
W2 = tf.get_variable('W_2', shape = [h1_dim, num_classes], initializer = tf.random_normal_initializer() )     # 5X3
b2 = tf.Variable(tf.constant(0.1, shape=[num_classes]), name="b2")                                             # 3

#First layer operations
H1 = tf.nn.xw_plus_b(X, W1, b1, name="H2")     # 100 X 5
Z1 = tf.sigmoid(H1)                            # 100 X 5
#Second layer operations
H2 = tf.nn.xw_plus_b(H1, W2, b2, name="H2")    # 100 X 3
#Loss function
losses = tf.nn.softmax_cross_entropy_with_logits(H2, input_y)   # 100
loss = tf.reduce_mean(losses) + 0.001 * (tf.nn.l2_loss(W1) + tf.nn.l2_loss(W2) )              # 1
#Predicitons of the batch
predictions = tf.argmax(H2, 1, name="predictions")
#Accuracy of correct prediction in batch
correct_predictions = tf.equal(predictions, tf.argmax(input_y, 1) )
accuracy = tf.reduce_mean(tf.cast(correct_predictions, "float"), name="accuracy")
#Optimization
optimizer = tf.train.AdamOptimizer(1e-2)
grads_and_vars = optimizer.compute_gradients(loss)
global_step = tf.Variable(0, name="global_step", trainable=False)
train_op = optimizer.apply_gradients(grads_and_vars, global_step = global_step)

with tf.Session() as sess :

        sess.run(tf.initialize_all_variables())
        # Create Dataset
        D = np.asarray( np.random.rand(1000, 10), dtype='float32')
        Y = np.asarray ( np.zeros((1000, 3)), dtype='float32' )
        for i in range(1000) :
                k = np.random.randint(3)
                Y[i][k] = 1.0
        X_train = D[0:800]; Y_train = Y[0:800]
        X_test = D[800:] ; Y_test = Y[800:]
        # Training
```

```
5
6 i_dim = 10
7 h1_dim = 5
8 num_classes = 3
9
10 #Symbolic or Place holder for input and output
11 X = tf.placeholder(tf.float32, [None, i_dim], name='input')                  # 100 X 10
12 input_y = tf.placeholder(tf.float32, [None, num_classes], name="input_y")    # 100 X 3
13
14 #Initialize parameters
15 W1 = tf.get_variable('W_1', shape = [i_dim, h1_dim], initializer = tf.random_normal_initializer() )    # 10 X 5
16 b1 = tf.Variable(tf.constant(0.1, shape=[h1_dim]), name="b1")                                          # 5
17 W2 = tf.get_variable('W_2', shape = [h1_dim, num_classes], initializer = tf.random_normal_initializer() )     # 5X3
18 b2 = tf.Variable(tf.constant(0.1, shape=[num_classes]), name="b2")                                             # 3
19
```

# Multi Layer Neural Network (3)

```
import tensorflow as tf

i_dim = 10
h1_dim = 5
num_classes = 3
#Symbolic or Place holder for input and output
X = tf.placeholder(tf.float32, [None, i_dim], name='input')                 # 100 X 10
input_y = tf.placeholder(tf.float32, [None, num_classes], name="input_y")   # 100 X 3
#Initialize parameters
W1 = tf.get_variable('W_1', shape = [i_dim, h1_dim], initializer = tf.random_normal_initializer() )    # 10 X 5
b1 = tf.Variable(tf.constant(0.1, shape=[h1_dim]), name='b1')                                           # 5
W2 = tf.get_variable('W_2', shape = [h1_dim, num_classes], initializer = tf.random_normal_initializer() )      # 5X3
b2 = tf.Variable(tf.constant(0.1, shape=[num_classes]), name='b2')                                              # 3

#First layer operations
H1 = tf.nn.xw_plus_b(X, W1, b1, name="H2")      # 100 X 5
Z1 = tf.sigmoid(H1)                             # 100 X 5
#Second layer operations
H2 = tf.nn.xw_plus_b(H1, W2, b2, name="H2")     # 100 X 3
#Loss function
losses = tf.nn.softmax_cross_entropy_with_logits(H2, input_y)   # 100
loss = tf.reduce_mean(losses) + 0.001 * (tf.nn.l2_loss(W1) + tf.nn.l2_loss(W2) )              # 1
#Predicitons of the batch
predictions = tf.argmax(H2, 1, name="predictions")
#Accuracy of correct prediction in batch
correct_predictions = tf.equal(predictions, tf.argmax(input_y, 1) )
accuracy = tf.reduce_mean(tf.cast(correct_predictions, "float"), name="accuracy")
#Optimization
optimizer = tf.train.AdamOptimizer(1e-2)
grads_and_vars = optimizer.compute_gradients(loss)
global_step = tf.Variable(0, name="global_step", trainable=False)
train_op = optimizer.apply_gradients(grads_and_vars, global_step = global_step)

with tf.Session() as sess :

        sess.run(tf.initialize_all_variables())
        # Create Dataset
        D = np.asarray( np.random.rand(1000, 10), dtype='float32')
        Y = np.asarray ( np.zeros((1000, 3)), dtype='float32' )
        for i in range(1000) :
                k = np.random.randint(3)
                Y[i][k] = 1.0
        X_train = D[0:800]; Y_train = Y[0:800]
        X_test = D[800:] ; Y_test = Y[800:]
        # Training
```

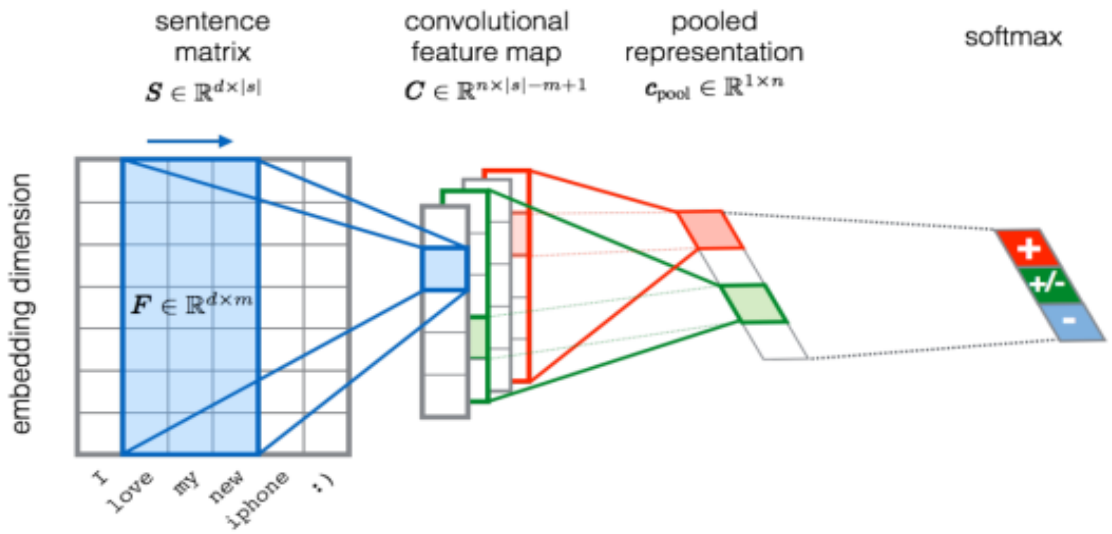
```
#First layer operations
H1 = tf.nn.xw_plus_b(X, W1, b1, name="H2")      # 100 X 5
Z1 = tf.sigmoid(H1)                             # 100 X 5
#Second layer operations
H2 = tf.nn.xw_plus_b(Z1, W2, b2, name="H2")     # 100 X 3

#Loss function
losses = tf.nn.softmax_cross_entropy_with_logits(H2, input_y)   # 100
loss = tf.reduce_mean(losses) + 0.001 * (tf.nn.l2_loss(W1) + tf.nn.l2_loss(W2) )              # 1

#Predicitons of the batch
predictions = tf.argmax(H2, 1, name="predictions")

#Accuracy of correct prediction in batch
correct_predictions = tf.equal(predictions, tf.argmax(input_y, 1) )
accuracy = tf.reduce_mean(tf.cast(correct_predictions, "float"), name="accuracy")

#Optimization
optimizer = tf.train.AdamOptimizer(1e-2)
grads_and_vars = optimizer.compute_gradients(loss)
global_step = tf.Variable(0, name="global_step", trainable=False)
train_op = optimizer.apply_gradients(grads_and_vars, global_step = global_step)
```

# Multi Layer Neural Network (4)

```
import tensorflow as tf

i_dim = 10
h1_dim = 5
num_classes = 3
#Symbolic or Place holder for input and output
X = tf.placeholder(tf.float32, [None, i_dim], name='input')                  # 100 X 10
input_y = tf.placeholder(tf.float32, [None, num_classes], name="input_y")    # 100 X 3
#Initialize parameters
W1 = tf.get_variable('W_1', shape = [i_dim, h1_dim], initializer = tf.random_normal_initializer() )    # 10 X 5
b1 = tf.Variable(tf.constant(0.1, shape=[h1_dim]), name='b1')                                          # 5
W2 = tf.get_variable('W_2', shape = [h1_dim, num_classes], initializer = tf.random_normal_initializer() )    # 5X3
b2 = tf.Variable(tf.constant(0.1, shape=[num_classes]), name='b2')                                     # 3

#First layer operations
H1 = tf.nn.xw_plus_b(X, W1, b1, name="H2")      # 100 X 5
Z1 = tf.sigmoid(H1)                             # 100 X 5
#Second layer operations
H2 = tf.nn.xw_plus_b(H1, W2, b2, name="H2")     # 100 X 3
#Loss function
losses = tf.nn.softmax_cross_entropy_with_logits(H2, input_y)   # 100
loss = tf.reduce_mean(losses) + 0.001 * (tf.nn.l2_loss(W1) + tf.nn.l2_loss(W2) )              # 1
#Predicitons of the batch
predictions = tf.argmax(H2, 1, name="predictions")
#Accuracy of correct prediction in batch
correct_predictions = tf.equal(predictions, tf.argmax(input_y, 1) )
accuracy = tf.reduce_mean(tf.cast(correct_predictions, "float"), name="accuracy")
#Optimization
optimizer = tf.train.AdamOptimizer(1e-2)
grads_and_vars = optimizer.compute_gradients(loss)
global_step = tf.Variable(0, name="global_step", trainable=False)
train_op = optimizer.apply_gradients(grads_and_vars, global_step = global_step)

with tf.Session() as sess :

        sess.run(tf.initialize_all_variables())
        # Create Dataset
        D = np.asarray( np.random.rand(1000, 10), dtype='float32')
        Y = np.asarray ( np.zeros((1000, 3)), dtype='float32' )
        for i in range(1000) :
                k = np.random.randint(3)
                Y[i][k] = 1.0
        X_train = D[0:800]; Y_train = Y[0:800]
        X_test = D[800:] ; Y_test = Y[800:]
        # Training
```

```
with tf.Session() as sess :

        sess.run(tf.initialize_all_variables())

        # Create Dataset
        D = np.asarray( np.random.rand(1000, 10), dtype='float32')
        Y = np.asarray ( np.zeros((1000, 3)), dtype='float32' )
        for i in range(1000) :
                k = np.random.randint(3)
                Y[i][k] = 1.0

        X_train = D[0:800]; Y_train = Y[0:800]
        X_test = D[800:] ; Y_test = Y[800:]


        # Training
        for k in range(100) :
                _,l, acc = sess.run([train_op, loss, accuracy], {X:X_train, input_y:Y_train} )
                print 'loss and accuracy', l, acc
        # Testing
        acc, pred = sess.run( [accuracy, predictions], {X:X_test, input_y:Y_test} )
        print "Accuracy in test set", acc
```

# Convolution Neural Network (1)




Severyn 2015

# Convolution Neural Network (2)

*tf.nn.conv2d(input, filter, strides, padding, name)*

***Arguments :***

- **input :** A 4-d tensor of shape [batch_size, len_sent, dim_we, num_channels]
- **filter :** A 4-d tensor of shape [filter_size, dim_we, num_channels, num_filters]
- **strides :** A list of *int* of size 4, [ 1, 1, 1, 1]
- **padding:** "VALID"
- **name :** Name of the node in computation graph

***Return :***

- A 4-d tensor of shape [batch_size, out_hight, num_channels, num_filters]

  where out_hight = ( len_sent - filter_size + 1 )

# Convolution Neural Network (3)

cnnEx.py

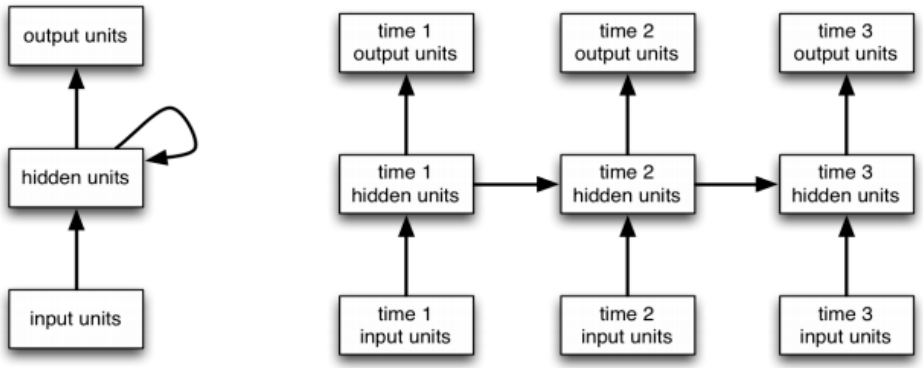
```
import tensorflow as tf
import numpy as np

word_dict_size = 100; sentMax=5; emb_size=4; filter_size=3; num_filters=8

w = tf.placeholder(tf.int32, [None, sentMax], name="x")         # word index matrix (N, 5)
W_wemb =  tf.Variable(tf.random_uniform([word_dict_size, emb_size], -1.0, +1.0))        # word embeddng matrix (100, 4)
emb0 = tf.nn.embedding_lookup(W_wemb, w)        # (N, 5, 4)
X = tf.expand_dims(emb0, -1)                    # (N, 5, 4, 1)

# Convolution layer
W_conv = tf.Variable(tf.truncated_normal([filter_size, emb_size, 1, num_filters], stddev=0.1), name="W_conv")   # ( 3, 4, 1, 8 )
b_conv = tf.Variable(tf.constant(0.1, shape=[num_filters]), name="b_conv")                      # ( 8 )

conv = tf.nn.conv2d(X, W_conv, strides=[1, 1, 1, 1], padding="VALID", name="conv")      # (N, 3, 1, 8)
conv1 = tf.nn.bias_add(conv, b_conv, name='conv1')              # add biase value
h1 = tf.nn.relu(conv1, name="relu")                             # apply activaiton function (N, 3, 1, 8)
pooled = tf.nn.max_pool(h1, ksize=[1, sentMax-filter_size+1, 1, 1], strides=[1, 1, 1, 1], padding='VALID', name="pool") # ( N, 1, 1, 8)
p1 = tf.squeeze(pooled)  # (N,8)

# Running
with tf.Session() as sess :

        sess.run( tf.initialize_all_variables() )
        D = np.asarray( np.random.randint(0, high=word_dict_size, size = [10, sentMax] ), dtype='int32')               # 1000 : size of dataset
        p = sess.run(p1, {w:D} )
        print np.shape(p)               # (10, 8)
```

# Convolution Neural Network (4)

- cnnEx1.py : Multiple fixed length filter used
- cnnEx2.py : Multiple variable length filter used [3,4,5]

# Recurrent Neural Network (0)

- RNN is a special kind of NN which utilize sequential information and maintains history through its intermediate layer




- $h^{(t)} = \tanh\left( U.x^{(t)} + W.h^{(t-1)} \right)$

# Recurrent Neural Network (1)

***tf.nn.rnn_cell.BasicRNNCell(num_units)***

*Argument:*

- *num_units:* *int, size of hidden layer [H]*

*Return:*

- *cell :* *we will use this in dynamtic_rnn() or bidirectional_dynamtic_rnn()*

***tf.nn.dynamic_rnn( cell, dtype, sequence_length, input )***

*Arguments:*

- *cell:* *Cell of particular RNN*
- *dtype:* *float32/float64*
- *sequence_length:* *Sequence length of each sequence*
- *input:* *input tensor [N,M,D]*

*Return:*

- *output :* *output for every word [N,M,H]*
- *last_state :* *output of last word in every sequence [N,H]*

# Recurrent Neural Network (2)

rnnEx.py

```
1  import tensorflow as tf
2  import numpy as np
3
4  X = tf.placeholder(tf.float64, [None, None, 8] )
5  X_lengths = tf.placeholder(tf.int32, [None] )
6
7  cell1 = tf.nn.rnn_cell.BasicRNNCell(num_units=4)
8  outputs, last_states = tf.nn.dynamic_rnn(
9                          cell = cell1,
10                         dtype = tf.float64,
11                         sequence_length = X_lengths,
12                         inputs = X
13                         )
14
15 # Create input data
16 x = np.random.randn(6, 5, 8)
17 x_lengths = [4, 3, 4, 5, 5, 4]
18
19 with tf.Session() as sess:
20         sess.run( tf.initialize_all_variables() )
21         out, sta = sess.run([outputs, last_states], {X:x, X_lengths:x_lengths} )
22         print 'outputs', out
23         print 'final_states', sta
24
```

# Recurrent Neural Network (3)

birnnEx.py

```
import tensorflow as tf
import numpy as np

X = tf.placeholder(tf.float64, [None, None, 8] )
X_lengths = tf.placeholder(tf.int32, [None] )

cell1 = tf.nn.rnn_cell.BasicRNNCell(num_units=4)
cell2 = tf.nn.rnn_cell.BasicRNNCell(num_units=4)
outputs, last_states = tf.nn.bidirectional_dynamic_rnn(
                        cell_fw = cell1,
                        cell_bw = cell2,
                        dtype = tf.float64,
                        sequence_length = X_lengths,
                        inputs = X
                        )

output_fw, output_bw = outputs
output_state_fw, output_state_bw = last_states

# Create input data
x = np.random.randn(6, 5, 8)
x_lengths = [4, 3, 4, 5, 5, 4]

with tf.Session() as sess:
        sess.run( tf.initialize_all_variables() )
        out_fw, out_bw, sta_fw, sta_bw = sess.run([output_fw, output_bw, output_state_fw, output_state_bw], {X:x, X_lengths:x_lengths} )
        print 'forword output', out_fw
        print 'farward final_outputs', sta_fw
        print 'backword output', out_bw
        print 'backword final_outputs', sta_bw


```

# Recurrent Neural Network (4)

lstmEx.py

```
import tensorflow as tf
import numpy as np

X = tf.placeholder(tf.float64, [None, None, 8] )
X_lengths = tf.placeholder(tf.int32, [None] )

cell = tf.nn.rnn_cell.LSTMCell(num_units=4)
outputs, last_states = tf.nn.dynamic_rnn(
                        cell = cell,
                        dtype = tf.float64,
                        sequence_length = X_lengths,
                        inputs = X
                        )


# Create input data
x = np.random.randn(6, 5, 8)
x_lengths = [4, 3, 4, 5, 5, 4]

with tf.Session() as sess:
        sess.run( tf.initialize_all_variables() )
        out, sta = sess.run([outputs, last_states], {X:x, X_lengths:x_lengths} )
        print 'output', out
        print 'cell_states', sta.c
        print 'final_outputs', sta.h

```

# Recurrent Neural Network (5)

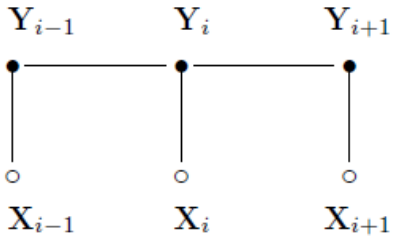
gruEx.py

```
import tensorflow as tf
import numpy as np

X = tf.placeholder(tf.float64, [None, None, 8] )
X_lengths = tf.placeholder(tf.int32, [None] )

cell1 = tf.nn.rnn_cell.GRUCell(num_units=4)
cell2 = tf.nn.rnn_cell.GRUCell(num_units=4)
outputs, last_states = tf.nn.bidirectional_dynamic_rnn(
                        cell_fw = cell1,
                        cell_bw = cell2,
                        dtype = tf.float64,
                        sequence_length = X_lengths,
                        inputs = X
                        )

output_fw, output_bw = outputs
output_state_fw, output_state_bw = last_states

# Create input data
x = np.random.randn(6, 5, 8)
x_lengths = [4, 3, 4, 5, 5, 4]

with tf.Session() as sess:
        sess.run( tf.initialize_all_variables() )
        out_fw, out_bw, sta_fw, sta_bw = sess.run([output_fw, output_bw, output_state_fw, output_state_bw], {X:x, X_lengths:x_lengths} )
        print 'forword output', out_fw
        print 'final_outputs', sta_fw
        print 'backword output', out_bw
        print 'backword final_outputs', sta_bw

```

# Recurrent Neural Network (6)

More concrete example is there in *rnn1Ex.py*

# Conditional Random Field (1)




- $P\left([t]_1^{|s|} \mid [w]_1^{|s|}\right) = \frac{\exp\left(\text{Score}\left([w]_1^{|s|}, [t]_1^{|s|}\right)\right)}{\sum_{x \in A} \exp\left(\text{Score}\left([w]_1^{|s|}, [t]_1^{|s|}\right)\right)}$

$$\text{Score}\left([w]_1^{|s|}, [t]_1^{|s|}\right) = \sum_{1 \le i \le |s|} \left(W^{trans}_{t_i - 1, ti} + Z^{(i)}_{t_i}\right)$$

# Conditional Random Field

*tf.contrib.crf.crf_log_likelihood( US, True_labels, lengths )*

*Arguments:*

1. *US :* *( N,M, c), tensor of unary potential scores for batch*
2. *True_labels :* *(N,M), matrix of true label for every word*
3. *lengths :* *(N) , actual length of every sentence*

*Return:*

1. *log_like :* *(N), log likelihood of every label sequence*
2. *W_pair:* *(c,c), Pairwise parameter matrix*

*tf.contrib.crf.viterbi_decode(us, W_pair)*

*Arguments:*

1. *us :* *(c ) vector of unary potential score for a pattern*
2. *W_pair :* *(c,c) Pair wise potential*

*Return:*

1. *seq :* *(M) highest probability label sequence*
2. *score:* *A float containing containing score of viterbi*

# Conditional Random Field (2)

crfEx.py

```
import tensorflow as tf
import numpy as np

sentMax = 10            # Max lenght of sentence
num_classes = 3         # number of classes
num_features = 15       # number of features

X = tf.placeholder(tf.float32, [None, sentMax, num_features] )  # (6, 10, 15)
input_y = tf.placeholder(tf.int32, [None, sentMax] )            # (6, 10)
X_lengths = tf.placeholder(tf.int32, [None] )                   # (6)
X1 = tf.reshape( X, [-1, num_features] )                        # (6*10, 15)

#Fully connected layer operations
W_ff = tf.Variable(tf.random_uniform([num_features, num_classes], -1.0, +1.0), name="W")  # (15,3)
b_ff = tf.Variable(tf.constant(0.1, shape=[num_classes]), name="b")
H1 = tf.nn.xw_plus_b(X1, W_ff, b_ff, name="H1")                 # ( 6*10, 3)

Z1 = tf.reshape(H1, [-1, sentMax, num_classes] )                # ( 6, 10, 3)

#CRF layer
log_likelihood, transition_params = tf.contrib.crf.crf_log_likelihood( Z1, input_y, X_lengths )
loss = tf.reduce_mean(-log_likelihood)

# Create input data
x = np.asarray( np.random.randn(6, sentMax, num_features), dtype='float32' )    # dataset: #sentence=6, #words = 10, #features = 15
y = np.random.randint(3, size=[6, sentMax])             # 3 number of lables ( B, I, O )
x_lengths = [8, 5, 7, 9, 10, 4]                         # actual length of each sentence

with tf.Session() as sess:
        sess.run( tf.initialize_all_variables() )
        l, tp = sess.run([loss, transition_params], {X:x, X_lengths:x_lengths, input_y:y } )
        print l

        #Decoding
        us, ps = sess.run([Z1, transition_params], {X:x, X_lengths:x_lengths, input_y:y } )
        viterbi_sequence,_ = tf.contrib.crf.viterbi_decode(us[1], ps)          # highest scoring sequence.
        print 'true seq', y[1]
        print 'pred seq', viterbi_sequence
```

# Conditional Random Field (3)

**crfEx1.py** : *Bi-RNN + CRF model for sequence labeling with dummy data*