With TF 1.0!

Lab 12
RNN

Sung Kim <hunkim+ml@gmail.com>
Code: https://github.com/hunkim/DeepLearningZeroToAll/

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Other slides: https://goo.gl/jPtWNt

Picture from http://www.tssablog.org/archives/3280

With TF 1.0!

Lab 12-1

RNN Basics

Sung Kim <hunkim+ml@gmail.com>

Code: https://github.com/hunkim/DeepLearningZeroToAll/

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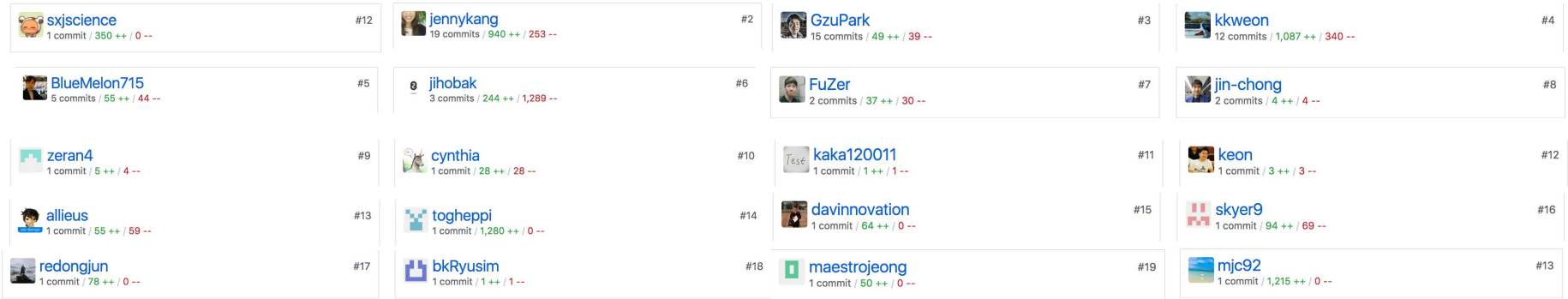
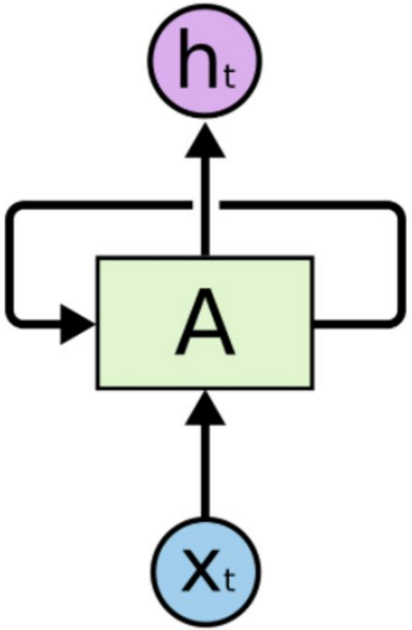


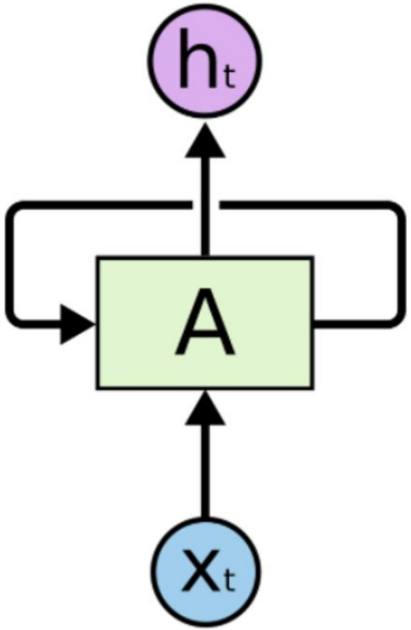
RNN in TensorFlow




```
cell = tf.contrib.rnn.BasicRNNCell(num_units=hidden_size)

...
outputs, _states = tf.nn.dynamic_rnn(cell, x_data, dtype=tf.float32)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

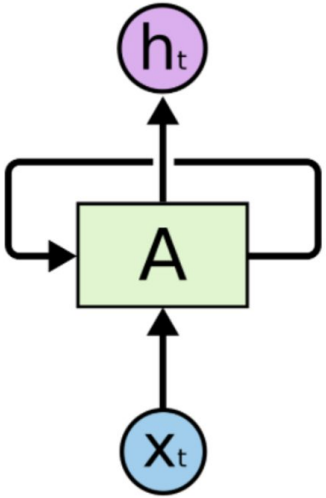
RNN in TensorFlow




```
cell = tf.contrib.rnn.BasicRNNCell(num_units=hidden_size)
cell = tf.contrib.rnn.BasicLSTMCell(num_units=hidden_size)
...
outputs, _states = tf.nn.dynamic_rnn(cell, x_data, dtype=tf.float32)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

One node: 4 (*input-dim*) in 2 (*hidden_size*)

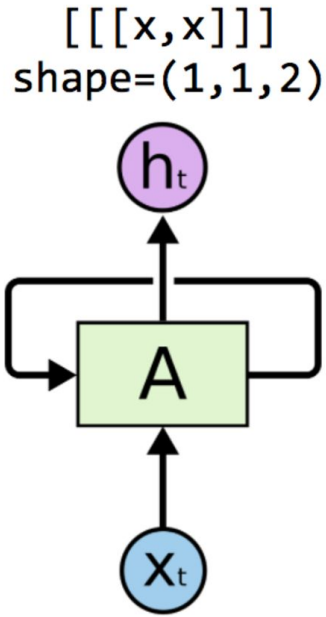



```
[[[1,0,0,0]]]
shape=(1,1,4)
```

```
# One hot encoding
h = [1, 0, 0, 0]
e = [0, 1, 0, 0]
l = [0, 0, 1, 0]
o = [0, 0, 0, 1]
```

One node: 4 (*input-dim*) in 2 (*hidden_size*)

hidden_size=2

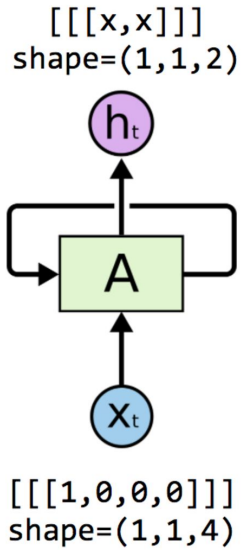



```
# One hot encoding
h = [1, 0, 0, 0]
e = [0, 1, 0, 0]
l = [0, 0, 1, 0]
o = [0, 0, 0, 1]
```

One node: 4 (*input-dim*) in 2 (*hidden_size*)

```
# One cell RNN input_dim (4) -> output_dim (2)
hidden_size = 2
cell = tf.contrib.rnn.BasicLSTMCell(num_units=hidden_size)

x_data = np.array([[[1,0,0,0]]], dtype=np.float32)
outputs, _states = tf.nn.dynamic_rnn(cell, x_data, dtype=tf.float32)

sess.run(tf.global_variables_initializer())
pp.pprint(outputs.eval())
```

```
array([[[-0.42409304,  0.64651132]]])
```



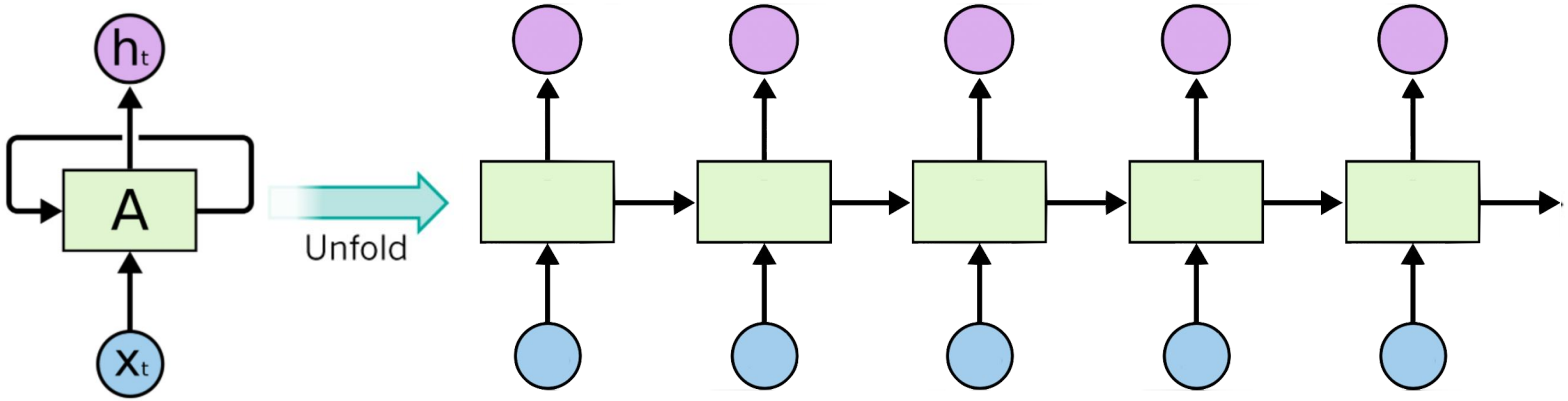
hidden_size=2

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

Unfolding to n sequences

```
Hidden_size=2
sequence_length=5
```

shape=(1,5,2): [[[x,x], [x,x], [x,x], [x,x], [x,x]]]



shape=(1,5,4): [[[1,0,0,0], [0,1,0,0], [0,0,1,0], [0,0,1,0], [0,0,0,1]]]

h e l l o

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

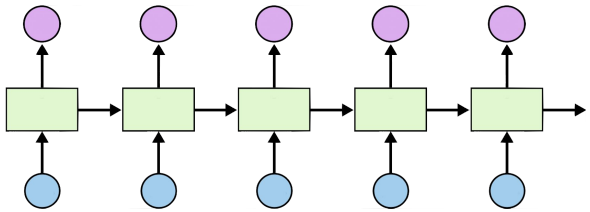
Unfolding to n sequences

```
# One cell RNN input_dim (4) -> output_dim (2). sequence: 5
    hidden_size = 2
    cell = tf.contrib.rnn.BasicLSTMCell(num_units=hidden_size)
    x_data = np.array([[h, e, l, l, o]], dtype=np.float32)
    print(x_data.shape)
    pp.pprint(x_data)
    outputs, states = tf.nn.dynamic_rnn(cell, x_data, dtype=tf.float32)
    sess.run(tf.global_variables_initializer())
    pp.pprint(outputs.eval())
```

```
# One hot encoding
h = [1, 0, 0, 0]
e = [0, 1, 0, 0]
l = [0, 0, 1, 0]
o = [0, 0, 0, 1]
```

Hidden_size=2
sequence_length=5

shape=(1,5,2): [[[x,x], [x,x], [x,x], [x,x], [x,x]]]



shape=(1,5,4): [[[1,0,0,0], [0,1,0,0], [0,0,1,0], [0,0,1,0], [0,0,0,1]]]
h e l l o

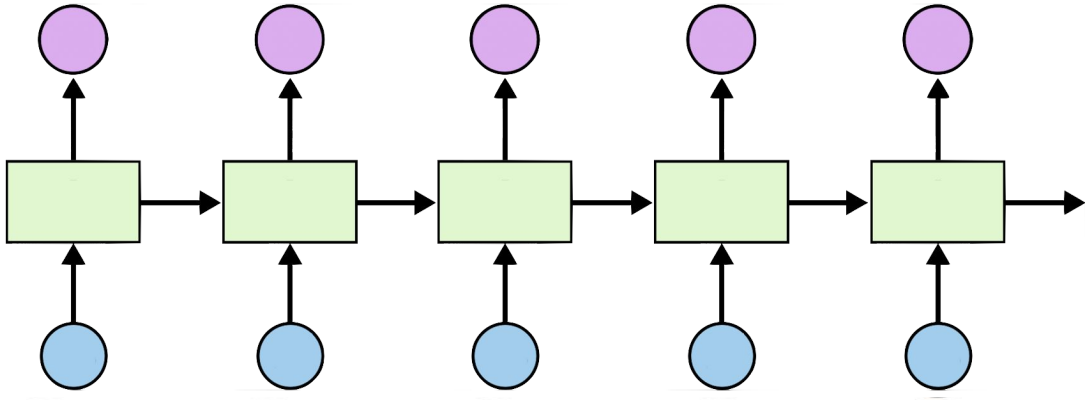
X_data = array
(([[[1., 0., 0., 0.],
[0., 1., 0., 0.],
[0., 0., 1., 0.],
[0., 0., 1., 0.],
[0., 0., 0., 1.]]], dtype=float32)
Outputs = array
(([[[0.19709368, 0.24918222],
[-0.11721198, 0.1784237],
[-0.35297349, -0.66278851],
[-0.70915914, -0.58334434],
[-0.38886023, 0.47304463]]], dtype=float32)

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

Batching input

```
Hidden_size=2
sequence_length=5
batch_size=3
```

```
shape=(3,5,2): [[[x,x], [x,x], [x,x], [x,x], [x,x]],
                [[x,x], [x,x], [x,x], [x,x], [x,x]],
                [[x,x], [x,x], [x,x], [x,x], [x,x]]]
```



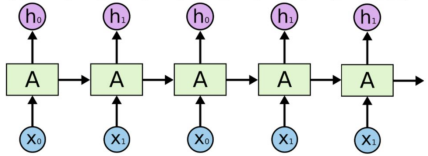
```
shape=(3,5,4): [[[1,0,0,0], [0,1,0,0], [0,0,1,0], [0,0,1,0], [0,0,0,1]], # hello
                [[0,1,0,0], [0,0,0,1], [0,0,1,0], [0,0,1,0], [0,0,1,0]]  # eolll
                [[0,0,1,0], [0,0,1,0], [0,1,0,0], [0,1,0,0], [0,0,1,0]]] # lleel
```

Batching input

```
# One cell RNN input_dim (4) -> output_dim (2). sequence: 5, batch 3
# 3 batches 'hello', 'eolll', 'lleel'
x_data = np.array([[h, e, l, l, o],
                   [e, o, l, l, l],
                   [l, l, e, e, l]], dtype=np.float32)
pp.pprint(x_data)

cell = rnn.BasicLSTMCell(num_units=2, state_is_tuple=True)
outputs, _states = tf.nn.dynamic_rnn(cell, x_data,
                                     dtype=tf.float32)
sess.run(tf.global_variables_initializer())
pp.pprint(outputs.eval())
```

```
array([[[ 1.,  0.,  0.,  0.],
        [ 0.,  1.,  0.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  0.,  1.]],

       [[ 0.,  1.,  0.,  0.],
        [ 0.,  0.,  0.,  1.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.]],

       [[ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  1.,  0.,  0.],
        [ 0.,  1.,  0.,  0.],
        [ 0.,  0.,  1.,  0.]]],
```

shape=(3,5,2): [[[x,x], [x,x], [x,x], [x,x], [x,x]],
[[x,x], [x,x], [x,x], [x,x], [x,x]],
[[x,x], [x,x], [x,x], [x,x], [x,x]]]



shape=(3,5,4): [[[1,0,0,0], [0,1,0,0], [0,0,1,0], [0,0,1,0], [0,0,0,1]], # hello
[[0,1,0,0], [0,0,0,1], [0,0,1,0], [0,0,1,0], [0,0,1,0]] # eolll
[[0,0,1,0], [0,0,1,0], [0,1,0,0], [0,1,0,0], [0,0,1,0]]] # lleel

Hidden_size=2
sequence_length=5
batch_size=3

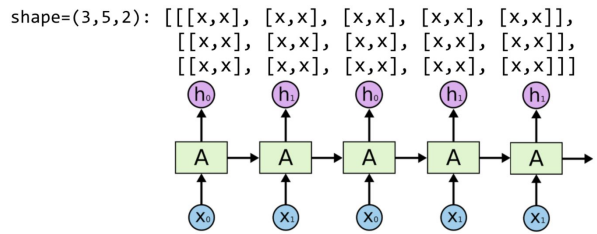
https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

Batching input

```
# One cell RNN input_dim (4) -> output_dim (2). sequence: 5, batch 3
# 3 batches 'hello', 'eolll', 'lleel'
x_data = np.array([[h, e, l, l, o],
                   [e, o, l, l, l],
                   [l, l, e, e, l]], dtype=np.float32)
pp.pprint(x_data)

cell = rnn.BasicLSTMCell(num_units=2, state_is_tuple=True)
outputs, _states = tf.nn.dynamic_rnn(cell, x_data,
                                     dtype=tf.float32)
sess.run(tf.global_variables_initializer())
pp.pprint(outputs.eval())
```

```
array([[[ 1.,  0.,  0.,  0.],
        [ 0.,  1.,  0.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  0.,  1.]],

       [[ 0.,  1.,  0.,  0.],
        [ 0.,  0.,  0.,  1.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.]],

       [[ 0.,  0.,  1.,  0.],
        [ 0.,  0.,  1.,  0.],
        [ 0.,  1.,  0.,  0.],
        [ 0.,  1.,  0.,  0.],
        [ 0.,  0.,  1.,  0.]]],
```

```
array([[[-0.0173022 , -0.12929453],
        [-0.14995177, -0.23189341],
        [ 0.03294011,  0.01962204],
        [ 0.12852104,  0.12375218],
        [ 0.13597946,  0.31746736]],

       [[-0.15243632, -0.14177315],
        [ 0.04586344,  0.12249056],
        [ 0.14292534,  0.15872268],
        [ 0.18998367,  0.21004884],
        [ 0.21788891,  0.24151592]],

       [[ 0.10713603,  0.11001928],
        [ 0.17076059,  0.1799853 ],
        [-0.03531617,  0.08993293],
        [-0.1881337 , -0.08296411],
        [-0.00404597,  0.07156041]]],
```



Hidden_size=2
sequence_length=5
batch_size=3

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

With TF 1.0!

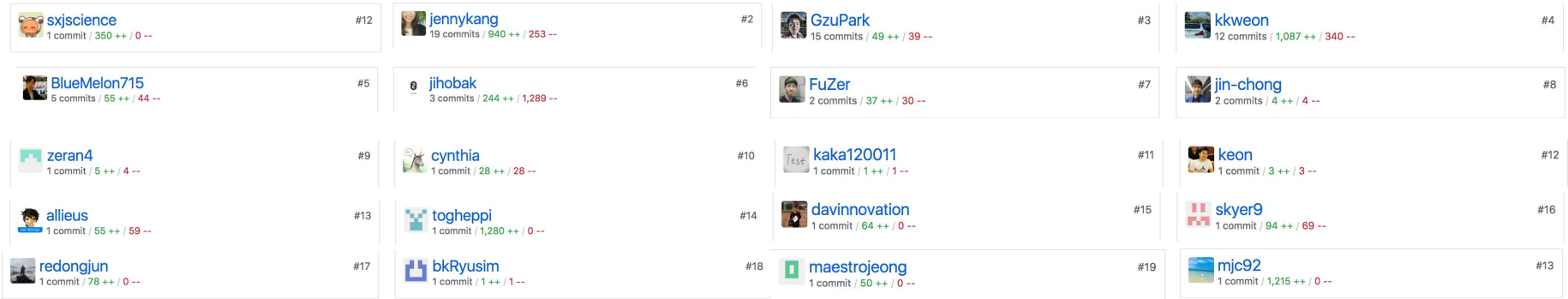
Lab 12-2

Hi Hello RNN

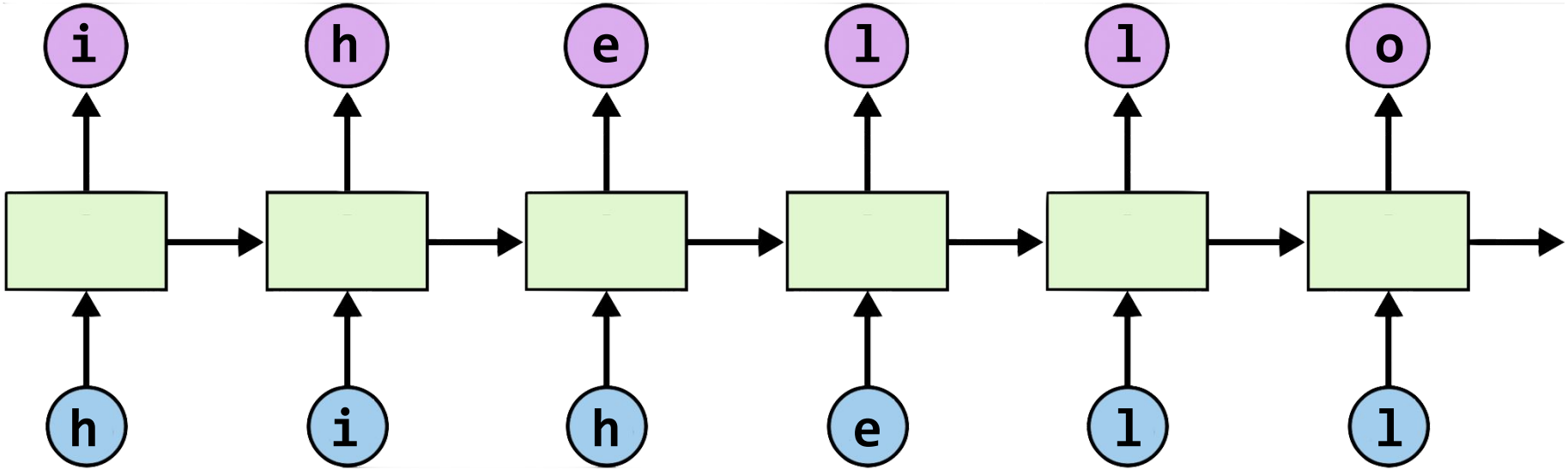
Sung Kim <hunkim+ml@gmail.com>

Code: https://github.com/hunkim/DeepLearningZeroToAll/

https://github.com/hunkim/DeepLearningZeroToAll/



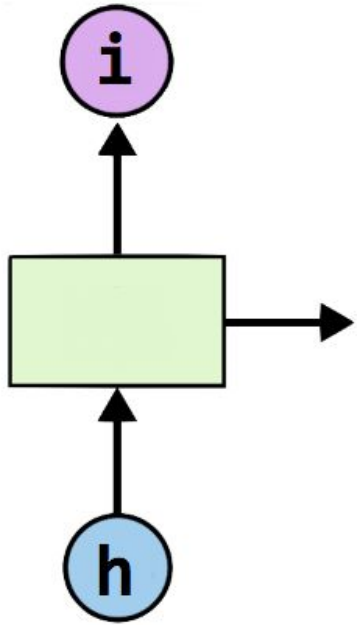
Teach RNN ‘hihello’



- text: ‘hihello’
- unique chars (vocabulary, voc):
  h, i, e, l, o
- voc index:
  h:0, i:1, e:2, l:3, o:4

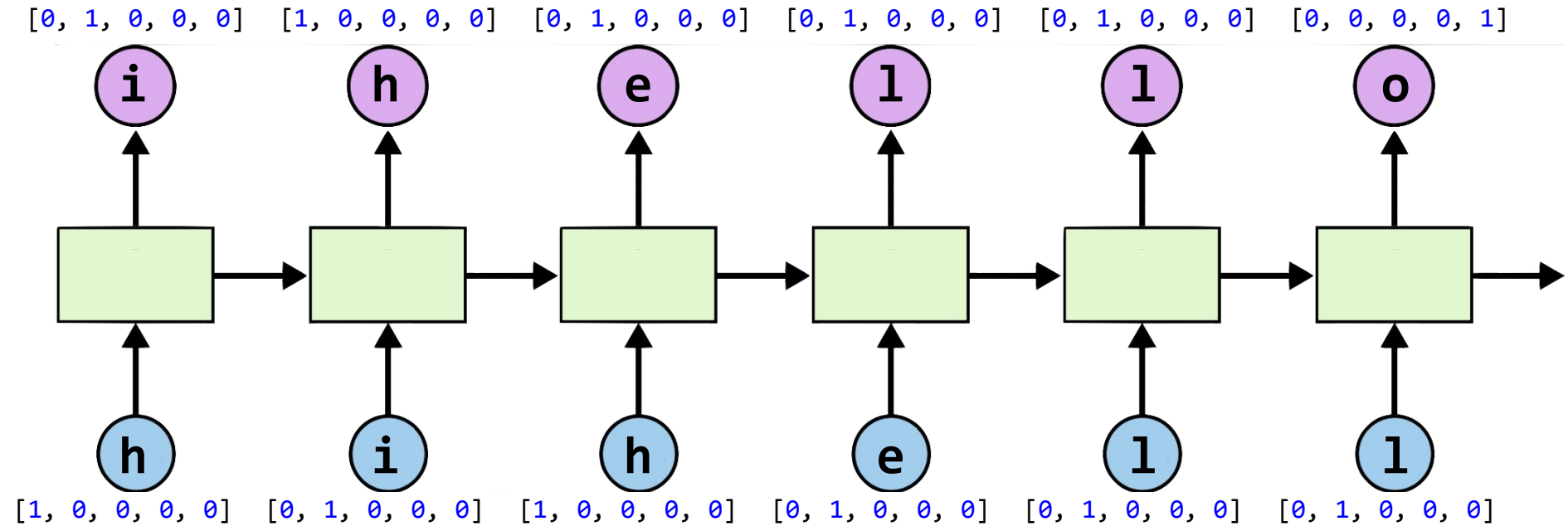
One-hot encoding

```
[1, 0, 0, 0, 0],   # h 0
[0, 1, 0, 0, 0],   # i 1
[0, 0, 1, 0, 0],   # e 2
[0, 0, 0, 1, 0],   # l 3
[0, 0, 0, 0, 1],   # o 4
```



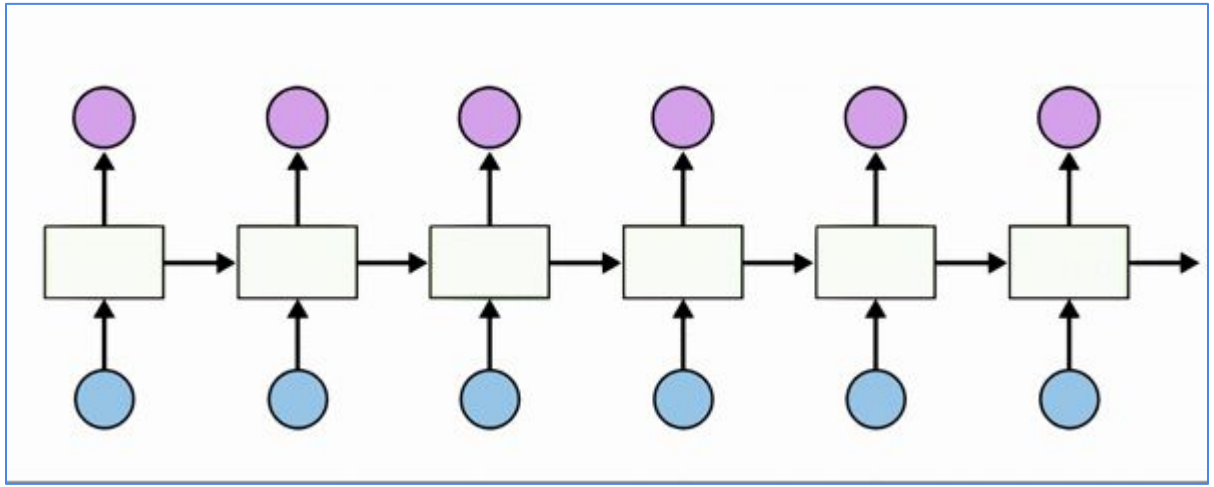
Teach RNN ‘hihello’

```
[1, 0, 0, 0, 0],   # h 0
[0, 1, 0, 0, 0],   # i 1
[0, 0, 1, 0, 0],   # e 2
[0, 0, 0, 1, 0],   # l 3
[0, 0, 0, 0, 1],   # o 4
```



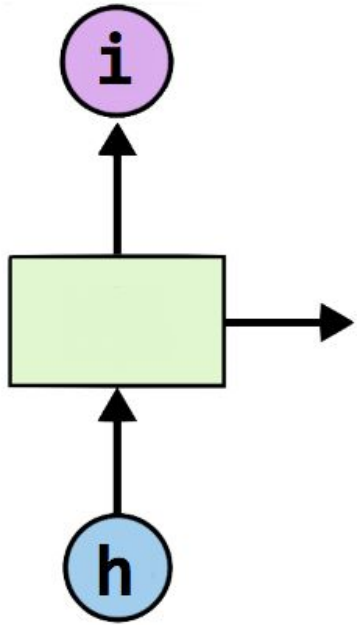
Teach RNN ‘hihello’

```
[1, 0, 0, 0, 0],   # h 0
[0, 1, 0, 0, 0],   # i 1
[0, 0, 1, 0, 0],   # e 2
[0, 0, 0, 1, 0],   # l 3
[0, 0, 0, 0, 1],   # o 4
```



Creating rnn cell

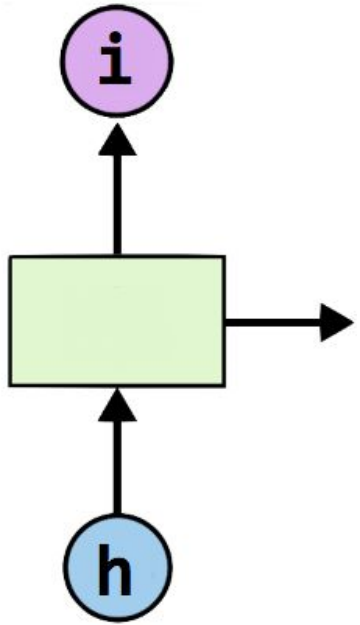
```
# RNN model
rnn_cell = rnn_cell.BasicRNNCell(rnn_size)
```



Creating rnn cell

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

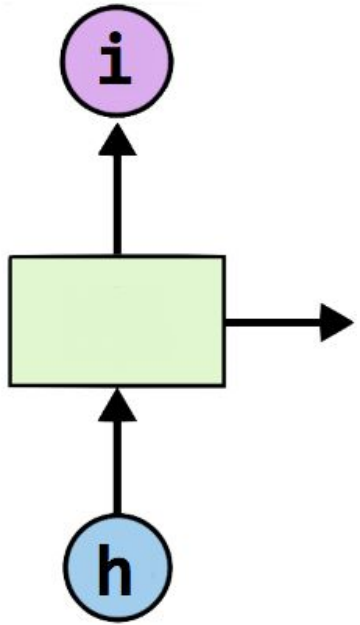
```
rnn_cell = rnn_cell. BasicLSTMCell(rnn_size)
rnn_cell = rnn_cell. GRUCell(rnn_size)
```



Execute RNN

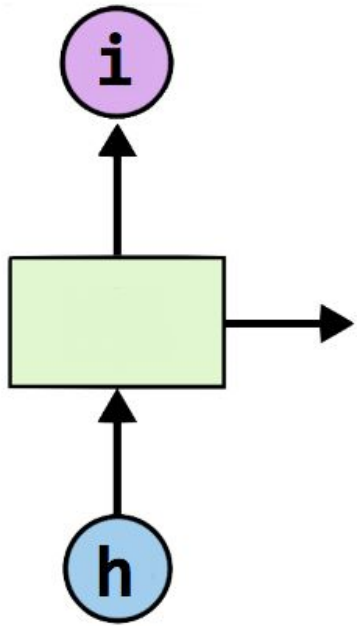
hidden_rnn_size

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


outputs, _states = tf.nn.dynamic_rnn(
                    rnn_cell,
                    X,
                    initial_state=initial_state,
                    dtype=tf.float32)
```



RNN parameters

```
hidden_size = 5       # output from the LSTM
input_dim = 5         # one-hot size
batch_size = 1        # one sentence
sequence_length = 6   # |ihello| == 6
```



https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-1-hello-rnn.py

Data creation

```
idx2char = ['h', 'i', 'e', 'l', 'o'] # h=0, i=1, e=2, l=3, o=4
x_data = [[0, 1, 0, 2, 3, 3]]        # hihell
x_one_hot = [[[1, 0, 0, 0, 0],       # h 0
              [0, 1, 0, 0, 0],       # i 1
              [1, 0, 0, 0, 0],       # h 0
              [0, 0, 1, 0, 0],       # e 2
              [0, 0, 0, 1, 0],       # l 3
              [0, 0, 0, 1, 0]]]      # l 3

y_data = [[1, 0, 2, 3, 3, 4]]        # ihello
X = tf.placeholder(tf.float32,
        [None, sequence_length, input_dim]) # X one-hot
Y = tf.placeholder(tf.int32, [None, sequence_length])  # Y label
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-1-hello-rnn.py

Feed to RNN

```
x_one_hot = [[[1, 0, 0, 0, 0],   # h 0
              [0, 1, 0, 0, 0],   # i 1
              [1, 0, 0, 0, 0],   # h 0
              [0, 0, 1, 0, 0],   # e 2
              [0, 0, 0, 1, 0],   # l 3
              [0, 0, 0, 1, 0]]]  # l 3

y_data = [[1, 0, 2, 3, 3, 4]]    # ihello
```

```
X = tf.placeholder(
    tf.float32, [None, sequence_length, hidden_size])  # X one-hot
Y = tf.placeholder(tf.int32, [None, sequence_length])  # Y label

cell = tf.contrib.rnn.BasicLSTMCell(num_units=hidden_size,
state_is_tuple=True)
initial_state = cell.zero_state(batch_size, tf.float32)
outputs, _states = tf.nn.dynamic_rnn(
    cell, X, initial_state=initial_state, dtype=tf.float32)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-1-hello-rnn.py

Cost: sequence_loss

```
# [batch_size, sequence_length]
y_data = tf.constant([[1, 1, 1]])

# [batch_size, sequence_length, emb_dim ]
prediction = tf.constant([[[0.2, 0.7], [0.6, 0.2], [0.2, 0.9]]], dtype=tf.float32)

# [batch_size * sequence_length]
weights = tf.constant([[1, 1, 1]], dtype=tf.float32)

sequence_loss = tf.contrib.seq2seq.sequence_loss(logits=prediction, targets=y_data, weights=weight
s)
sess.run(tf.global_variables_initializer())
print("Loss: ", sequence_loss.eval())
```

```
Loss:  0.596759
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

Cost: sequence_loss

```
# [batch_size, sequence_length]
y_data = tf.constant([[1, 1, 1]])

# [batch_size, sequence_length, emb_dim ]
prediction1 = tf.constant([[[0.3, 0.7], [0.3, 0.7], [0.3, 0.7]]],
dtype=tf.float32)
prediction2 = tf.constant([[[0.1, 0.9], [0.1, 0.9], [0.1, 0.9]]],
dtype=tf.float32)

# [batch_size * sequence_length]
weights = tf.constant([[1, 1, 1]], dtype=tf.float32)

sequence_loss1 = tf.contrib.seq2seq.sequence_loss(prediction1, y_data,
weights)
sequence_loss2 = tf.contrib.seq2seq.sequence_loss(prediction2, y_data,
weights)

sess.run(tf.global_variables_initializer())
print("Loss1: ", sequence_loss1.eval(),
        "Loss2: ", sequence_loss2.eval())
```

Loss1: 0.513015
Loss2: 0.371101

Cost: sequence_loss

```
outputs, _states = tf.nn.dynamic_rnn(
   cell, X, initial_state=initial_state, dtype=tf.float32)
weights = tf.ones([batch_size, sequence_length])

sequence_loss = tf.contrib.seq2seq.sequence_loss(
                        logits=outputs, targets=Y, weights=weights)
loss = tf.reduce_mean(sequence_loss)
train = tf.train.AdamOptimizer(learning_rate=0.1).minimize(loss)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-1-hello-rnn.py

Training

```
prediction = tf.argmax(outputs, axis=2)

with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
    for i in range(2000):
        l, _ = sess.run([loss, train], feed_dict={X: x_one_hot, Y: y_data})
        result = sess.run(prediction, feed_dict={X: x_one_hot})
        print(i, "loss:", l, "prediction: ", result, "true Y: ", y_data)

        # print char using dic
        result_str = [idx2char[c] for c in np.squeeze(result)]
        print("\tPrediction str: ", ''.join(result_str))
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-1-hello-rnn.py

Results

```
prediction = tf.argmax(outputs, axis=2)

with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
    for i in range(2000):
        l, _ = sess.run([loss, train], feed_dict={X: x_one_hot, Y: y_data})
        result = sess.run(prediction, feed_dict={X: x_one_hot})
        print(i, "loss:", l, "prediction: ", result, "true Y: ", y_data)

        # print char using dic
        result_str = [idx2char[c] for c in np.squeeze(result)]
        print("\tPrediction str: ", ''.join(result_str))
```

```
0 loss: 1.55474 prediction:  [[3 3 3 3 4 4]] true Y:  [[1, 0, 2, 3, 3, 4]] Prediction str:  llllloo
1 loss: 1.55081 prediction:  [[3 3 3 3 4 4]] true Y:  [[1, 0, 2, 3, 3, 4]] Prediction str:  llllloo
2 loss: 1.54704 prediction:  [[3 3 3 3 4 4]] true Y:  [[1, 0, 2, 3, 3, 4]] Prediction str:  llllloo
3 loss: 1.54342 prediction:  [[3 3 3 3 4 4]] true Y:  [[1, 0, 2, 3, 3, 4]] Prediction str:  llllloo
...
1998 loss: 0.75305 prediction:  [[1 0 2 3 3 4]] true Y:  [[1, 0, 2, 3, 3, 4]] Prediction str:  ihello
1999 loss: 0.752973 prediction:  [[1 0 2 3 3 4]] true Y:  [[1, 0, 2, 3, 3, 4]] Prediction str:  ihello
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-1-hello-rnn.py

With TF 1.0!

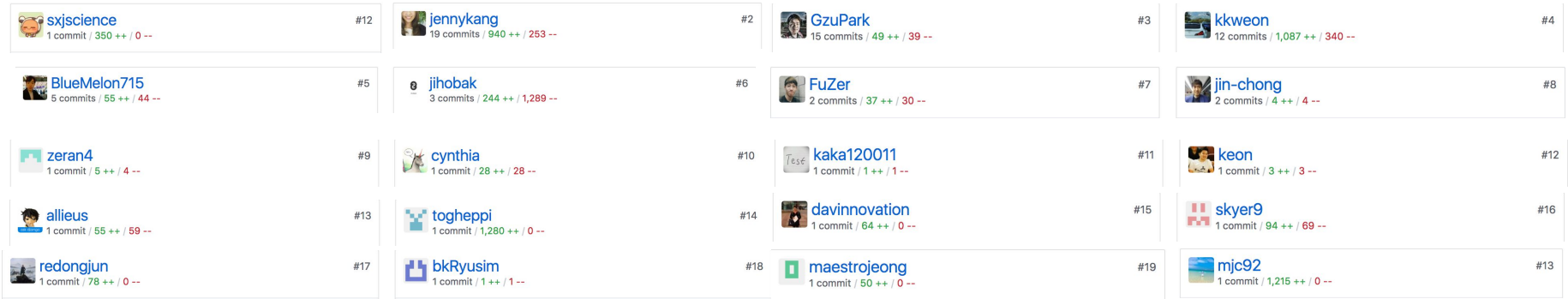
Lab 12-3

RNN with long sequences

Sung Kim <hunkim+ml@gmail.com>

Code: https://github.com/hunkim/DeepLearningZeroToAll/

https://github.com/hunkim/DeepLearningZeroToAll/



Manual data creation

```
idx2char = ['h', 'i', 'e', 'l', 'o']
x_data = [[0, 1, 0, 2, 3, 3]]    # hihell
x_one_hot = [[[1, 0, 0, 0, 0],   # h 0
              [0, 1, 0, 0, 0],   # i 1
              [1, 0, 0, 0, 0],   # h 0
              [0, 0, 1, 0, 0],   # e 2
              [0, 0, 0, 1, 0],   # l 3
              [0, 0, 0, 1, 0]]]  # l 3

y_data = [[1, 0, 2, 3, 3, 4]]    # ihello
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-1-hello-rnn.py

Better data creation

```
sample = " if you want you"
idx2char = list(set(sample))  # index -> char
char2idx = {c: i for i, c in enumerate(idx2char)}  # char -> idx

sample_idx = [char2idx[c] for c in sample]  # char to index
x_data = [sample_idx[:-1]]  # X data sample (0 ~ n-1) hello: hell
y_data = [sample_idx[1:]]   # Y label sample (1 ~ n)  hello: ello

X = tf.placeholder(tf.int32, [None, sequence_length])  # X data
Y = tf.placeholder(tf.int32, [None, sequence_length])  # Y label

X_one_hot = tf.one_hot(X, num_classes)  # one hot: 1 -> 0 1 0 0 0 0 0 0 0 0
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-2-char-seq-rnn.py

Hyper parameters

```
sample = " if you want you"
idx2char = list(set(sample))  # index -> char
char2idx = {c: i for i, c in enumerate(idx2char)}  # char -> idx

# hyper parameters
dic_size = len(char2idx)  # RNN input size (one hot size)
rnn_hidden_size = len(char2idx)  # RNN output size
num_classes = len(char2idx)  # final output size (RNN or softmax, etc.)
batch_size = 1  # one sample data, one batch
sequence_length = len(sample) - 1  # number of lstm unfolding (unit #)
```

LSTM and Loss

```
X = tf.placeholder(tf.int32, [None, sequence_length])  # X data
Y = tf.placeholder(tf.int32, [None, sequence_length])  # Y label

X_one_hot = tf.one_hot(X, num_classes)  # one hot: 1 -> 0 1 0 0 0 0 0 0 0 0

cell = tf.contrib.rnn.BasicLSTMCell(num_units=rnn_hidden_size, state_is_tuple=True)
initial_state = cell.zero_state(batch_size, tf.float32)
outputs, _states = tf.nn.dynamic_rnn(
   cell, X_one_hot, initial_state=initial_state, dtype=tf.float32)

weights = tf.ones([batch_size, sequence_length])
sequence_loss = tf.contrib.seq2seq.sequence_loss(logits=outputs, targets=Y,weights=weights)
loss = tf.reduce_mean(sequence_loss)
train = tf.train.GradientDescentOptimizer(learning_rate=0.1).minimize(loss)

prediction = tf.argmax(outputs, axis=2)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-2-char-seq-rnn.py

Training and Results

```
with tf.Session() as sess:
    sess.run(tf.global_variables_initializer())
    for i in range(3000):
        l, _ = sess.run([loss, train], feed_dict={X: x_data, Y: y_data})
        result = sess.run(prediction, feed_dict={X: x_data})
        # print char using dic
        result_str = [idx2char[c] for c in np.squeeze(result)]
        print(i, "loss:", l, "Prediction:", ''.join(result_str))
```

```
0 loss: 2.29895 Prediction: nnuffuunnuuuyuy
1 loss: 2.29675 Prediction: nnuffuunnuuuyuy
...

1418 loss: 1.37351 Prediction: if you want you
1419 loss: 1.37331 Prediction: if you want you
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-2-char-seq-rnn.py

Really long sentence?

```
sentence = ("if you want to build a ship, don't drum up people together to "
            "collect wood and don't assign them tasks and work, but rather "
            "teach them to long for the endless immensity of the sea.")
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Really long sentence?

```
sentence = ("if you want to build a ship, don't drum up people together to "
           "collect wood and don't assign them tasks and work, but rather "
           "teach them to long for the endless immensity of the sea.")
```

```
# training dataset
0 if you wan -> f you want
1 f you want ->  you want
2  you want  -> you want t
3 you want t -> ou want to
…
168  of the se -> of the sea
169 of the sea -> f the sea.
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Making dataset

```
char_set = list(set(sentence))
char_dic = {w: i for i, w in enumerate(char_set)}

dataX = []
dataY = []
for i in range(0, len(sentence) - seq_length):
    x_str = sentence[i:i + seq_length]
    y_str = sentence[i + 1: i + seq_length + 1]
    print(i, x_str, '->', y_str)

    x = [char_dic[c] for c in x_str]  # x str to index
    y = [char_dic[c] for c in y_str]  # y str to index

    dataX.append(x)
    dataY.append(y)
```

 # training dataset
0 if you wan -> f you want
1 f you want -> you want
2 you want -> you want t
3 you want t -> ou want to
…
168 of the se -> of the sea
169 of the sea -> f the sea.

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

RNN parameters

```
char_set = list(set(sentence))
char_dic = {w: i for i, w in enumerate(char_set)}

data_dim = len(char_set)
hidden_size = len(char_set)
num_classes = len(char_set)
seq_length = 10  # Any arbitrary number

batch_size = len(dataX)
```

 # training dataset
0 if you wan -> f you want
1 f you want -> you want
2 you want -> you want t
3 you want t -> ou want to
…
168 of the se -> of the sea
169 of the sea -> f the sea.

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

LSTM and Loss

```
X = tf.placeholder(tf.int32, [None, sequence_length])  # X data
Y = tf.placeholder(tf.int32, [None, sequence_length])  # Y label

X_one_hot = tf.one_hot(X, num_classes)  # one hot: 1 -> 0 1 0 0 0 0 0 0 0 0

cell = tf.contrib.rnn.BasicLSTMCell(num_units=rnn_hidden_size, state_is_tuple=True)
initial_state = cell.zero_state(batch_size, tf.float32)
outputs, _states = tf.nn.dynamic_rnn(
   cell, X_one_hot, initial_state=initial_state, dtype=tf.float32)

weights = tf.ones([batch_size, sequence_length])
sequence_loss = tf.contrib.seq2seq.sequence_loss(logits=outputs, targets=Y,weights=weights)
loss = tf.reduce_mean(sequence_loss)
train = tf.train.GradientDescentOptimizer(learning_rate=0.1).minimize(loss)

prediction = tf.argmax(outputs, axis=2)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-2-char-seq-rnn.py

Exercise

- Run long sequence RNN
- Why it does not work?

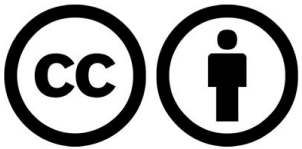
With TF 1.0!

Lab 12-4

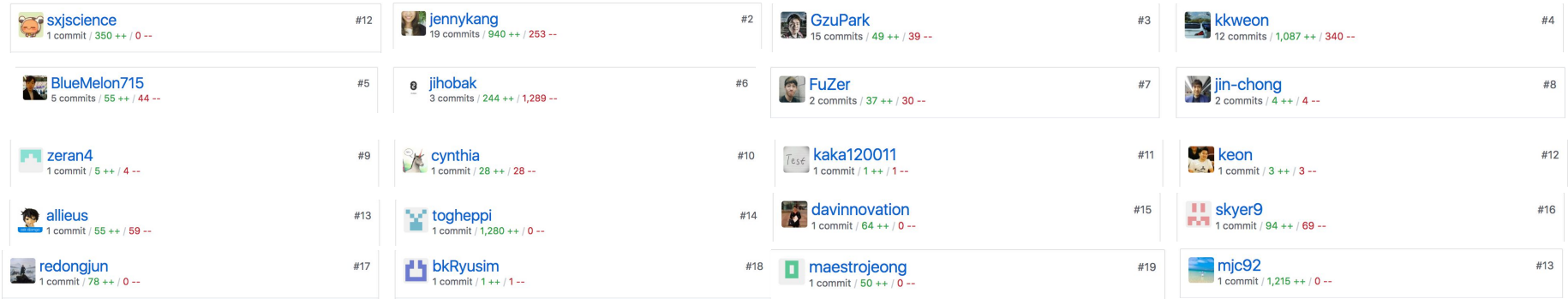
RNN with long sequences: Stacked RNN + Softmax layer

Sung Kim <hunkim+ml@gmail.com>

Code: https://github.com/hunkim/DeepLearningZeroToAll/



https://github.com/hunkim/DeepLearningZeroToAll/



Really long sentence?

```
sentence = ("if you want to build a ship, don't drum up people together to "
            "collect wood and don't assign them tasks and work, but rather "
            "teach them to long for the endless immensity of the sea.")
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Making dataset

```
char_set = list(set(sentence))
char_dic = {w: i for i, w in enumerate(char_set)}

dataX = []
dataY = []
for i in range(0, len(sentence) - seq_length):
    x_str = sentence[i:i + seq_length]
    y_str = sentence[i + 1: i + seq_length + 1]
    print(i, x_str, '->', y_str)

    x = [char_dic[c] for c in x_str]  # x str to index
    y = [char_dic[c] for c in y_str]  # y str to index

    dataX.append(x)
    dataY.append(y)
```

 # training dataset
0 if you wan -> f you want
1 f you want -> you want
2 you want -> you want t
3 you want t -> ou want to
…
168 of the se -> of the sea
169 of the sea -> f the sea.

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

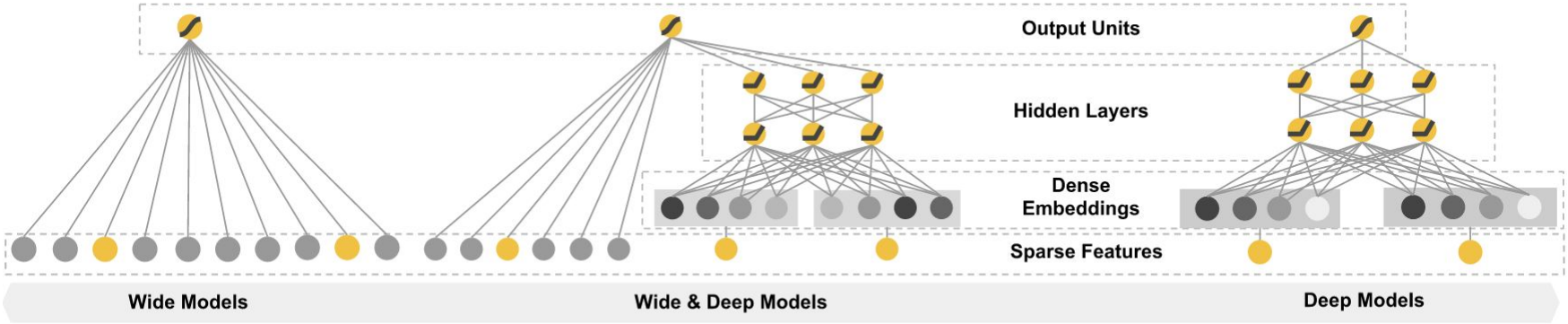
RNN parameters

```
char_set = list(set(sentence))
char_dic = {w: i for i, w in enumerate(char_set)}

data_dim = len(char_set)
hidden_size = len(char_set)
num_classes = len(char_set)
seq_length = 10  # Any arbitrary number

batch_size = len(dataX)
```

 # training dataset
0 if you wan -> f you want
1 f you want -> you want
2 you want -> you want t
3 you want t -> ou want to
…
168 of the se -> of the sea
169 of the sea -> f the sea.

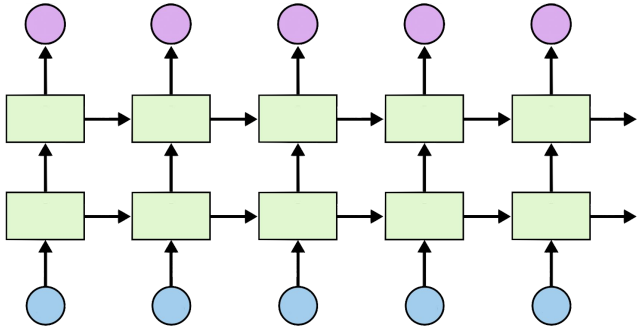
https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Wide & Deep



https://www.tensorflow.org/versions/r0.11/tutorials/wide_and_deep/index.html

Stacked RNN



```
X = tf.placeholder(tf.int32, [None, seq_length])
Y = tf.placeholder(tf.int32, [None, seq_length])

# One-hot encoding
X_one_hot = tf.one_hot(X, num_classes)
print(X_one_hot)  # check out the shape

# Make a lstm cell with hidden_size (each unit output vector size)
cell = rnn.BasicLSTMCell(hidden_size, state_is_tuple=True)
cell = rnn.MultiRNNCell([cell] * 2, state_is_tuple=True)

# outputs: unfolding size x hidden size, state = hidden size
outputs, _states = tf.nn.dynamic_rnn(cell, X_one_hot, dtype=tf.float32)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Softmax (FC) in Deep CNN

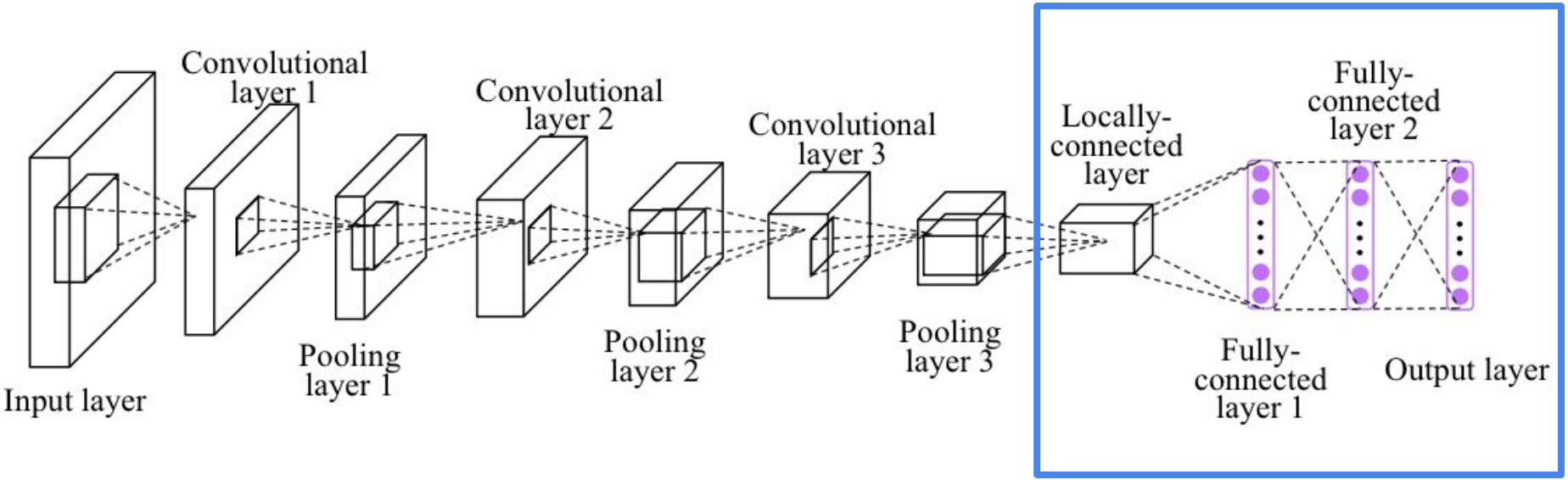
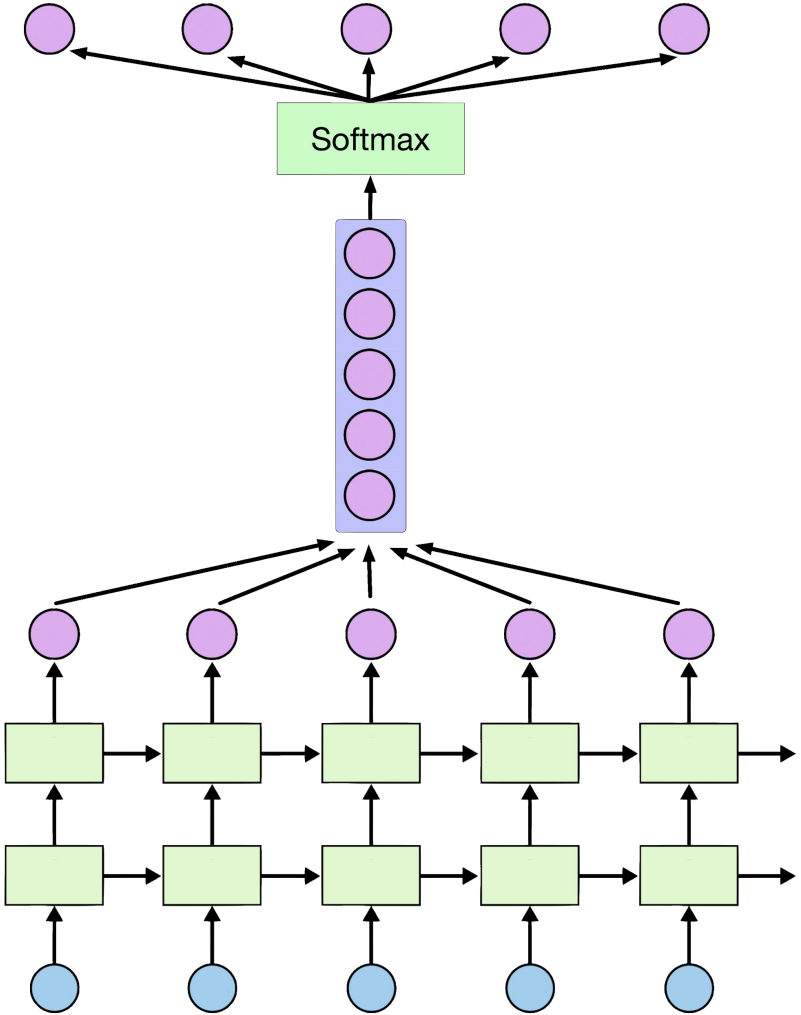


Image credit: http://personal.ie.cuhk.edu.hk/~ccloy/project_target_code/index.html

Softmax

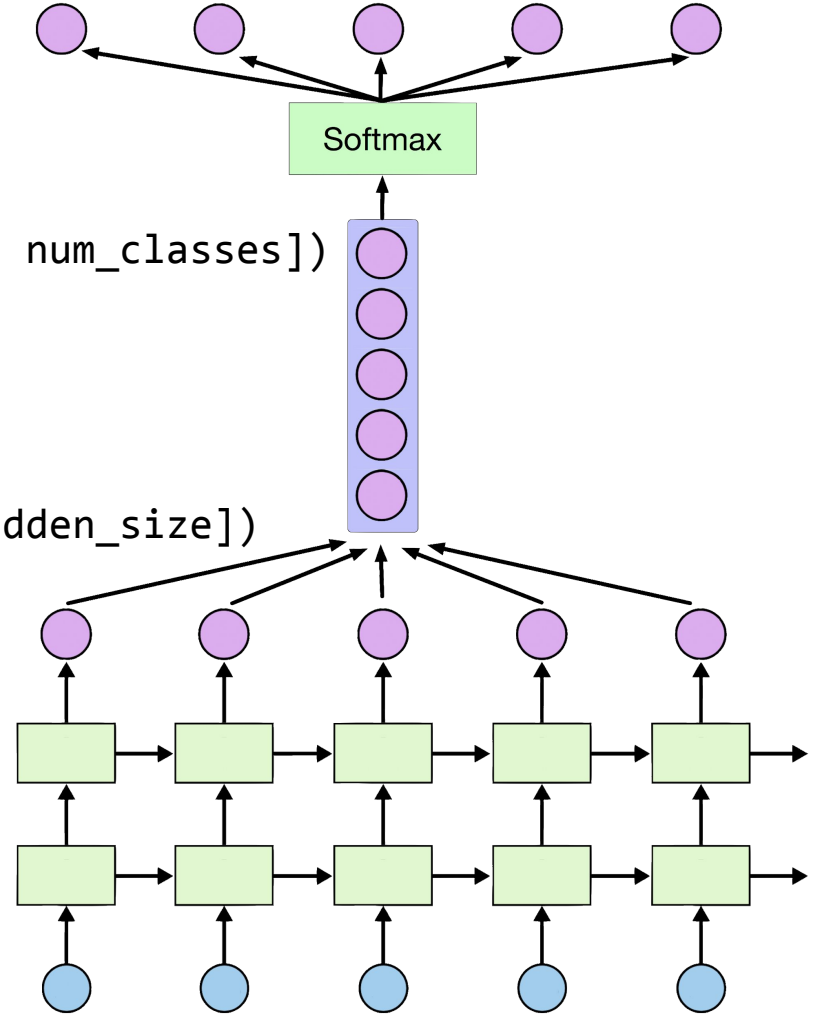


https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Softmax

```
outputs = tf.reshape(outputs,
     [batch_size, seq_length, num_classes])
```

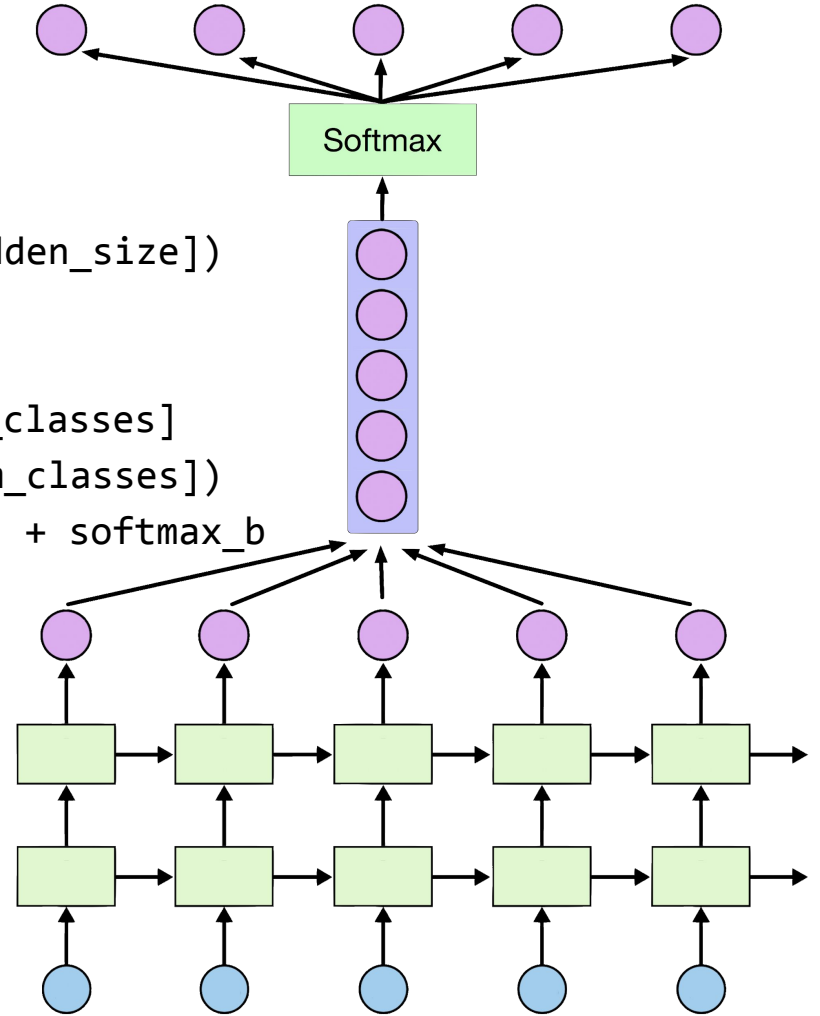
```
X_for_softmax = tf.reshape(outputs,
                           [-1, hidden_size])
```



https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

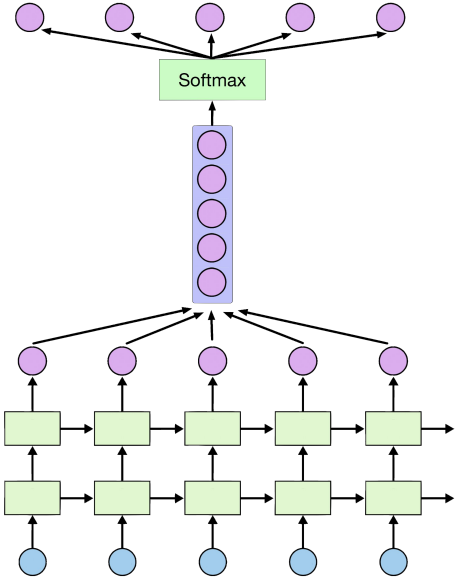
Softmax

```
# (optional) softmax layer
X_for_softmax = tf.reshape(outputs, [-1, hidden_size])

softmax_w = tf.get_variable("softmax_w",
                            [hidden_size, num_classes]
softmax_b = tf.get_variable("softmax_b",[num_classes])
outputs = tf.matmul(X_for_softmax,softmax_w) + softmax_b

outputs = tf.reshape(outputs,
      [batch_size, seq_length, num_classes])
```



https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Loss




```
# reshape out for sequence_loss
outputs = tf.reshape(outputs,
           [batch_size, seq_length, num_classes])
# All weights are 1 (equal weights)
weights = tf.ones([batch_size, seq_length])

sequence_loss = tf.contrib.seq2seq.sequence_loss(
   logits=outputs, targets=Y, weights=weights)
mean_loss = tf.reduce_mean(sequence_loss)

train_op =
       tf.train.AdamOptimizer(learning_rate=0.1).minimize(mean_loss)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

Training and print results

```
sess = tf.Session()
sess.run(tf.global_variables_initializer()

for i in range(500):
    _, l, results = sess.run(
                [train_op, mean_loss, outputs],
                feed_dict={X: dataX, Y: dataY})

    for j, result in enumerate(results):
        index = np.argmax(result, axis=1)
        print(i, j, ''.join([char_set[t] for t in index]), l)
```

```
0 167 ttttttttt 3.23111
0 168 ttttttttt 3.23111
0 169 ttttttttt 3.23111
…
499 167 oof the se 0.229306
499 168 tf the sea 0.229306
499 169 n the sea. 0.229306
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

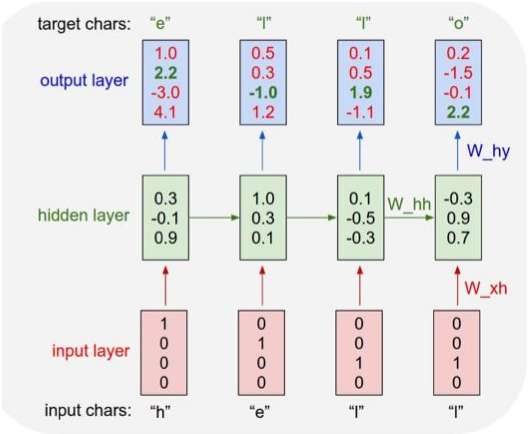
Training and print results

```
# Let's print the last char of each result to check it works
results = sess.run(outputs, feed_dict={X: dataX})
for j, result in enumerate(results):
    index = np.argmax(result, axis=1)
    if j is 0:  # print all for the first result to make a sentence
        print(''.join([char_set[t] for t in index]), end='')
    else:
        print(char_set[index[-1]], end='')
```

g you want to build a ship, don't drum up people together to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea.

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-4-rnn_long_char.py

char-rnn

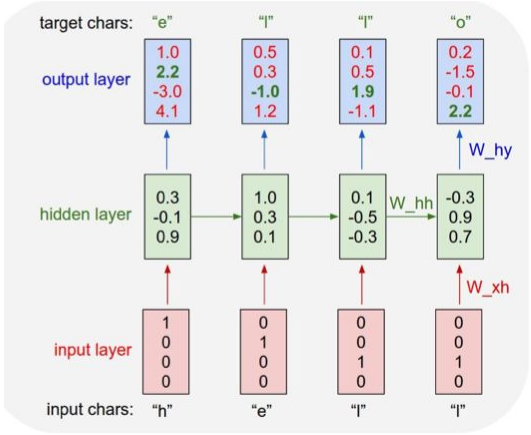


Shakespeare

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.
```

http://karpathy.github.io/2015/05/21/rnn-effectiveness/



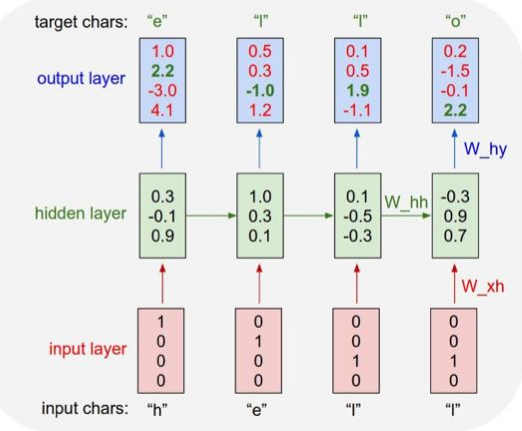
Linux Source Code

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;
}
```

http://karpathy.github.io/2015/05/21/rnn-effectiveness/

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



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

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

With TF 1.0!

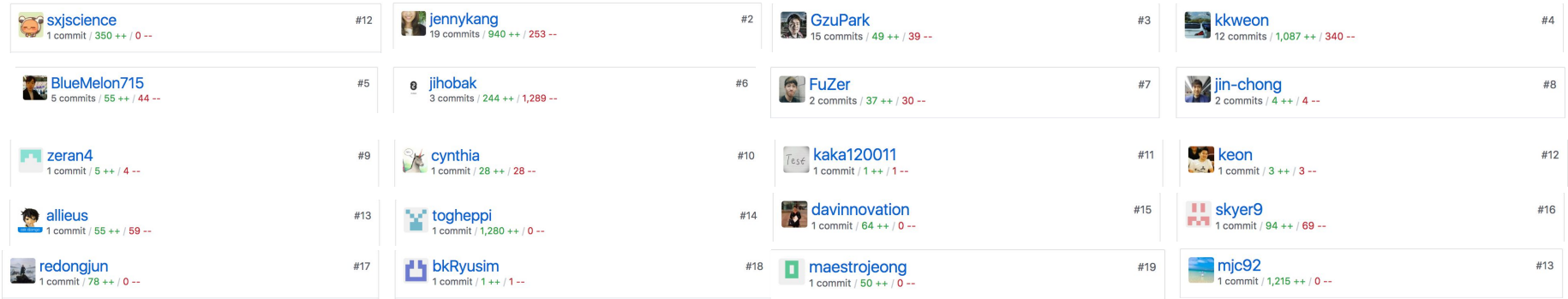
Lab 12-5

Dynamic RNN

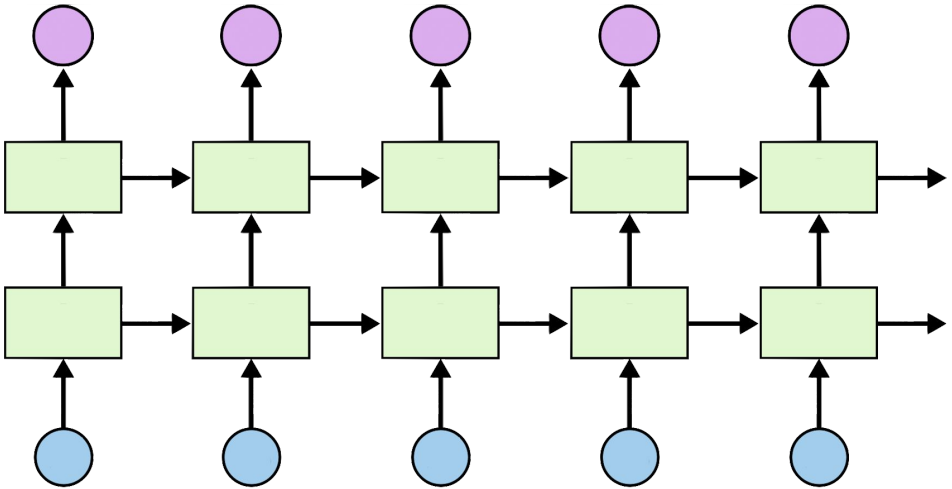
Sung Kim <hunkim+ml@gmail.com>

Code: https://github.com/hunkim/DeepLearningZeroToAll/

https://github.com/hunkim/DeepLearningZeroToAll/

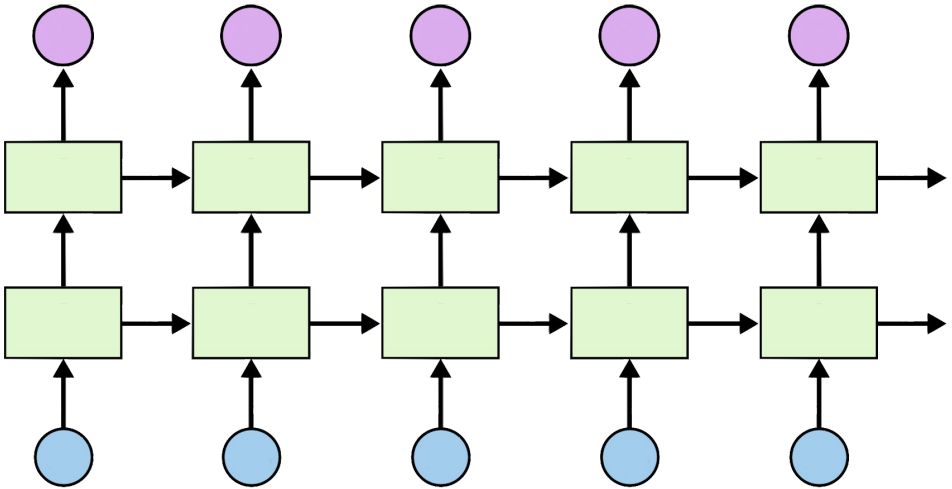


Different sequence length



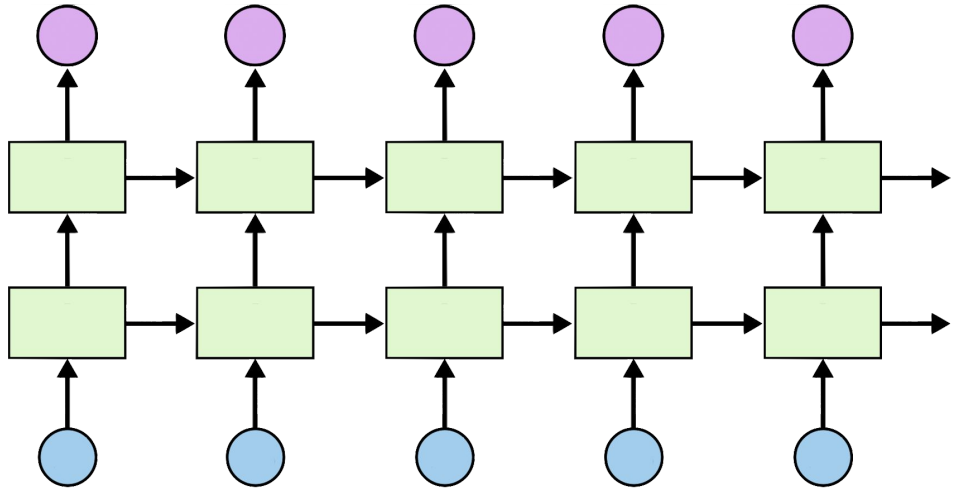
h	e	l	l	o
h	i			
w	h	y		
...				

Different sequence length



h	e	l	l	o
h	i	<pad>	<pad>	<pad>
w	h	y	<pad>	<pad>
...				

Different sequence length



`sequence_length=[5,2,3]`

h	e	l	l	o
h	i			
w	h	y		
...				

Dynamic RNN

```
# 3 batches 'hello', 'eolll', 'lleel'
x_data = np.array([[[...]]], dtype=np.float32)

hidden_size = 2
cell = rnn.BasicLSTMCell(num_units=hidden_size,
                                 state_is_tuple=True)
outputs, _states = tf.nn.dynamic_rnn(
        cell, x_data, sequence_length=[5,3,4],
        dtype=tf.float32)
sess.run(tf.global_variables_initializer())
print(outputs.eval())
```

```
array([[[-0.17904168, -0.08053244],
        [-0.01294809,  0.01660814],
        [-0.05754048, -0.1368292 ],
        [-0.08655578, -0.20553185],
        [ 0.07297077, -0.21743253]],

       [[ 0.10272847,  0.06519825],
        [ 0.20188759, -0.05027055],
        [ 0.09514933, -0.16452041],
        [ 0.        ,  0.        ],
        [ 0.        ,  0.        ]],

       [[-0.04893036, -0.14655617],
        [-0.07947272, -0.20996611],
        [ 0.06466491, -0.02576563],
        [ 0.15087658,  0.05166111],
        [ 0.        ,  0.        ]]],
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-0-rnn_basics.ipynb

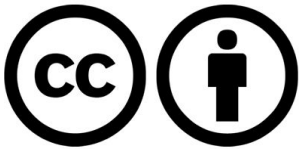
With TF 1.0!

Lab 12-6

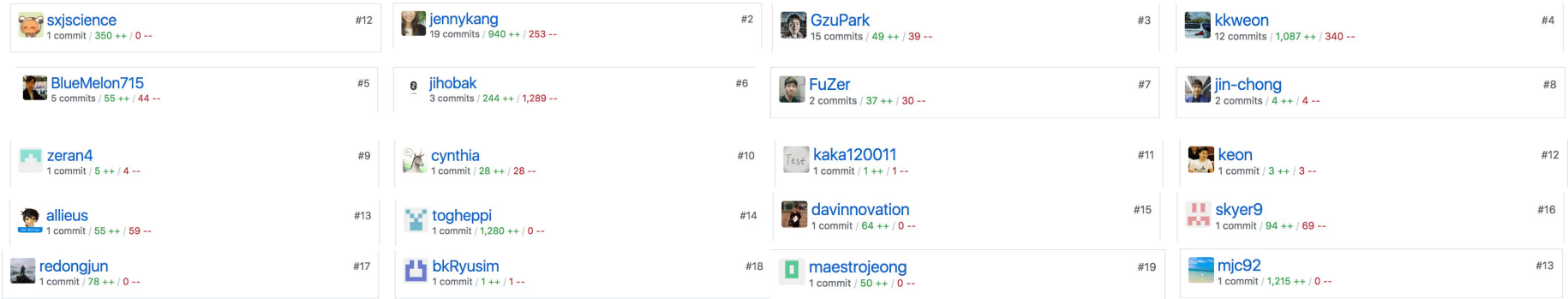
RNN with time series data (stock)

Sung Kim <hunkim+ml@gmail.com>

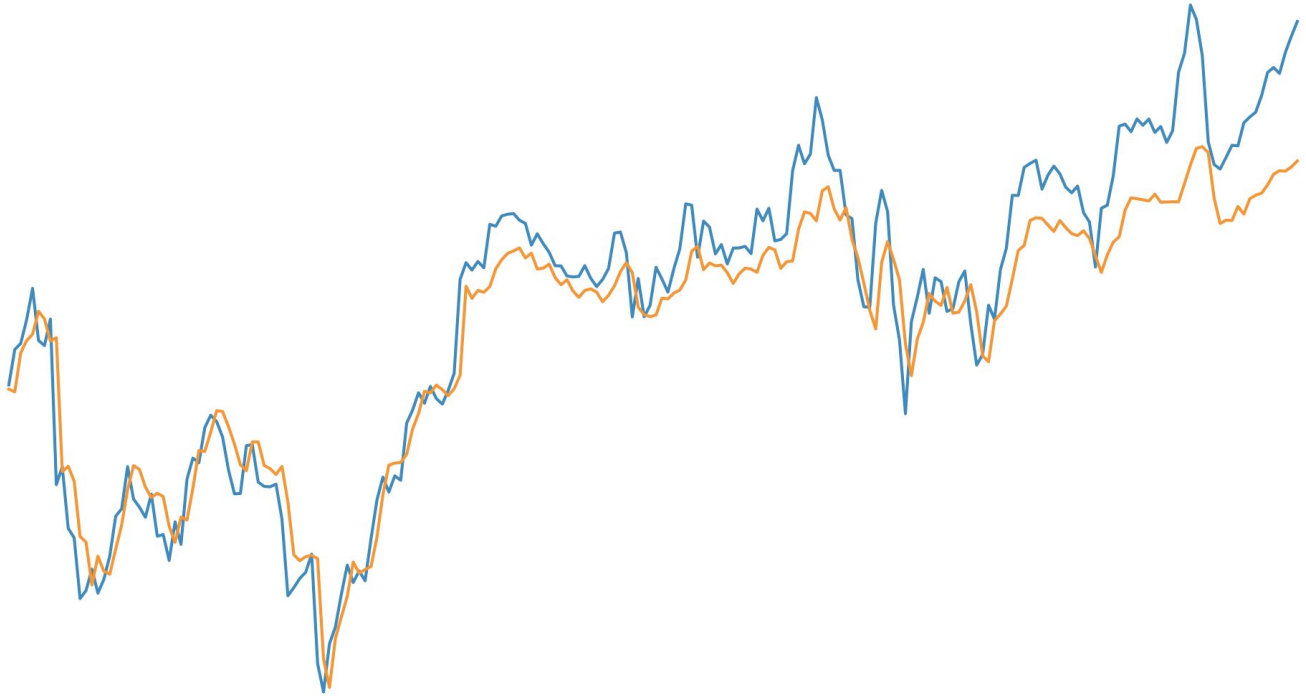
Code: https://github.com/hunkim/DeepLearningZeroToAll/



https://github.com/hunkim/DeepLearningZeroToAll/



Time series data

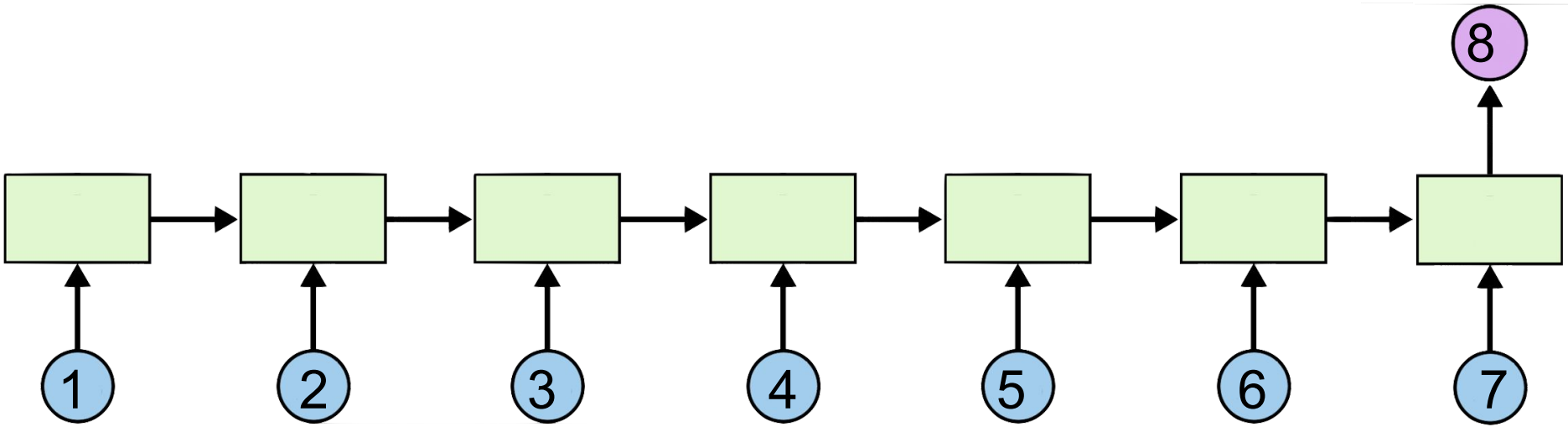


Time series data

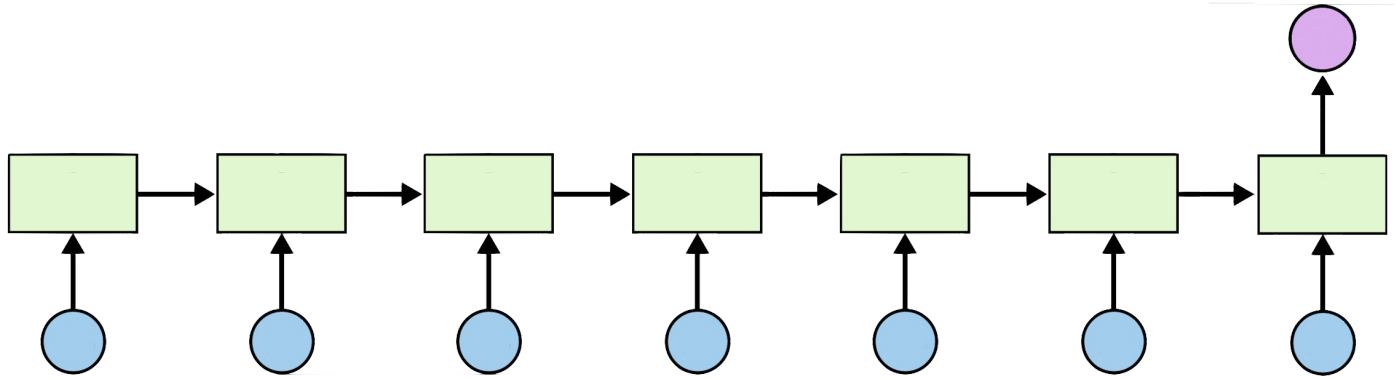
Open	High	Low	Volume	Close
828.659973	833.450012	828.349976	1247700	**831.659973**
823.02002	828.070007	821.655029	1597800	**828.070007**
819.929993	824.400024	818.97998	1281700	**824.159973**
819.359985	823	818.469971	1304000	**818.97998**
819	823	816	1053600	**820.450012**
816	820.958984	815.48999	1198100	**819.23999**
811.700012	815.25	809.780029	1129100	**813.669983**
809.51001	810.659973	804.539978	989700	**809.559998**
807	811.840027	803.190002	1155300	**808.380005**

`'data-02-stock_daily.csv'`

Many to one



https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-5-rnn_stock_prediction.py



Open	High	Low	Volume	Close
828.659973	833.450012	828.349976	1247700	**831.659973**
823.02002	828.070007	821.655029	1597800	**828.070007**
819.929993	824.400024	818.97998	1281700	**824.159973**
819.359985	823	818.469971	1304000	**818.97998**
819	823	816	1053600	**820.450012**
816	820.958984	815.48999	1198100	**819.23999**
811.700012	815.25	809.780029	1129100	**813.669983**
809.51001	810.659973	804.539978	989700	**?**
807	811.840027	803.190002	1155300	**?**

Reading data

```
timesteps = seq_length = 7
data_dim = 5
output_dim = 1
# Open,High,Low,Close,Volume
xy = np.loadtxt('data-02-stock_daily.csv', delimiter=',')
xy = xy[::-1]  # reverse order (chronically ordered)
xy = MinMaxScaler(xy)
x = xy
y = xy[:, [-1]]  # Close as label

dataX = []
dataY = []
for i in range(0, len(y) - seq_length):
    _x = x[i:i + seq_length]
    _y = y[i + seq_length]  # Next close price
    print(_x, "->", _y)
    dataX.append(_x)
    dataY.append(_y)
```

```
[ 0.18667876  0.20948057  0.20878184  0.
0.21744815]

[ 0.30697388  0.31463414  0.21899367
0.01247647  0.21698189]

[ 0.21914211  0.26390721  0.2246864
0.45632338  0.22496747]

[ 0.23312993  0.23641916  0.16268272
0.57017119  0.14744274]

[ 0.13431201  0.15175877  0.11617252
0.39380658  0.13289962]

[ 0.13973232  0.17060429  0.15860382
0.28173344  0.18171679]

[ 0.18933069  0.20057799  0.19187983
0.29783096  0.2086465 ]]

-> [ 0.14106001]
```

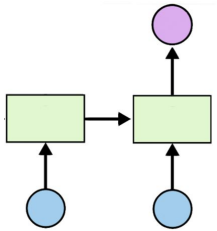
https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-5-rnn_stock_prediction.py

Training and test datasets

```
# split to train and testing
train_size = int(len(dataY) * 0.7)
test_size = len(dataY) - train_size
trainX, testX = np.array(dataX[0:train_size]),
                np.array(dataX[train_size:len(dataX)])
trainY, testY = np.array(dataY[0:train_size]),
                np.array(dataY[train_size:len(dataY)])

# input placeholders
X = tf.placeholder(tf.float32, [None, seq_length, data_dim])
Y = tf.placeholder(tf.float32, [None, 1])
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-5-rnn_stock_prediction.py

LSTM and Loss

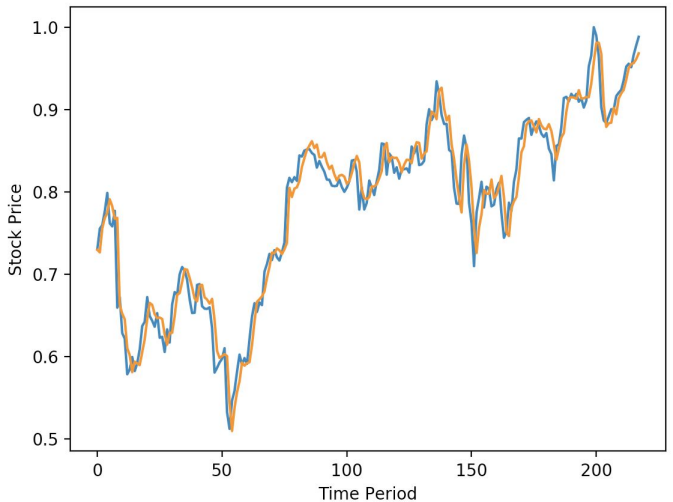


```
# input placeholders
X = tf.placeholder(tf.float32, [None, seq_length, data_dim])
Y = tf.placeholder(tf.float32, [None, 1])

cell = tf.contrib.rnn.BasicLSTMCell(num_units=hidden_dim, state_is_tuple=True)
outputs, _states = tf.nn.dynamic_rnn(cell, X, dtype=tf.float32)
Y_pred = tf.contrib.layers.fully_connected(
   outputs[:, -1], output_dim, activation_fn=None)
   # We use the last cell's output

# cost/loss
loss = tf.reduce_sum(tf.square(Y_pred - Y))  # sum of the squares
# optimizer
optimizer = tf.train.AdamOptimizer(0.01)
train = optimizer.minimize(loss)
```

https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-5-rnn_stock_prediction.py

Training and Results

```
sess = tf.Session()
sess.run(tf.global_variables_initializer())

for i in range(1000):
    _, l = sess.run([train, loss],
            feed_dict={X: trainX, Y: trainY})
    print(i, l)

testPredict = sess.run(Y_pred, feed_dict={X: testX})

import matplotlib.pyplot as plt
plt.plot(testY)
plt.plot(testPredict)
plt.show()
```



https://github.com/hunkim/DeepLearningZeroToAll/blob/master/lab-12-5-rnn_stock_prediction.py

Exercise

- Implement stock prediction using linear regression only
- Improve results using more features such as keywords and/or sentiments in top news

Other RNN applications

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

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