2017 UNITEC-NTHU Summer School
on the Frontier of Information Technology

Deep Learning Lab (Prof. Min Sun)
-- TensorFlow Tutorial

Speaker: Tz-Ying (Gina) Wu

Outline

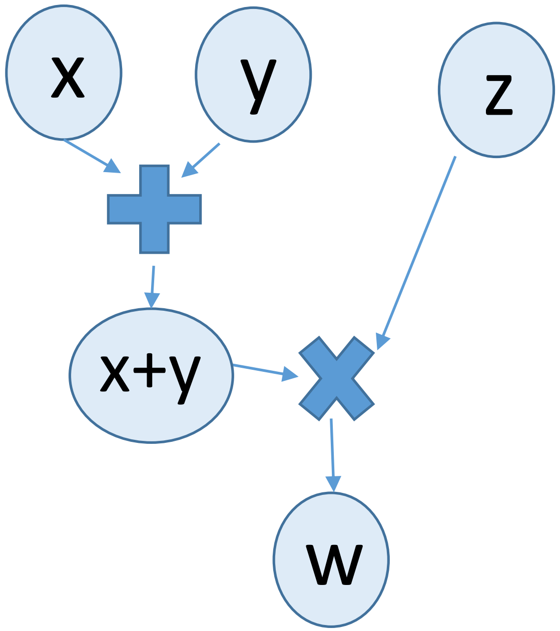
- Introduction to TensorFlow

- Exercise

- TensorFlow sample codes of
  - CNN
  - RNN

Introduction to TensorFlow

What is TensorFlow?



TensorFlow

data graph

multidimensional
data array

computation using data
flow graphs

What is TensorFlow?

- TensorFlow is a ***deep learning*** library open-sourced by Google in 2015

- provides primitives for defining functions on tensors and automatically computing their derivatives

  You don't need to write backpropagation by yourself

- Support CPU-only, GPU usage

To write a TensorFlow program, we need to …

- Build a graph (define your model)
- Create a session
- Run the session
  - Initialize variables (if there are variables in the graph)
  - Feed the data
  - Run the graph

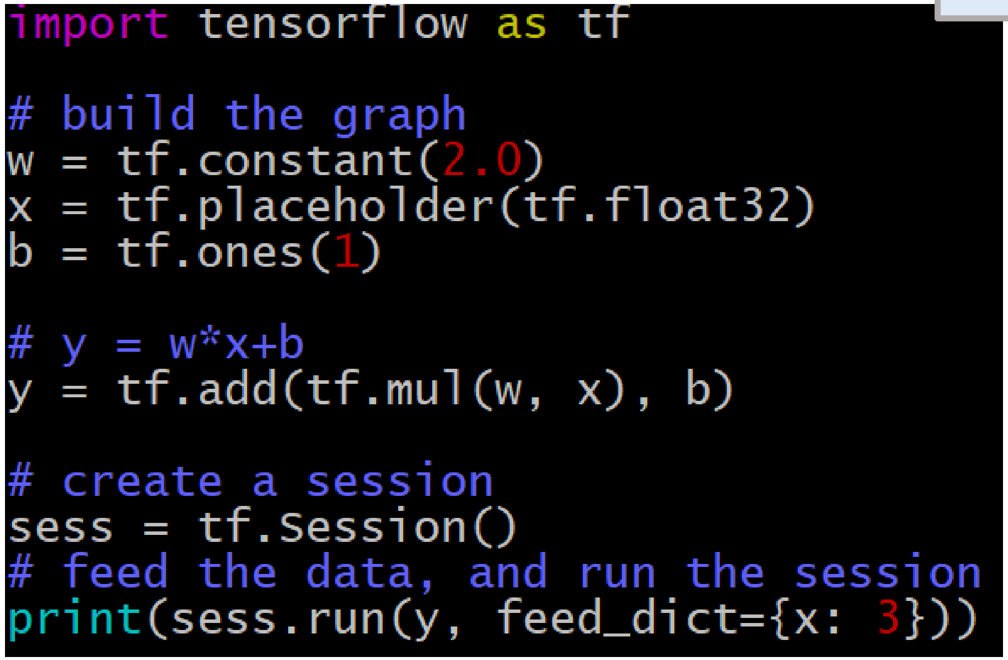
To write a TensorFlow program, we need to …

- Build a graph (define your model)
- Create a session
- Run the session
  - Initialize variables (if there are variables in the graph)
  - Feed the data
  - Run the graph

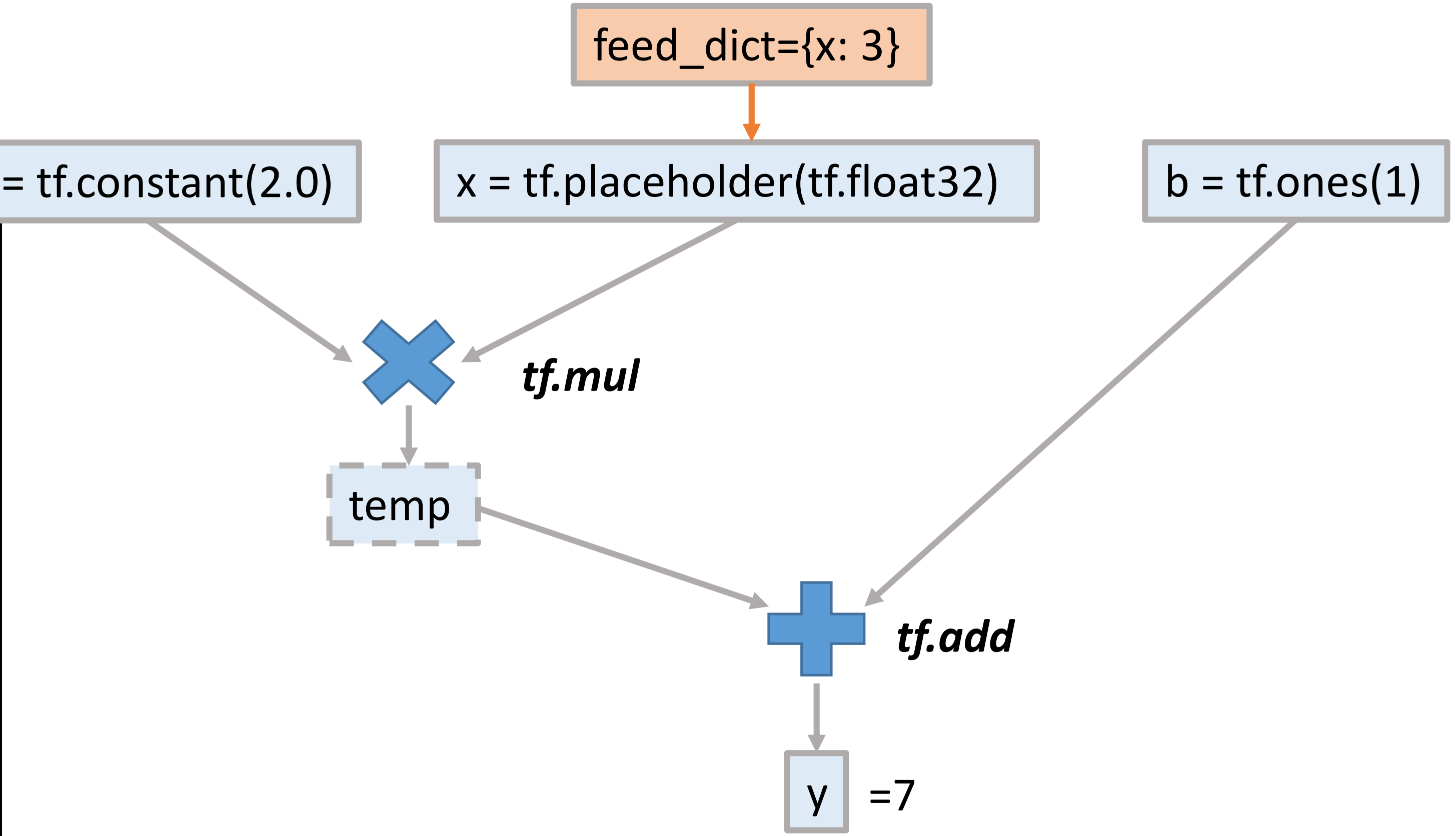
Build a graph (define your model)

- All the computations in TensorFlow graph are tensor operations

E.g. $\boldsymbol{y} = \boldsymbol{w} \cdot \boldsymbol{x} + \boldsymbol{b}$



```
import tensorflow as tf

# build the graph
w = tf.constant(2.0)
x = tf.placeholder(tf.float32)
b = tf.ones(1)

# y = w*x+b
y = tf.add(tf.mul(w, x), b)

# create a session
sess = tf.Session()
# feed the data, and run the session
print(sess.run(y, feed_dict={x: 3}))
```



feed_dict={x: 3}

w = tf.constant(2.0)

x = tf.placeholder(tf.float32)

b = tf.ones(1)

tf.mul

temp

tf.add

y =7

Build a graph (define your model)

- Tensors can be declared by various ways, e.g.,
  - *tf.zeros*((2,2)), *tf.ones*((1, 2, 3)) ↔ np.zeros((2, 2), np.ones((1, 2, 3))
  - *tf.constant*([2, 3]) ↔ np.array([2, 3])
  - *tf.Variable*(*tf.zeros*((2,2)), name="weights") ↔ np.array([[0, 0],[0, 0]])
  - *tf.placeholder*(*tf.float32*, shape=(10, 1))

  etc.

- Variables should be initialized before running
- ***tf.placeholder()*** is to reserve the place for input data

To write a TensorFlow program, we need to …

- Build a graph (define your model)
- Create a session
- Run the session
    - Initialize variables (if there are variables in the graph)
    - Feed the data
    - Run the graph

Create a session

- "A **Session** object encapsulates the environment in which **Operation** objects are executed, and **Tensor** objects are evaluated." - TensorFlow Docs

- Use ***tf.Session()*** or ***tf.InteractiveSession()*** to create a session

```
sess = tf.Session()
…
sess.close()
```

or

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

To write a TensorFlow program, we need to …

- Build a graph (define your model)

- Create a session

- Run the session
  - Initialize variables (if there are variables in the graph)
  - Feed the data
  - Run the graph

Initialize variables

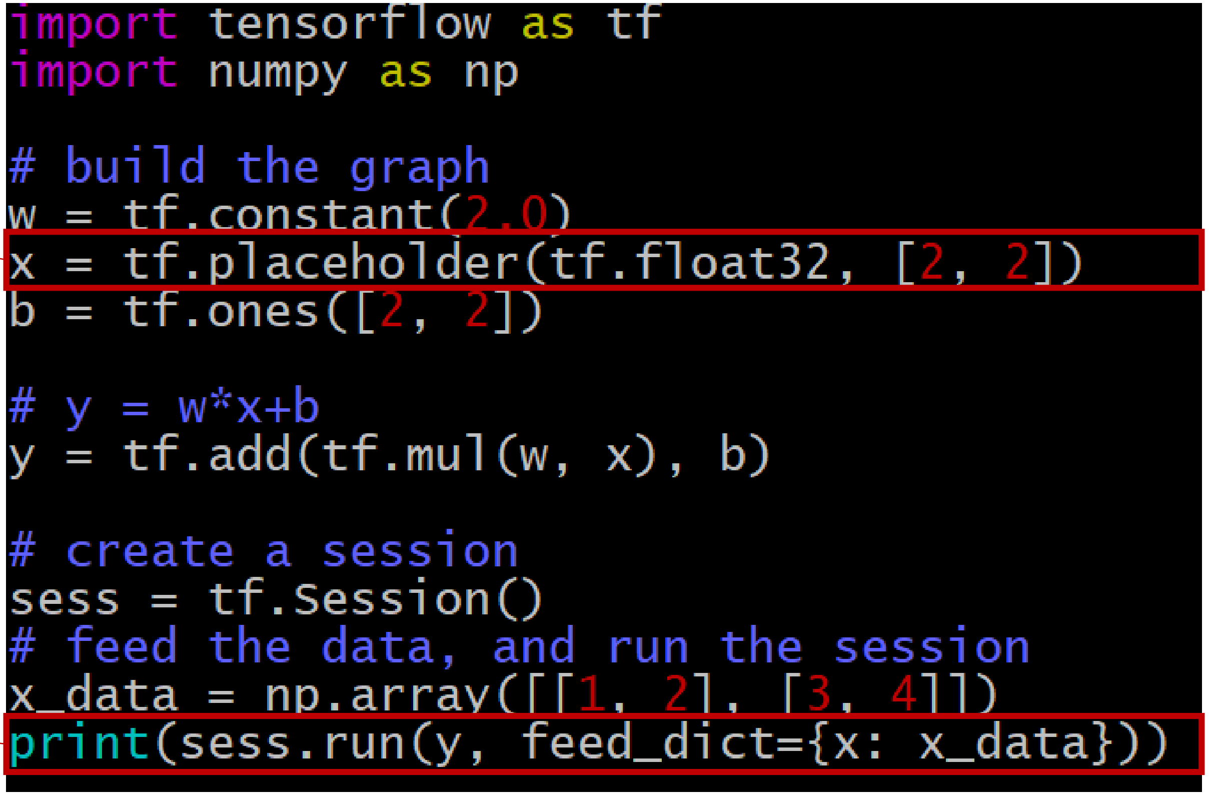
- “The **Variable()** constructor requires an initial value for the variable, which can be a **Tensor** of any type and shape. ” - TensorFlow Docs

- Declaration: ***tf.Variable(<initial-value>, name=<optional-name>)***
  - ***<initial-value>*** can be a fixed-value tensor or be random initialized from a distribution
  - E.g. *tf.Variable*(*tf.zeros*((2,2)), name="weights")
  - E.g. *tf.Variable(tf.random_uniform([100, 2], -1.0, 1.0))*

- Initialization: ***sess.run(tf.initialize_all_variables())***
- [Optional: restore parameters from a TensorFlow model (use Saver)]

Feed the data

- Tensorflow provide ***feed_dict*** as the bridge between **numpy array** and **tensor**
- Usage: *feed_dict={<placeholder_name>: <numpy_array>}*
- e.g.



```
import tensorflow as tf
import numpy as np

# build the graph
w = tf.constant(2.0)
x = tf.placeholder(tf.float32, [2, 2])
b = tf.ones([2, 2])

# y = w*x+b
y = tf.add(tf.mul(w, x), b)

# create a session
sess = tf.Session()
# feed the data, and run the session
x_data = np.array([[1, 2], [3, 4]])
print(sess.run(y, feed_dict={x: x_data}))
```

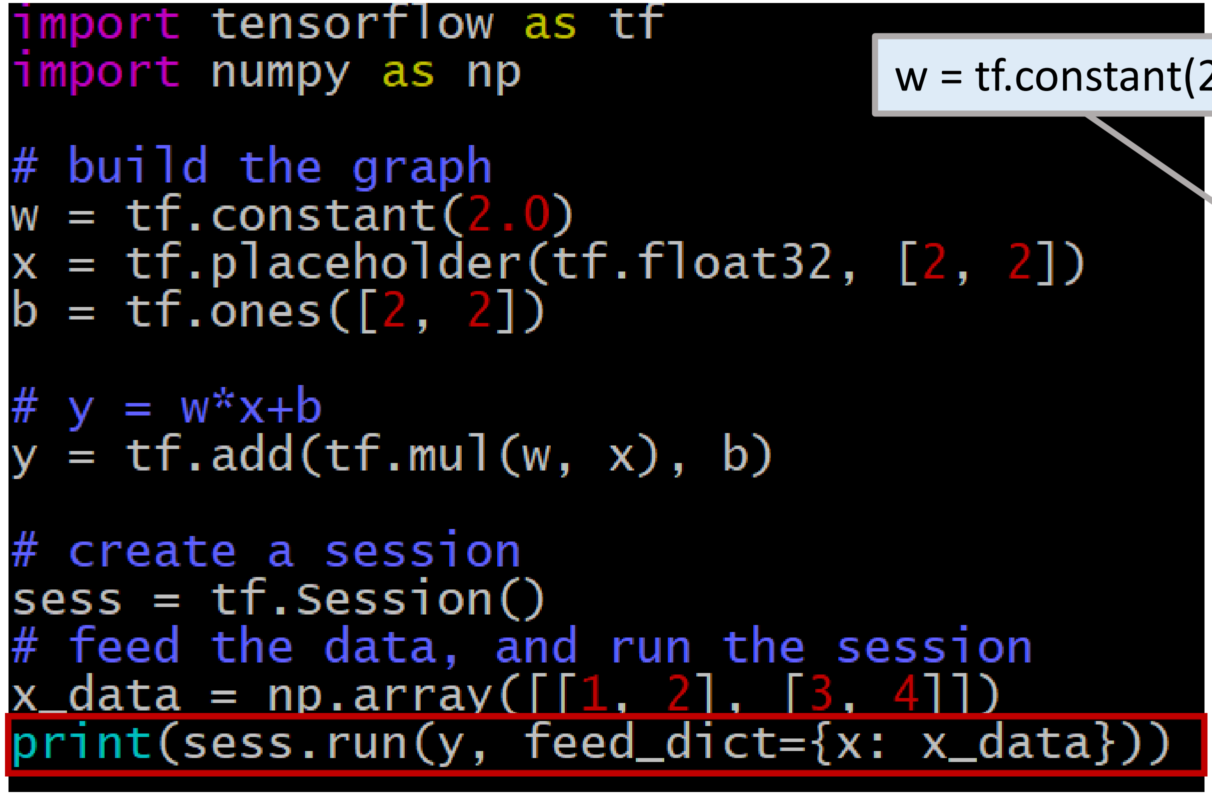
declaring placeholder when building the graph

The shape of the placeholder and the data fed in must be same!!!

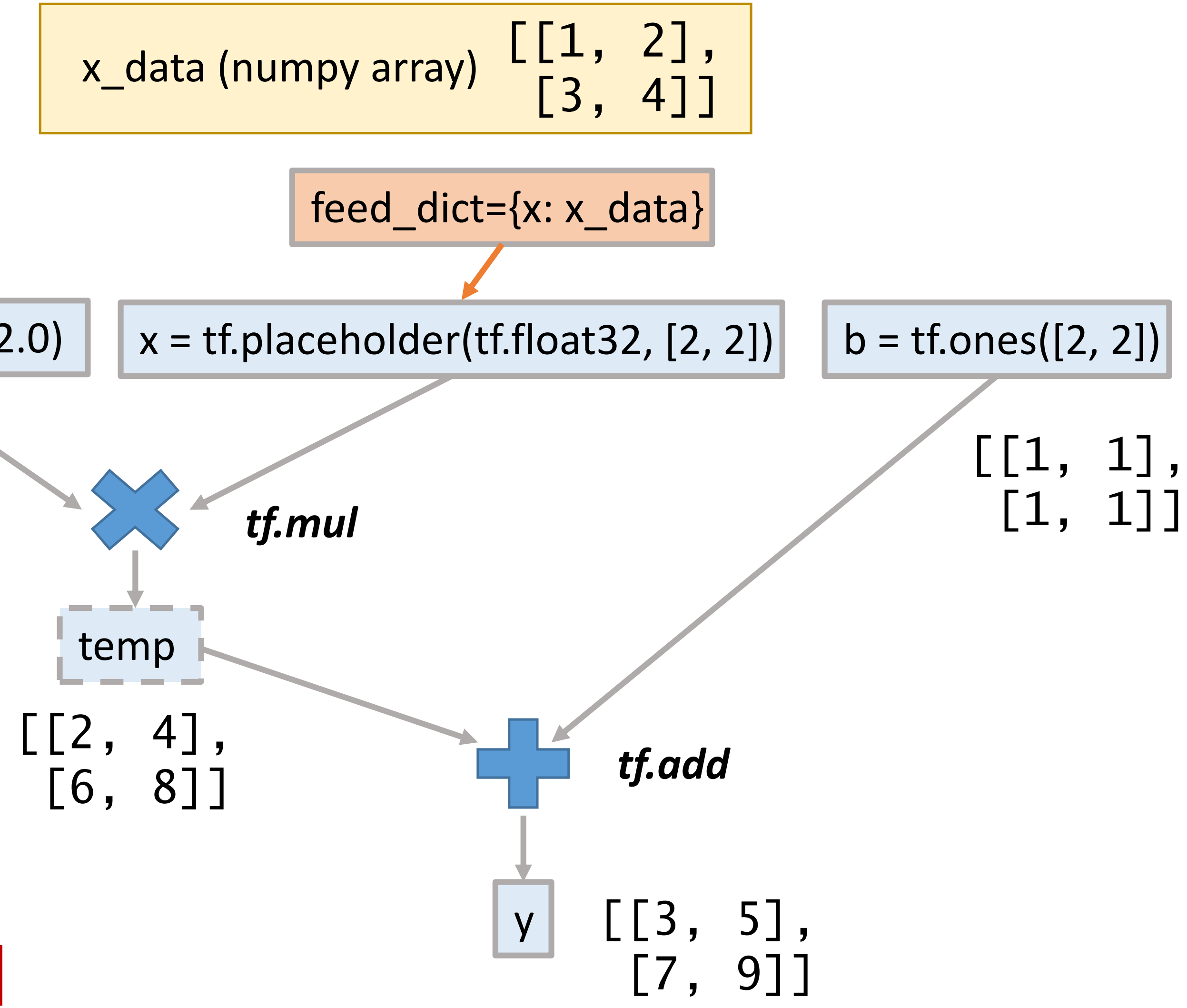
feed the data into the placeholder when running the session

Feed the data

E.g. $\boldsymbol{y} = \boldsymbol{w} \cdot \boldsymbol{x} + \boldsymbol{b}$



```
import tensorflow as tf
import numpy as np

# build the graph
w = tf.constant(2.0)
x = tf.placeholder(tf.float32, [2, 2])
b = tf.ones([2, 2])

# y = w*x+b
y = tf.add(tf.mul(w, x), b)

# create a session
sess = tf.Session()
# feed the data, and run the session
x_data = np.array([[1, 2], [3, 4]])
print(sess.run(y, feed_dict={x: x_data}))
```



x_data (numpy array) [[1, 2], [3, 4]]

feed_dict={x: x_data}

w = tf.constant(2.0)

x = tf.placeholder(tf.float32, [2, 2])

b = tf.ones([2, 2])

[[1, 1], [1, 1]]

tf.mul

temp

[[2, 4], [6, 8]]

tf.add

y

[[3, 5], [7, 9]]

How to get the result?

Run the graph

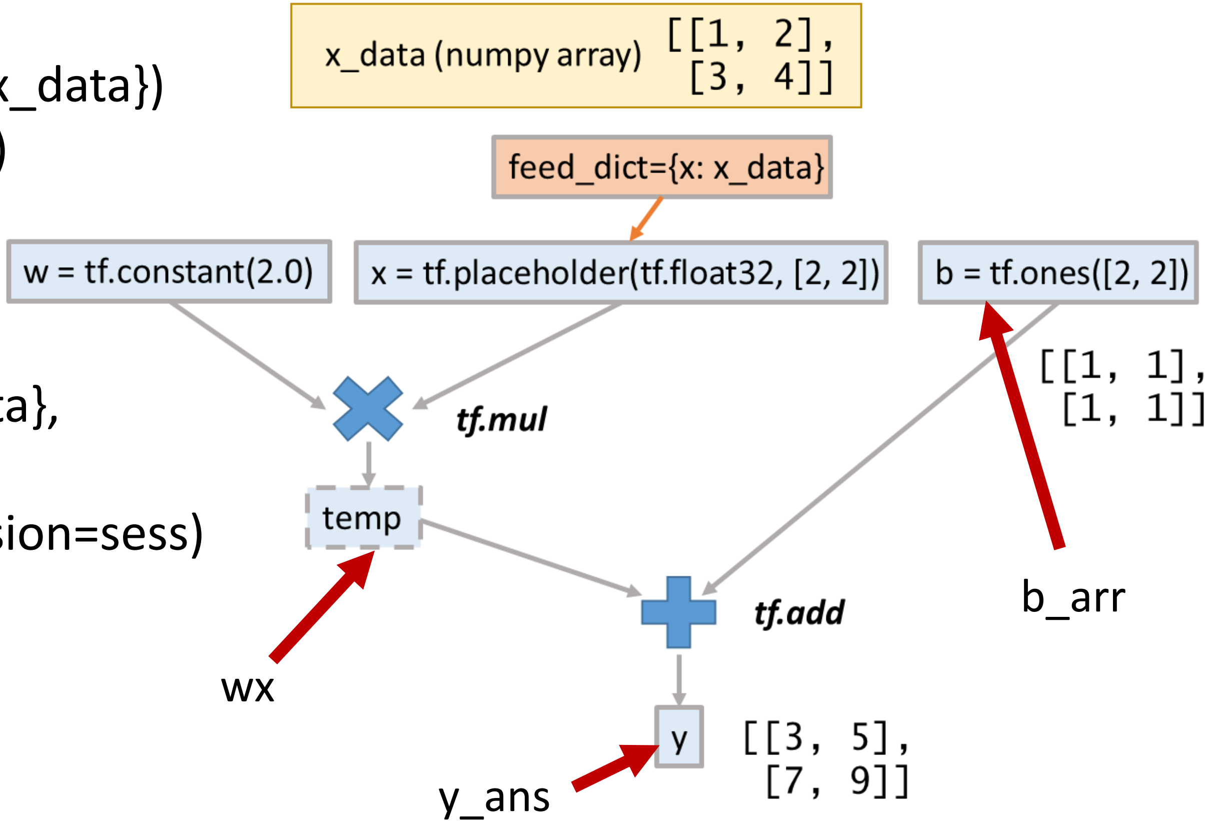
Usage:

- ***sess.run([<nodes>], <feed_dict>)***
  - E.g. b_arr = sess.run(b)
  - E.g. wx = sess.run(tf.mul(w, x), feed_dict={x: x_data})
  - E.g. y_ans = sess.run(y, feed_dict={x: x_data})

- ***<tensor>.eval(session=sess)***
  - E.g. b_arr = b.eval(session=sess)
  - E.g. wx = tf.mul(w, x).eval(feed_dict={x: x_data}, session=sess)
  - E.g. y_ans = y.eval(feed_dict={x: x_data}, session=sess)

Only run the graph before the node you designate!

E.g. $\boldsymbol{y} = \boldsymbol{w} \cdot \boldsymbol{x} + \boldsymbol{b}$



References

- Stanford CS224d: TensorFlow Tutorial
- Stanford CS231n: Deep Learning Software
- TensorFlow docs

Exercise

Environment Setup

# install miniconda (python2.7)

# if you don’t have wget, you can directly go to the website to download the script

```
wget https://repo.continuum.io/miniconda/Miniconda2-latest-MacOSX-x86_64.sh

bash Miniconda2-latest-MacOSX-x86_64.sh
```

# append the following line to ~/.bashrc if it is not done automatically

```
export PATH="path/to/anaconda2/bin":$PATH
```

# check conda installation

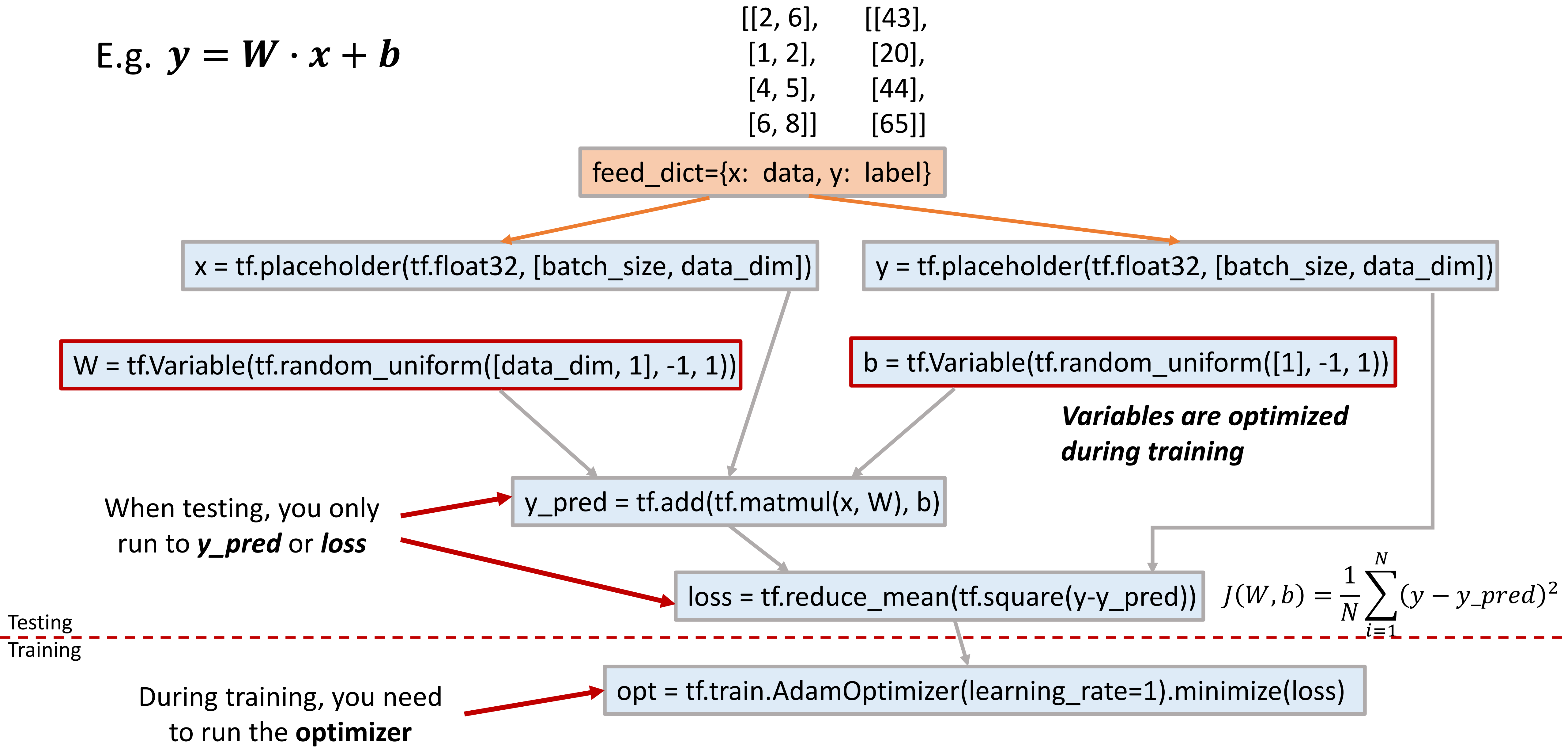
```
conda list
```

Environment Setup

```
# create new environment
conda create -n tensorflow
# activate the environment
source activate tensorflow

# install required package in the environment
pip install opencv
pip install matplotlib
pip install --ignore-installed --upgrade https://storage.googleapis.com/tensorflow/mac/cpu/tensorflow-1.2.0-py2-none-any.whl
pip install jupyter notebook
```

Training and testing example (linear regression)

E.g. $\boldsymbol{y} = \boldsymbol{W} \cdot \boldsymbol{x} + \boldsymbol{b}$



```
[[2, 6],
 [1, 2],
 [4, 5],
 [6, 8]]
```

```
[[43],
 [20],
 [44],
 [65]]
```

```
feed_dict={x:  data, y:  label}
```

```
x = tf.placeholder(tf.float32, [batch_size, data_dim])
```

```
y = tf.placeholder(tf.float32, [batch_size, data_dim])
```

```
W = tf.Variable(tf.random_uniform([data_dim, 1], -1, 1))
```

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

Variables are optimized during training

```
y_pred = tf.add(tf.matmul(x, W), b)
```

When testing, you only run to ***y_pred*** or ***loss***

```
loss = tf.reduce_mean(tf.square(y-y_pred))
```

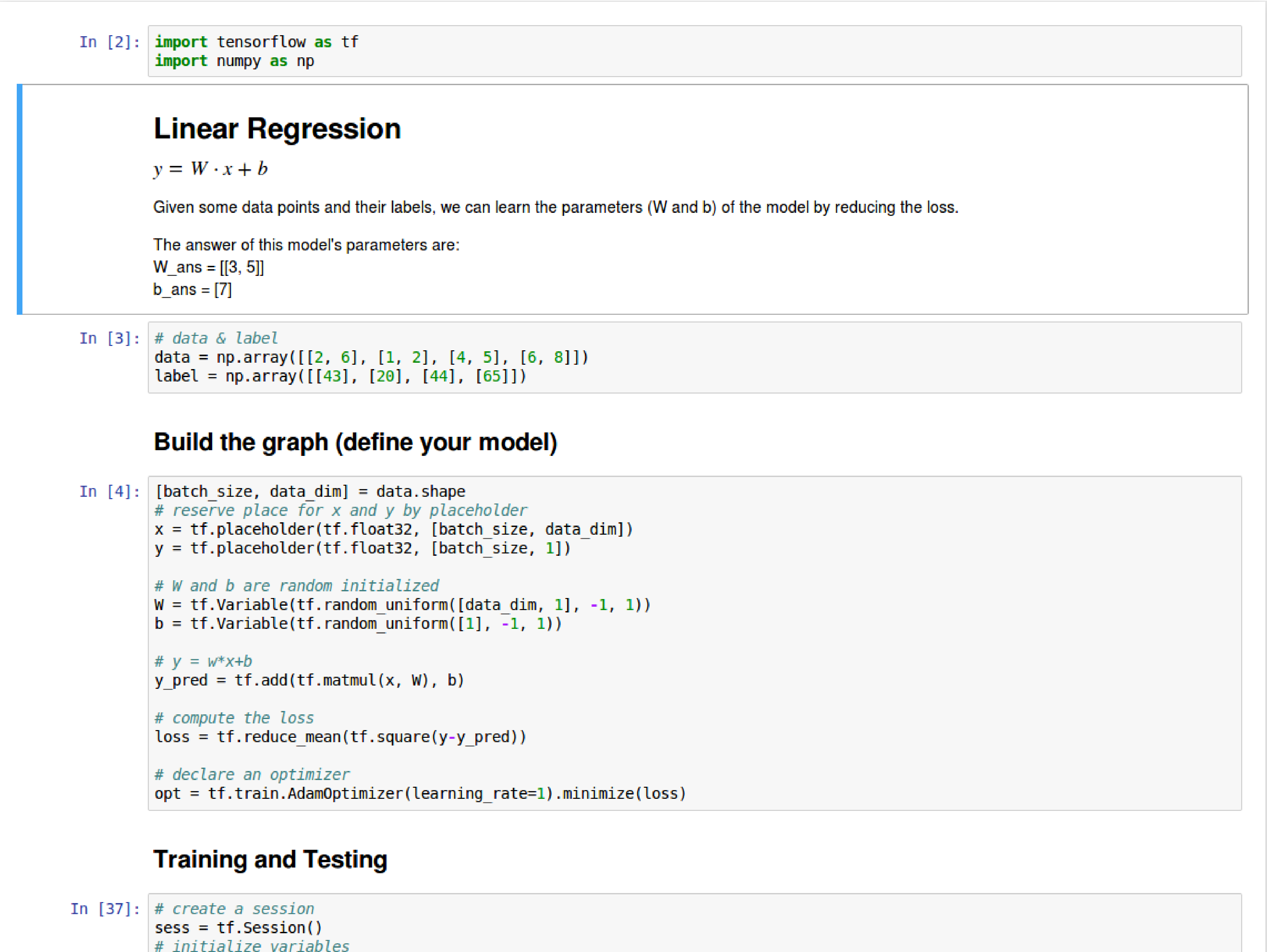
$$J(W, b) = \frac{1}{N}\sum_{i=1}^{N}(y - y\_pred)^2$$

Testing

Training

```
opt = tf.train.AdamOptimizer(learning_rate=1).minimize(loss)
```

During training, you need to run the **optimizer**



In [2]:
```
import tensorflow as tf
import numpy as np
```

Linear Regression

$y = W \cdot x + b$

Given some data points and their labels, we can learn the parameters (W and b) of the model by reducing the loss.

The answer of this model's parameters are:
W_ans = [[3, 5]]
b_ans = [7]

In [3]:
```
# data & label
data = np.array([[2, 6], [1, 2], [4, 5], [6, 8]])
label = np.array([[43], [20], [44], [65]])
```

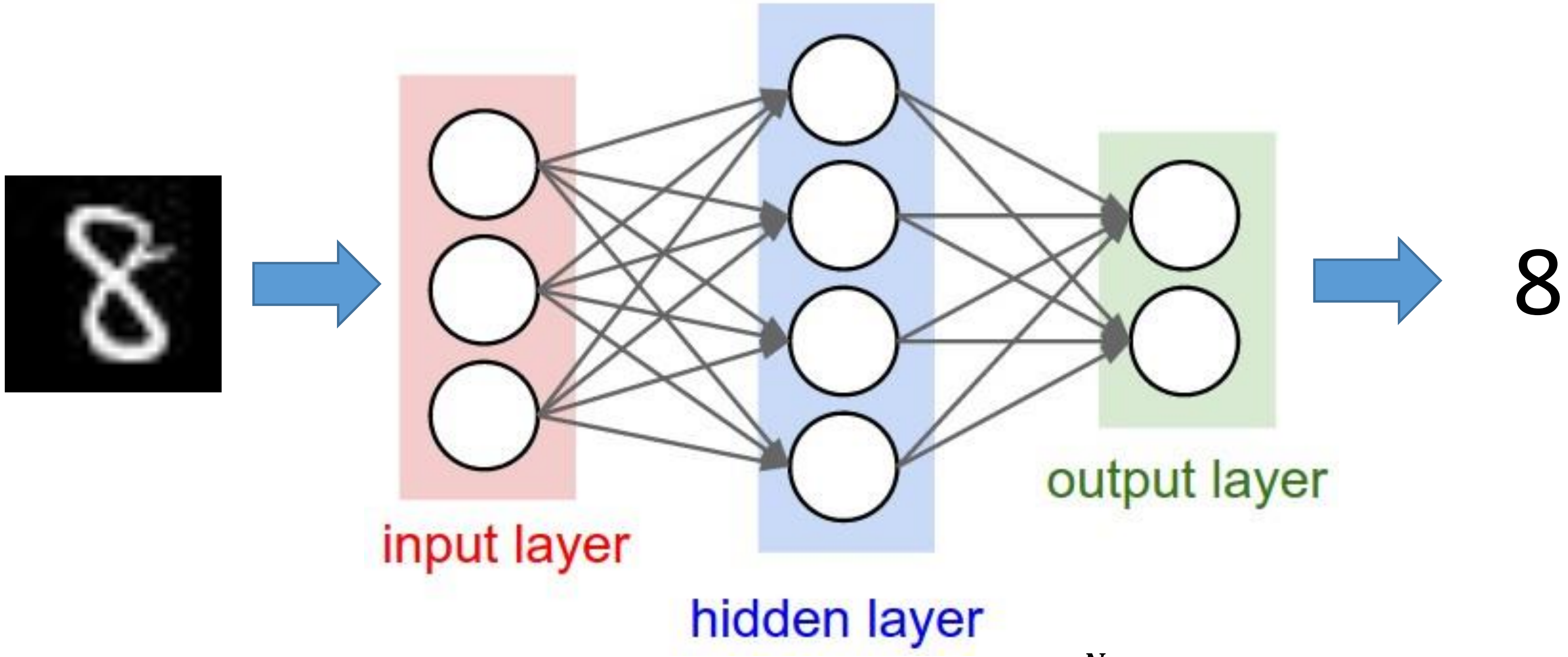
Build the graph (define your model)

In [4]:
```
[batch_size, data_dim] = data.shape
# reserve place for x and y by placeholder
x = tf.placeholder(tf.float32, [batch_size, data_dim])
y = tf.placeholder(tf.float32, [batch_size, 1])

# W and b are random initialized
W = tf.Variable(tf.random_uniform([data_dim, 1], -1, 1))
b = tf.Variable(tf.random_uniform([1], -1, 1))

# y = w*x+b
y_pred = tf.add(tf.matmul(x, W), b)

# compute the loss
loss = tf.reduce_mean(tf.square(y-y_pred))

# declare an optimizer
opt = tf.train.AdamOptimizer(learning_rate=1).minimize(loss)
```

Training and Testing

In [37]:
```
# create a session
sess = tf.Session()
# initialize variables
```

Exercise: Mnist classification using Neural Network



8

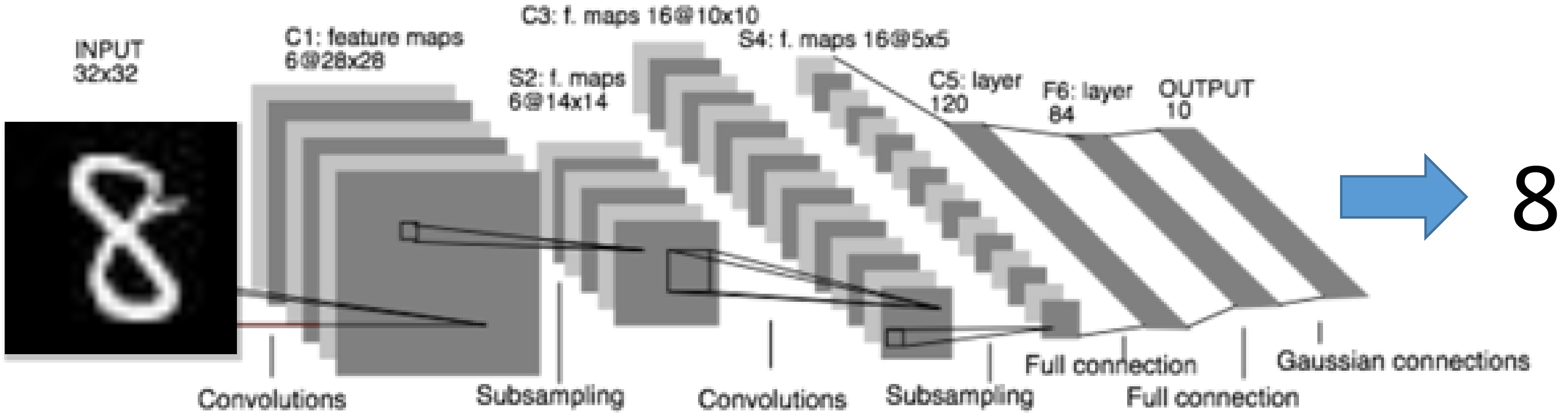
$$cross - entropy\ loss = -\sum_{i=1}^{N} y_i * \log(\widehat{y}_i)$$

y is one hot encoding of the correct class

CNN sample codes

Mnist classification using LeNet

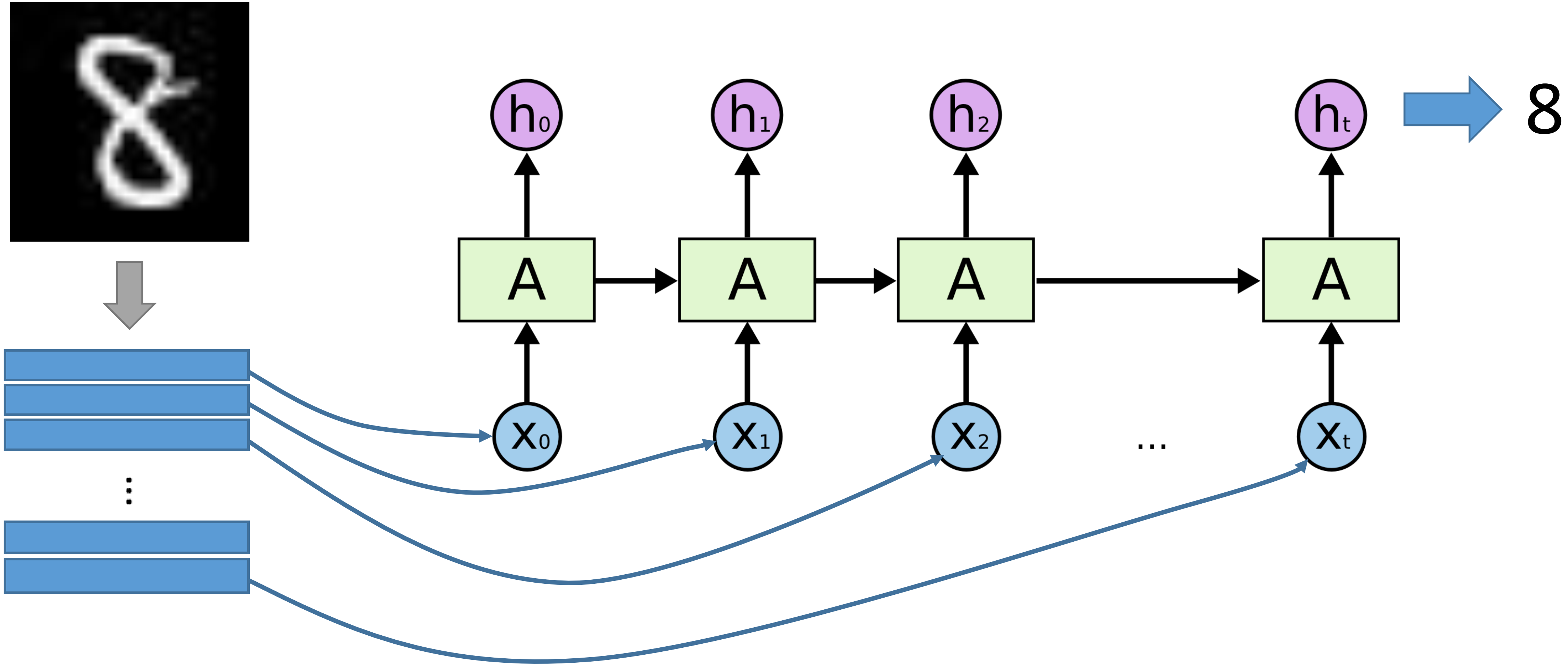
Convolutional Networks: 1989



LeNet: a layered model composed of convolution and subsampling operations followed by a holistic representation and ultimately a classifier for handwritten digits. [LeNet]

RNN sample codes

Mnist classification using RNN



h_0
h_1
h_2
h_t
8
A
A
A
A
x_0
x_1
x_2
...
x_t