Agenda

Welcome

Overview of TensorFlow

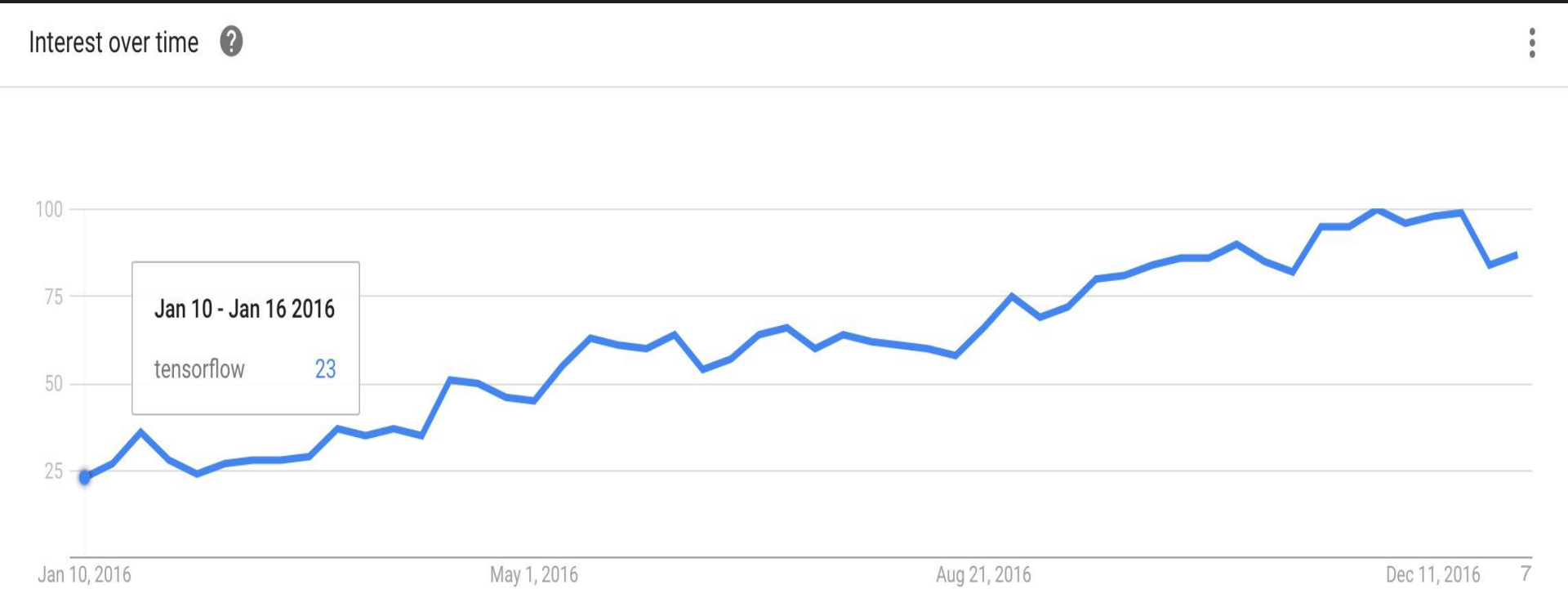
Graphs and Sessions

What's TensorFlow™?

- Open source software library for numerical computation using data flow graphs
- Originally developed by Google Brain Team to conduct machine learning and deep neural networks research
- General enough to be applicable in a wide variety of other domains as well

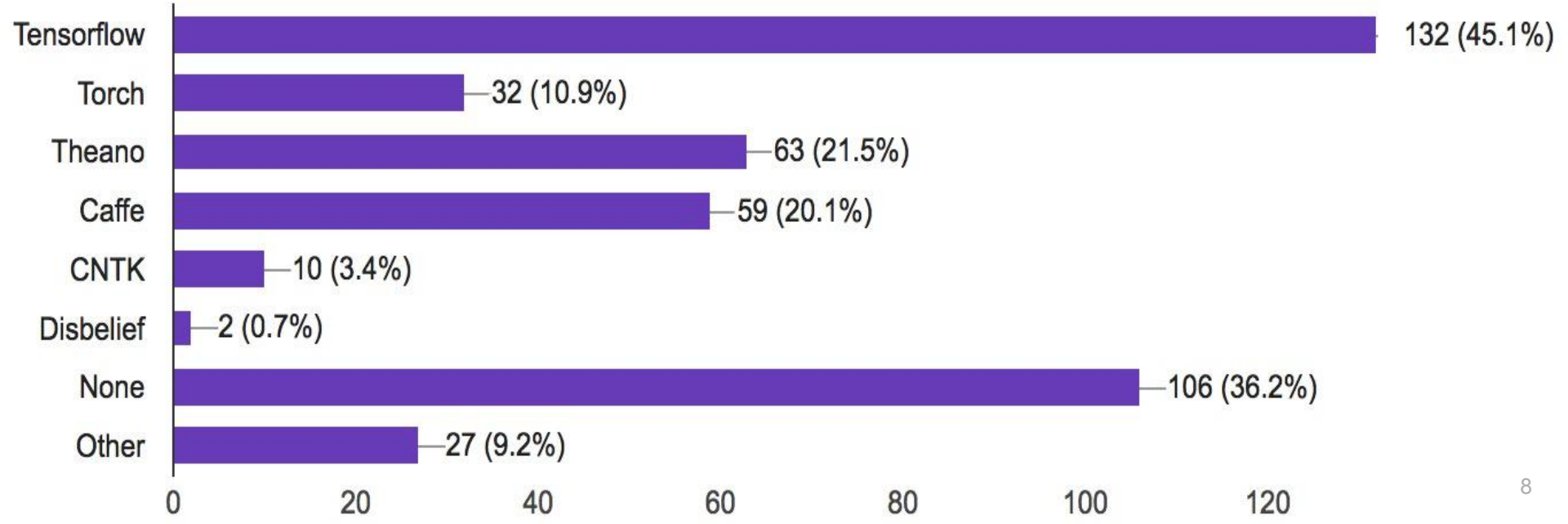
TensorFlow provides an extensive suite of functions and classes that allow users to build various models from scratch.

Launched Nov 2015

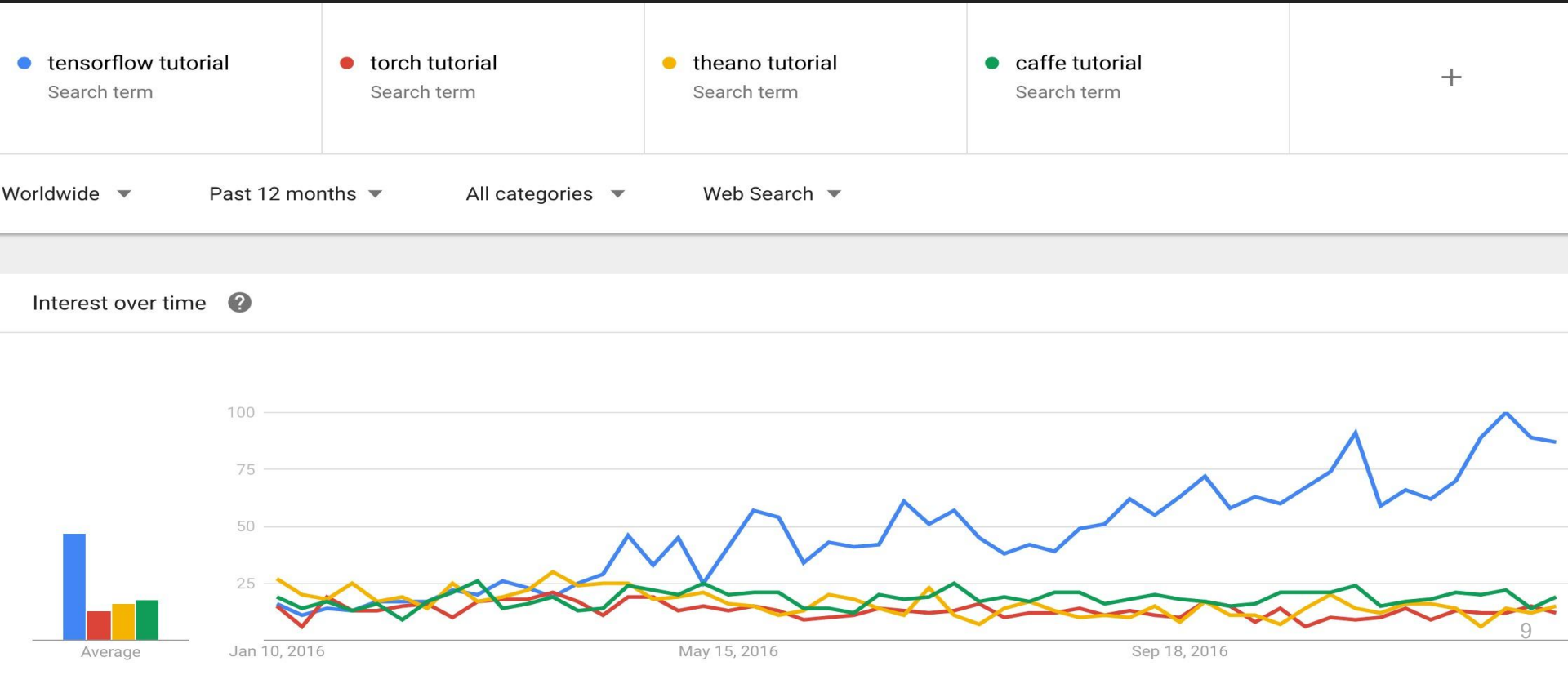


TF is not the only deep learning library

From students signed up for this class



Why TensorFlow?



Why TensorFlow?

- Python API
- Portability: deploy computation to one or more CPUs or GPUs in a desktop, server, or mobile device with a single API
- Flexibility: from Raspberry Pi, Android, Windows, iOS, Linux to server farms
- Visualization (TensorBoard is da bomb)
- Checkpoints (for managing experiments)
- Auto-differentiation *autodiff* (no more taking derivatives by hand. Yay)
- Large community (> 10,000 commits and > 3000 TF-related repos in 1 year)
- Awesome projects already using TensorFlow

Companies using Tensorflow

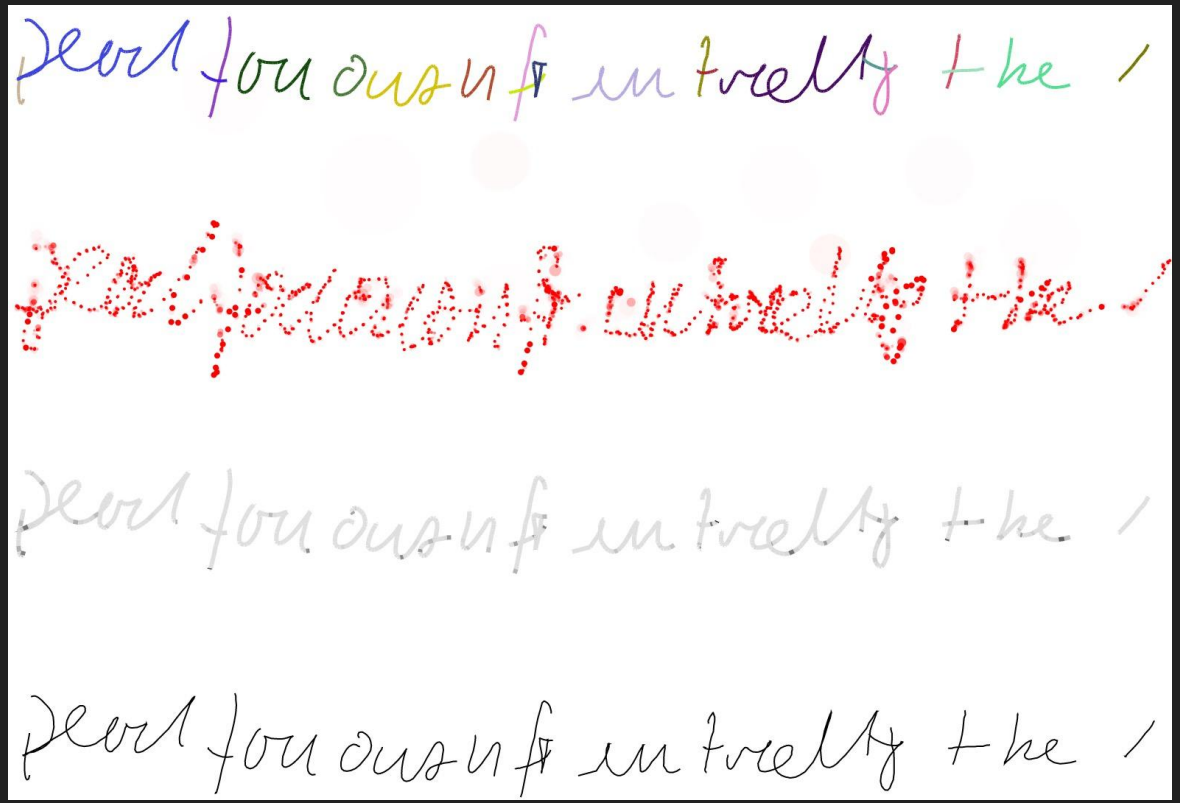
- Google
- OpenAI
- DeepMind
- Snapchat
- Uber
- Airbus
- eBay
- Dropbox
- A bunch of startups

Some cool projects using TensorFlow

Neural Style Translation

"Image Style Transfer Using Convolutional Neural Networks" by Leon A. Gatys et al. (2016)

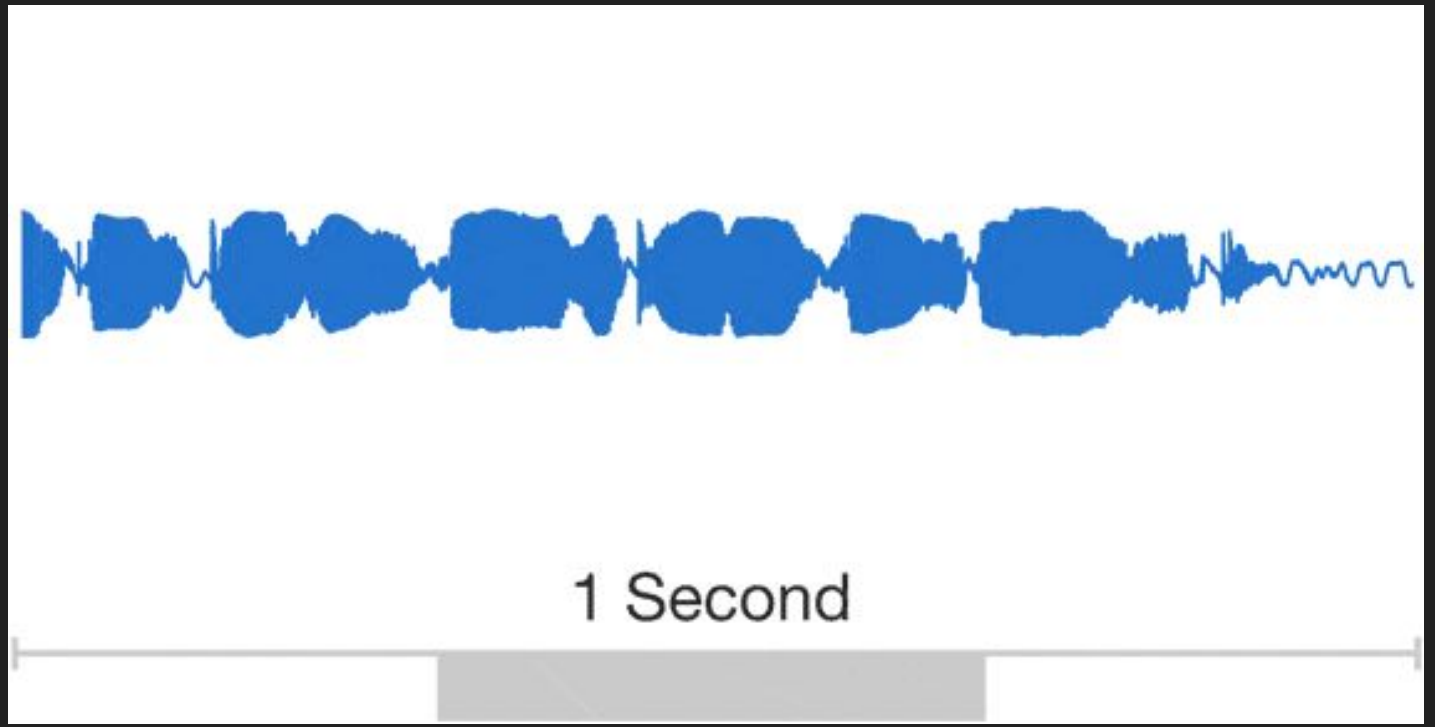
Generative Handwriting



"Generative Handwriting using LSTM Mixture Density Network with TensorFlow" by hardmaru@GitHub (2016)

WaveNet: Text to Speech

It takes several hours to synthesize 1 second!



“Wavenet: A generative model for raw audio” by Aaron van den Oord et al. (2016)

Goals

- Understand TF's computation graph approach
- Explore TF's built-in functions
- Learn how to build and structure models best suited for a deep learning project.

Introduction

Books

- TensorFlow for Machine Intelligence (TFFMI)
- Hands-On Machine Learning with Scikit-Learn and TensorFlow. Chapter 9: Up and running with TensorFlow
- Fundamentals of Deep Learning. Chapter 3: Implementing Neural Networks in TensorFlow (FODL)

TensorFlow is being constantly updated so books might become outdated fast

Check tensorflow.org directly

Getting Started

```
import tensorflow as tf
```

Simplified TensorFlow?

1. TF Learn (`tf.contrib.learn`): simplified interface that helps users transition from the the world of one-liner such as scikit-learn
2. TF Slim (`tf.contrib.slim`): lightweight library for defining, training and evaluating complex models in TensorFlow.
3. High level API: Keras, TFLearn, Pretty Tensor

But we don’t need baby TensorFlow …

Off-the-shelf models are not the main purpose of TensorFlow.

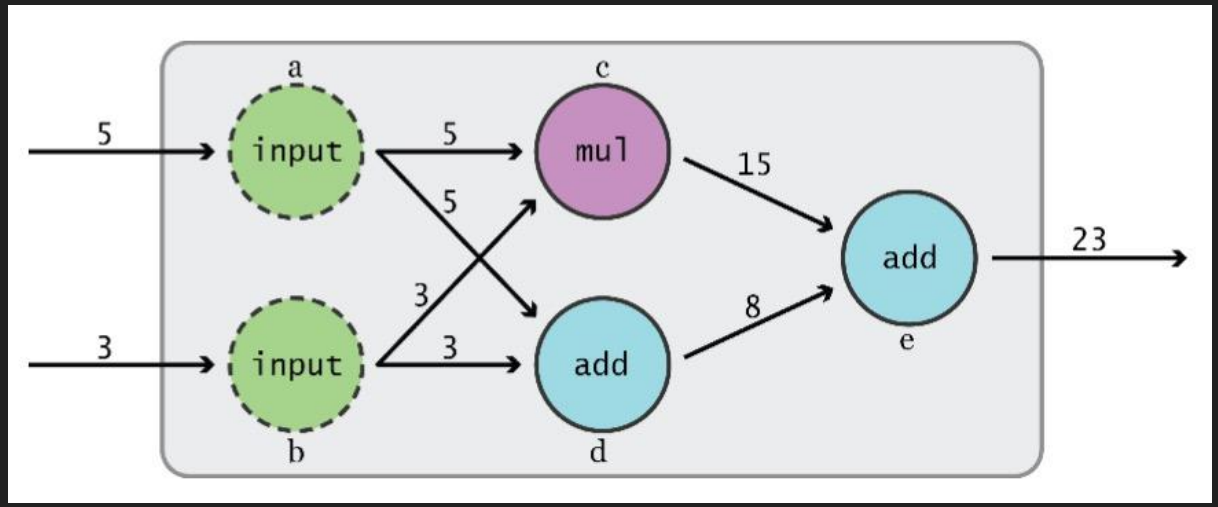
TensorFlow provides an extensive suite of functions and classes that allow users to define models from scratch.

And this is what we are going to learn.

Graphs and Sessions

Data Flow Graphs

TensorFlow separates definition of computations from their execution

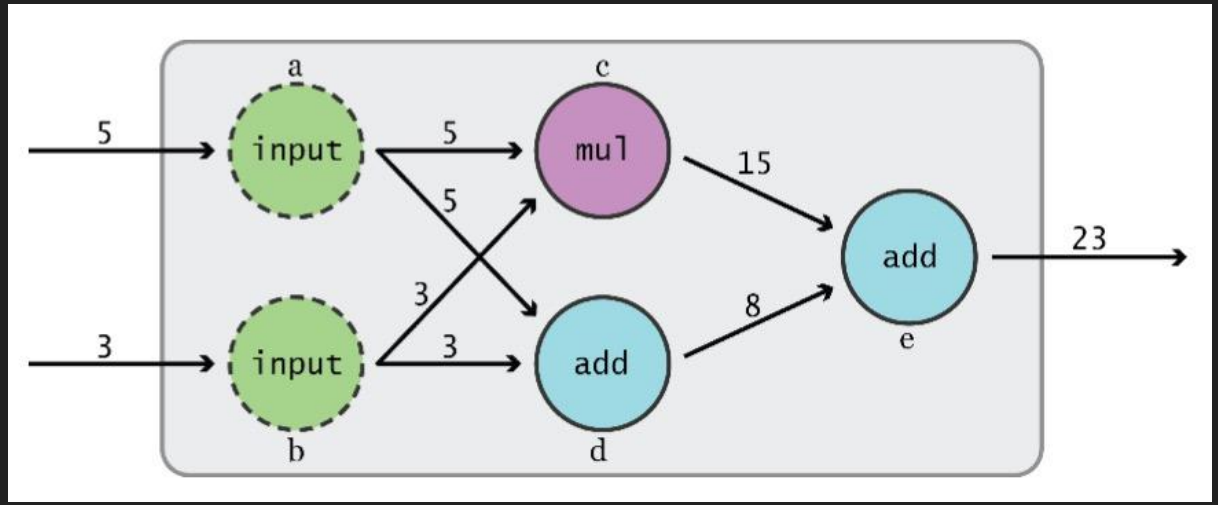


Graph by TFFMI

Data Flow Graphs

Phase 1: assemble a graph

Phase 2: use a session to execute operations in the graph.



Graph by TFFMI

What’s a tensor?

What's a tensor?

An n-dimensional matrix

0-d tensor: scalar (number)

1-d tensor: vector

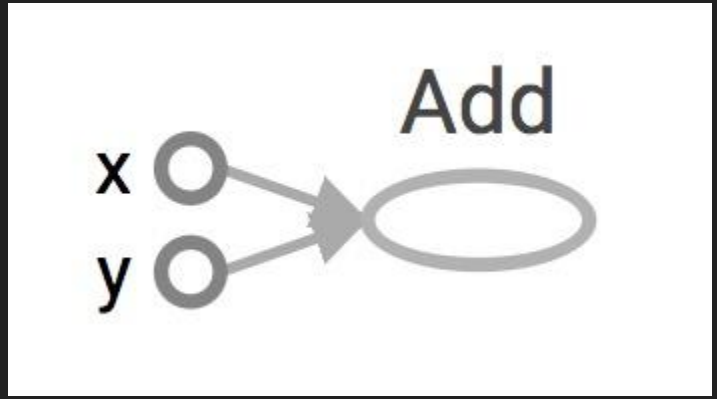
2-d tensor: matrix

and so on

Data Flow Graphs

```
import tensorflow as tf

a = tf.add(2, 3)
```

Visualized by TensorBoard



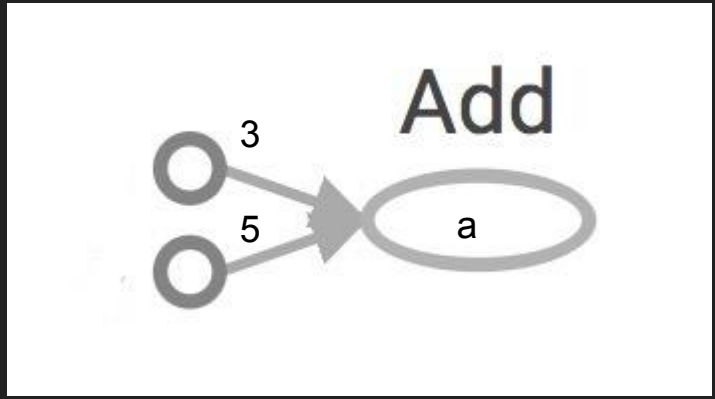
Why x, y?

TF automatically names the nodes when you don't explicitly name them. More about this next lecture! For now:
x = 3
y = 5

Data Flow Graphs

```
import tensorflow as tf

a = tf.add(3, 5)
```

Interpreted?

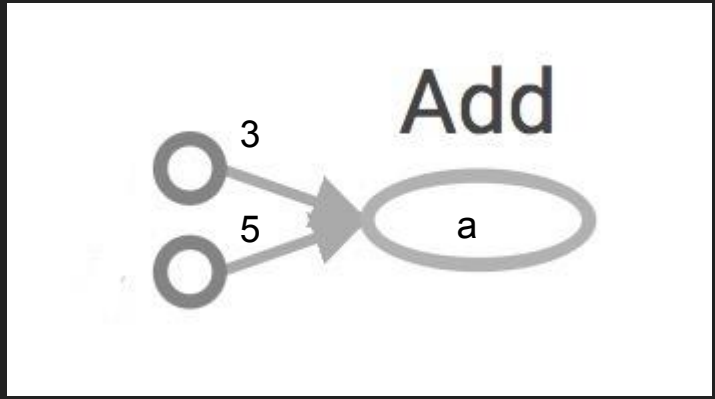


Nodes: operators, variables, and constants
Edges: tensors

Data Flow Graphs

```
import tensorflow as tf

a = tf.add(3, 5)
```

Interpreted?

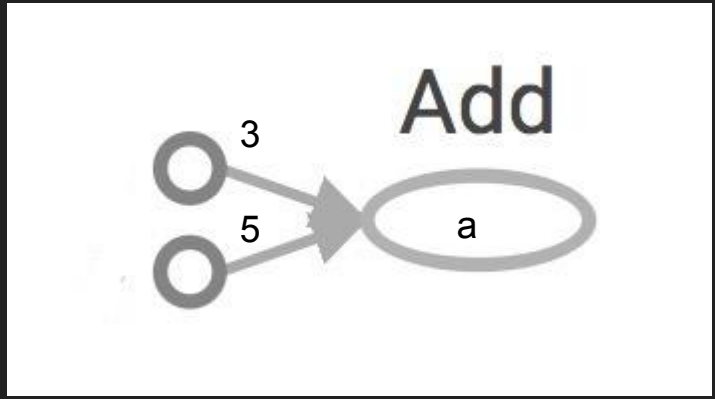


Nodes: operators, variables, and constants
Edges: tensors

Tensors are data.
Data Flow -> Tensor Flow (I know, mind=blown)

Data Flow Graphs

```
import tensorflow as tf

a = tf.add(3, 5)

print  a
```




```
>> Tensor("Add:0", shape=(), dtype=int32)
```

(Not 5)

How to get the value of a?

Create a **session**, assign it to variable sess so we can call it later

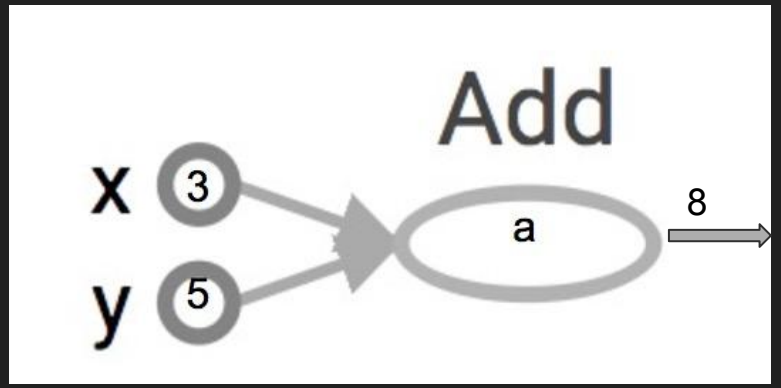
Within the session, evaluate the graph to fetch the value of a

How to get the value of a?

Create a **session**, assign it to variable sess so we can call it later

Within the session, evaluate the graph to fetch the value of a

```
import tensorflow as tf

a = tf.add(3, 5)

sess = tf.Session()

print sess.run(a)

sess.close()                    >> 8
```



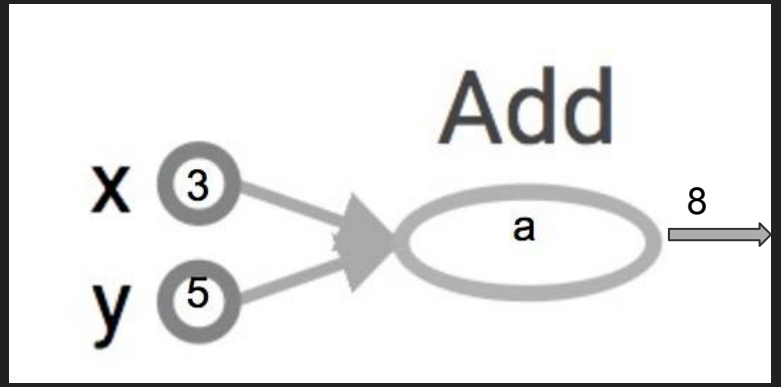
The session will look at the graph, trying to think: hmm, how can I get the value of a, then it computes all the nodes that leads to a.

How to get the value of a?

Create a session

Within the session, evaluate the graph to fetch the value of a

```
import tensorflow as tf

a = tf.add(3, 5)

# with clause takes care

# of sess.close()

with tf.Session() as sess:

     print sess.run(a)
```



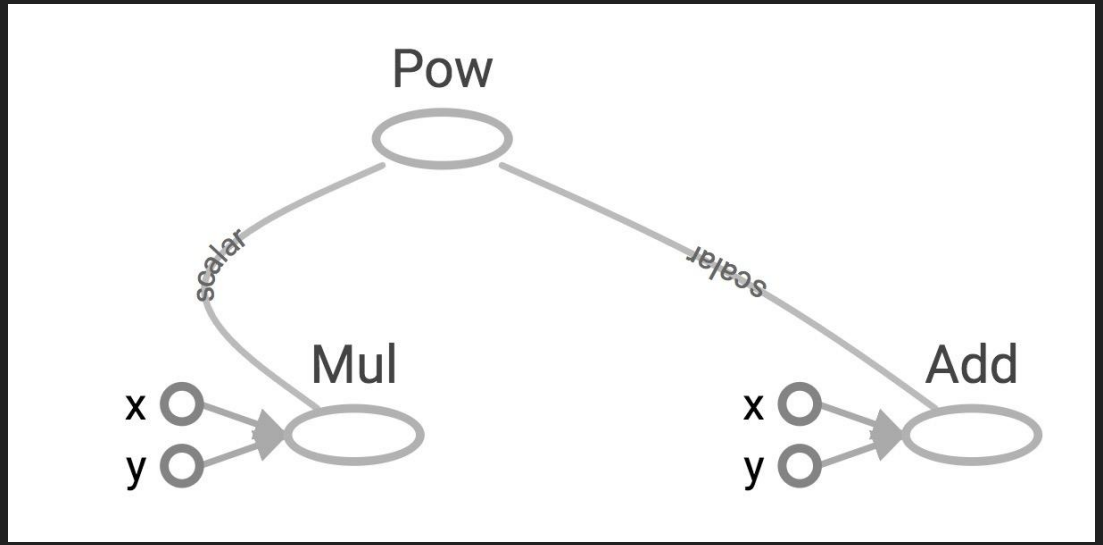
tf.Session()

A Session object encapsulates the environment in which Operation objects are executed, and Tensor objects are evaluated.

More graphs

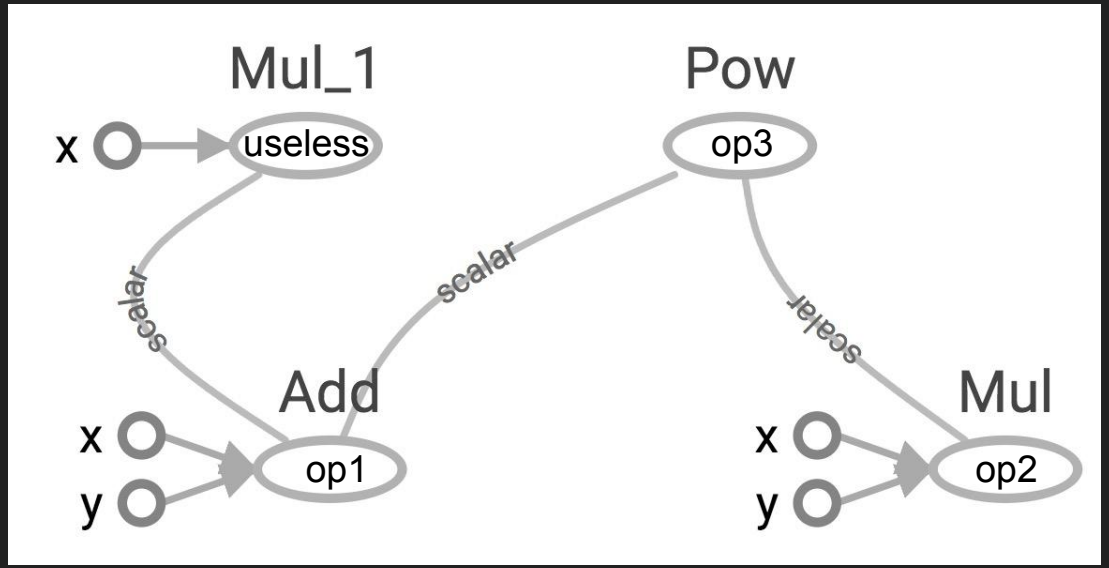
```
x = 2

y = 3

op1 = tf.add(x, y)

op2 = tf.mul(x, y)

op3 = tf.pow(op2, op1)

with tf.Session() as sess:

      op3 = sess.run(op3)
```

Visualized by TensorBoard



More (sub)graphs

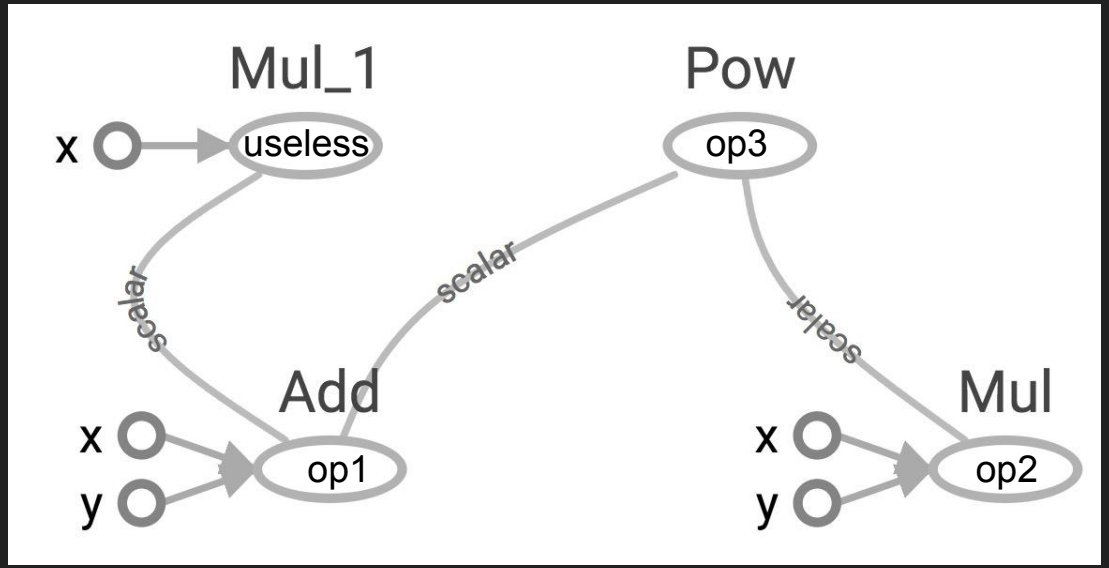
```
x = 2

y = 3

op1 = tf.add(x, y)

op2 = tf.mul(x, y)

useless = tf.mul(x, op1)

op3 = tf.pow(op2, op1)

with tf.Session() as sess:

      op3 = sess.run(op3)
```



Because we only want the value of z and z doesn't depend on useless, session won't compute values of useless
→ save computation

More (sub)graphs

```
x = 2

y = 3

op1 = tf.add(x, y)

op2 = tf.mul(x, y)

useless = tf.mul(x, op1)

op3 = tf.pow(op2, op1)

with tf.Session() as sess:

      op3, not_useless = sess.run([op3, useless])
```

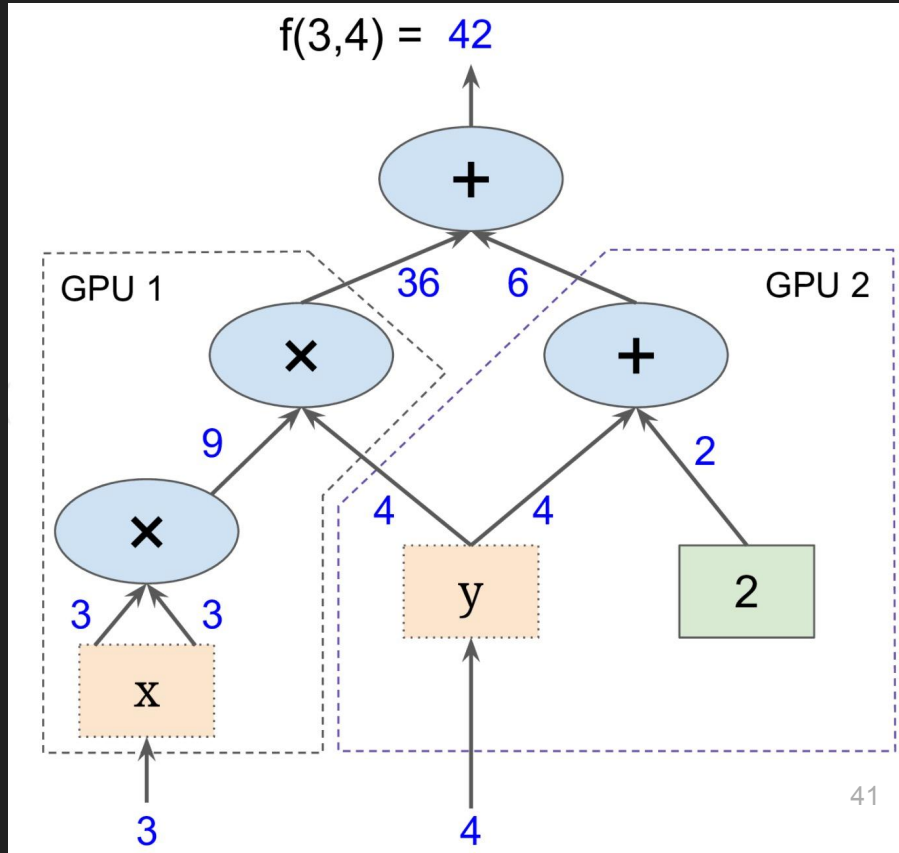



```
tf.Session.run(fetches, feed_dict=None,
options=None, run_metadata=None)
```

pass all variables whose values you want to a list in fetches

More (sub)graphs

Possible to break graphs into several chunks and run them parallelly across multiple CPUs, GPUs, or devices



Graph from the book “Hands-On Machine Learning with Scikit-Learn and TensorFlow”

Distributed Computation

To put part of a graph on a specific CPU or GPU:

```
# Creates a graph.
with tf.device('/gpu:2'):
  a = tf.constant([1.0, 2.0, 3.0, 4.0, 5.0, 6.0], name='a')
  b = tf.constant([1.0, 2.0, 3.0, 4.0, 5.0, 6.0], name='b')
  c = tf.matmul(a, b)

# Creates a session with log_device_placement set to True.
sess = tf.Session(config=tf.ConfigProto(log_device_placement=True))

# Runs the op.
print sess.run(c)
```

Don’t worry about this yet.
More on this in week 8!

What if I want to build more than one graph?

You can
but you don’t need more than one graph
The session runs the default graph

But what if I really want to?

URGH, NO

- Multiple graphs require multiple sessions, each will try to use all available resources by default
- Can't pass data between them without passing them through python/numpy, which doesn't work in distributed
- It’s better to have disconnected subgraphs within one graph

I insist …

tf.Graph()

create a graph:

```
g = tf.Graph()
```

tf.Graph()

to add operators to a graph, set it as default:

```
g = tf.Graph()

with g.as_default():

      x = tf.add(3, 5)



sess = tf.Session(graph=g)

with tf.Session() as sess:

      sess.run(x)
```

tf.Graph()

to add operators to a graph, set it as default:

```
g = tf.Graph()
with g.as_default():
      a = 3
      b = 5
      x = tf.add(a, b)
sess = tf.Session(graph=g) # session is run on the graph g
# run session
sess.close()
```

Same as previous

tf.Graph()

To handle the default graph:

```
g = tf.get_default_graph()
```

tf.Graph()

Do not mix default graph and user created graphs

```
g = tf.Graph()

# add ops to the default graph

a = tf.constant(3)

# add ops to the user created graph

with g.as_default():

     b = tf.constant(5)
```

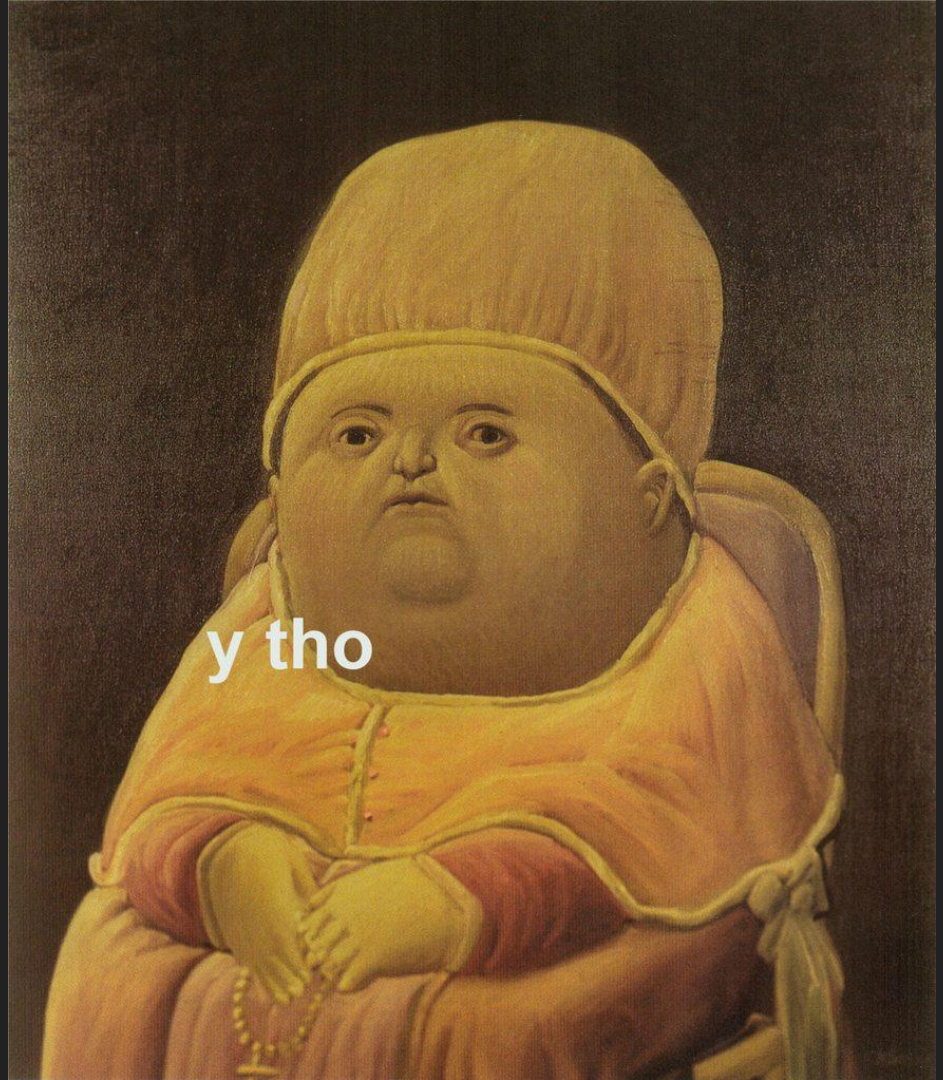
Prone to errors

tf.Graph()

Do not mix default graph and user created graphs

```
g1 = tf.get_default_graph()

g2 = tf.Graph()

# add ops to the default graph

with g1.as_default():

     a = tf.Constant(3)

# add ops to the user created graph

with g2.as_default():

     b = tf.Constant(5)
```

Better
But still not good enough because no more than one graph!


y tho

Why graphs

1. Save computation (only run subgraphs that lead to the values you want to fetch)
2. Break computation into small, differential pieces to facilitates auto-differentiation
3. Facilitate distributed computation, spread the work across multiple CPUs, GPUs, or devices
4. Many common machine learning models are commonly taught and visualized as directed graphs already

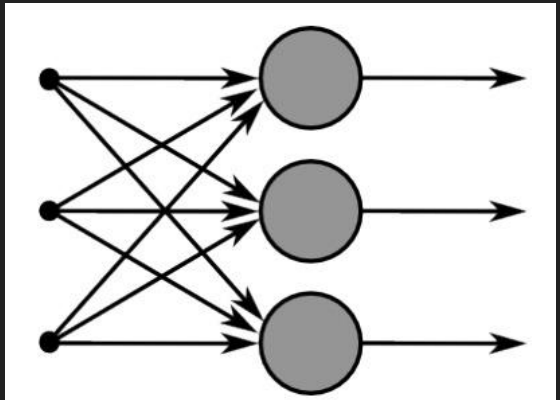


Figure 3: This image captures how multiple sigmoid units are stacked on the right, all of which receive the same input x.

A neural net graph by Richard Socher (CS224D)