# The introduction of Tensorflow with Python

## Parallel session of UCSAS 2020

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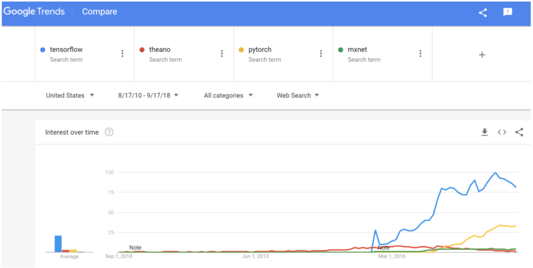
# Advantage

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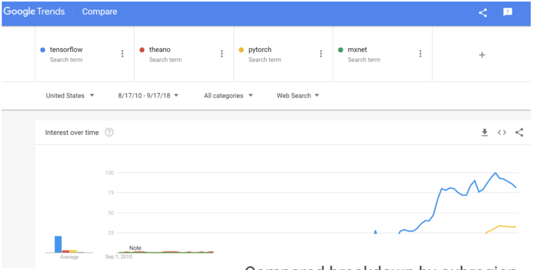
# Advantage


Google Trends
Compare
tensorflow
Search term
theano
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United States
8/17/10 - 9/17/18
All categories
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Interest over time
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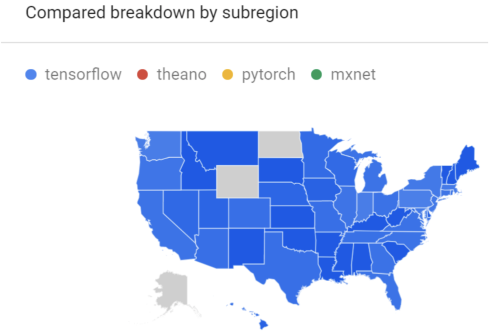
Compared breakdown by subregion
tensorflow
theano
pytorch
mxnet

# What is Tensor?

- Tensor is the data with dimension.
- 0-d tensor: scalar

$$c = 5$$

- 1-d tensor: vector

$$\mathrm{c} = \begin{pmatrix} 1 \\ \vdots \\ 5 \end{pmatrix}$$

- 2-d tensor: matrix

$$\mathrm{c} = \begin{pmatrix} 1 & \cdots & 5 \\ \vdots & \ddots & \vdots \\ 5 & \cdots & 5 \end{pmatrix}$$

# Why Tensor special?

- Vector and matrix operations are dominant in machine learning and deep learning.

Example

$$(GD) : \hat{\beta}^{(t+1)} = \hat{\beta}^{(t)} - \gamma \nabla E_n \left[ \ell \left( y, \hat{y} \left( \hat{\beta}^{(t)} \right) \right) \right]$$

- GPU structure leads to a powerful ability to solve linear tensor operations.

# How to install Tensorflow in Python

- Anaconda management (GUI): click "environment" –> choose "Not installed" –> search "tensorflow"
- Anaconda Prompt:

  `conda install tensorflow`

- Pip:

  `pip install tensorflow`

- Verify whether your installation is successful: (open jupyter notebook or run at .py file)

```
import tensorflow as tf
import tensorflow.compat.v1 as tfv1
tf.__version__
```

# 3 key concepts in tensorflow programming

- Operations: Data operations like "matmul" (matrix multiplication), "add".
- Graph: Build GRAPH which represents the data flow of the computation.
- Session: Run SESSION which executes the operations on the graph.

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  multiplication),
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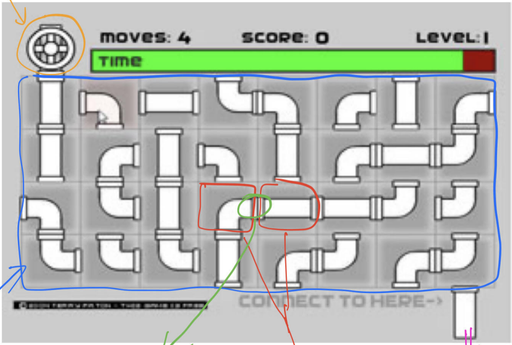
  graph.

tf. Session ( )




Graph.

Operation:
e.g. add, matrix multiply

Nodes
e.g. constants, variables

obtain result

# Basic widget: Constant

The constant can be either scalar, vector, or matrix. It is just a concept which is opposite with variable. Variable can be changed in the future by using tf.assign() method, while the constant can not.

```
s = tf.constant(2)
m = tf.constant([[1,2],[3,4]])
m = tf.constant([1,2,3,4],shape=[2,2])
```

With these two node, we can conduct a GRAPH and SESSION example. Here we use "tensorboard" for GRAPH and tf.Session() function for SESSION.

# A simplest graph and session

```
g = tf.Graph()
with g.as_default():
    s = tf.constant(2)
    m = tf.constant([[1,2],[3,4]])
    mmul = s*m
g
```

Here, we have already completed a graph, to "open the faucet", we use tf.Session(), like:

```
with tfv1.Session(graph=g) as sess:
    print(sess.run(mmul))
```

Finally, we get the result. Remark: The tf.Session() only exist in tensorflow v1, so we call this function under v1 platform.

# Basic widget: Variable

Variables are used to hold and update parameters. Another important difference with the constant is that it be treated as variable in the calculation of gradient. To create a variable,

```
w = tf.Variable(tf.ones((2,2))) # 2*2 matrix with all elements as 1
```

**Alert**

The variable must be initialized immediately after "the data faucet is open" (i.e. tfv1.Session()).

```
with tfv1.Session() as sess:
    sess.run(tfv1.global_variables_initializer())
    print(sess.run(w))
```

# Basic widget: Variable

As we mentioned earlier, variable can be assigned with a new value.

```
with tfv1.Session() as sess:
    sess.run(tfv1.global_variables_initializer())
    print(sess.run(w))
    # Change w to a 2*2 matrix with all elements as 0
    sess.run(w.assign(tf.zeros((2,2))))
    print(sess.run(w))
```

# Basic widget: Placeholder

We can notice that although variable is more flexible than constant, it still need a initial value. In practice, sometimes the value of a parameter is determined by the actual data. So we need the placeholder to tell the PC, there is a variable, but I don't tell you the value, I will give you the value when I open the data faucet.

```
import numpy as np
node1 = tfv1.placeholder(tf.float32,shape = [1,2])
node2 = tfv1.placeholder(tf.float32,shape = [1,2])
w_linear = tf.matmul(node1,w) + node2
with tfv1.Session() as sess:
    sess.run(tfv1.global_variables_initializer())
    print(sess.run(w))
    print(sess.run(w_linear,feed_dict={node1:np.matrix([1.0,2.0]),
        node2:np.matrix([1.0,2.0])}))
```

# Basic Operations

Given $x$ and $y$,

- x+y (element-wise): tf.add(x,y)
- x-y (element-wise): tf.subtract(x,y)
- x*y (element-wise): tf.multiply(x,y)
- x/y (element-wise): tf.divide(x,y)
- x*y (matrix style): tf.matmul(x,y)
- x<y (judgment): tf.less(x,y)
- x>y (judgment): tf.greater(x,y)
- x<=y (judgment): tf.less_equal(x,y)

# Gradient

One of the most powerful thing for the Tensorflow is that it can calculate the gradient with a high flexibility and high speed. The core lines are:

```
with tf.GradientTape() as tape:
        y1 = <Expression of x1, x2,...>
        y2 = <Expression of y1>
tape.gradient(y2,[x1,x2,...])
```

It returns the gradients of y2 with respect to x1, x2,... separately.

**Alert**

The gradient operation can only return value when it is with respect to a trainable variable.

# Gradient

```
x = tf.Variable(3.0)
with tf.GradientTape() as tape:
  y = x**2
dy_dx = tape.gradient(y, x)
# dy = 2x * dx
with tfv1.Session() as sess:
    sess.run(tfv1.global_variables_initializer())
    print(sess.run(dy_dx))
```

# Basic Logic: If

The core line is:

```
tf.cond(tf_statement,A,B)
```

It implement a function that if tf_statement is true, then run A, otherwise, run B. By the way, it we want to choose from options more than 2, we can use tf.switch_case() function, that is not included in this session.

## Example

```
t1 = tf.constant(1)
t2 = tf.constant(2)
def f1(): return t1+t2
def f2(): return t1-t2
res = tf.cond(t1<t2,f1,f2)
with tfv1.Session() as sess:
        print(sess.run(res))
```

It will return 1+2 as 1 is indeed less than 2.

# Basic Logic: While

The core line is:

```
tf.while_loop(tf_statement,body,variables)
```

It implement a function that if tf_statement is true, then run body, until tf_statement is false. The variables position need a tuple or list including all the tensorflow variables needed in the body part and tf_statement part. The loop will return the variables after the final iteration.

## Example

```
t1 = tf.constant(1)
t2 = tf.constant(5)
body = (tf.add(t1,1),t2)
def cond(t1,t2): return t1<t2
def body(t1,t2):
    t1 = tf.add(t1,1)
    return (t1,t2)
res = tf.while_loop(cond,body,(t1,t2))
with tfv1.Session() as sess:
    print(sess.run(res))
```

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# Framework

With all the knowledge we have learned, we now turn to something practical. Generally, we'd like the model training and model predicting to be simple, we prefer a using style likes the following:

```
model = model_creation_function()
```

Firstly, we use a certain model_creation_function to implement the initialization of variables and parameters we need, actually, it create a *class* data in Python. Then:

```
model.fit(x=...,y=...)
```

we hope this class type model hold a function called "fit", and the input should be $x$ and $y$ (in most cases of supervised learning). Finally,

```
predict_value = model.predict(x=...)
```

we also hope this class type model hold functions for prediction, evaluation and etc.

# Linear Regression Excercise

Given $\mathrm{X} \in \mathrm{R}^{n*2}$ and $Y \in R^n$, find a $\beta \in R^2$ which is the OLS estimator for model

$$Y = X\beta + \varepsilon, \varepsilon \sim N\left(0, \sigma^2\right).$$

Key idea:

Implement the (loss) objective function:

$$L(\beta) = \|Y - X\beta\|^2.$$

Give any initial value $\hat{\beta}^{(0)} = (0, 0)^T$ and use the Gradient Descent method. The solution of this excercise is attached in the code directory. Thank you for listening.

# Useful info

The material of this session is in Session Material.

Our department website is Department of Statistics.

Our website for statistical data science lab at Uconn is Data Science Lab