Constants and variables

INTRODUCTION TO TENSORFLOW IN PYTHON



Isaiah Hull Economist



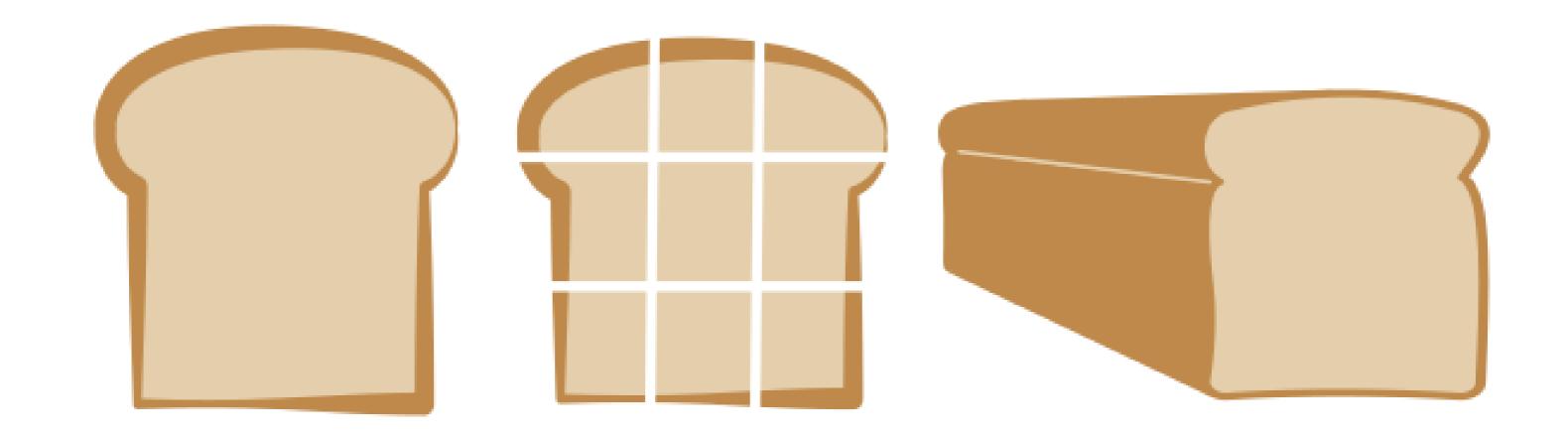
What is TensorFlow?

- Open-source library for graph-based numerical computation
 - Developed by the Google Brain Team
- Low and high level APIs
 - Addition, multiplication, differentiation
 - Machine learning models
- Important changes in TensorFlow 2.0
 - Eager execution by default
 - Model building with Keras and Estimators

What is a tensor?

- Generalization of vectors and matrices
- Collection of numbers
- Specific shape

What is a tensor?



Source: Public Domain Vectors

Defining tensors in TensorFlow

```
import tensorflow as tf
# 0D Tensor
d\theta = tf.ones((1,))
# 1D Tensor
d1 = tf.ones((2,))
# 2D Tensor
d2 = tf.ones((2, 2))
# 3D Tensor
d3 = tf.ones((2, 2, 2))
```



Defining tensors in TensorFlow

```
# Print the 3D tensor
print(d3.numpy())
```

```
[[[1. 1.]
[1. 1.]]
[[1. 1.]
[1. 1.]]]
```

Defining constants in TensorFlow

- A constant is the simplest category of tensor
 - Not trainable
 - Can have any dimension

```
from tensorflow import constant

# Define a 2x3 constant.
a = constant(3, shape=[2, 3])

# Define a 2x2 constant.
b = constant([1, 2, 3, 4], shape=[2, 2])
```

Using convenience functions to define constants

Operation	Example
tf.constant()	constant([1, 2, 3])
tf.zeros()	zeros([2, 2])
tf.zeros_like()	<pre>zeros_like(input_tensor)</pre>
tf.ones()	ones([2, 2])
tf.ones_like()	<pre>ones_like(input_tensor)</pre>
tf.fill()	fill([3, 3], 7)

Defining and initializing variables

```
import tensorflow as tf
# Define a variable
a0 = tf.Variable([1, 2, 3, 4, 5, 6], dtype=tf.float32)
a1 = tf.Variable([1, 2, 3, 4, 5, 6], dtype=tf.int16)
# Define a constant
b = tf.constant(2, tf.float32)
# Compute their product
c0 = tf.multiply(a0, b)
c1 = a0*b
```

Let's practice!

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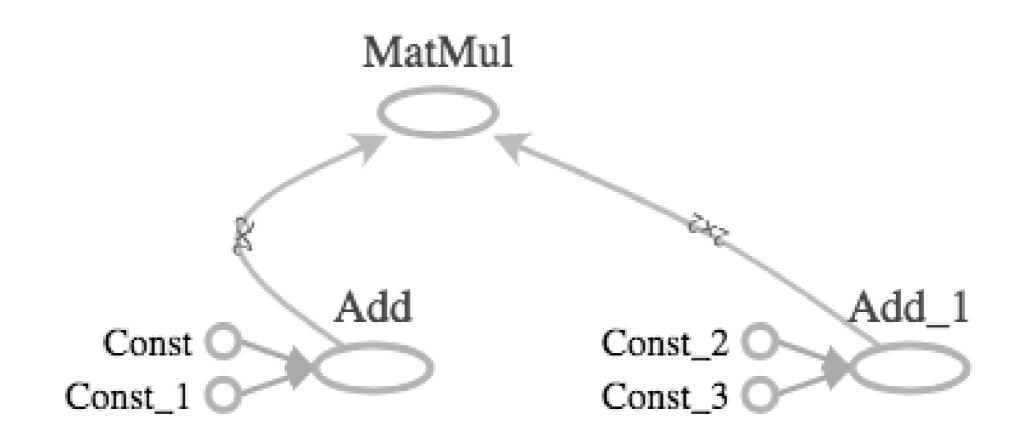
Basic operations

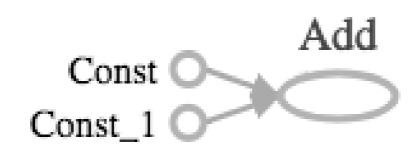
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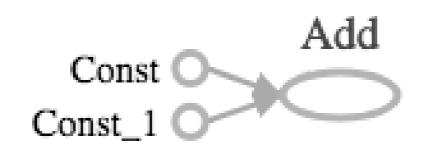


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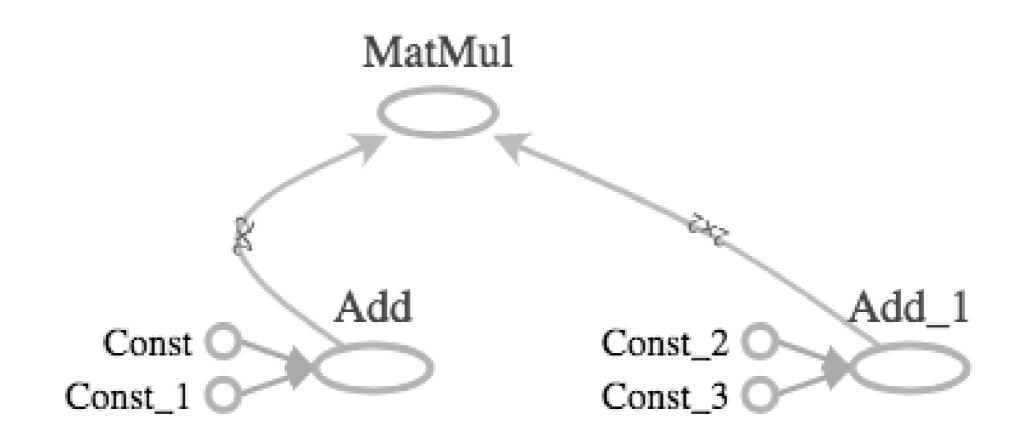












Applying the addition operator

```
#Import constant and add from tensorflow
from tensorflow import constant, add
# Define 0-dimensional tensors
A0 = constant([1])
B0 = constant([2])
# Define 1-dimensional tensors
A1 = constant([1, 2])
B1 = constant([3, 4])
# Define 2-dimensional tensors
A2 = constant([[1, 2], [3, 4]])
B2 = constant([[5, 6], [7, 8]])
```



Applying the addition operator

```
# Perform tensor addition with add()
C0 = add(A0, B0)
C1 = add(A1, B1)
C2 = add(A2, B2)
```

Performing tensor addition

- The add() operation performs element-wise addition with two tensors
- Element-wise addition requires both tensors to have the same shape:
 - \circ Scalar addition: 1+2=3
 - $\circ \quad \text{Vector addition:} \ [1,2] + [3,4] = [4,6]$
 - \circ Matrix addition: $egin{bmatrix} 1 & 2 \ 3 & 4 \end{bmatrix} + egin{bmatrix} 5 & 6 \ 7 & 8 \end{bmatrix} = egin{bmatrix} 6 & 8 \ 10 & 12 \end{bmatrix}$
- The add() operator is overloaded

How to perform multiplication in TensorFlow

- Element-wise multiplication performed using multiply() operation
 - The tensors multiplied must have the same shape
 - E.g. [1,2,3] and [3,4,5] or [1,2] and [3,4]
- Matrix multiplication performed with matmul() operator
 - The matmul(A,B) operation multiplies A by B
 - Number of columns of A must equal the number of rows of B

Applying the multiplication operators

```
# Import operators from tensorflow
from tensorflow import ones, matmul, multiply

# Define tensors
A0 = ones(1)
A31 = ones([3, 1])
A34 = ones([3, 4])
A43 = ones([4, 3])
```

- What types of operations are valid?
 - multiply(A0, A0), multiply(A31, A31), and multiply(A34, A34)
 - o matmul(A43, A34), but not matmul(A43, A43)

Summing over tensor dimensions

The reduce_sum() operator sums over the dimensions of a tensor
 reduce_sum(A) sums over all dimensions of A
 reduce_sum(A, i) sums over dimension i

```
# Import operations from tensorflow
from tensorflow import ones, reduce_sum

# Define a 2x3x4 tensor of ones
A = ones([2, 3, 4])
```

Summing over tensor dimensions

```
# Sum over all dimensions
B = reduce_sum(A)

# Sum over dimensions 0, 1, and 2

B0 = reduce_sum(A, 0)

B1 = reduce_sum(A, 1)

B2 = reduce_sum(A, 2)
```

Let's practice!

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Advanced operations

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Overview of advanced operations

We have covered basic operations in TensorFlow

```
o add(), multiply(), matmul(), and reduce_sum()
```

- In this lesson, we explore advanced operations
 - o gradient() , reshape() ,and random()

Overview of advanced operations

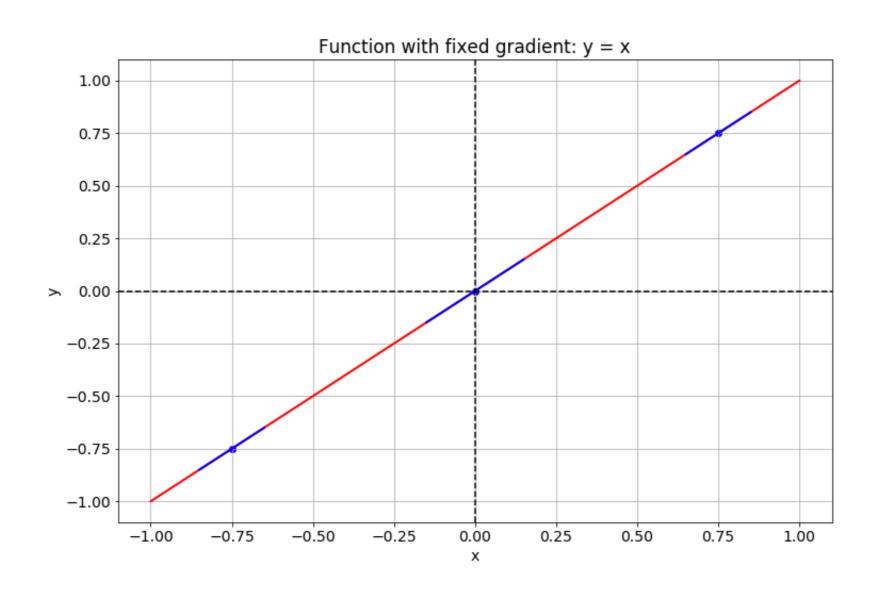
Operation	Use
gradient()	Computes the slope of a function at a point
reshape()	Reshapes a tensor (e.g. 10x10 to 100x1)
random()	Populates tensor with entries drawn from a probability distribution



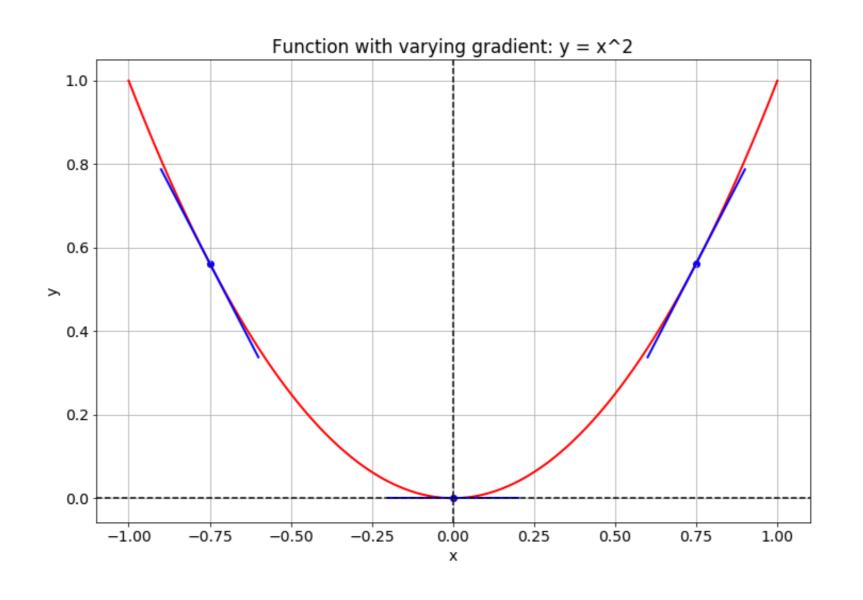
Finding the optimum

- In many problems, we will want to find the optimum of a function.
 - Minimum: Lowest value of a loss function.
 - Maximum: Highest value of objective function.
- We can do this using the gradient() operation.
 - Optimum: Find a point where gradient = 0.
 - Minimum: Change in gradient > 0
 - Maximum: Change in gradient < 0

Calculating the gradient



Calculating the gradient



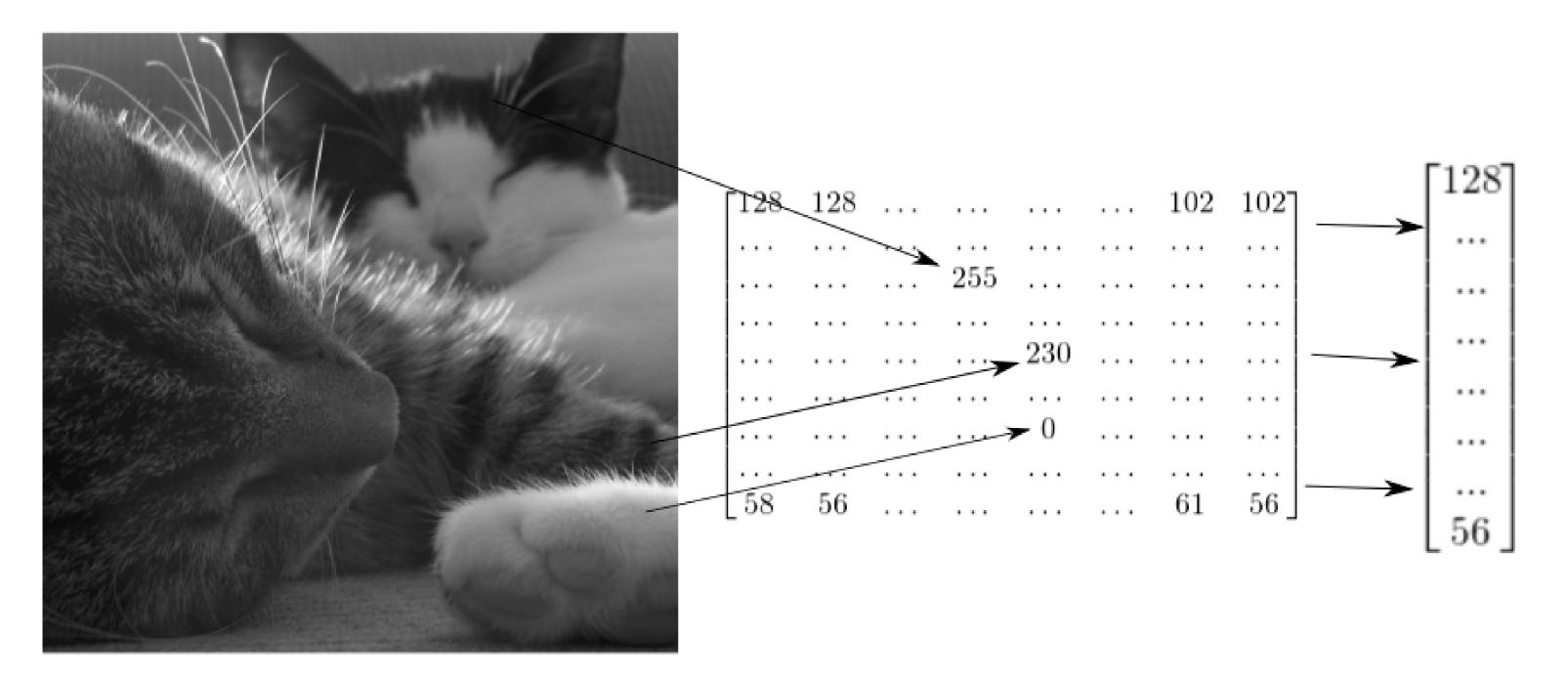
Gradients in TensorFlow

```
# Import tensorflow under the alias tf
import tensorflow as tf
# Define x
x = tf.Variable(-1.0)
# Define y within instance of GradientTape
with tf.GradientTape() as tape:
    tape.watch(x)
    y = tf.multiply(x, x)
# Evaluate the gradient of y at x = -1
g = tape.gradient(y, x)
print(g.numpy())
```

-2.0



Images as tensors

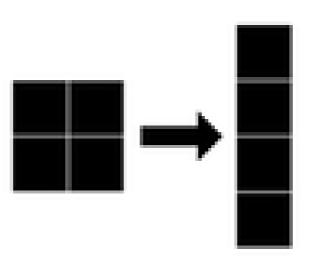


How to reshape a grayscale image

```
# Import tensorflow as alias tf
import tensorflow as tf

# Generate grayscale image
gray = tf.random.uniform([2, 2], maxval=255, dtype='int32')

# Reshape grayscale image
gray = tf.reshape(gray, [2*2, 1])
```

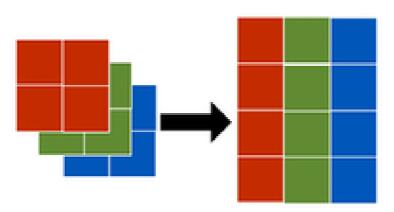


How to reshape a color image

```
# Import tensorflow as alias tf
import tensorflow as tf

# Generate color image
color = tf.random.uniform([2, 2, 3], maxval=255, dtype='int32')

# Reshape color image
color = tf.reshape(color, [2*2, 3])
```



Let's practice!

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