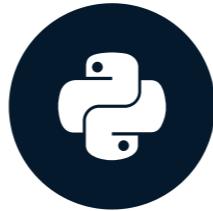


Dense layers

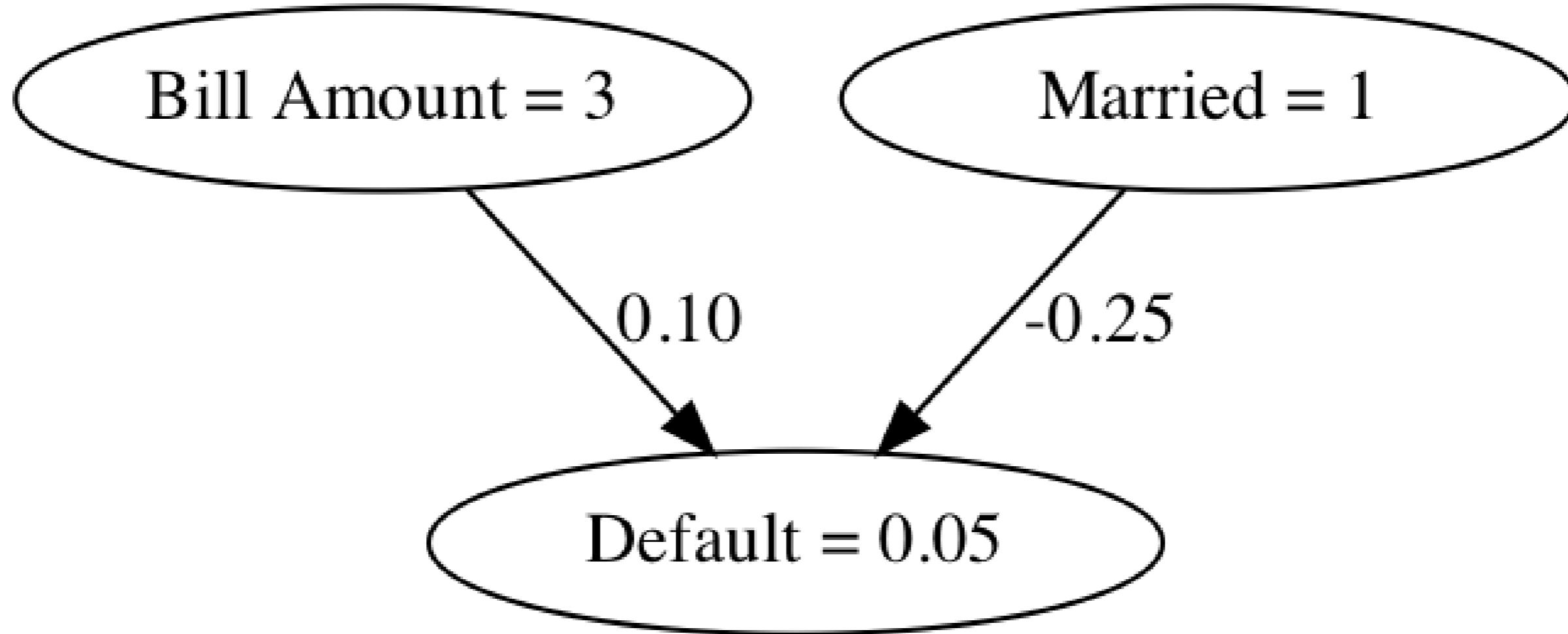
INTRODUCTION TO TENSORFLOW IN PYTHON



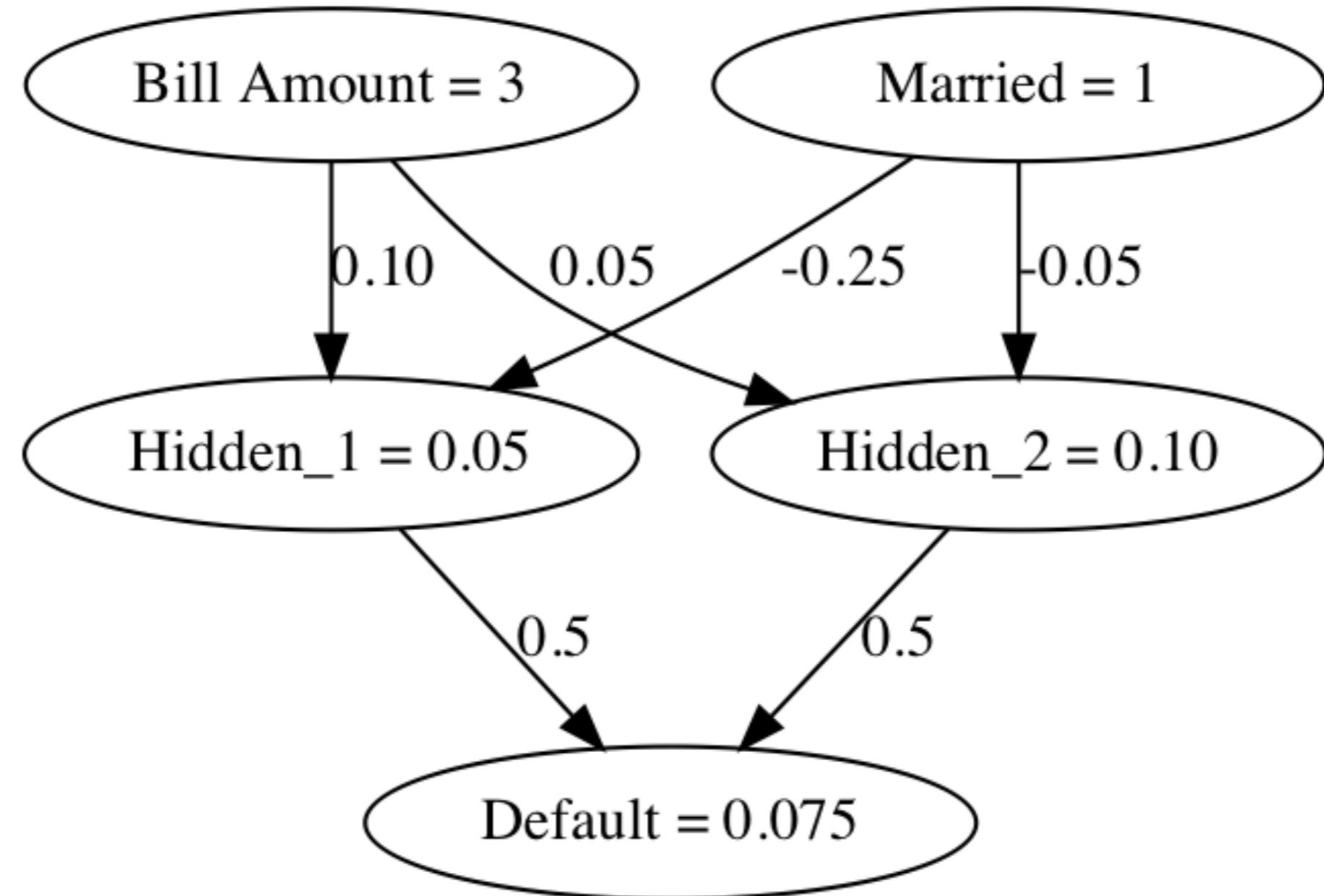
Isaiah Hull

Visiting Associate Professor of Finance,
BI Norwegian Business School

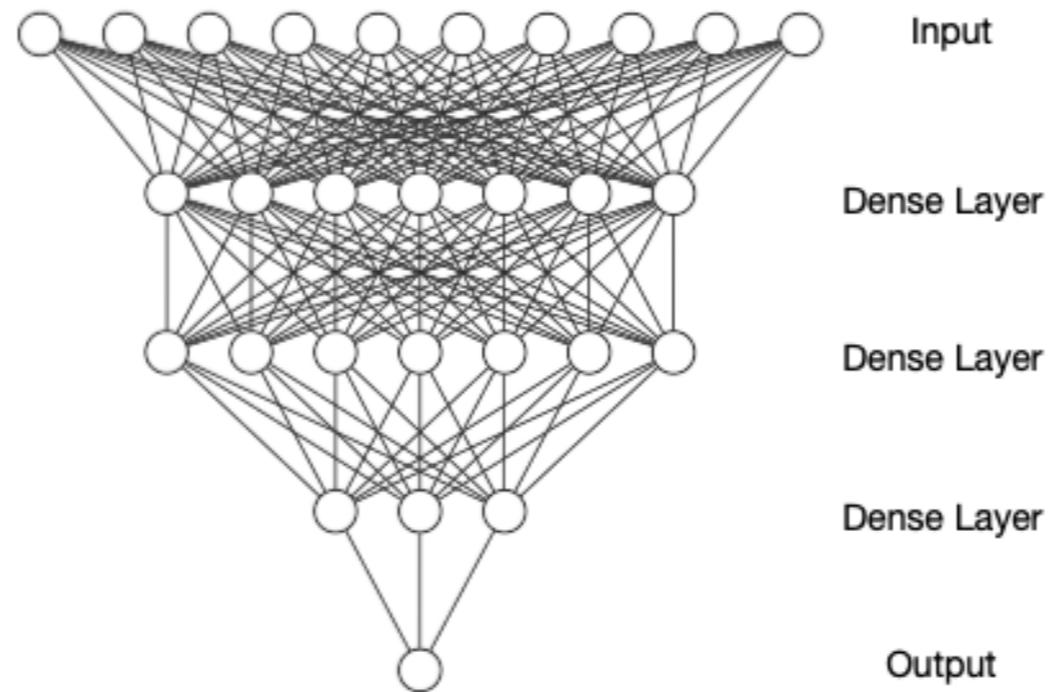
The linear regression model



What is a neural network?



What is a neural network?



- A dense layer applies weights to all nodes from the previous layer.

A simple dense layer

```
import tensorflow as tf
```

```
# Define inputs (features)
inputs = tf.constant([[1, 35]])
```

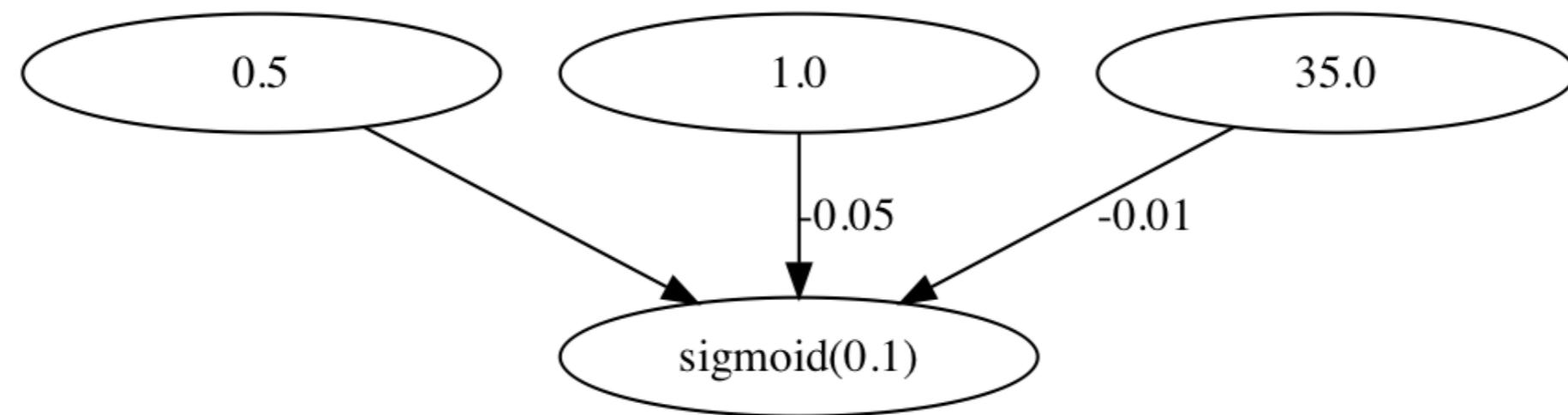
```
# Define weights
weights = tf.Variable([[-0.05], [-0.01]])
```

```
# Define the bias
bias = tf.Variable([0.5])
```

A simple dense layer

```
# Multiply inputs (features) by the weights  
product = tf.matmul(inputs, weights)
```

```
# Define dense layer  
dense = tf.keras.activations.sigmoid(product+bias)
```



Defining a complete model

```
import tensorflow as tf
```

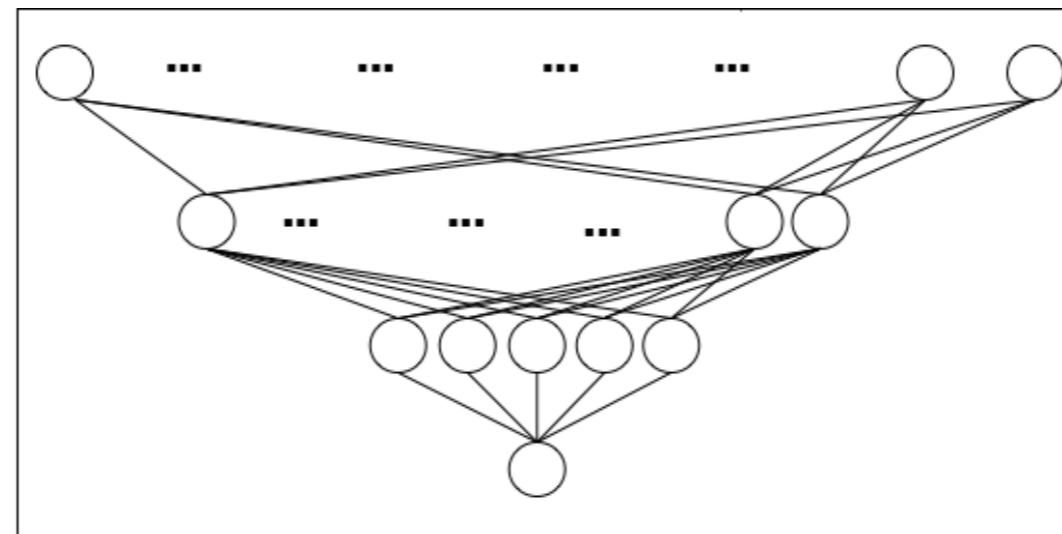
```
# Define input (features) layer  
inputs = tf.constant(data, tf.float32)
```

```
# Define first dense layer  
dense1 = tf.keras.layers.Dense(10, activation='sigmoid')(inputs)
```

Defining a complete model

```
# Define second dense layer  
dense2 = tf.keras.layers.Dense(5, activation='sigmoid')(dense1)
```

```
# Define output (predictions) layer  
outputs = tf.keras.layers.Dense(1, activation='sigmoid')(dense2)
```



High-level versus low-level approach

- **High-level approach**
 - High-level API operations
- **Low-level approach**
 - Linear-algebraic operations

```
dense = keras.layers.Dense(10,\n    activation='sigmoid')
```

```
prod = matmul(inputs, weights)\ndense = keras.activations.sigmoid(prod)
```

Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON

Activation functions

INTRODUCTION TO TENSORFLOW IN PYTHON



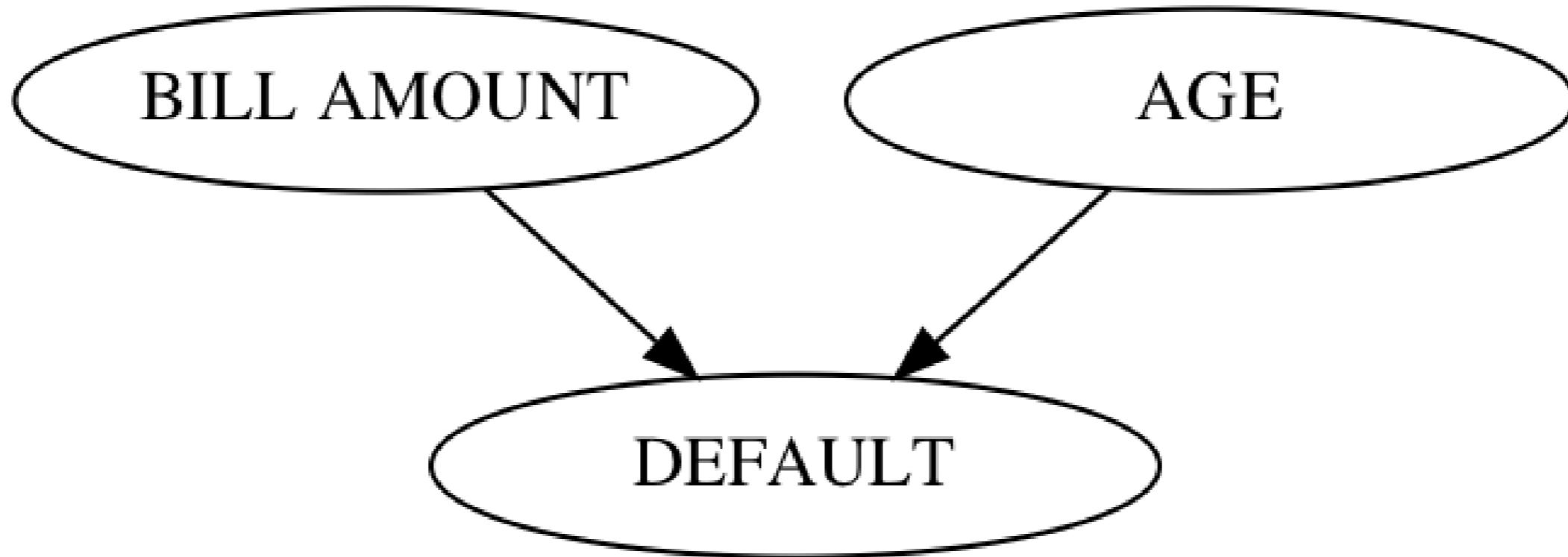
Isaiah Hull

Visiting Associate Professor of Finance,
BI Norwegian Business School

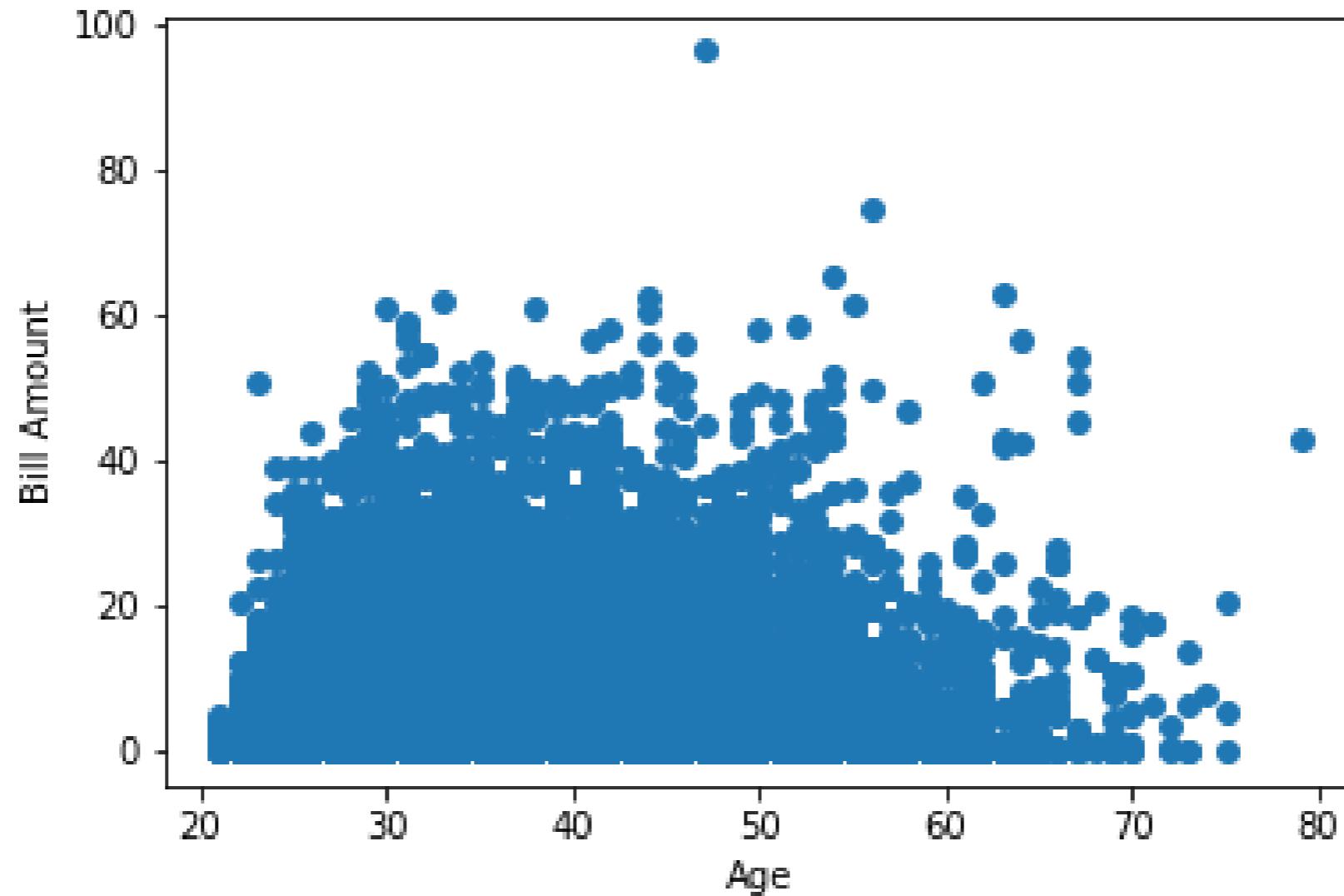
What is an activation function?

- Components of a typical hidden layer
 - Linear: Matrix multiplication
 - Nonlinear: Activation function

Why nonlinearities are important



Why nonlinearities are important



A simple example

```
import numpy as np
import tensorflow as tf

# Define example borrower features
young, old = 0.3, 0.6
low_bill, high_bill = 0.1, 0.5

# Apply matrix multiplication step for all feature combinations
young_high = 1.0*young + 2.0*high_bill
young_low = 1.0*young + 2.0*low_bill
old_high = 1.0*old + 2.0*high_bill
old_low = 1.0*old + 2.0*low_bill
```

A simple example

```
# Difference in default predictions for young  
print(young_high - young_low)
```

```
# Difference in default predictions for old  
print(old_high - old_low)
```

```
0.8
```

```
0.8
```

A simple example

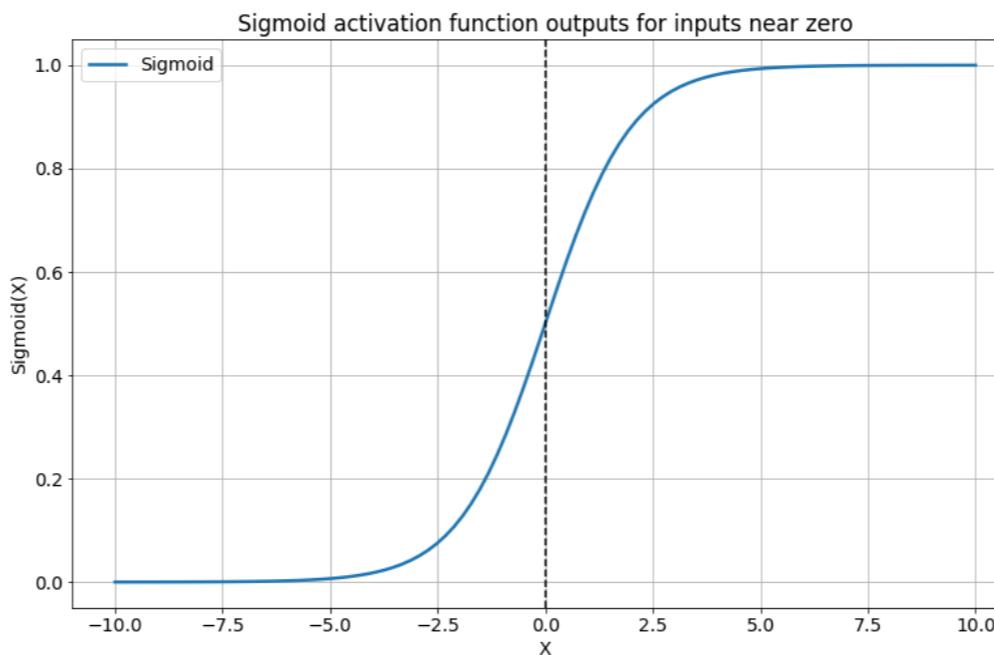
```
# Difference in default predictions for young  
print(tf.keras.activations.sigmoid(young_high).numpy() -  
tf.keras.activations.sigmoid(young_low).numpy())  
  
# Difference in default predictions for old  
print(tf.keras.activations.sigmoid(old_high).numpy() -  
tf.keras.activations.sigmoid(old_low).numpy())
```

0.16337568

0.14204389

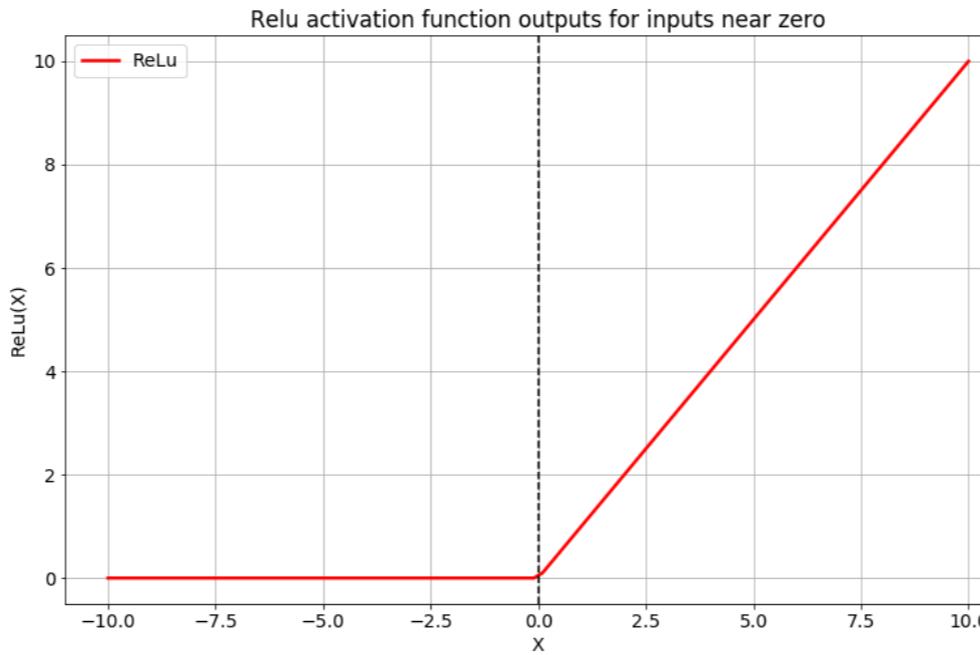
The sigmoid activation function

- **Sigmoid activation function**
 - Binary classification
 - Low-level: `tf.keras.activations.sigmoid()`
 - High-level: `sigmoid`



The relu activation function

- ReLu activation function
 - Hidden layers
 - Low-level: `tf.keras.activations.relu()`
 - High-level: `relu`



The softmax activation function

- **Softmax activation function**
 - Output layer (>2 classes)
 - Low-level: `tf.keras.activations.softmax()`
 - High-level: `softmax`

Activation functions in neural networks

```
import tensorflow as tf
```

```
# Define input layer  
inputs = tf.constant(borrower_features, tf.float32)
```

```
# Define dense layer 1  
dense1 = tf.keras.layers.Dense(16, activation='relu')(inputs)
```

```
# Define dense layer 2  
dense2 = tf.keras.layers.Dense(8, activation='sigmoid')(dense1)
```

```
# Define output layer  
outputs = tf.keras.layers.Dense(4, activation='softmax')(dense2)
```

Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON

Optimizers

INTRODUCTION TO TENSORFLOW IN PYTHON



Isaiah Hull

Visiting Associate Professor of Finance,
BI Norwegian Business School

How to find a minimum



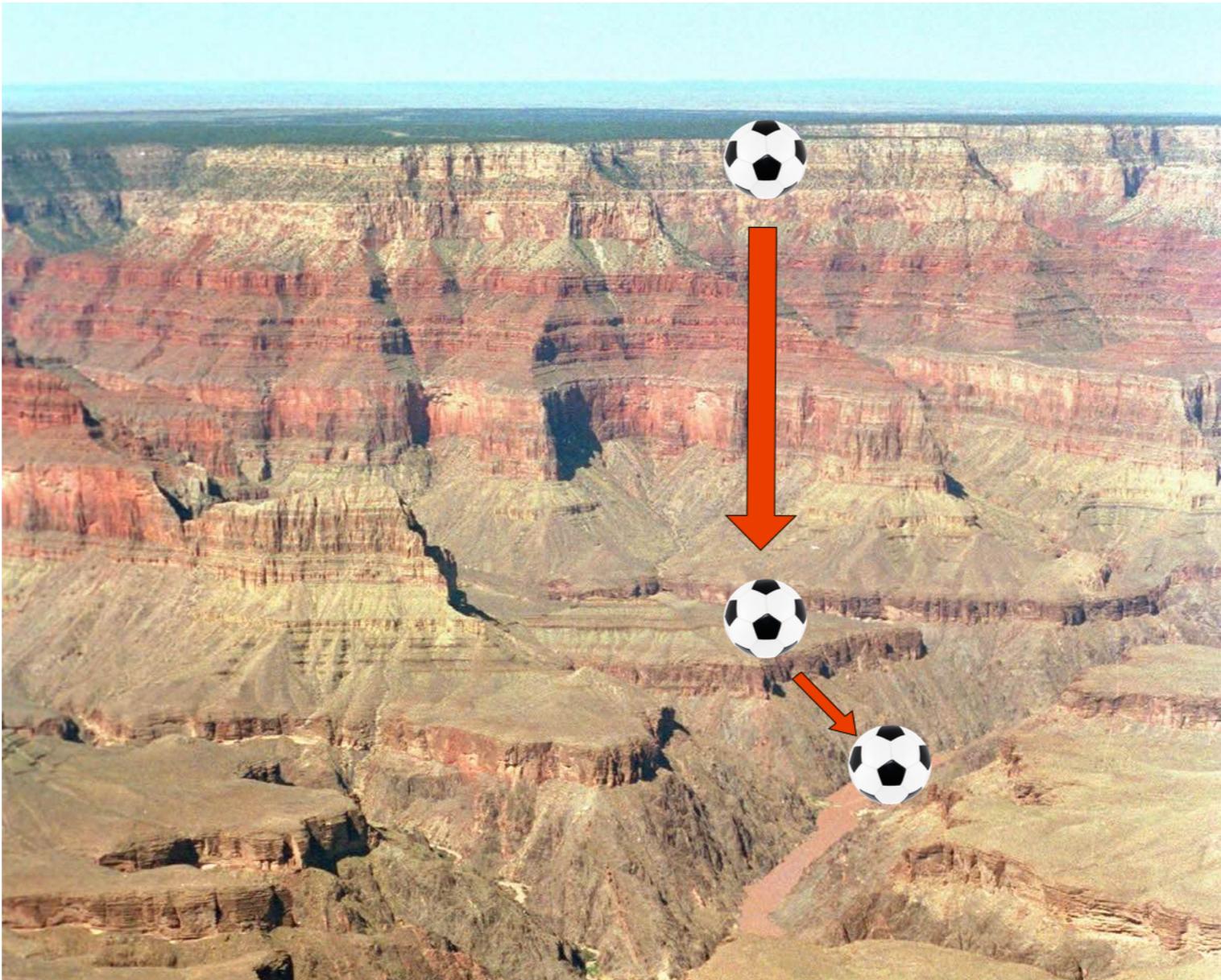
¹ Source: U.S. National Park Service

How to find a minimum



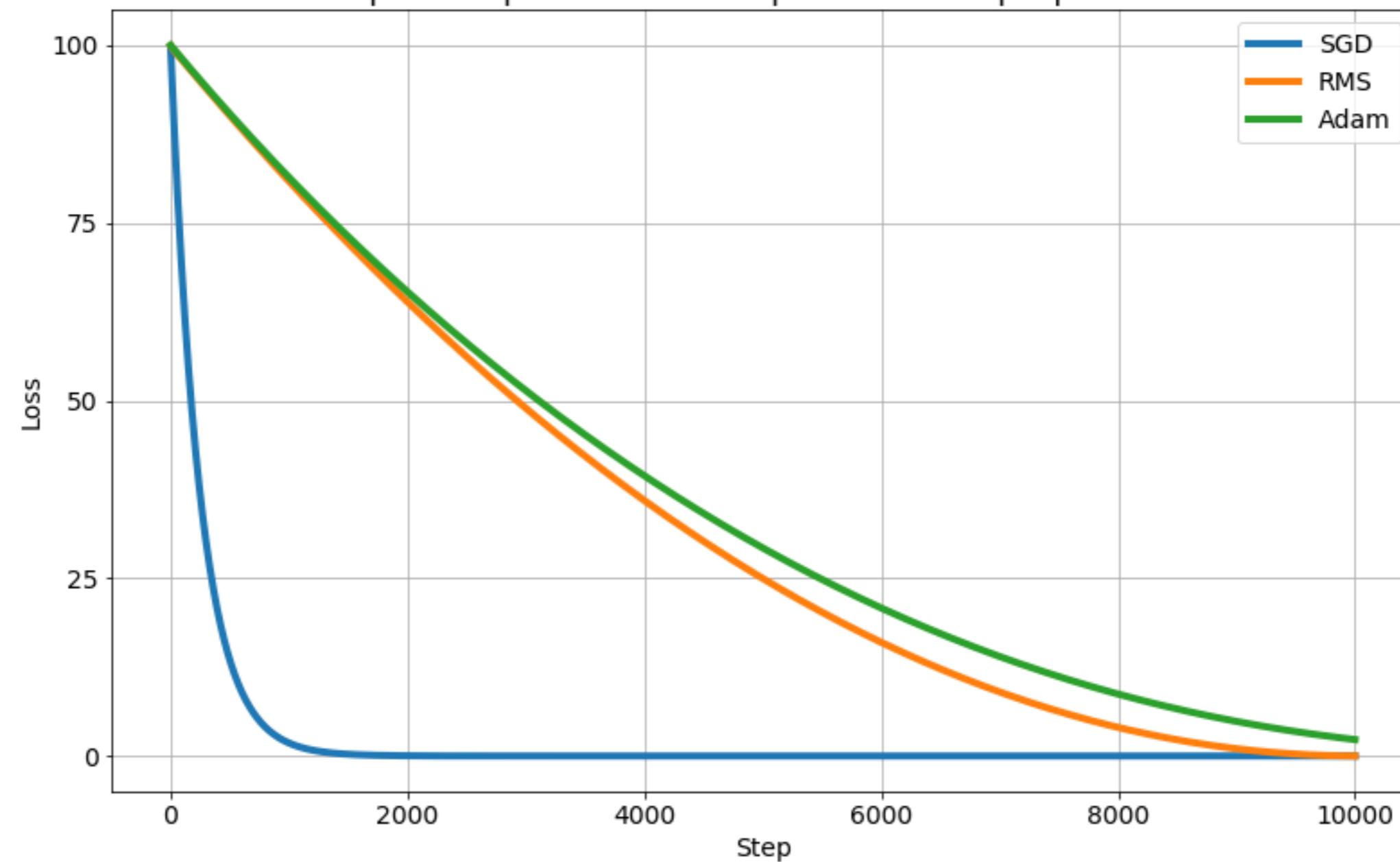
¹ Source: U.S. National Park Service

How to find a minimum



¹ Source: U.S. National Park Service

Optimizer performance comparison for simple problem



The gradient descent optimizer

- **Stochastic gradient descent (SGD) optimizer**
 - `tf.keras.optimizers.SGD()`
 - `learning_rate`
- **Simple and easy to interpret**

The RMS prop optimizer

- Root mean squared (RMS) propagation optimizer
 - Applies different learning rates to each feature
 - `tf.keras.optimizers.RMSprop()`
 - `learning_rate`
 - `momentum`
 - `decay`
- Allows for momentum to both build and decay

The adam optimizer

- Adaptive moment (adam) optimizer
 - `tf.keras.optimizers.Adam()`
 - `learning_rate`
 - `beta1`
- Performs well with default parameter values

A complete example

```
import tensorflow as tf

# Define the model function
def model(bias, weights, features = borrower_features):
    product = tf.matmul(features, weights)
    return tf.keras.activations.sigmoid(product+bias)
```

```
# Compute the predicted values and loss
def loss_function(bias, weights, targets = default, features = borrower_features):
    predictions = model(bias, weights)
    return tf.keras.losses.binary_crossentropy(targets, predictions)
```

```
# Minimize the loss function with RMS propagation
opt = tf.keras.optimizers.RMSprop(learning_rate=0.01, momentum=0.9)
opt.minimize(lambda: loss_function(bias, weights), var_list=[bias, weights])
```

Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON

Training a network in TensorFlow

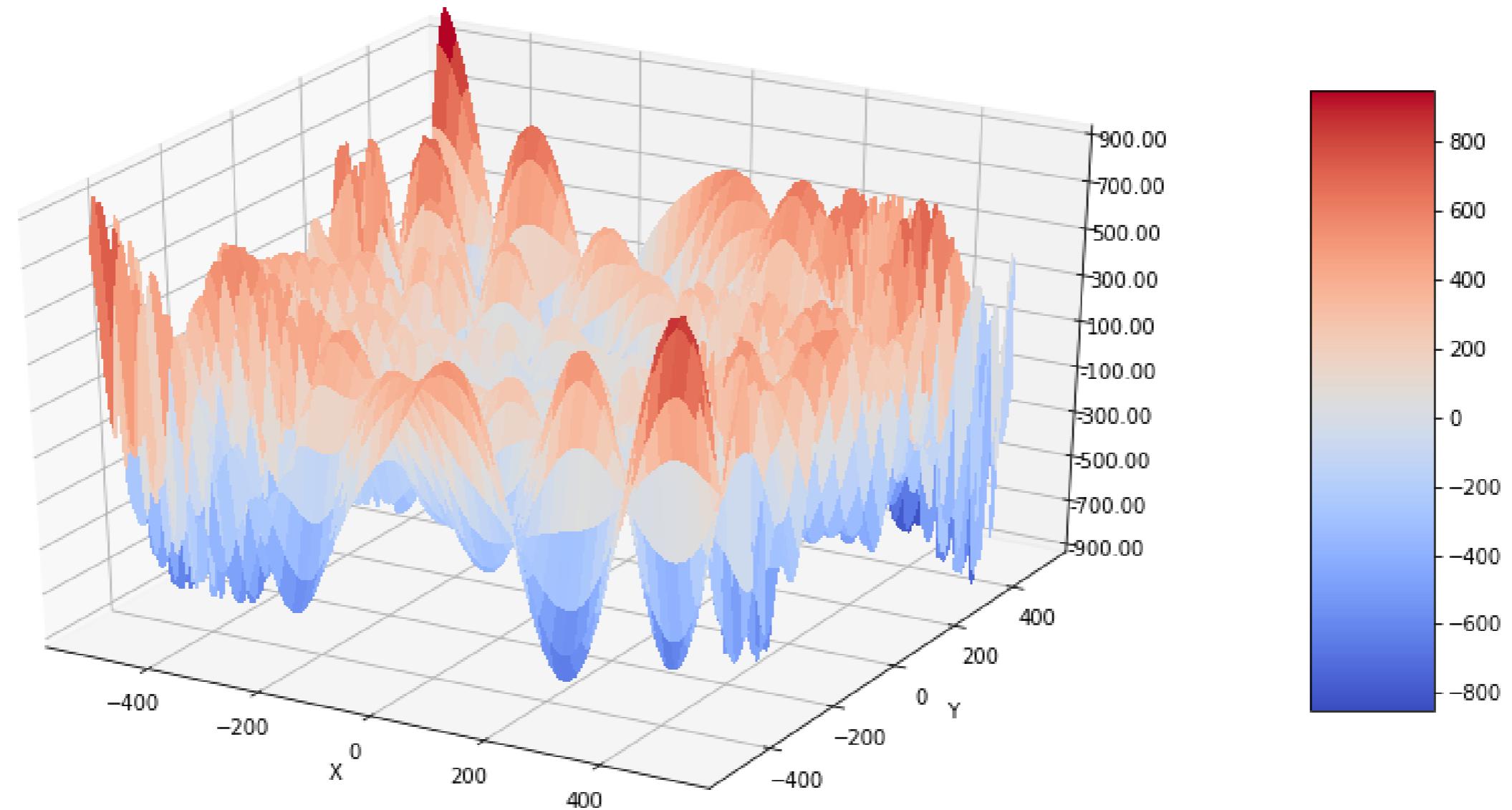
INTRODUCTION TO TENSORFLOW IN PYTHON



Isaiah Hull

Visiting Associate Professor of Finance,
BI Norwegian Business School

The Eggholder Function



Random initializers

- Often need to initialize thousands of variables
 - `tf.ones()` may perform poorly
 - Tedious and difficult to initialize variables individually
- Alternatively, draw initial values from distribution
 - Normal
 - Uniform
 - Glorot initializer

Initializing variables in TensorFlow

```
import tensorflow as tf

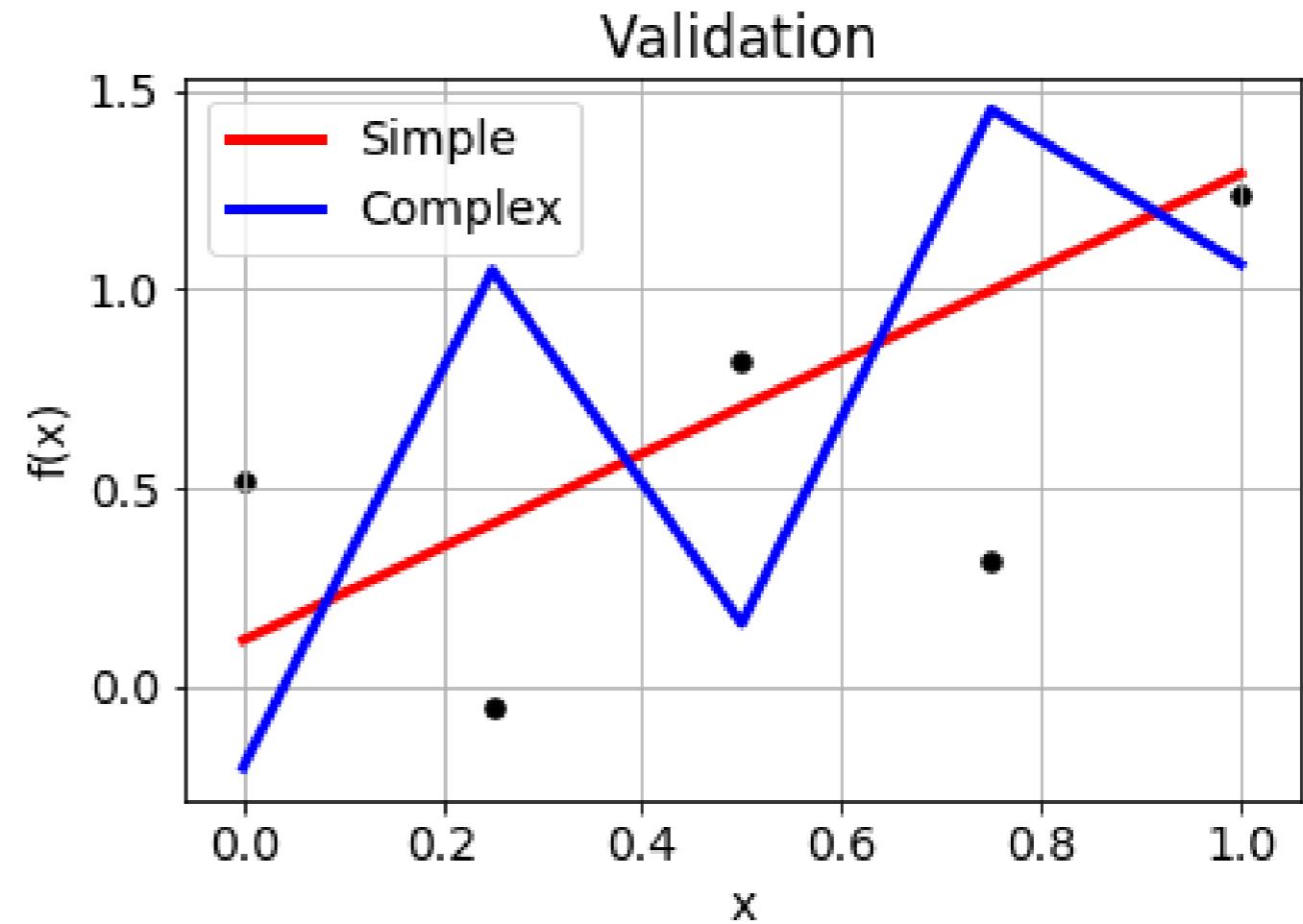
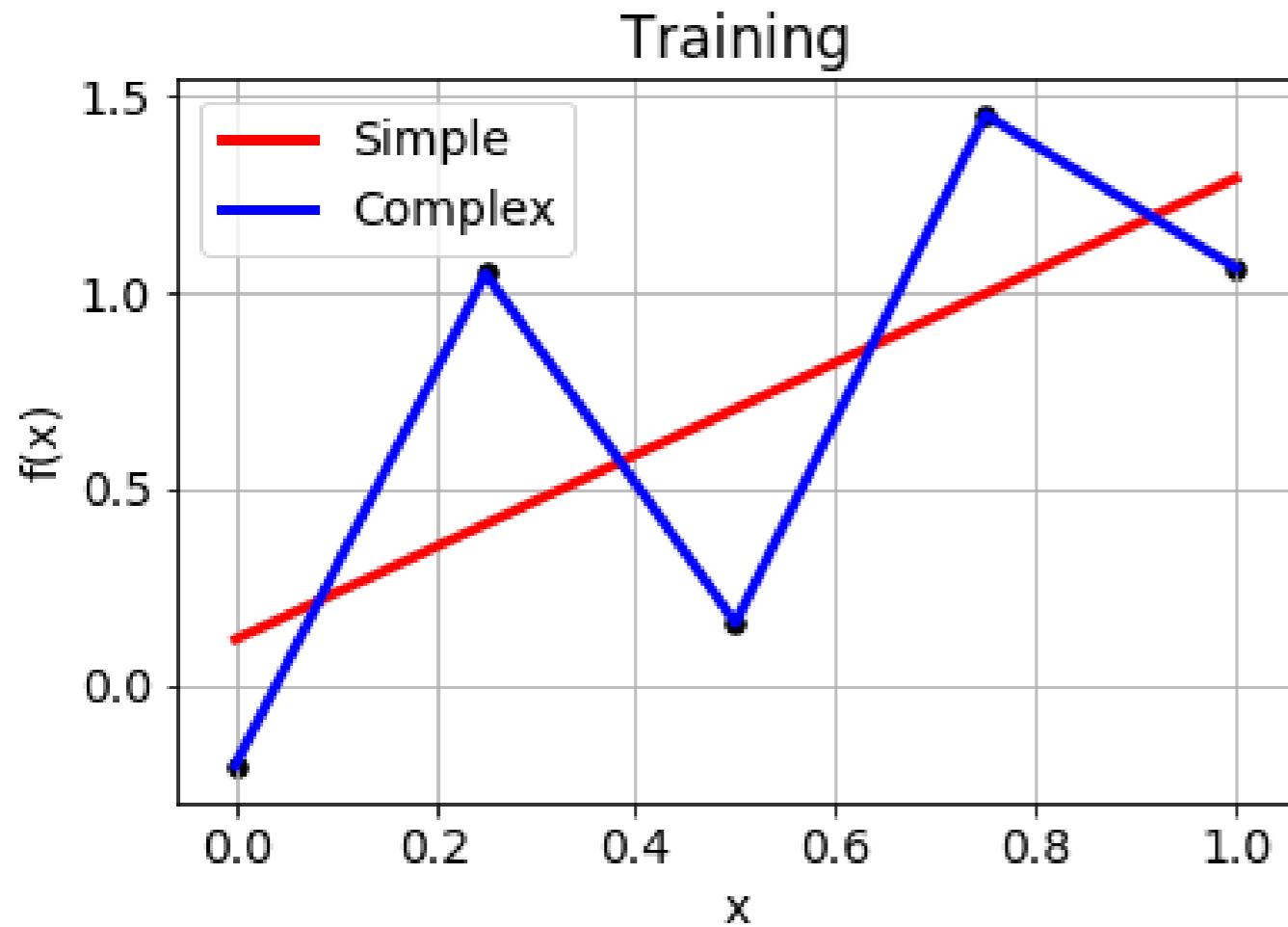
# Define 500x500 random normal variable
weights = tf.Variable(tf.random.normal([500, 500]))

# Define 500x500 truncated random normal variable
weights = tf.Variable(tf.random.truncated_normal([500, 500]))
```

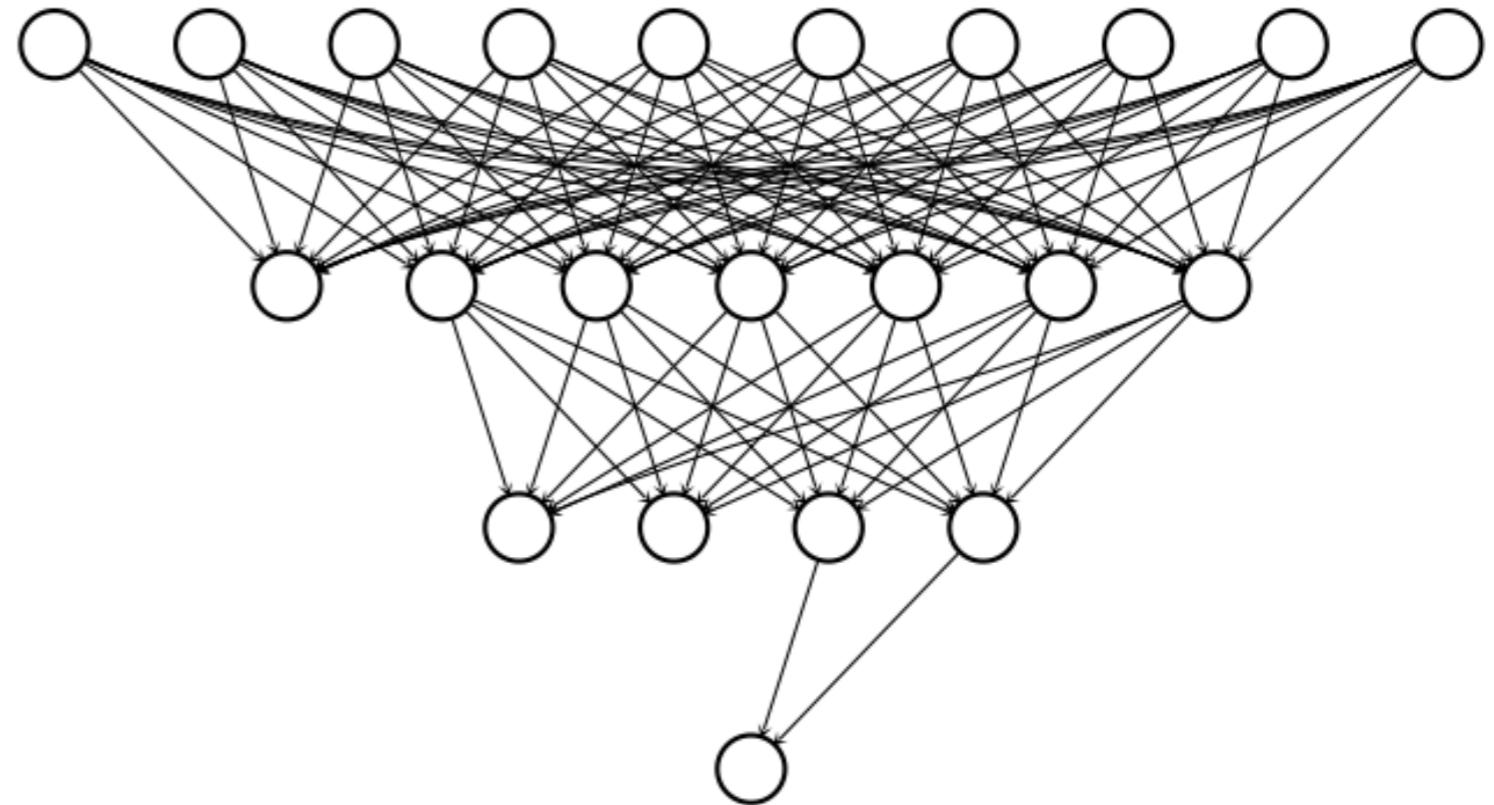
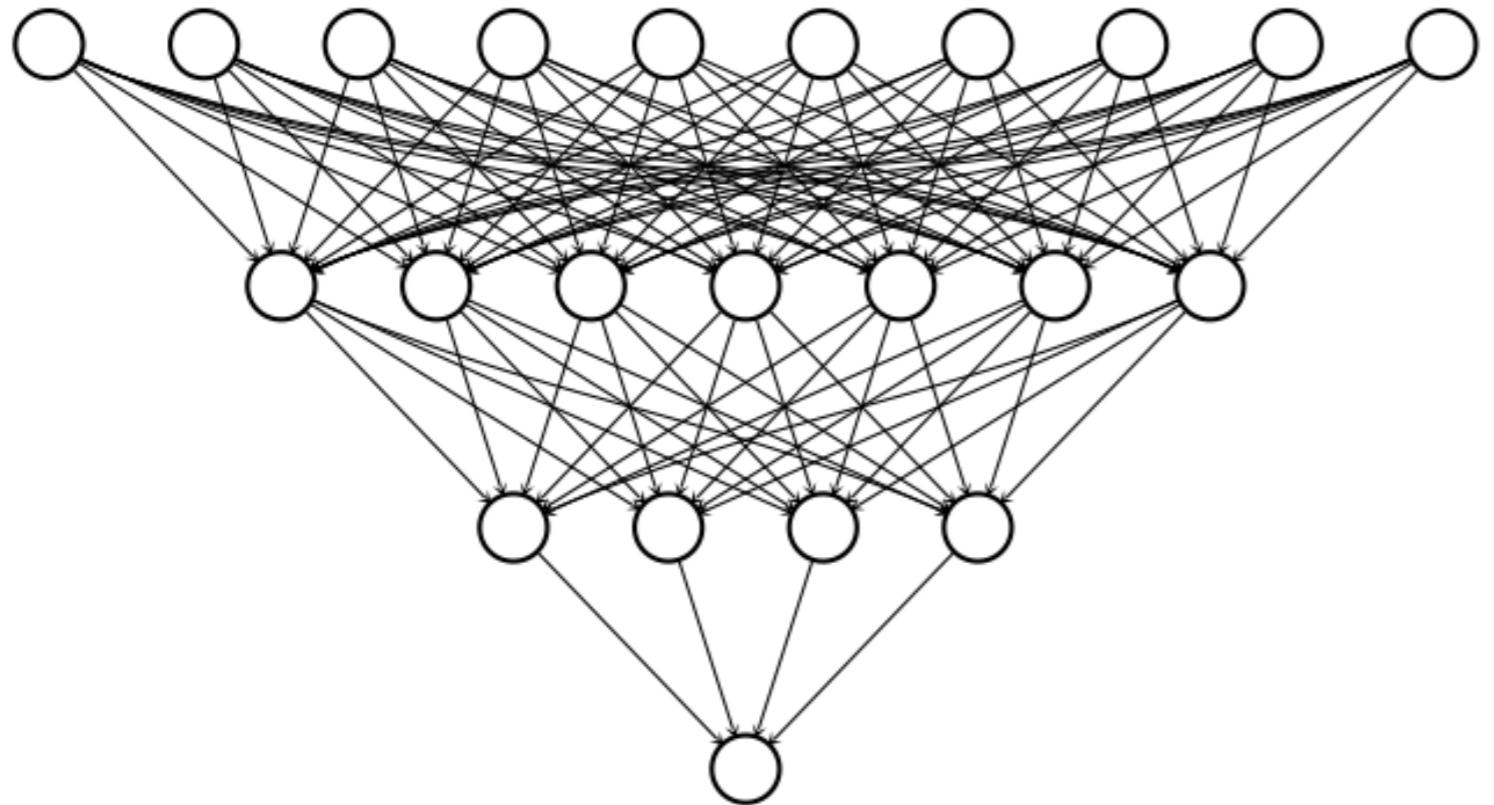
Initializing variables in TensorFlow

```
# Define a dense layer with the default initializer  
dense = tf.keras.layers.Dense(32, activation='relu')  
  
# Define a dense layer with the zeros initializer  
dense = tf.keras.layers.Dense(32, activation='relu', \  
    kernel_initializer='zeros')
```

Neural networks and overfitting



Applying dropout



Implementing dropout in a network

```
import numpy as np  
import tensorflow as tf  
  
# Define input data  
inputs = np.array(borrower_features, np.float32)
```

```
# Define dense layer 1  
dense1 = tf.keras.layers.Dense(32, activation='relu')(inputs)
```

Implementing dropout in a network

```
# Define dense layer 2  
dense2 = tf.keras.layers.Dense(16, activation='relu')(dense1)
```

```
# Apply dropout operation  
dropout1 = tf.keras.layers.Dropout(0.25)(dense2)
```

```
# Define output layer  
outputs = tf.keras.layers.Dense(1, activation='sigmoid')(dropout1)
```

Let's practice!

INTRODUCTION TO TENSORFLOW IN PYTHON