Gentlest Intro to Tensorflow

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In collaboration with (Sam & Edmund):

AheadConsulting

Goal

- Perform **linear regression** in its most basic form through simplest example
  - Predict house price with just single feature, i.e., house size

What We Will Learn Together

- 4 steps of Machine Learning:
  - Create model
  - Define cost function
  - Collect data
  - Train
- 2 parts of Tensorflow:
  - Model linear regression & cost function as Tensorflow graph
  - Train Tensorflow graph with dataset

Machine Learning

Machine Learning Purpose

Predict something given a set of **features** that influences prediction:

- Predict house price given its size, location, configuration (features)

Machine Learning Training

Before predicting, we have to:

- Choose/Create a **model**
- **Train** the model to learn prediction with **data**

Problem

Predict House Price Given House Size

y = house price

x = house size (feature)

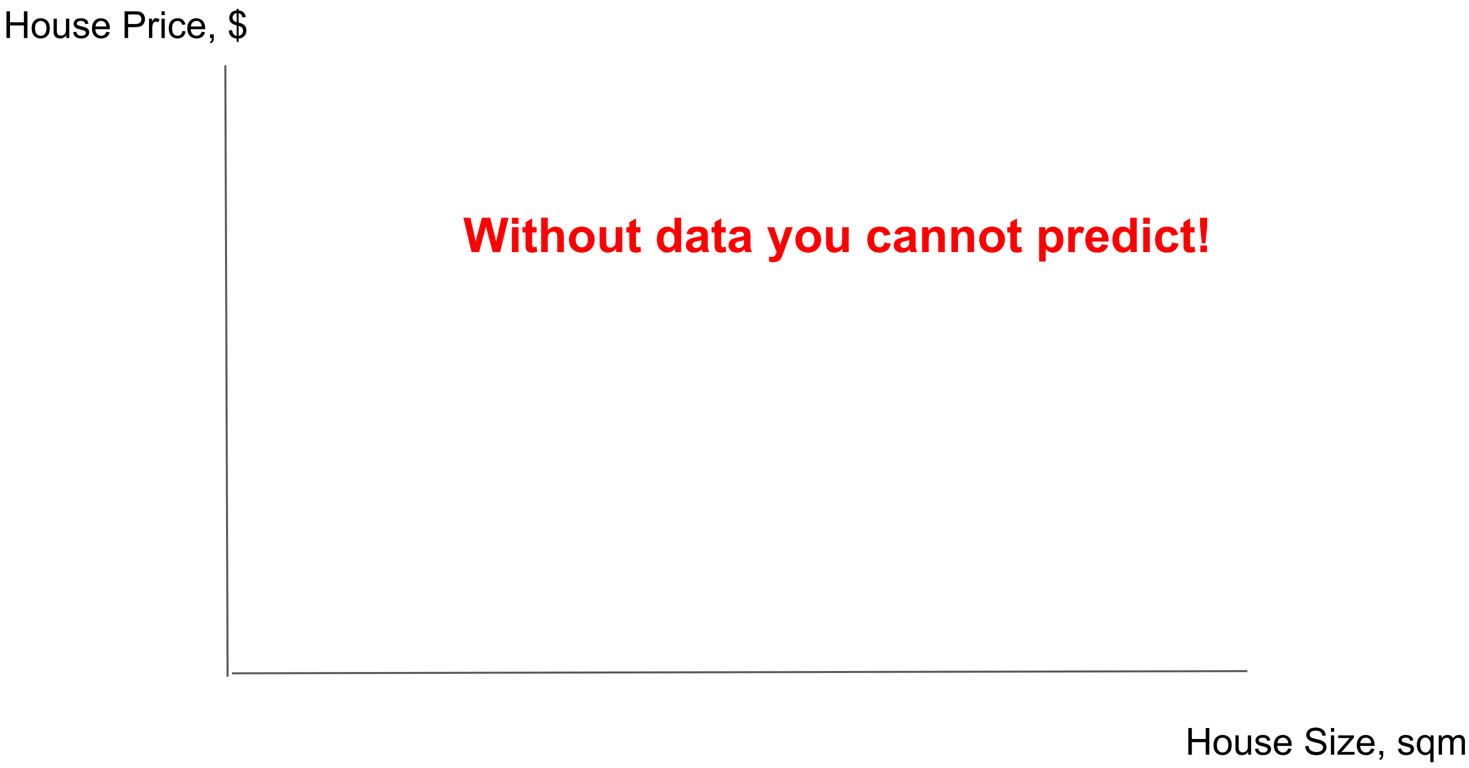
Solve:

- Given a house size, what should be the house price?

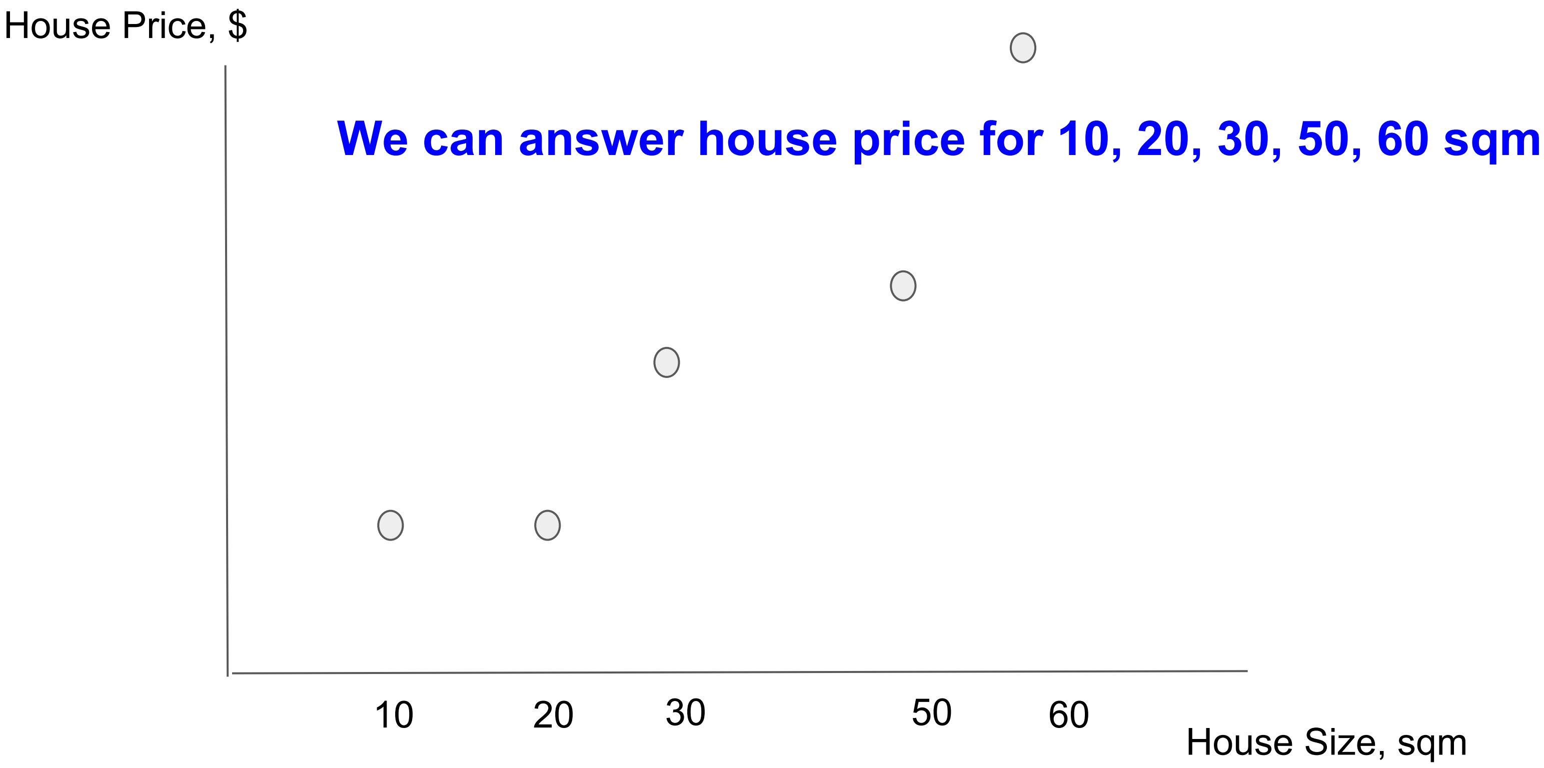
Model

What is the House Price?

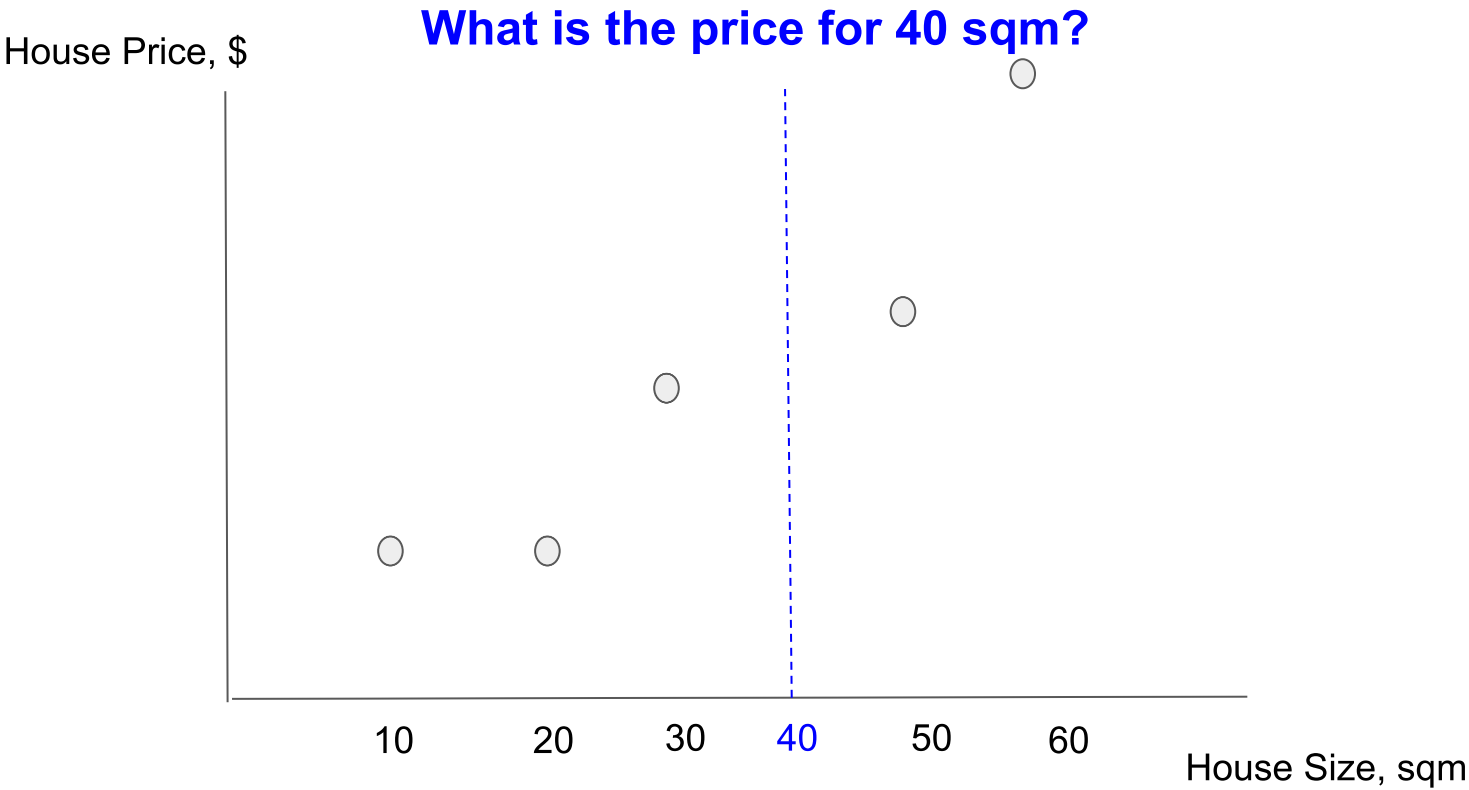
What is the House Price?



What is the House Price?



What is the House Price?



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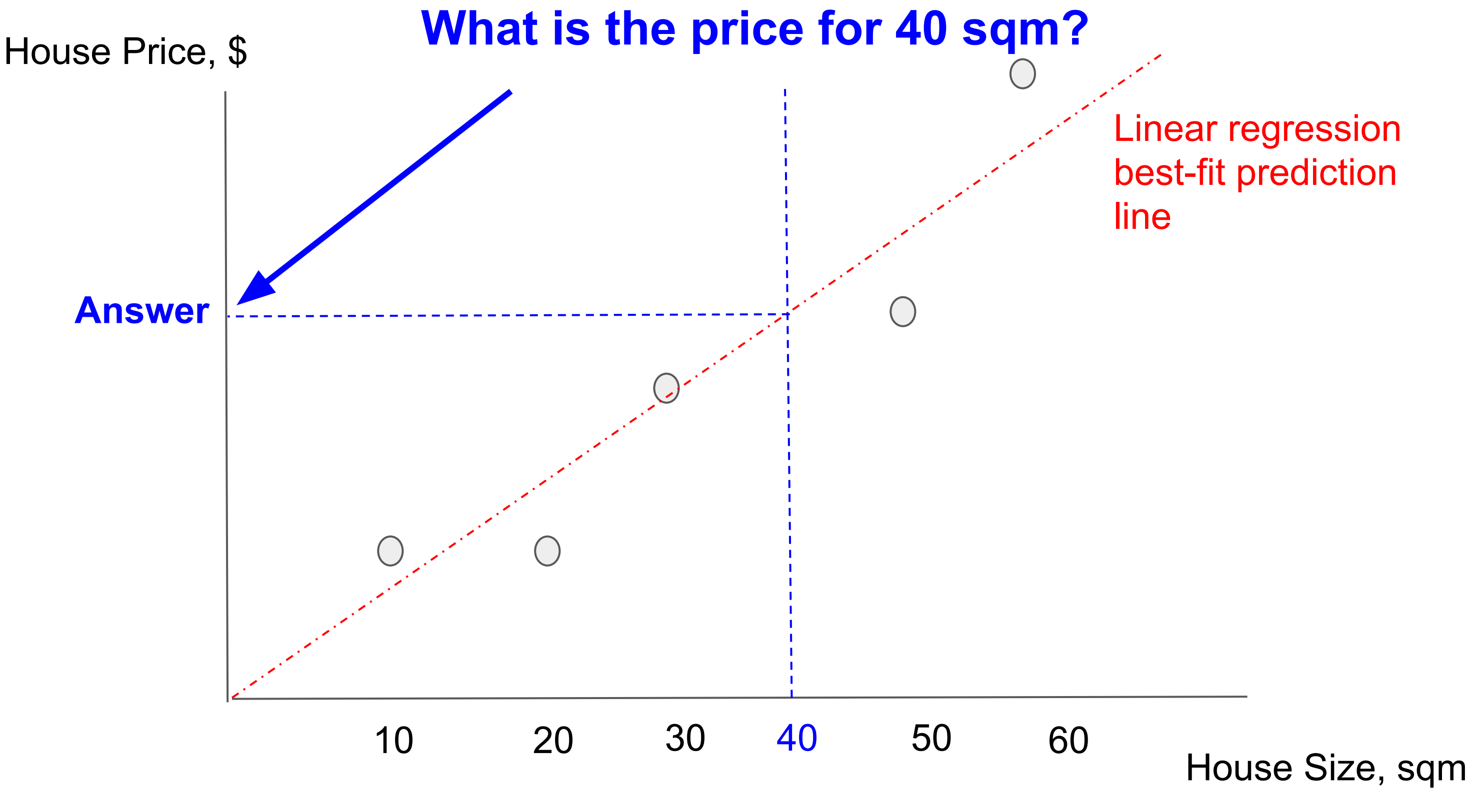
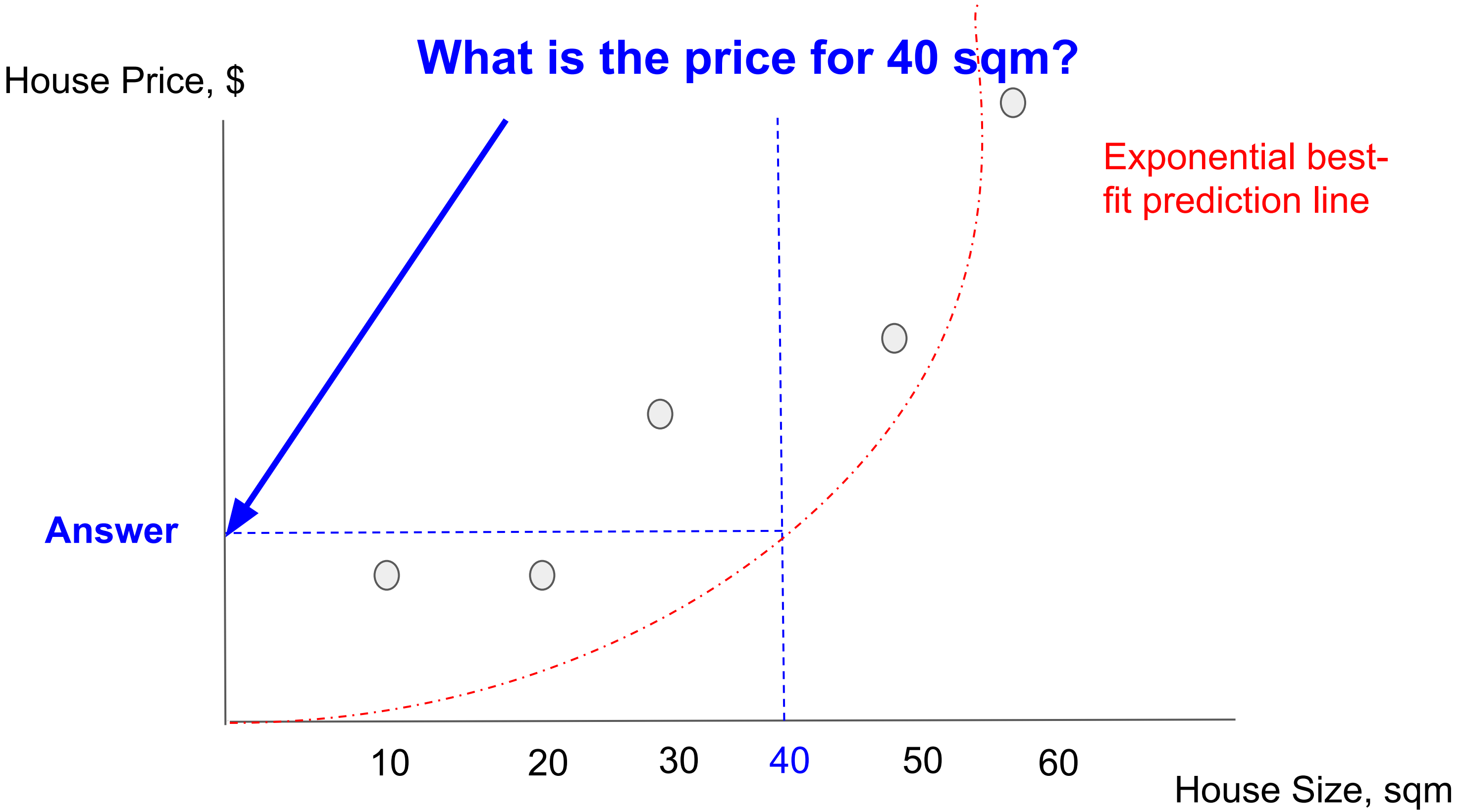


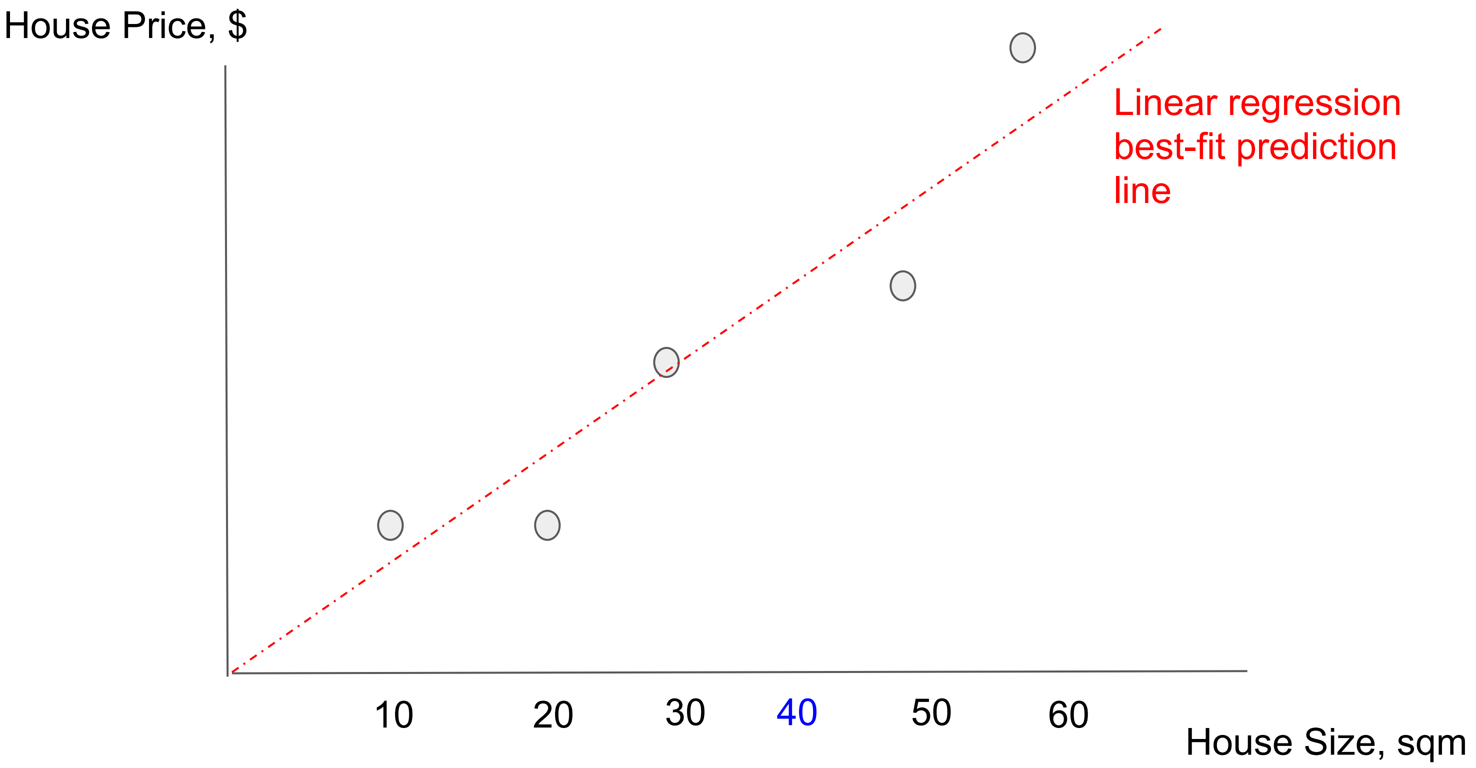
What is the House Price?



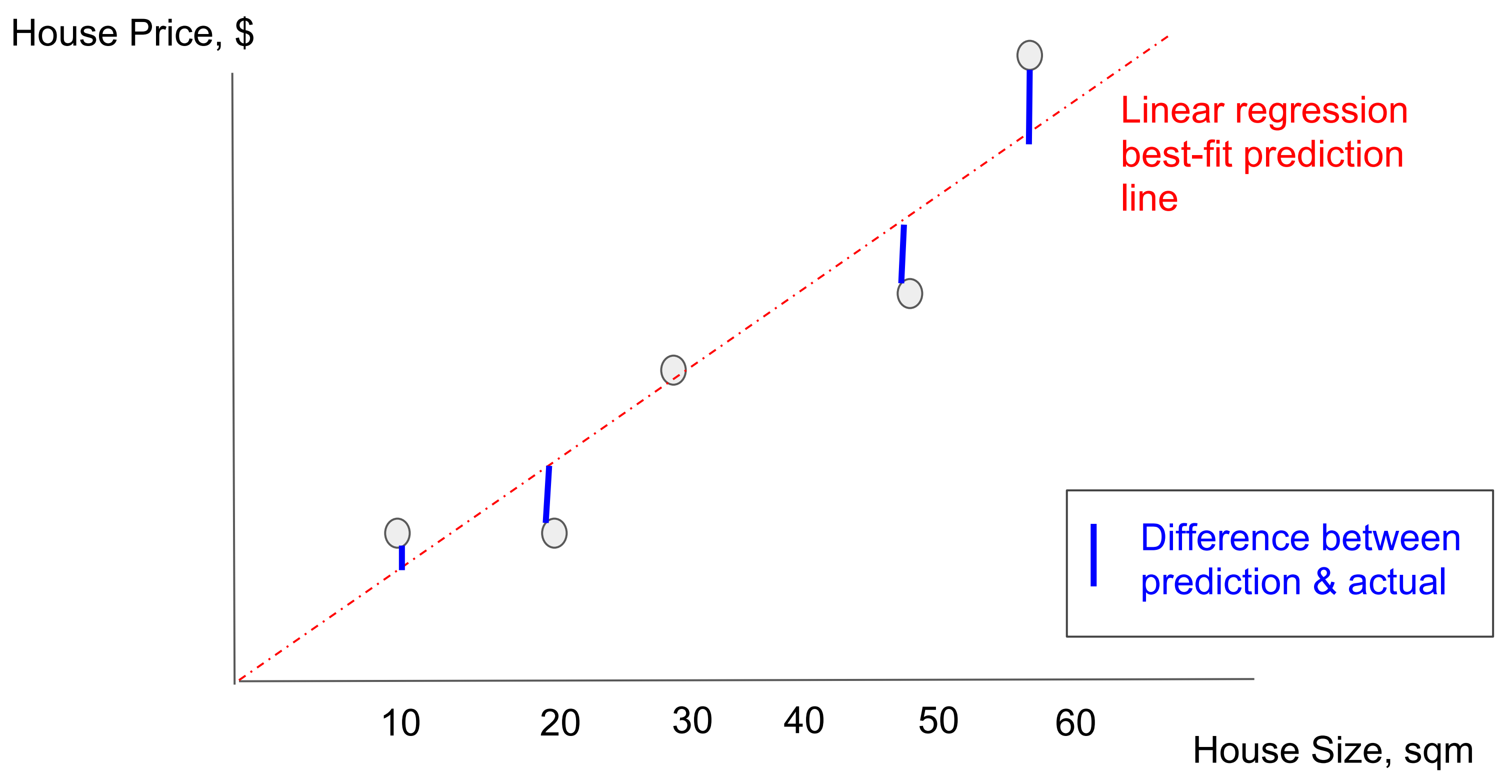
Cost Function: Best-fit Prediction

Minimize difference between predicted & actual values

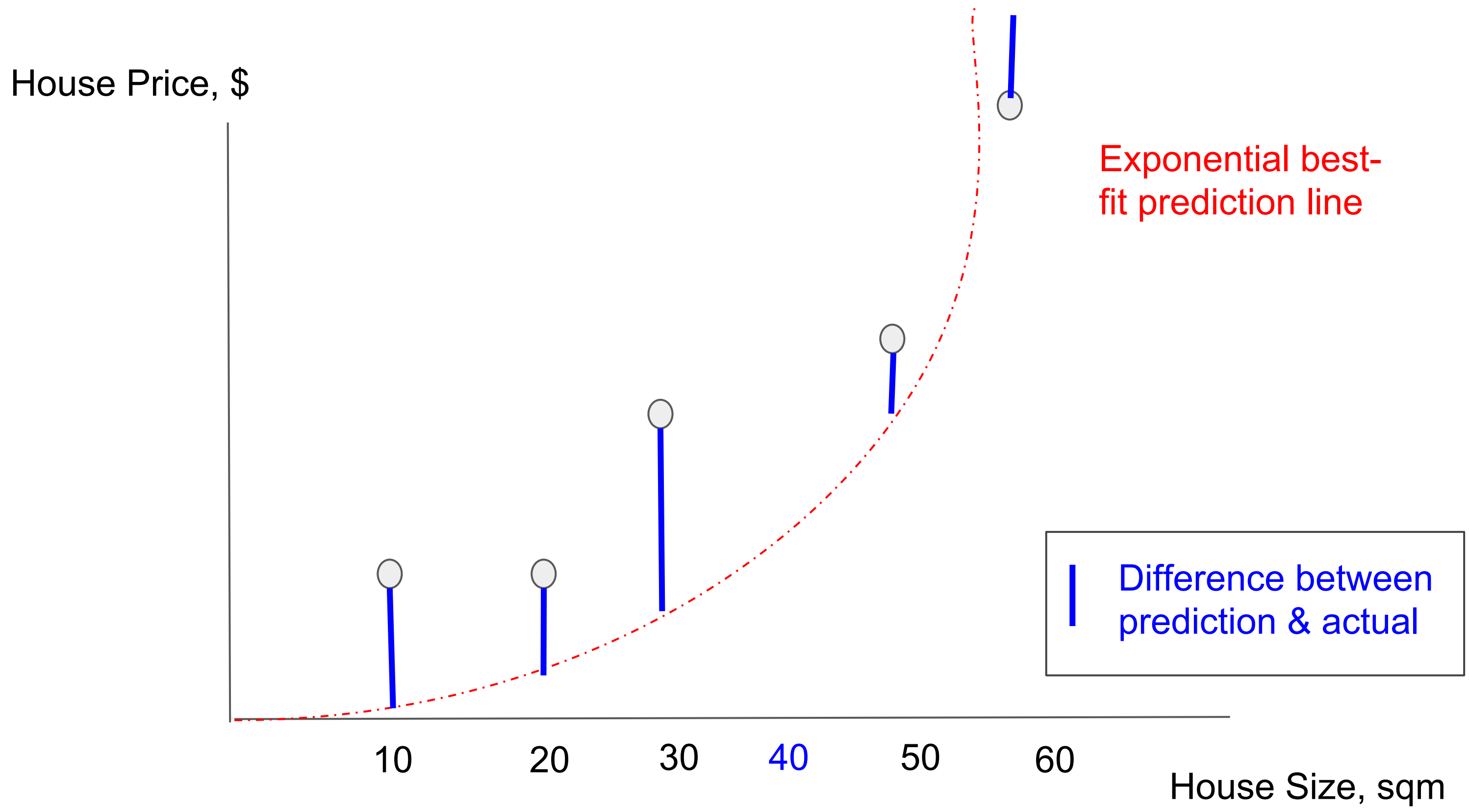
What is the House Price?



What is the House Price?



What is the House Price?



Cost function: How different is your model from reality

sum((y_ - y)**2)

Where:

- y_: Actual value
- y: Predicted value
- **2: Power of 2

Linear Regression

Linear Regression

$$y = W.x + b$$

y: Predicted house price

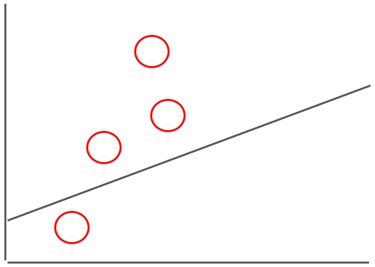
x: House size from dataset

Find a good W, b

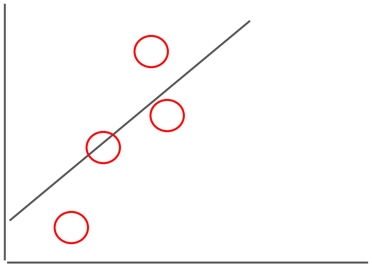
W: Gradient (Steepness)

$$W1 < W2 < W3$$

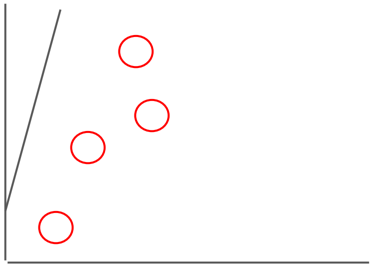
$y = W1.x + b$



$y = W2.x + b$



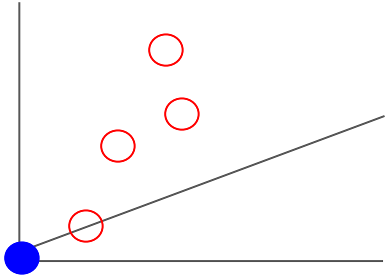
$y = W3.x + b$



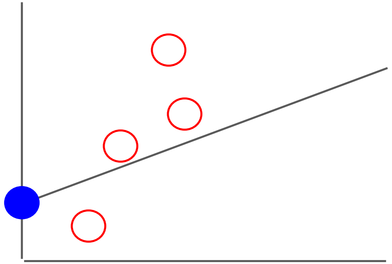
b: Intersect

$b1 < b2 < b3$

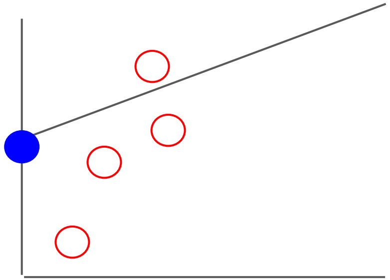
$y = W.x + b1$



$y = W.x + b2$



$y = W.x + b3$



Train

Train: Find W, b

```
W_best, b_best = 0, 0
Loop J times:
  Choose current_W, current_b
  If cost(current_W, current_b) < cost(W_best, b_best):
    W_best, b_best = current_W, current_b
```

Train: Find W, b

W_best, b_best = 0, 0

Loop J times:

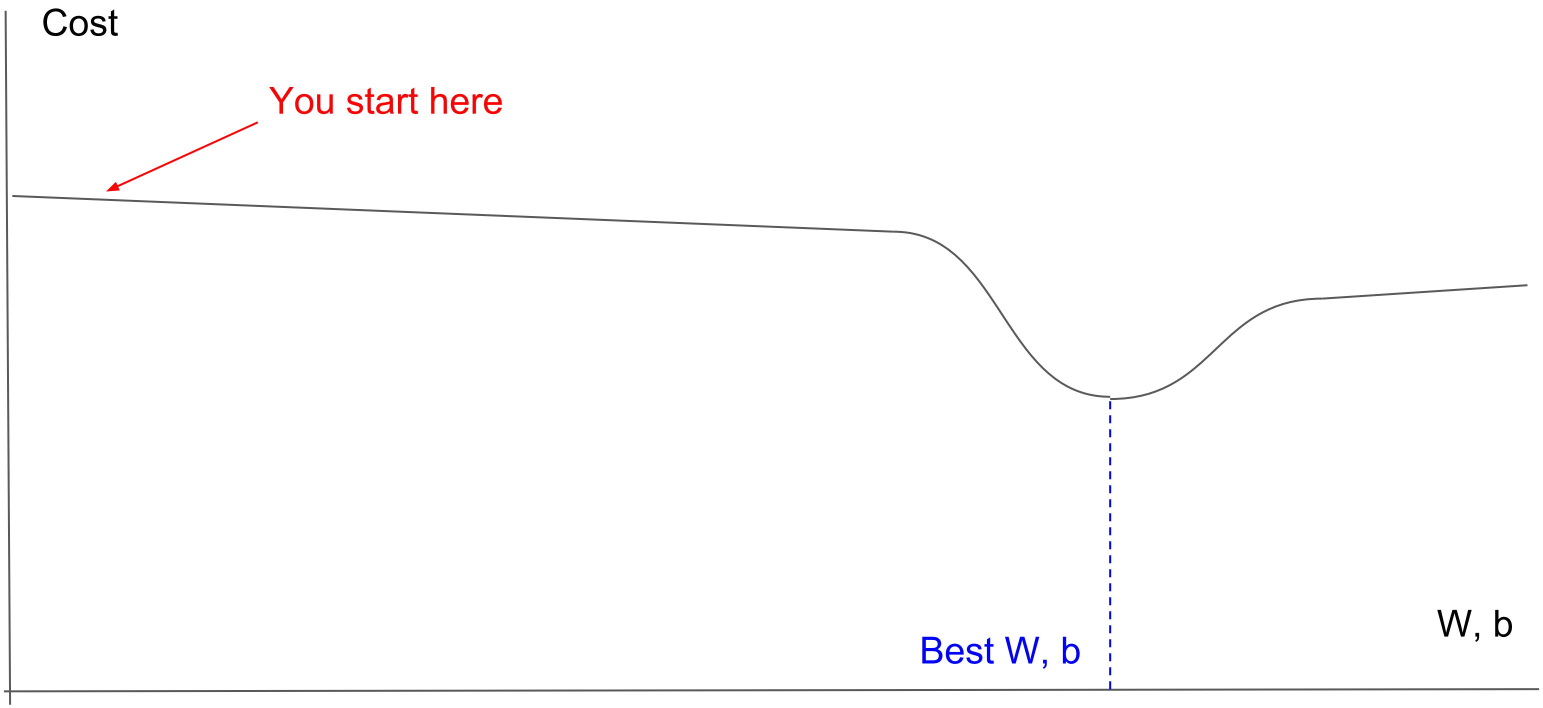
  Choose current_W, current_b

  If cost(current_W, current_b) < cost(W_best, b_best):

    W_best, b_best = current_W, current_b

What is the best way to choose current_W, current_b?

Finding Minimum Cost Function



How to Reach Minimum?

Choosing Training Method

- Random
  - Could take forever
- Gradient descent
  - From current viewpoint, move towards direction where steepness is greatest

Ready?

Recap:

- Model: Linear regression, y = W.x + b
- Cost: Least squared, cost = sum((y_ - y)**2)
- Train: Gradient descent

Step 1: Model $y = W.x + b$

Tensorflow Model

tf.placeholder

- Hold data to be feed into the model
- x = tf.placeholder(tf.float32, [None, 1])

tf.Variable

One output, house price

One feature, house size

- Hold variables to be trained
- W = tf.Variable(tf.zeros([1,1]))
- b = tf.Variable(tf.zeros([1]))

Tensorflow Model

tf.matmul(x,W)

- Multiply 2 matrices
- product = tf.matmul(x,W)

‘+’

- y = product + b
- Expands to:
  - y = tf.matmul(x,W) + b = W.x + b **Done!**

Step 2: Cost Function sum((y_ - y)** 2)

Best-fit: Minimize Difference Prediction and Actual

Actual values:

One output, house price

- y_ = tf.placeholder(tf.float32, [None, 1])

Minimize difference between actual and prediction:

- cost = tf.reduce_sum(tf.pow((y_-y), 2))

Step 3: Data

Faking Data

```
for i in range(100):
  // Create fake data for actual data
  xs = np.array([[i]])
  ys = np.array([[2*i]])
```

- xs = 0, 1, 2, …., 99
- ys = 0, 2, 4, …., 198
- ys is always twice of xs
- **y = W.x + b where W = 2, b = 0 => Best fit: y = 2x**

Step 4: Train

Train using Gradient Descent

Train using Gradient Descent with steps in 0.000001

- train_step = tf.train.GradientDescentOptimizer(0.00001).minimize(cost)

Train Model

- sess = tf.Session()
- init = tf.initialize_all_variables()
- sess.run(init)
- steps = 100

Tensorflow Non-interactive Mode

Nothing is actually executed until sess.run(...)

Go!!!!!

```
for i in range(steps):
  # Create fake data for y = W.x + b where W = 2, b = 0
  xs = np.array([[i]])
  ys = np.array([[2*i]])

  # Train
  feed = { x: xs, y_: ys }
  sess.run(train_step, feed_dict=feed)

  print("After %d iteration:" % i)
  print("W: %f" % sess.run(W))
  print("b: %f" % sess.run(b))
```

Result

Output

After 0 iteration:

W: 0.000000

b: 0.000000

After 1 iteration:

W: 0.000040

b: 0.000040

…

…

After 98 iteration:

W: 1.997181

b: 0.051121

After 99 iteration:

W: 1.997632

b: 0.051126

After 100 iterations:
W ~ 2.0 and b ~ 0.0

Debugging

When Gradient Descent Go Awry?

Re-run:

```
sess.run(tf.initialize_all_variables())
train_step = tf.train.GradientDescentOptimizer(0.01).minimize(cost)
for i in range(steps):
  ....
```

Output

After 0 iteration:

W: 0.000000

b: 0.000000

After 1 iteration:

W: 0.040000

b: 0.040000

After 2 iteration:

W: 0.195200

b: 0.117600

...

...

After 46 iteration:

W: 323066974878921632721935905090174976.000000

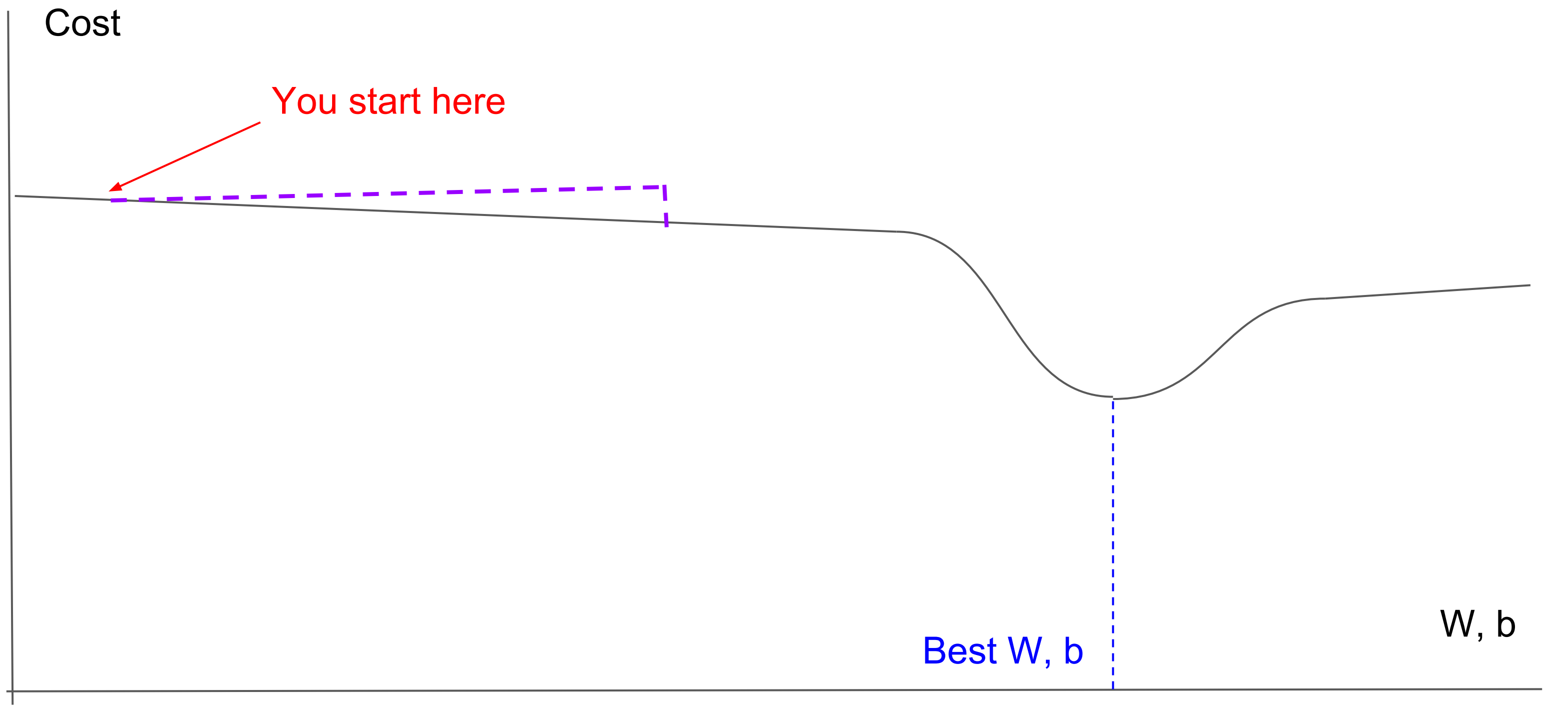
b: 701951740150071676574627696895590 4.000000

After 47 iteration:

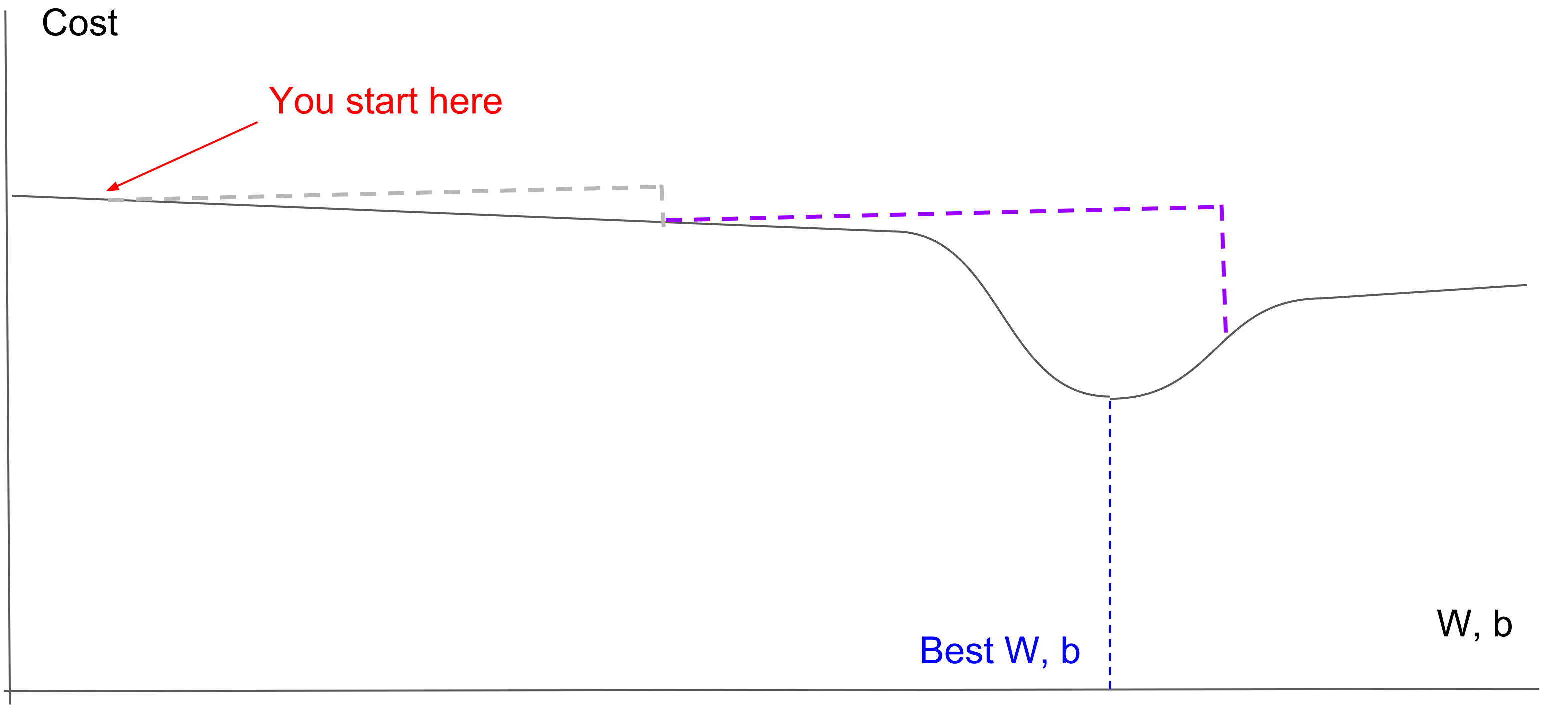
W: -inf

b: -2968038293574744331138960048531701 76.000000

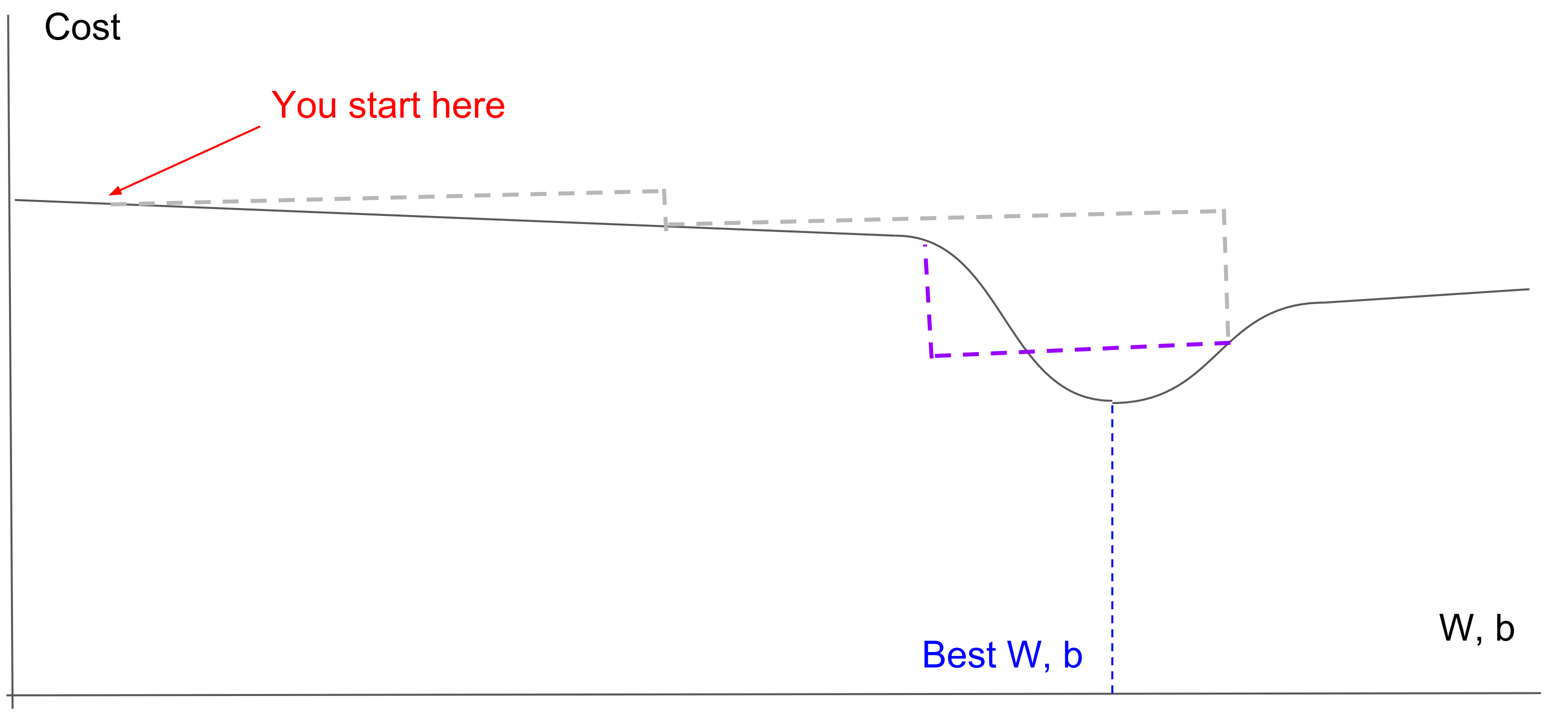
Finding Minimum Cost Function



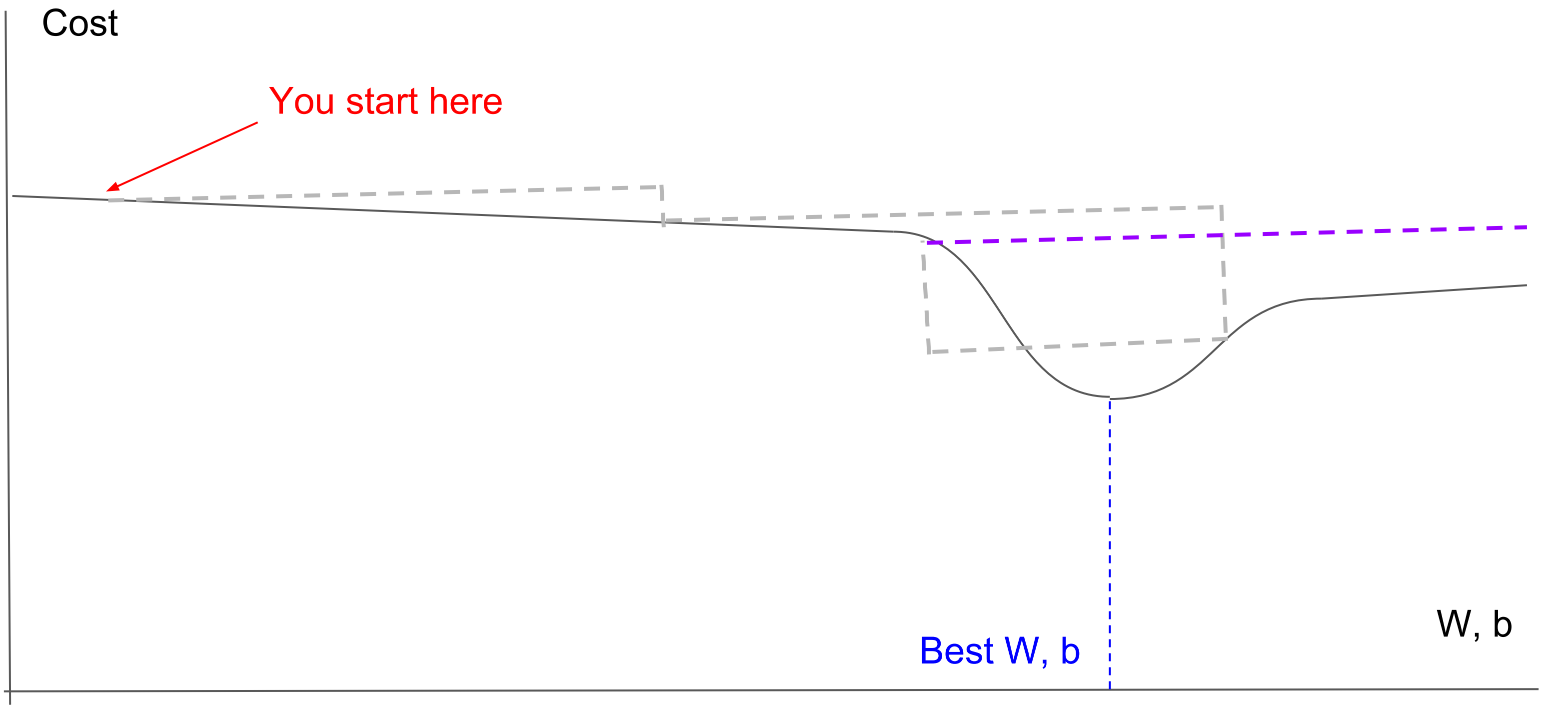
Finding Minimum Cost Function



Finding Minimum Cost Function



Finding Minimum Cost Function



Errors: Missing Placeholders

feed = { x: xs, y: ys }

sess.run(train_step, feed_dict=feed)

- y should be y_

W tensorflow/core/common_runtime/executor.cc:1076] 0x229e510 Compute status: Invalid argument: You must feed a value for placeholder tensor 'Placeholder_1' with dtype float

[[Node: Placeholder_1 = Placeholder[dtype=DT_FLOAT, shape=[], _device="/job:localhost/replica:0/task:0/cpu:0"]()]]

Placeholder Numbers

```
cost = tf.reduce_sum(tf.pow((y_-y), 2))
```

```
y_ = tf.placeholder(tf.float32, [None, 1])
```

Placeholder_1

```
y = product + b
```

```
product = tf.matmul(x,W)
```

```
x = tf.placeholder(tf.float32, [None, 1])
```

Placeholder_0

Assigning Names to Placeholders

cost = tf.reduce_sum(tf.pow((y_-y), 2))

y_ = tf.placeholder(tf.float32, [None, 1],
name='y-input')

Placeholder_1

y = product + b

product = tf.matmul(x,W)

x = tf.placeholder(tf.float32, [None, 1])

Placeholder_0

Errors: Wrong Shape

```
for i in range(steps):
  xs = np.array([i])
  ys = np.array([[2*i]])
```

- xs should be np.array([[i]])

Traceback (most recent call last):
File "<stdin>", line 7, in <module>
File "/usr/local/lib/python2.7/dist-packages/tensorflow/python/client/session.py", line 364, in run
tuple(subfeed_t.get_shape().dims)))
ValueError: Cannot feed value of shape (1,) for Tensor u'Placeholder:0', which has shape (Dimension(None), Dimension(1))

Placeholder Numbers

```
cost = tf.reduce_sum(tf.pow((y_-y), 2))
```

```
y_ = tf.placeholder(tf.float32, [None, 1])
```

Placeholder_1

```
y = product + b

product = tf.matmul(x,W)

x = tf.placeholder(tf.float32, [None, 1])
```

Placeholder_0

Print: Simplest Debugger

print (sess.run(product), feed_dict={ x: np.array([1]) })

```
  File "<stdin>", line 1
        print (sess.run(product), feed_dict={ x: np.array([1]) })
                                 ^
SyntaxError: invalid syntax
>>> print (sess.run(product, feed_dict={ x: np.array([1]) }))
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "/usr/local/lib/python2.7/dist-packages/tensorflow/python/client/session.py", line 364, in run
        tuple(subfeed_t.get_shape().dims)))
ValueError: Cannot feed value of shape (1,) for Tensor u'Placeholder:0', which has shape (Dimension(None), Dimension(1))
```

Same error so must be it!

Progressing to Tensorflow Tutorial

Difference

Parameters	Gentlest Tensorflow Tutorial	Tensorflow Tutorial
Purpose	Find house price (Float32)	Classify image
y	Each sample is 1 x 1; Single-outcome (house price). Feature value is Float32.	Each sample is 10 x 1: One-hot vector for 10 possible values. Vector element is binary.
x	Each sample is 1 x 1: Single-feature (house size) 1 x 1. Feature value is Float32.	Each sample is 1 x 784: 784 features (28 x 28 bits for each image). Feature value is binary
W	1 x 1: Single-outcome, single-feature	784 x 10: one for each 784 bits and 10 probability its one of 10 possible values

One-hot vector for image 4

$$\begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Difference

Parameters	Gentlest Tensorflow Tutorial	Tensorflow Tutorial
b	1 x 1: Bias for single-outcome	10 x 1: Bias for 10 possible values of on-hot vector
cost	Square of difference	Entropy-based
gradient descent batch size	Single sample x, y	100 samples each batch

Summary Machine Learning

4 steps:

- Build **model** (linear regression, logistic regression, neural networks, etc.)
- Define **cost function** to determine how well current model fits actual
- Collect and prepare **data**
- **Train** model to tweak model based on cost function using data

Summary of Tensorflow

- Modelling
  - tf.zeros
  - tf.placeholder
  - tf.Variable
  - tf.matmul
  - tf.reduce_sum
  - tf.pow
  - tf.train.GradientDescentOptimizer(step_size).minimize(cost)
- Train
  - init = tf.initialize_all_variables()
  - sess = tf.session()
  - sess.run(init)
  - sess.run(train, feed_dict={ x: …, y: … })

Questions

- Why not just use numpy.dot methods instead of tf.matmul?
    - tf.matmul is a Tensorflow Operation, and Tensorflow can easily assign each parallelizable operation to an available nodes to speed up operations

References

Code: https://github.com/nethsix/gentle_tensorflow/blob/master/code/linear_regression_one_feature.py