Gentlest Intro to Tensorflow (Part 2)

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In collaboration with Sam & Edmund

Next Steps

- Review of Tensorflow
  - In illustrations
  - tf.placeholder & feed
  - Training process
- Tensorboard: Visualize **cost**, **W**, **b**
- Training batch size: Stochastic/Mini-batch/Full-batch

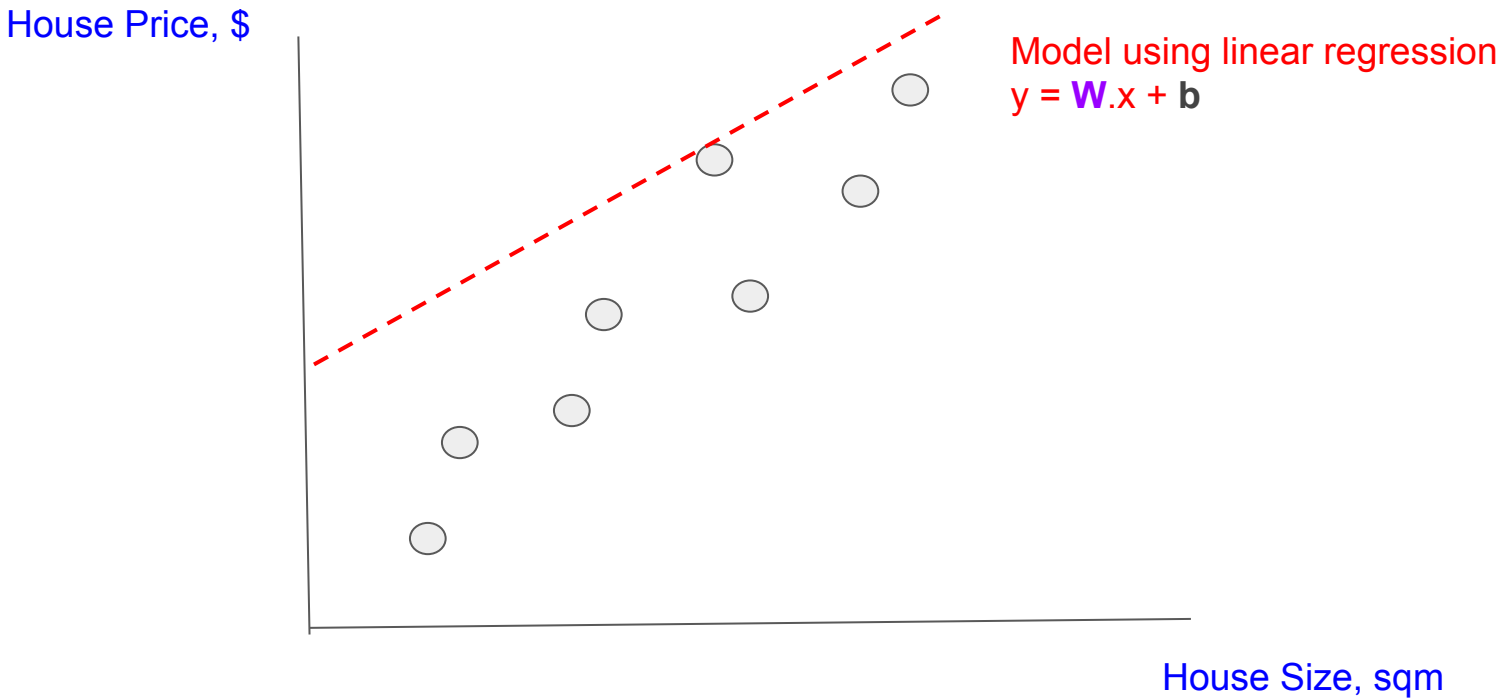
Quick Review

Given house size, use machine learning to predict house price

Quick Review

Quick Review

Quick Review



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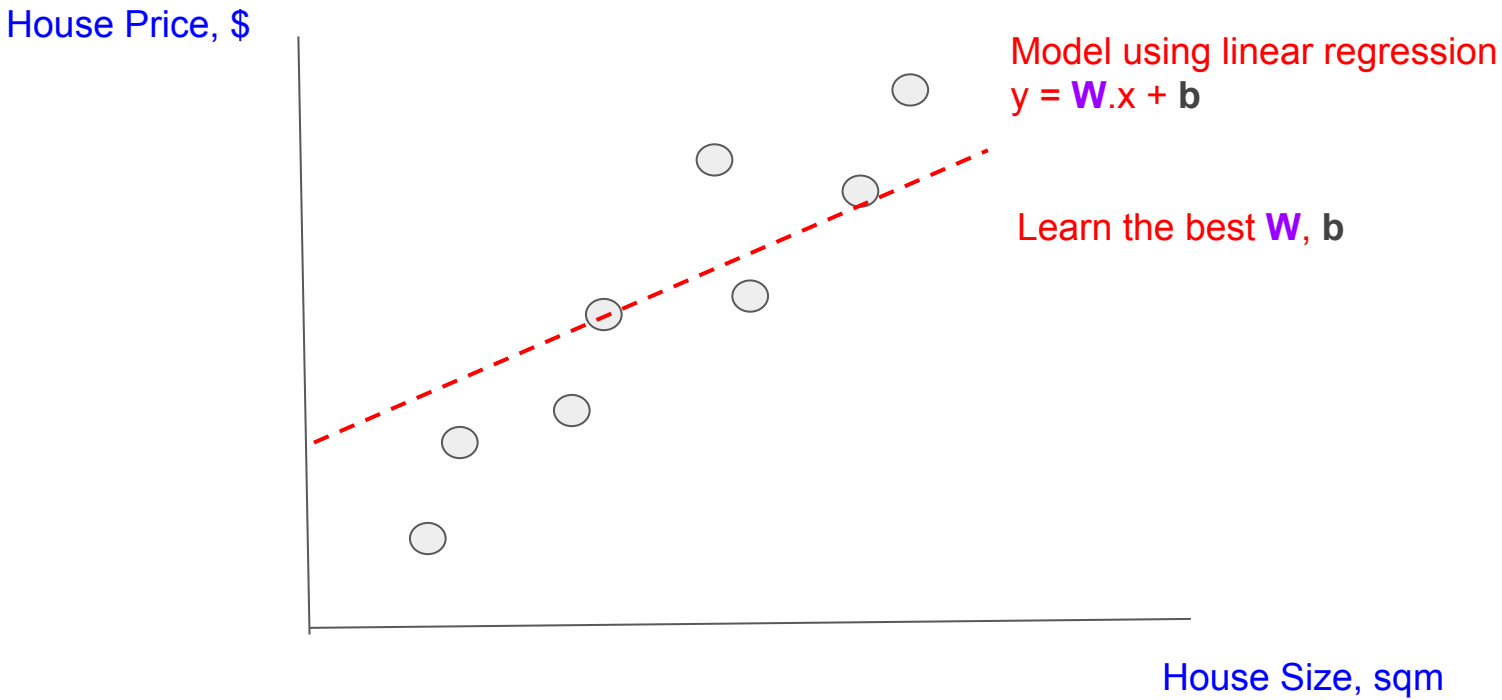

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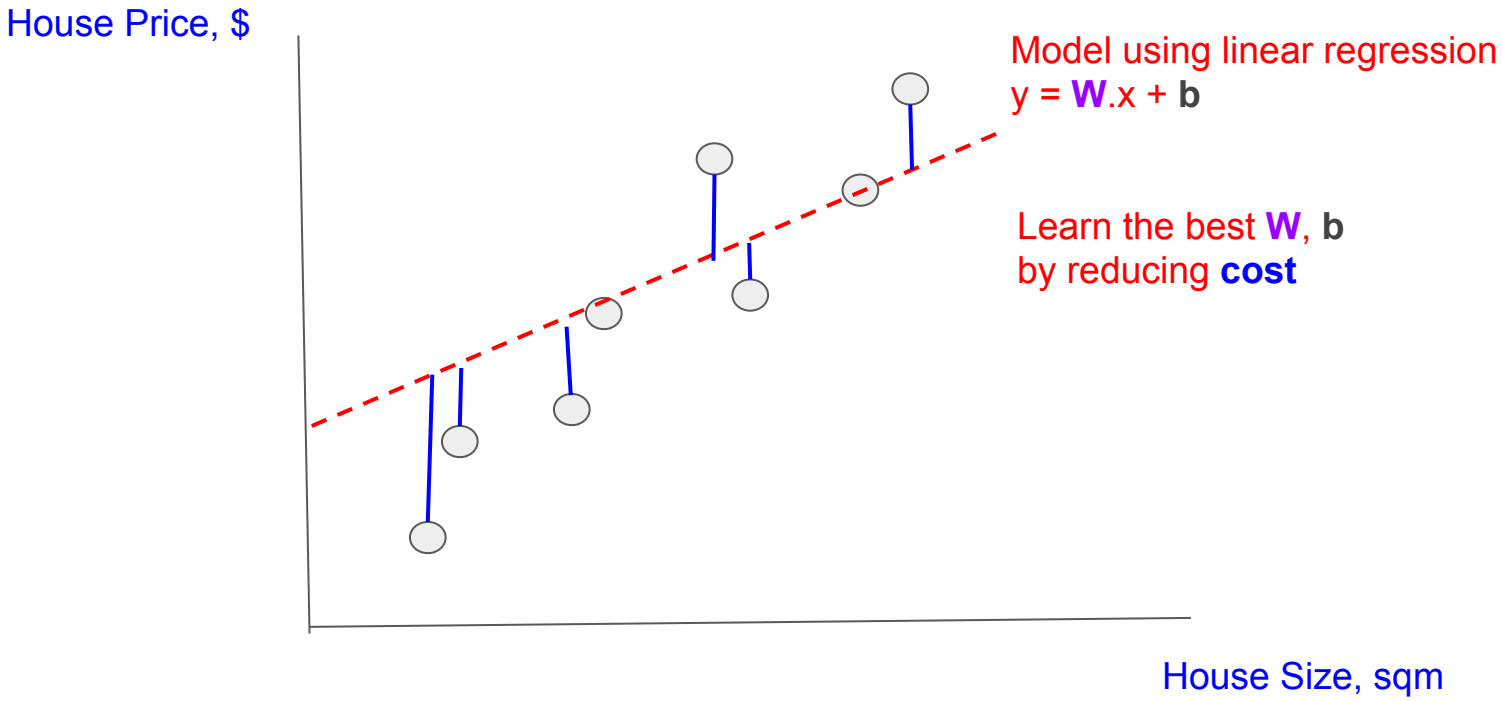

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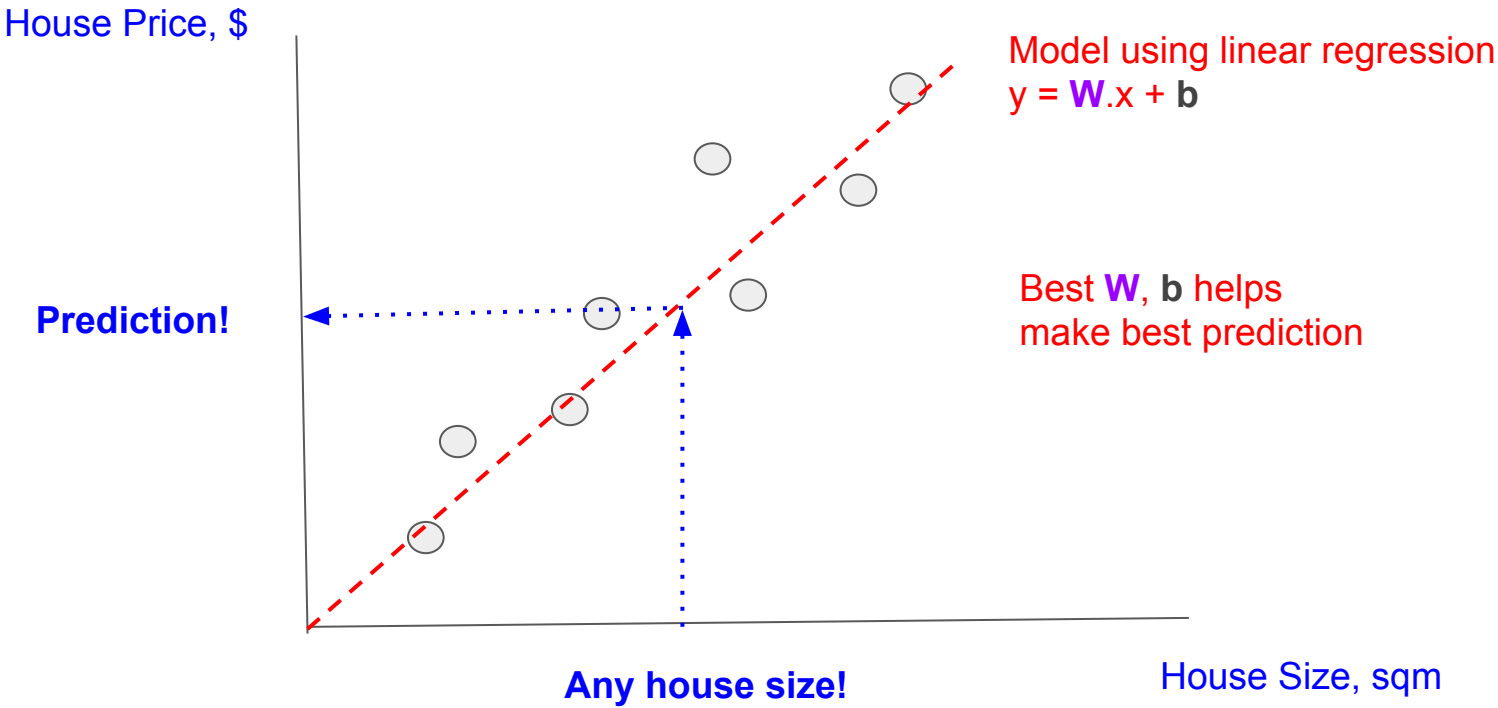

Quick Review

Modeling linear regression in Tensorflow

Tensorflow Graph

Model: y = W.x + b

Cost: tf.reduce_mean(tf.square(y_ - y))

Tensorflow Graph

prediction

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Goal: Train

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How: Minimizing actual vs. prediction

Tensorflow Graph

prediction

Goal: Train

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How: Minimizing actual vs. prediction

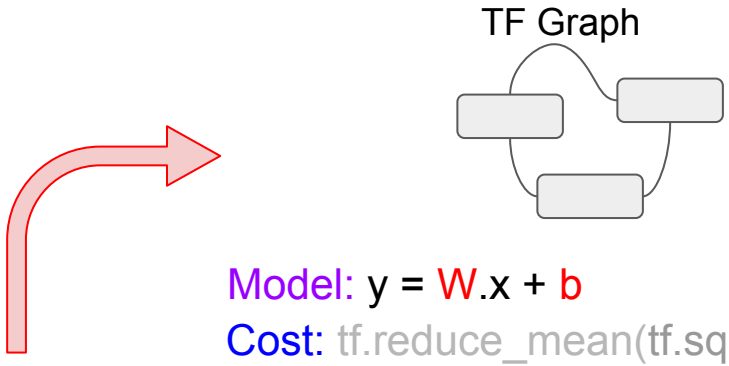
Train: tf.train.GradientDescentOptimizer(learning_rate).minimize(cost)

What is Train?

W, b

Init with some values

What is Train?



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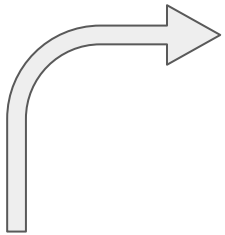
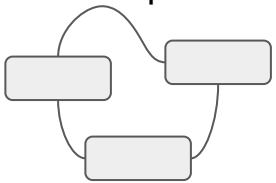
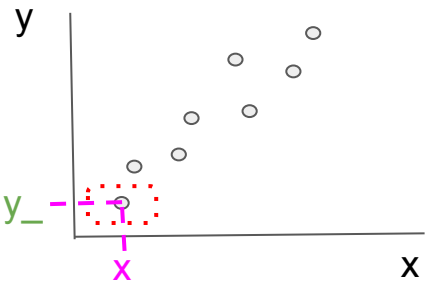


TF Graph



Actual Datapoints



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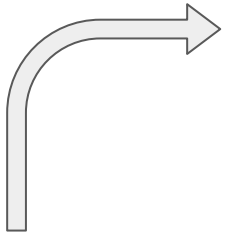

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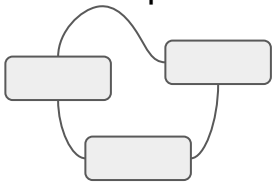

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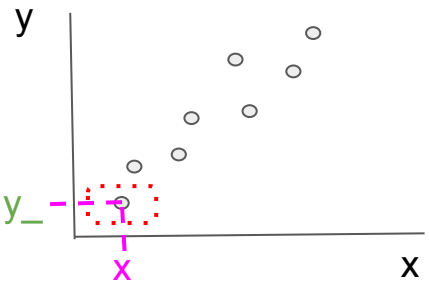

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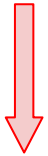
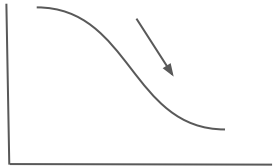


Train: tf.train.GradientDescentOptimizer(01).minimize(cost)

Gradient Descent

Cost



Tweak W', b'

Reduce Cost for (x, y_)

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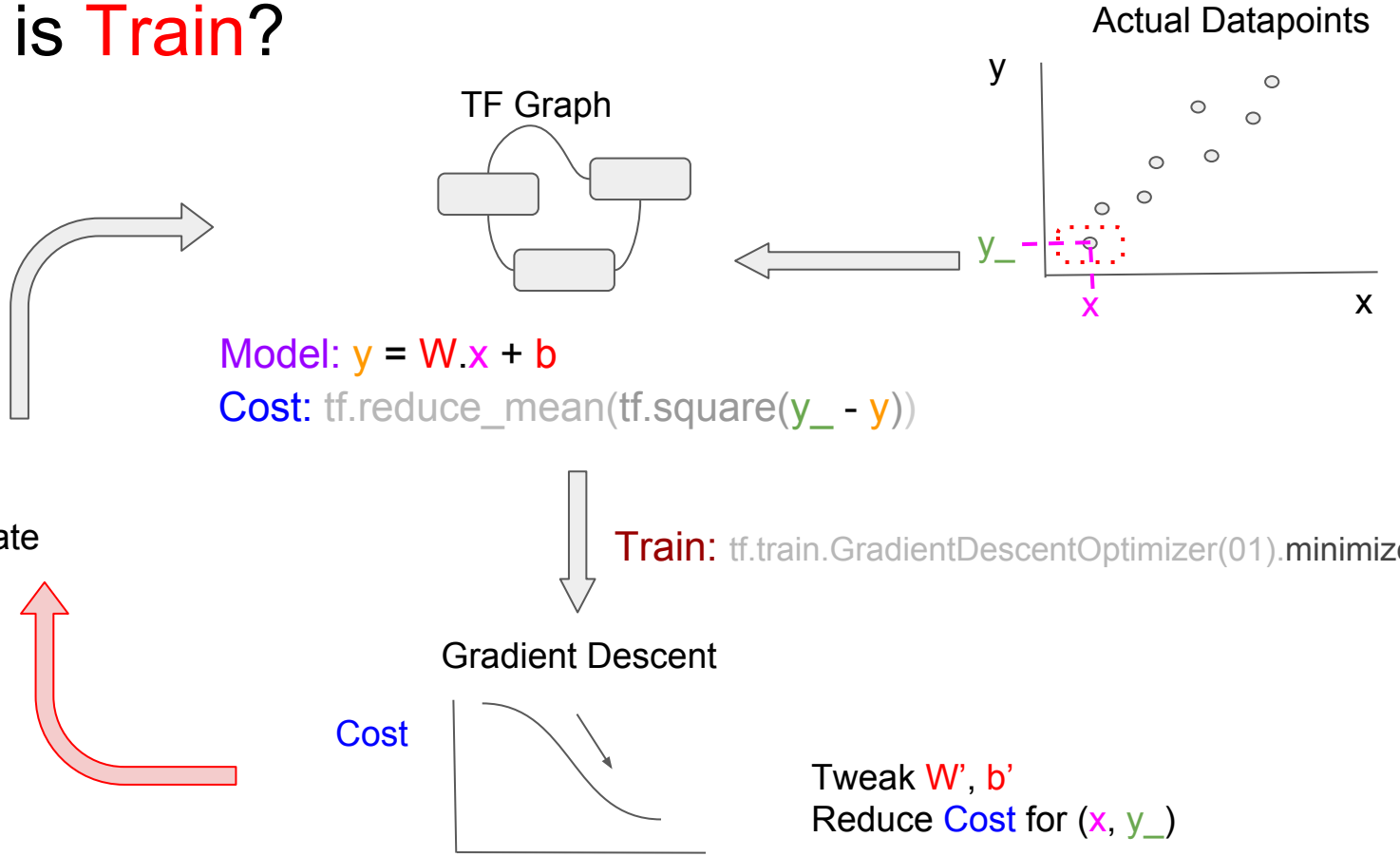

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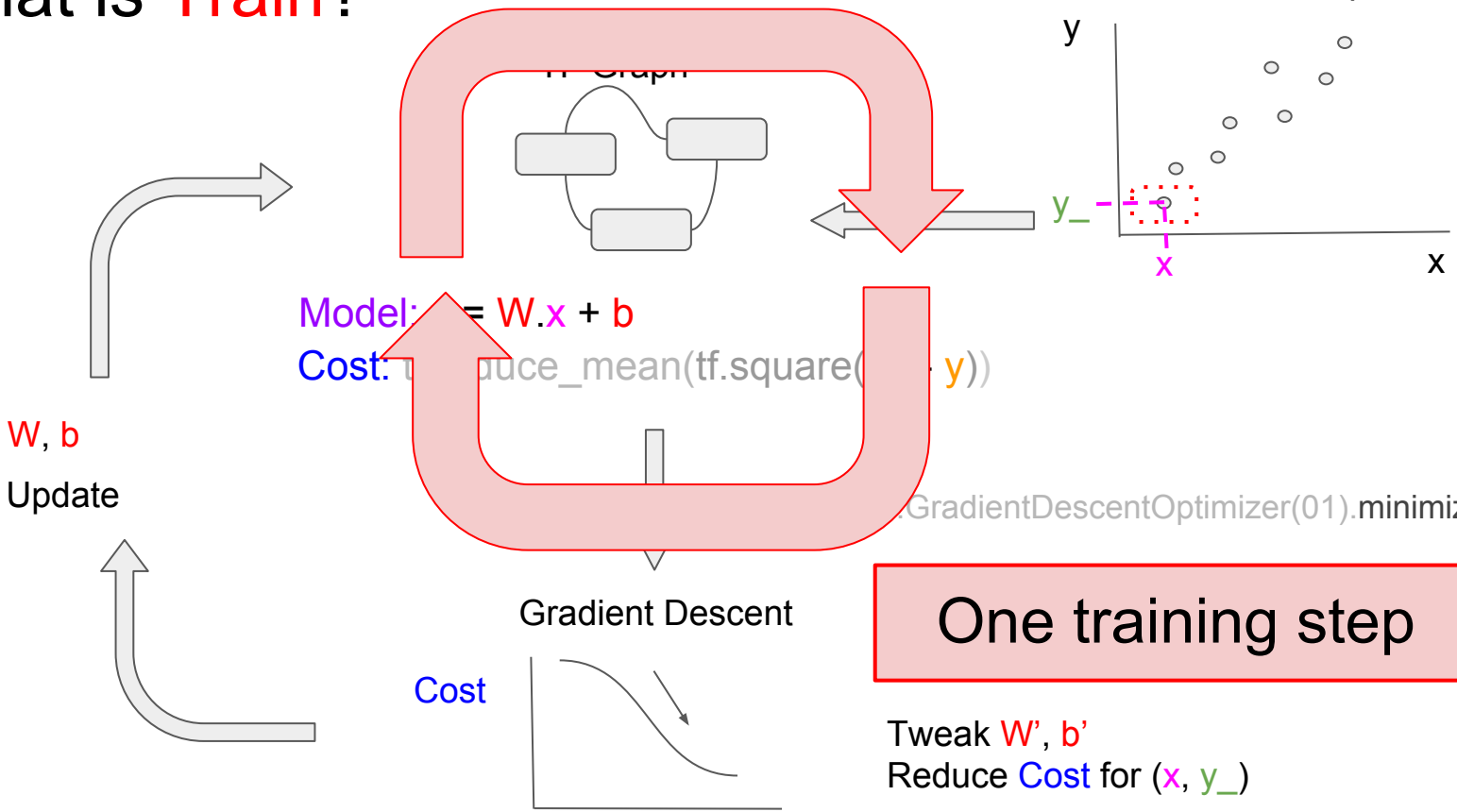

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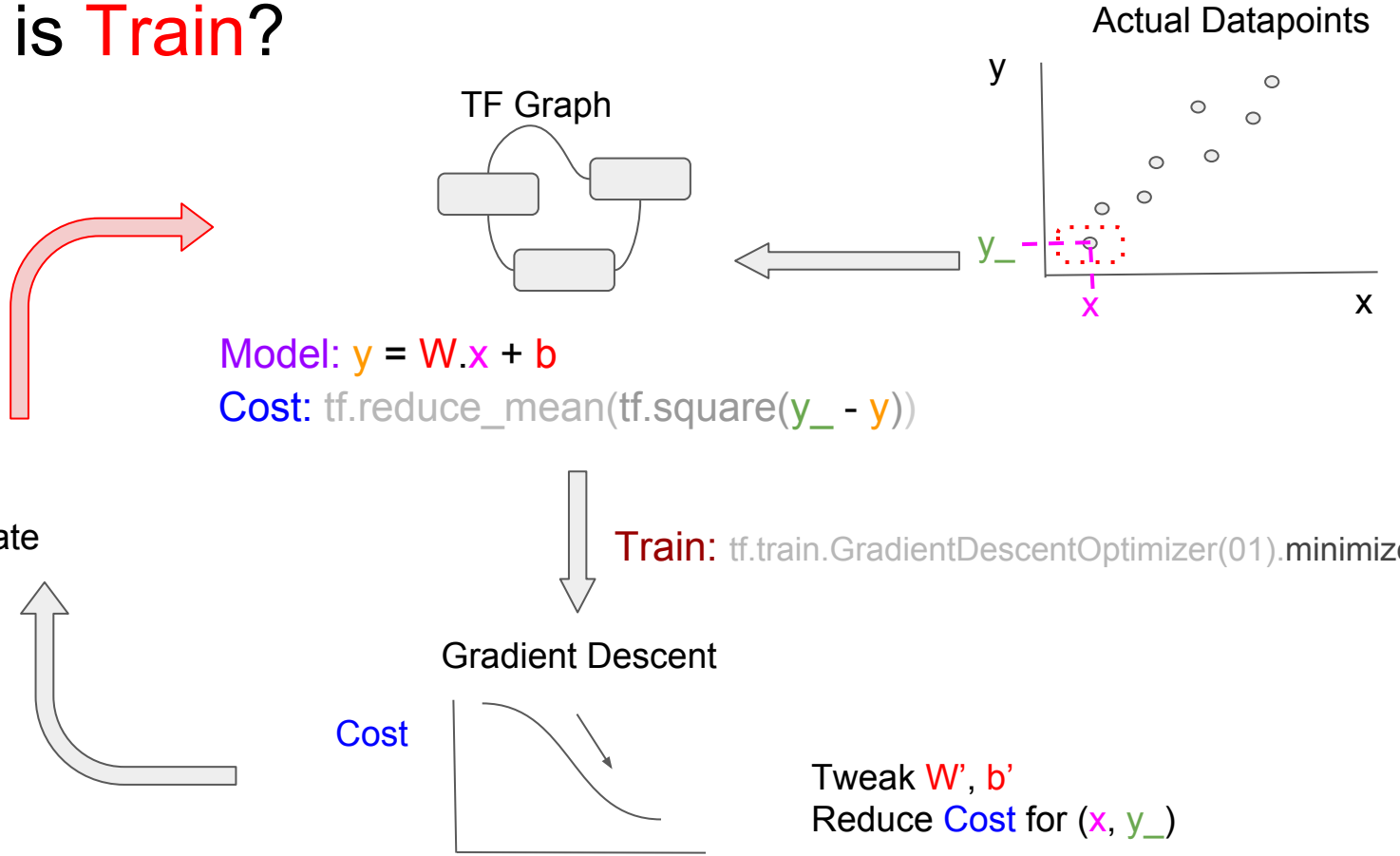

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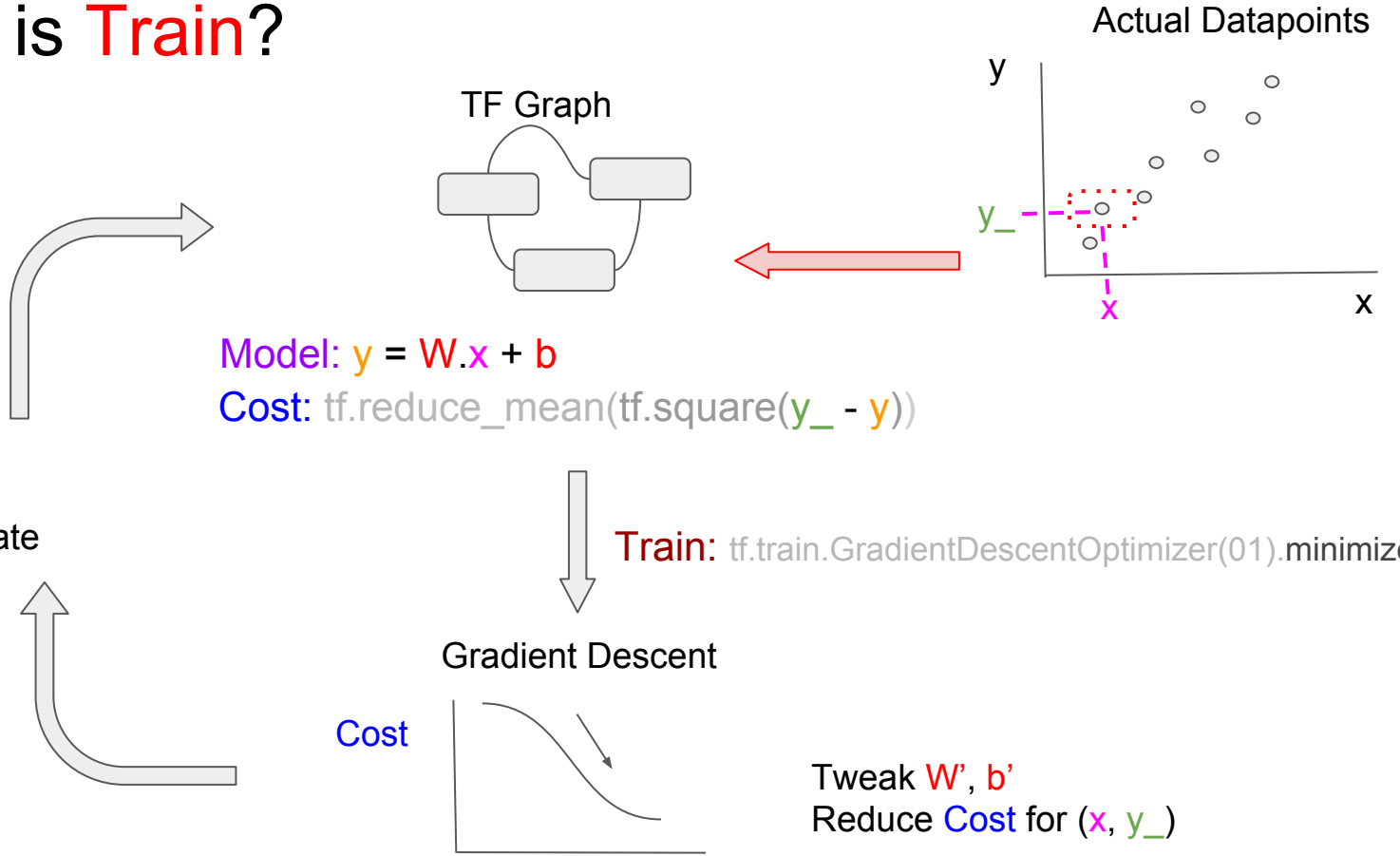

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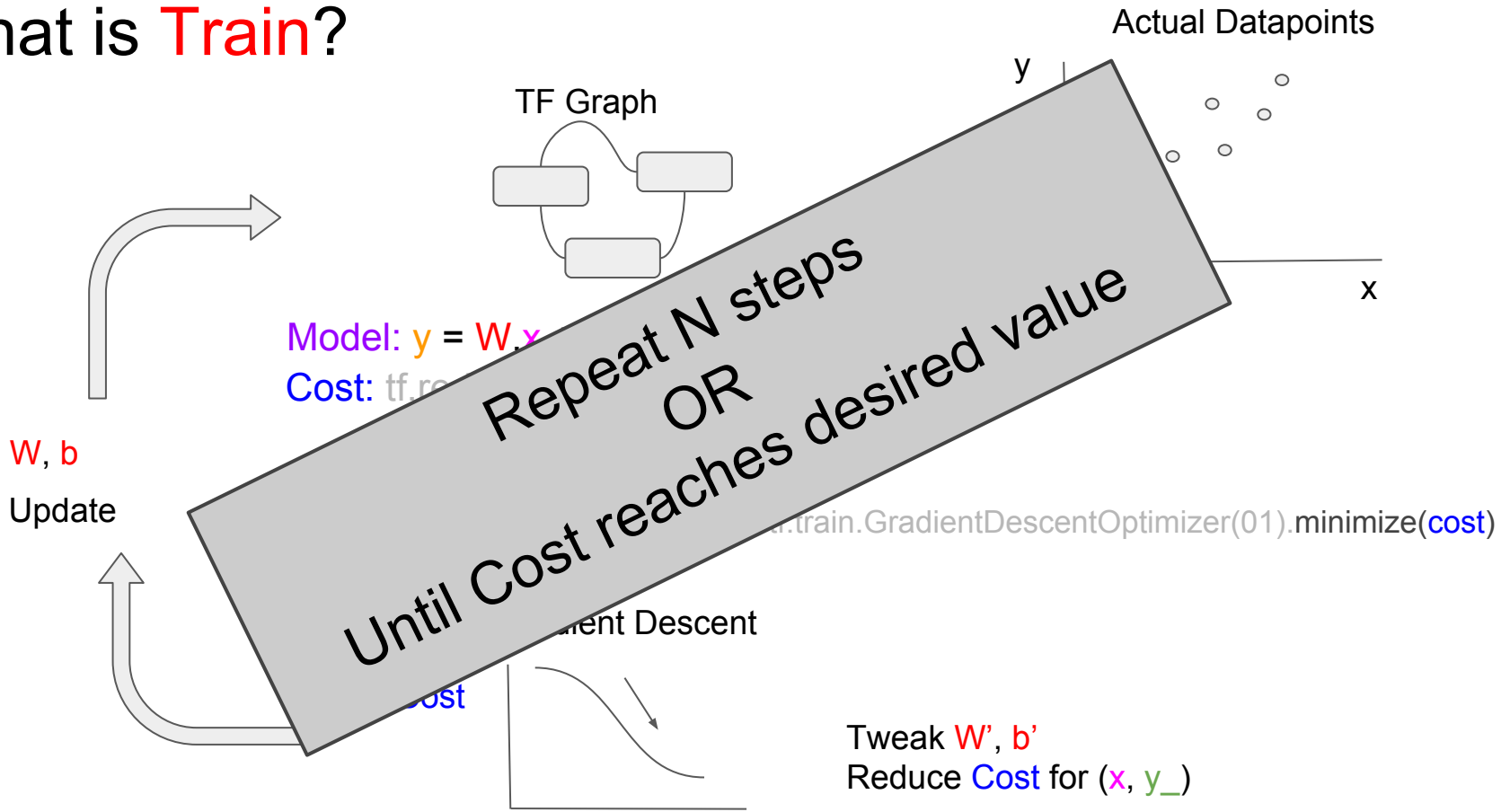
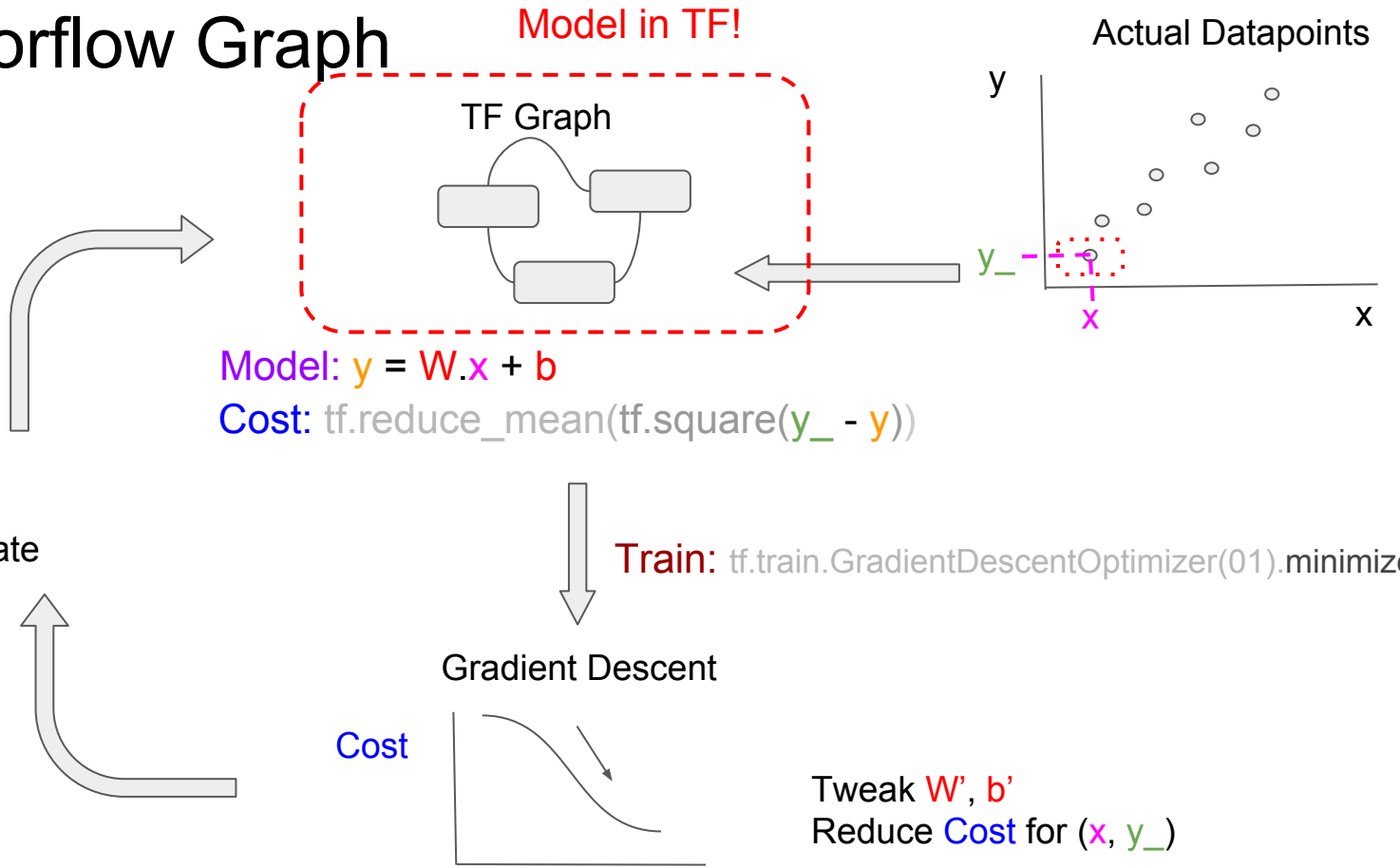


Creating Tensorflow Graph

Tensorflow Graph



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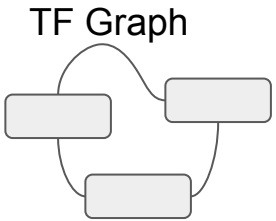
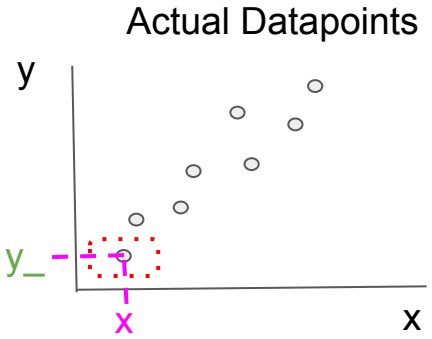




Model: y = W.x + b

Cost: tf.reduce_mean(tf.square(y_ - y))

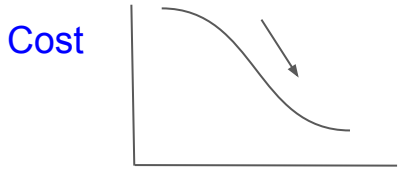
W, b

Update

Define as tf.Variable

Train: tf.train.GradientDescentOptimizer(01).minimize(cost)

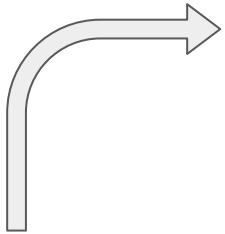
Gradient Descent



Tweak W', b'

Reduce Cost for (x, y_)

Tensorflow Graph



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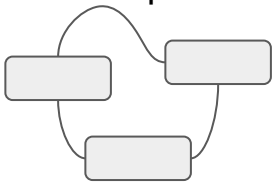

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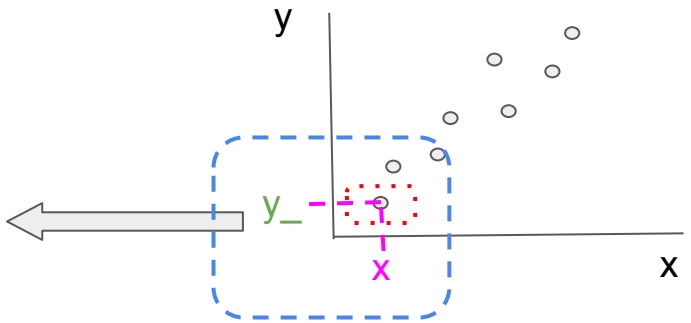

Model: y = W.x + b

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Define as tf.placeholder

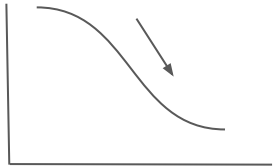
W, b

Update

Train: tf.train.GradientDescentOptimizer(01).minimize(cost)

Gradient Descent

Cost

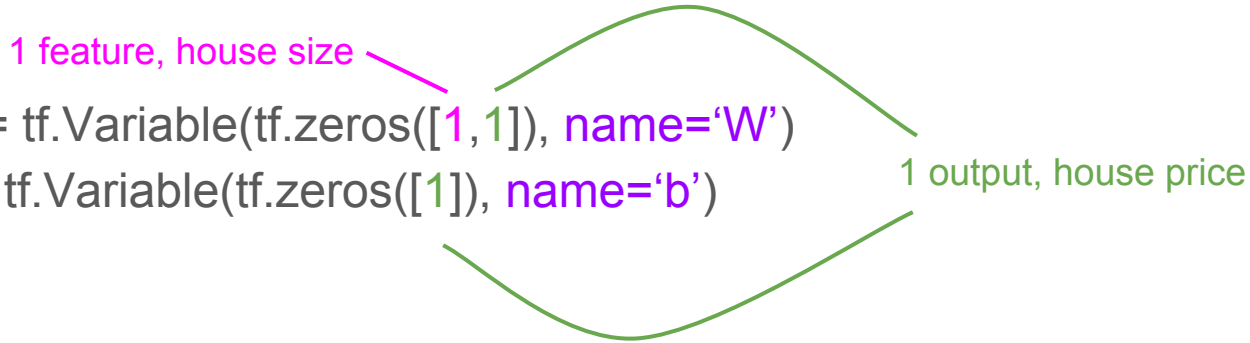


Tweak W', b'

Reduce Cost for (x, y_)

Tensorflow Graph: tf.Variable (Enhance visualization)

tf.Variable for holding variables we want to learn, W, b



NOTE: Without *name=XXX*, the variables will be assigned names like Variable_0, Variable_1, etc.

Tensorflow Graph: tf.placeholder (Enhance visualization)

tf.placeholder for actual data, e.g., house size (x), house price (y_)

1 feature, house size

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

1 output, house price

NOTE: Without *name=XXX*, the placeholders will be assigned names like Placeholder_0, Placeholder_1, etc.

Tensorflow Graph: Model (Enhance visualization)

```
# Model linear regression y = Wx + b

with tf.name_scope("Wx_b") as scope:
  product = tf.matmul(x,W)
  y = product + b
```

NOTE: With *scope*, the all definitions under it, will appear as a black-box that is expandable!

Tensorflow Graph: Cost (Enhance visualization)

```
# Cost function: Least-squared difference

with tf.name_scope("cost") as scope:
  cost = tf.reduce_mean(tf.square(y_-y))
```

Tensorflow Graph: Train (Enhance visualization)

```
# Train step

with tf.name_scope("train") as scope:
  train_step = tf.train.GradientDescentOptimizer(learning_rate).minimize(cost)
```

Tensorboard

Two Main Components

- Summary
  - Mark data we want to collect
    - W, b, cost
- Writer
  - Write data collected to event file

Tensorflow Summary: Scalar

tf.scalar_summary

```
# cost is single-dimension so
# mark it as data to be collected using scalar_summary

cost = tf.reduce_mean(tf.square(y_-y))
cost_sum = tf.scalar_summary("cost", cost)
```

Tensorflow Summary: Histogram

tf.histogram_summary

```
# W and b can be multi-dimensional so
# mark them as data to be collected using histogram_summary

W = tf.Variable(tf.zeros([1,1]), name="W")
W_hist = tf.histogram_summary("weights", W)

b = tf.Variable(tf.zeros([1]), name="b")
b_hist = tf.histogram_summary("biases", b)
```

Tensorflow Summary: Merge

tf.merge_all_summaries

merged = tf.merge_all_summaries()

tf.merge_summary

merged = tf.merge_summary([W_hist, b_hist, cost_sum])

Tensorflow Writer

```
# The specified log directory will be:
# * Created if it does not exist
# * If exist and not empty data is merged
# sess.graph_def will enable Tensorflow to draw graph representation
# for network

writer = tf.train.SummaryWriter("/event_log_dir", sess.graph_def)
```

Tensorflow Writer: When to Record Data

```
# NOTE: Train using #steps
for i in steps:
  ...
  # NOTE: Write summary every 10 samples
  if i % 10 == 0:
    all_feed = { x: all_xs, y_: all_ys }
    # NOTE:
    # * merged is our merged summary name
    # * feed is the batch of all  x, y data points, to calculate TOTAL cost
    result = sess.run(merged, feed_dict=all_feed)
    writer.add_summary(result, i)
  ...
```

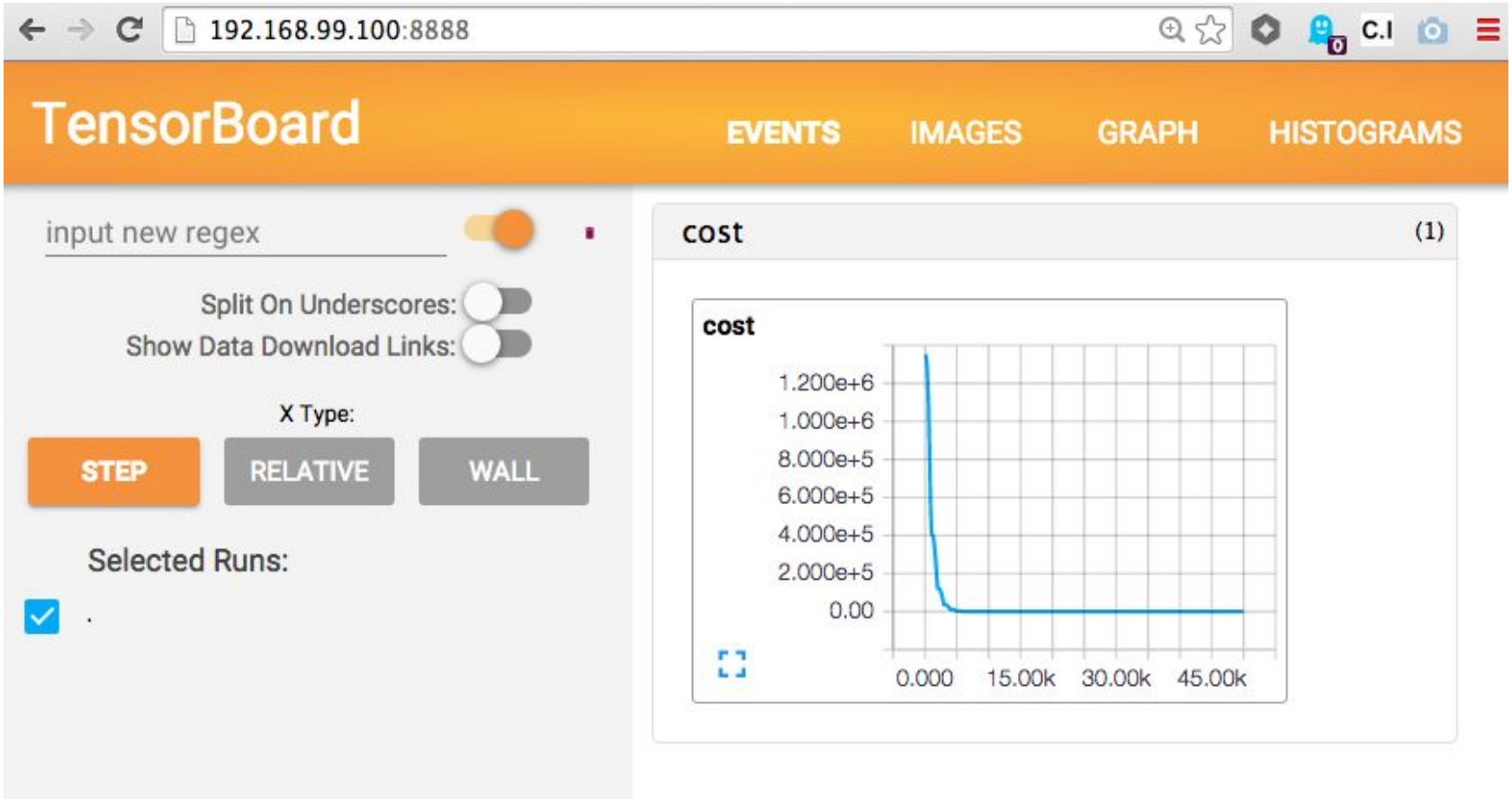
Start Tensorboard Server

NOTE: Single line

python /usr/local/lib/python2.7/dist-packages/tensorflow/tensorboard/tensorboard.py --logdir /event_log_dir/ --port 8888

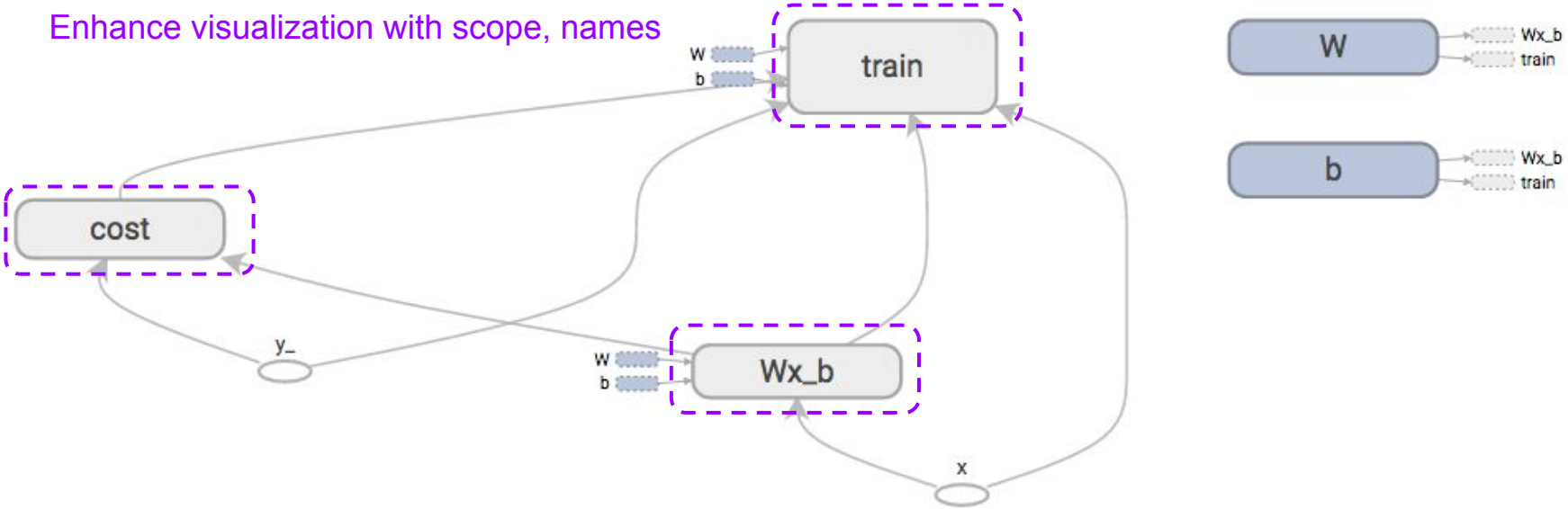
WARNING:tensorflow:Found more than one graph event per run.Overwritting the graph with the newest event

Access Using Browser



Tensorflow Graph

Enhance visualization with scope, names



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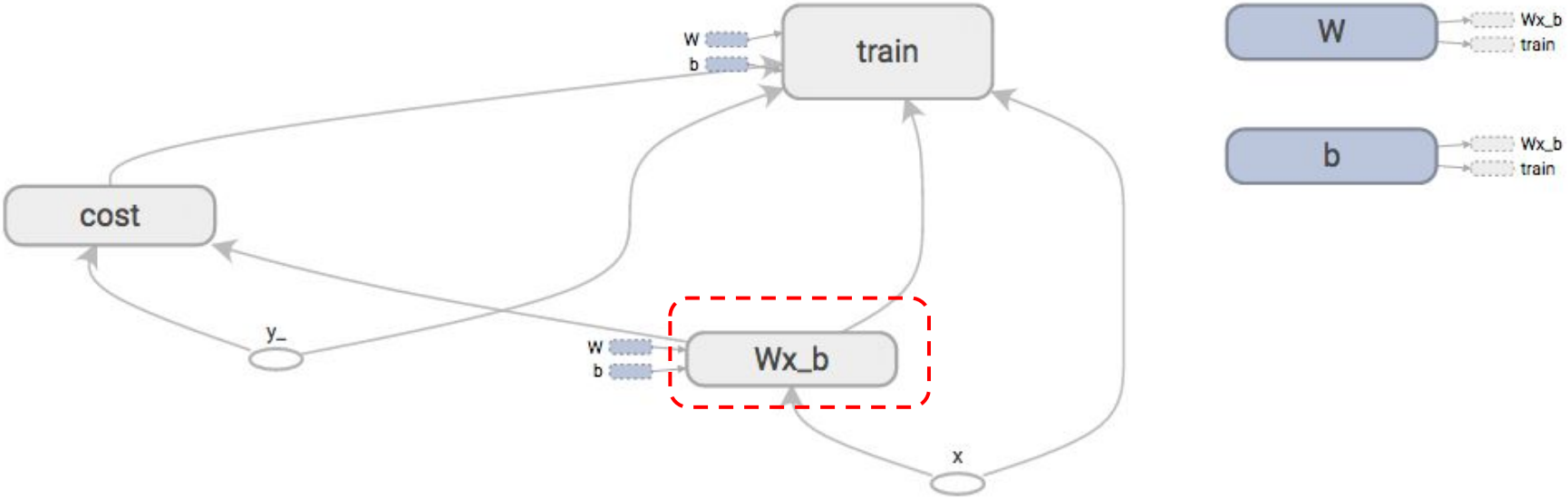
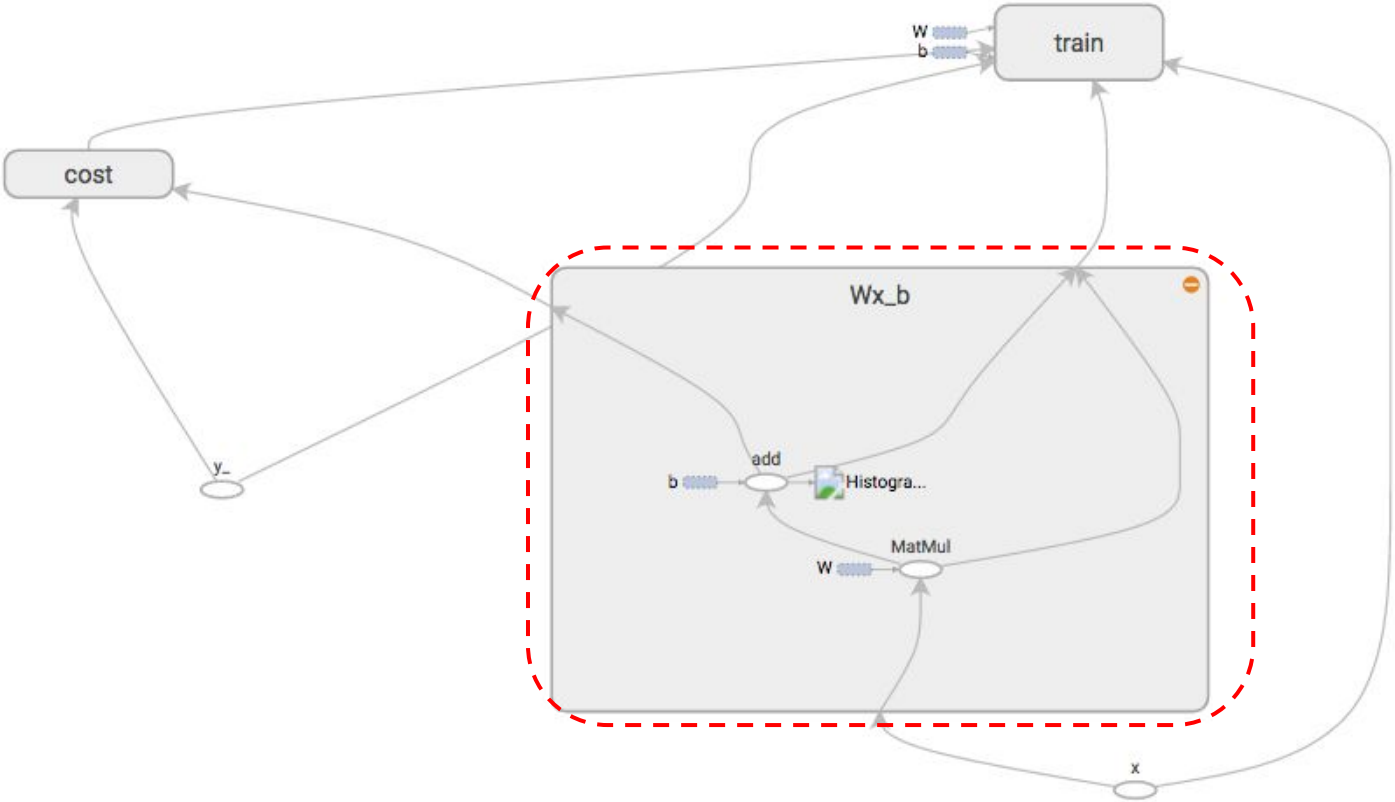
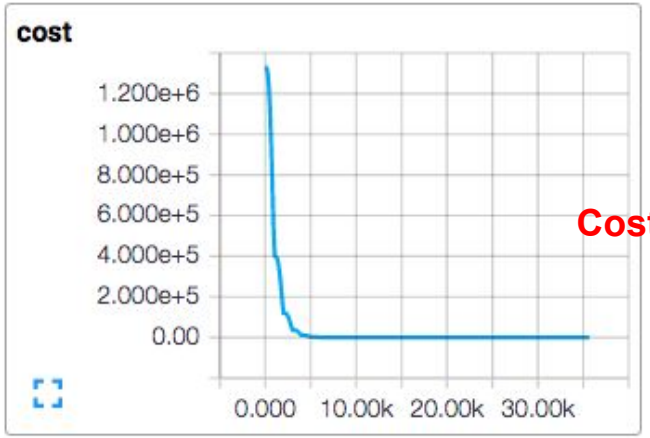


Tensorflow Graph: Expanded



Importance of Visualization: Have we found a good fit?

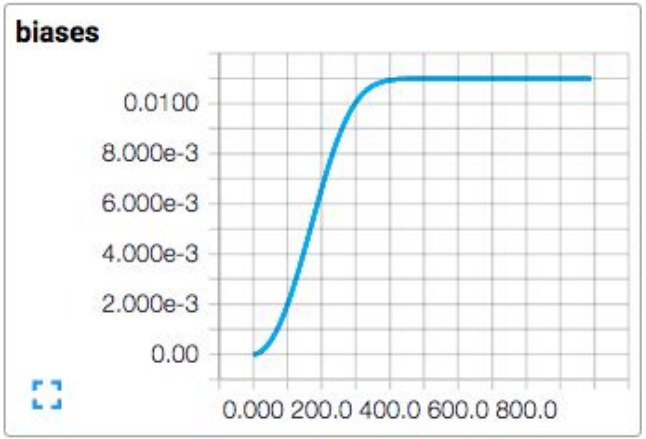
Linear Regression with 1-Feature

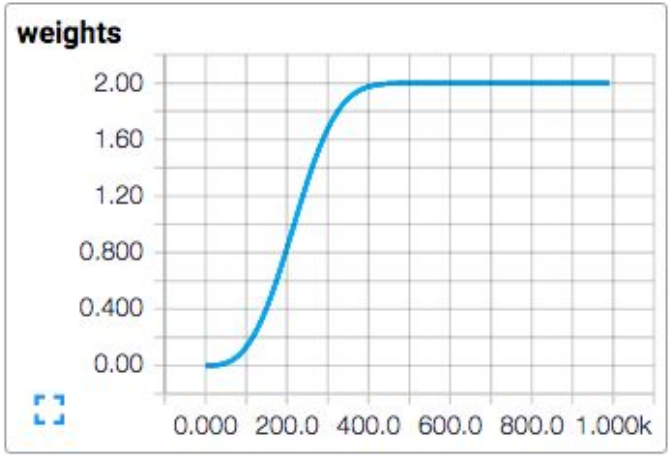


Cost reaches zero = good model fit

b ~ 0.0

W ~ 2.0

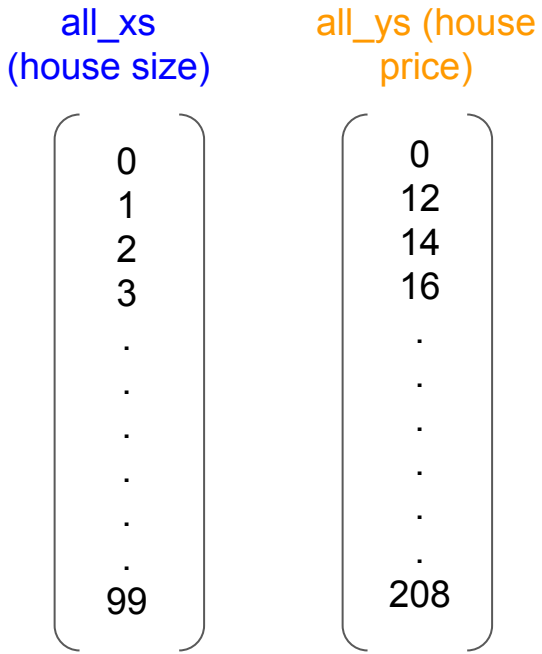




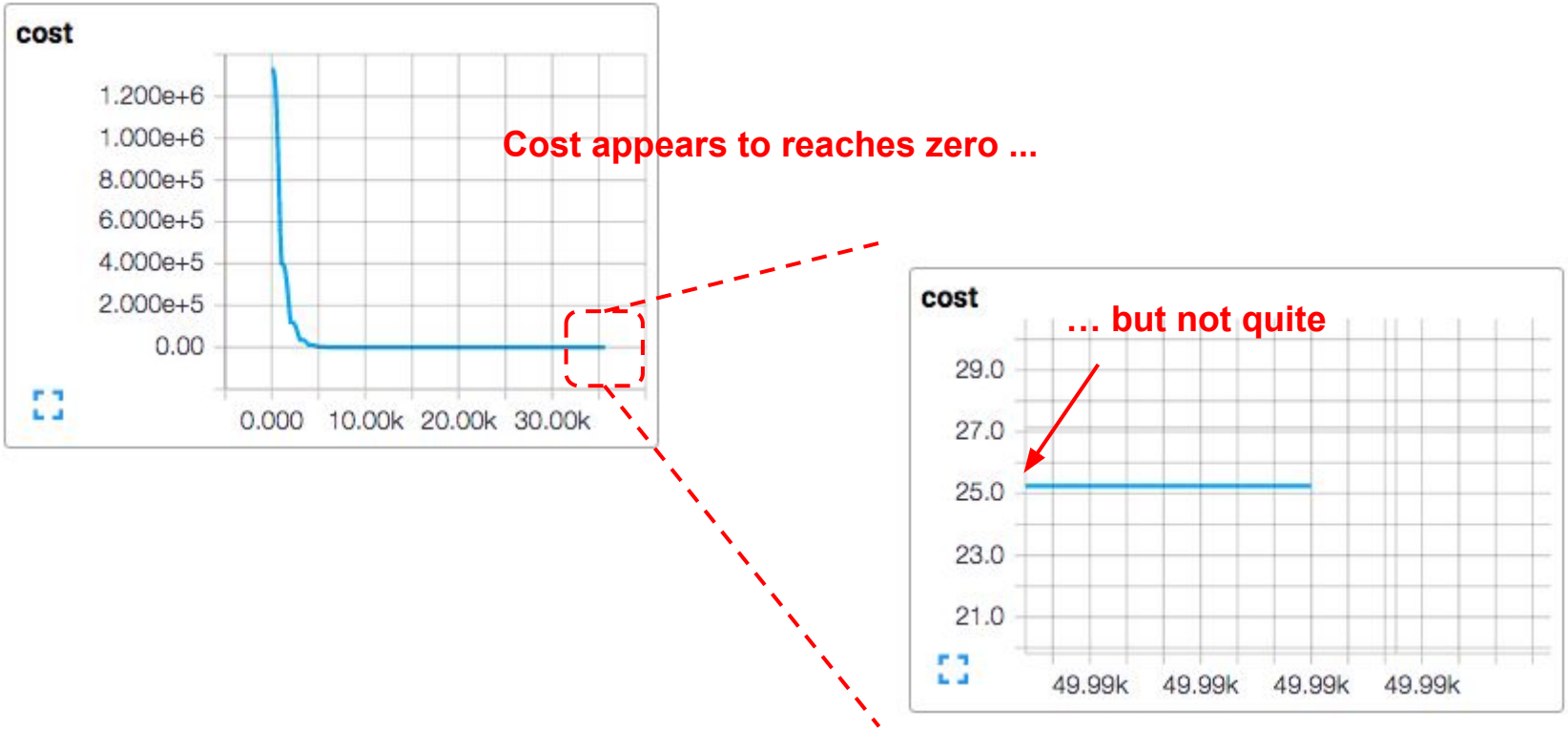
Training Linear Regression with b > 0

```
# Generate fake data for y = 2.x + 10, i.e., W = 2, b = 10

all_xs = []
all_ys = []
for i in range(datapoint_size):
  # Create fake data for y = W.x + b where W = 2, b = 10
  all_xs.append(i)
  all_ys.append(2*i+10)
```



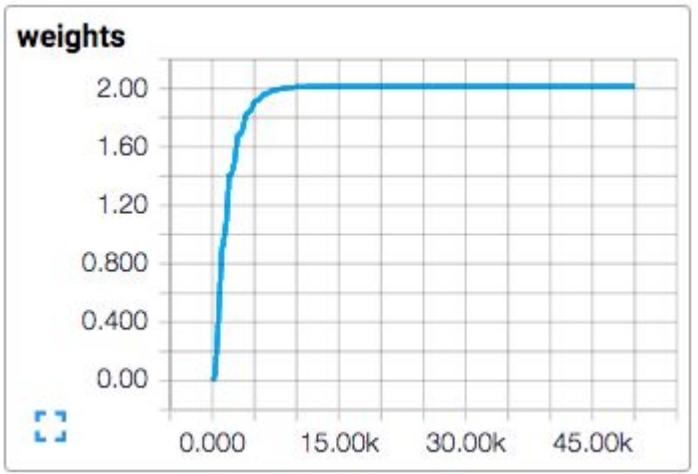
Linear Regression with 1-Feature (b > 0)



Linear Regression with 1-Feature (b > 0)

W ~ 2.0

b slowly learning … (ideally 10)

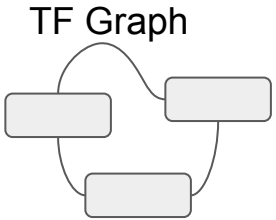


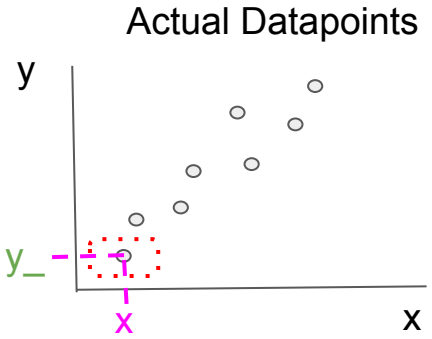
Is there a way to learn faster?

- Faster gradient descent learning rate?
- Different model?
- Different cost function?

Batch Size

Stochastic Gradient Descent





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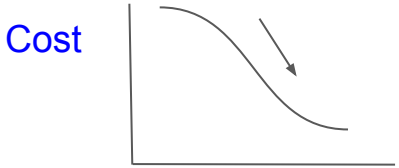
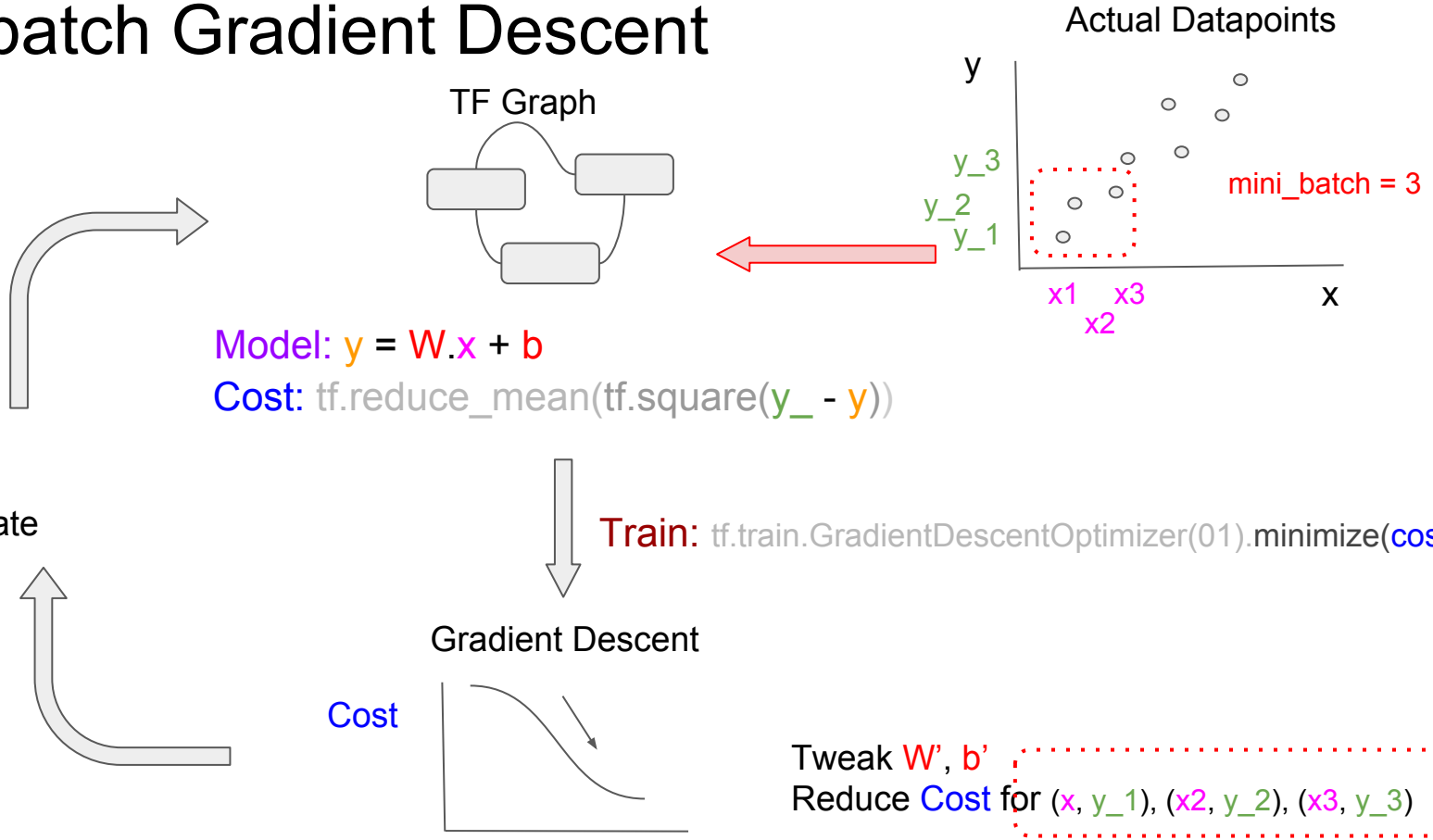


Tweak W', b'
Reduce Cost for (x, y_)

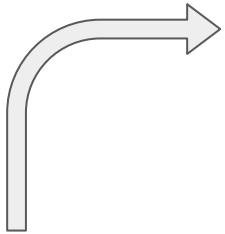
W, b

Update

Mini-batch Gradient Descent



Batch Gradient Descent



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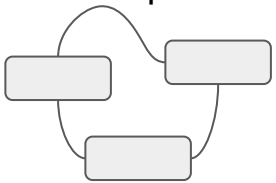

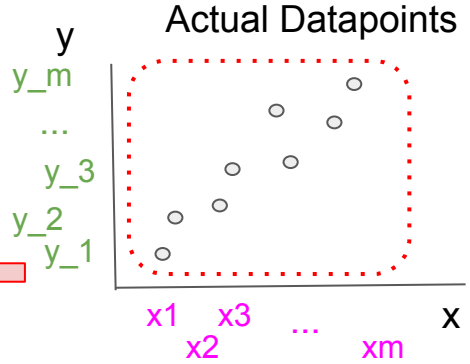

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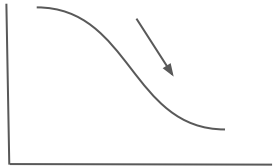
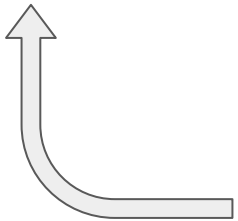
Gradient Descent

Cost





W, b

Update

Tweak W', b'

Reduce Cost for (x, y_1), (x2, y_2), ... (xm, y_m)

Stochastic/Mini-batch/Batch Gradient Descent

One feature, house size

```
x = tf.placeholder(tf.float32, [None, 1])
y_ = tf.placeholder(tf.float32, [None, 1])
...
train_step = tf.train.GradientDescentOptimizer(01).minimize(cost)
```

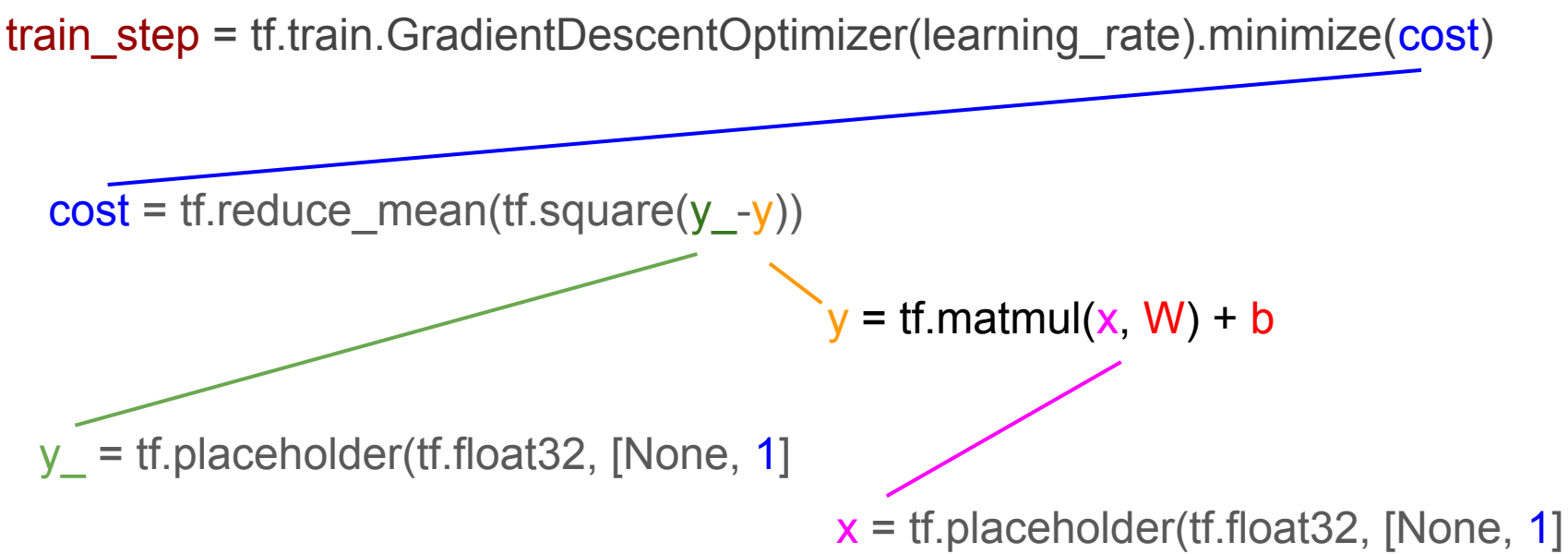
One output, house price

```
xs = ....
ys = ....
```

ONLY this part is different!

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

Why Feed train_step, with feed_dict = x, y_



train_step has dependency on x, y_

Stochastic Gradient Descent

Stochastic Gradient Descent

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

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]])

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

One feature, house size

One output, house price

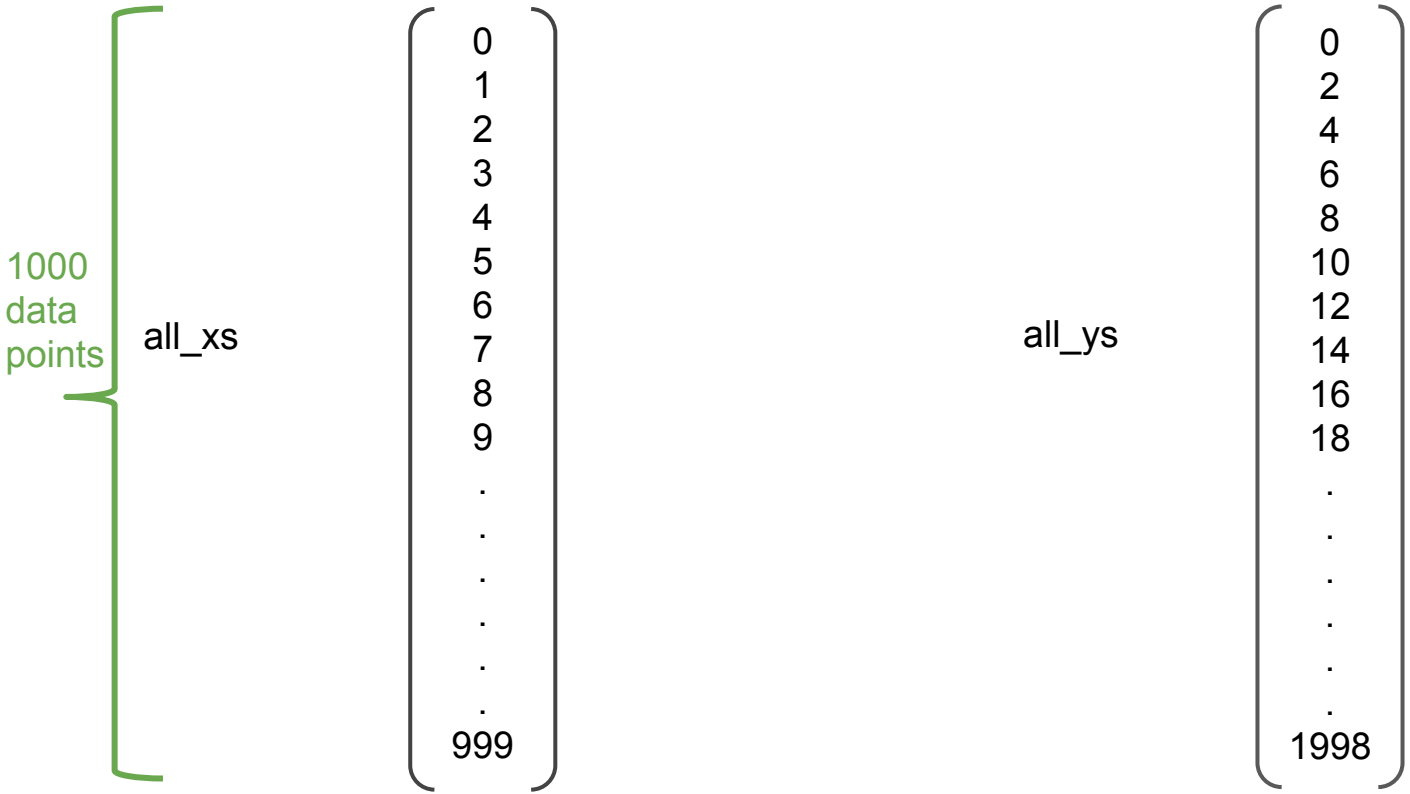
Provide datapoint for feature, house size each step

Provide datapoint for output, house price, each step

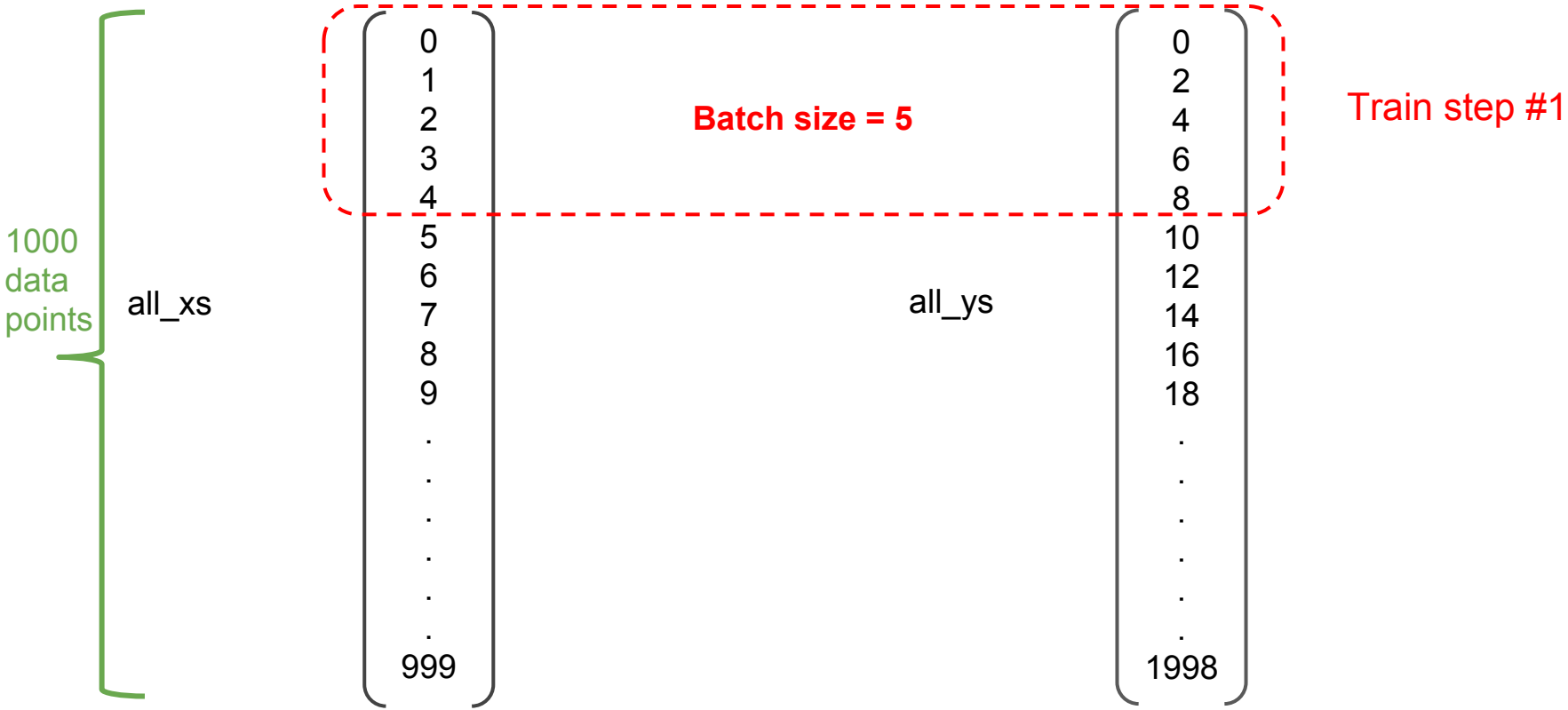
Stochastic Gradient Descent

Mini-batch Gradient Descent

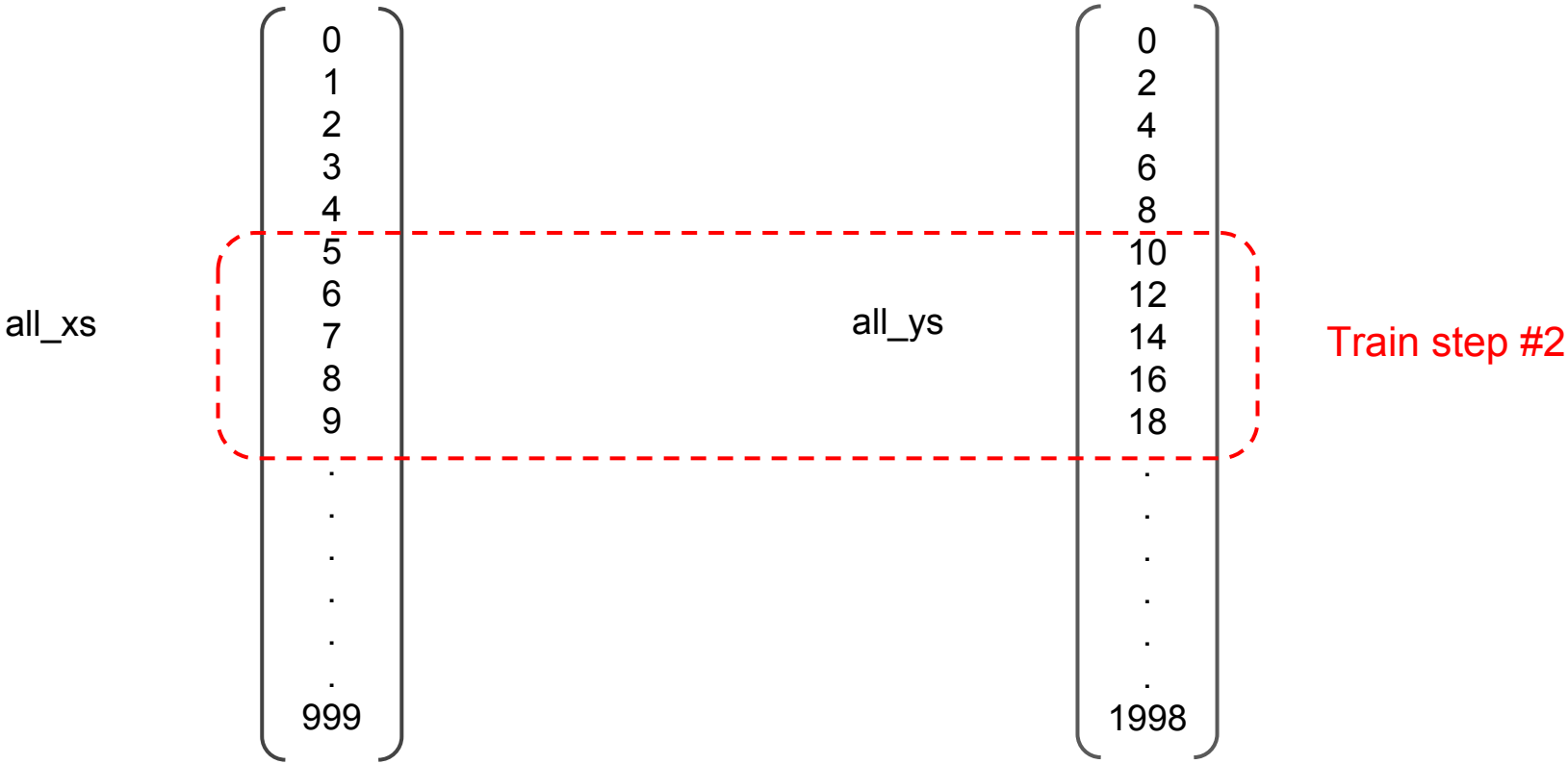
Mini-batch Gradient Descent: x, y_



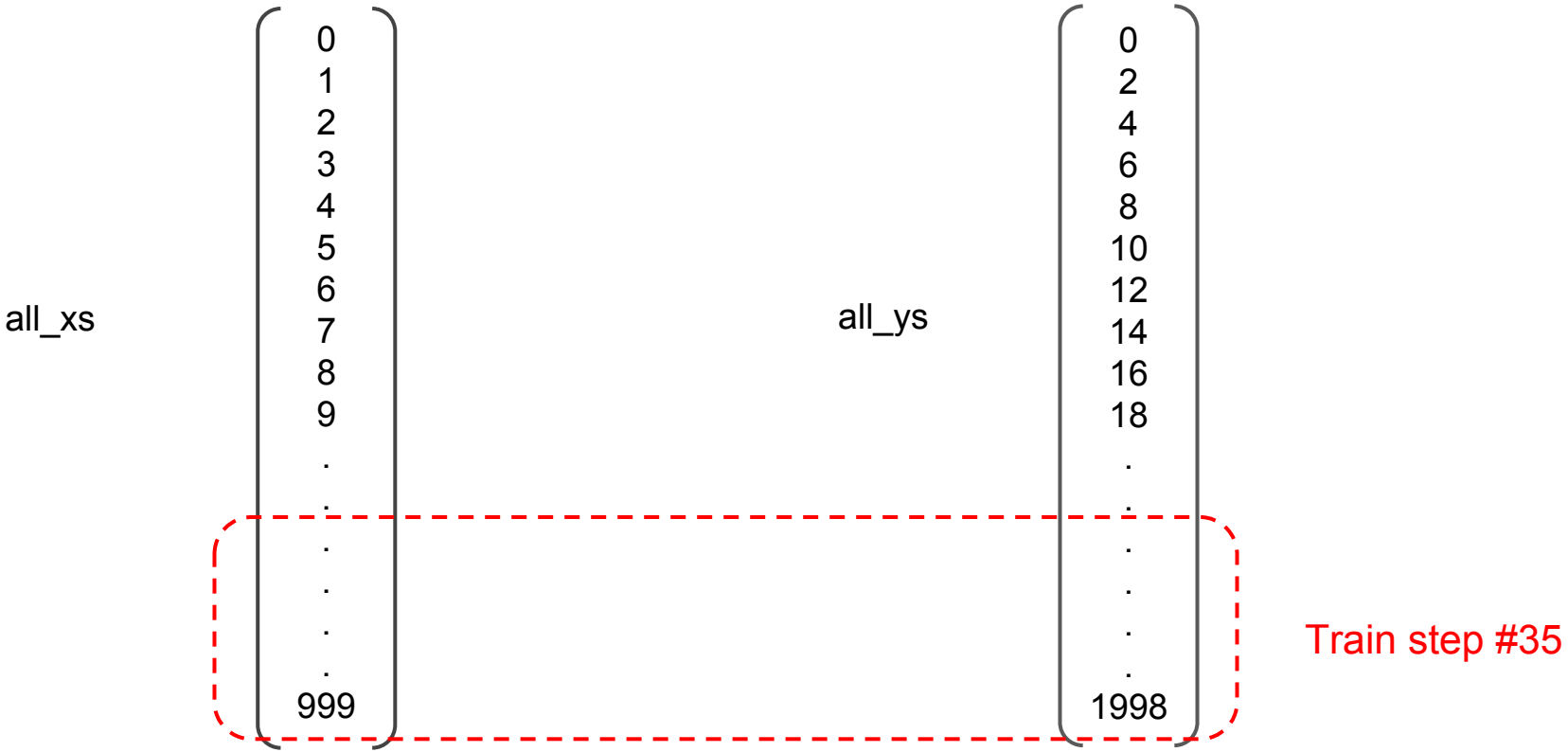
Mini-batch Gradient Descent: x, y_



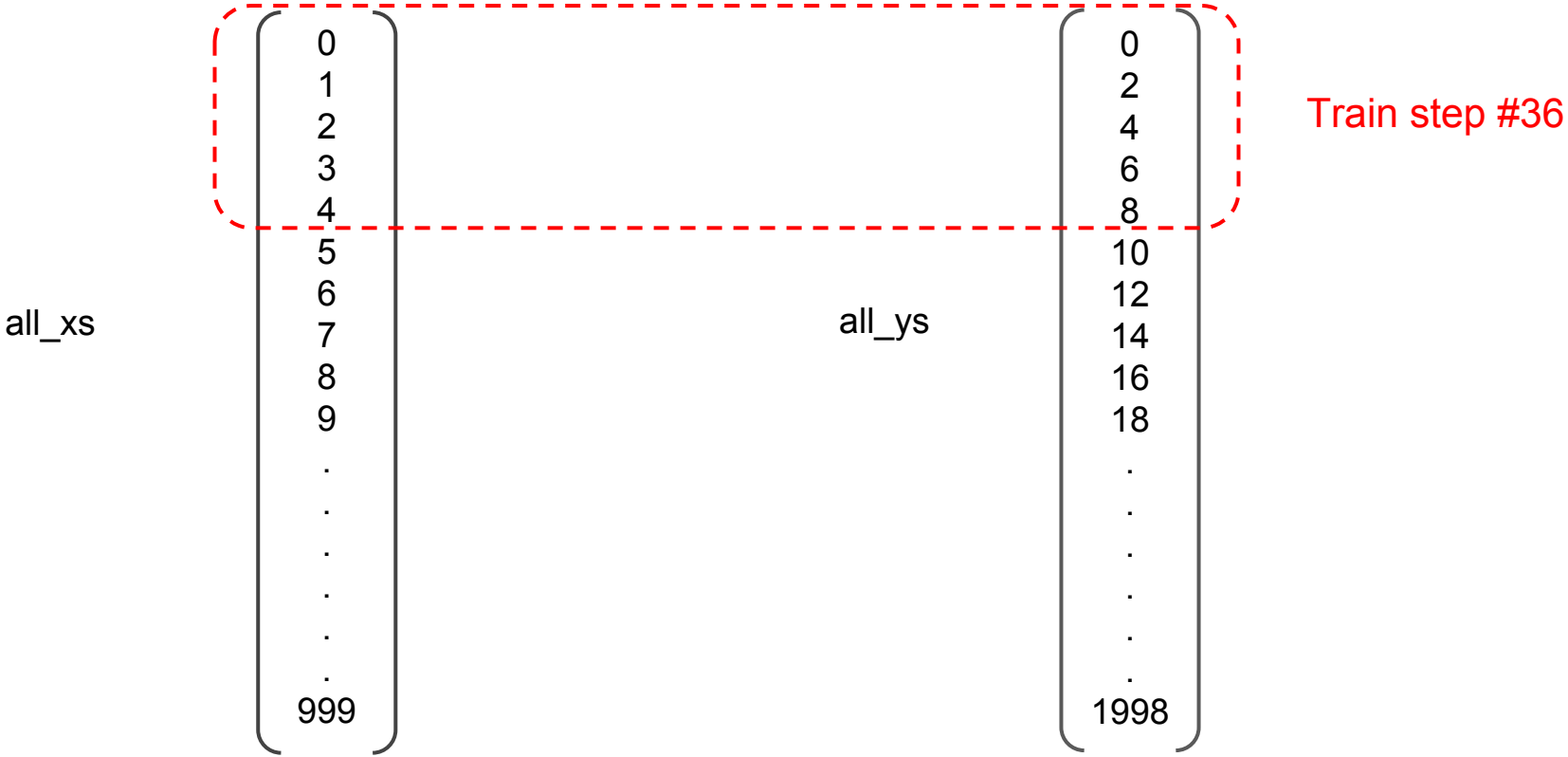
Mini-batch Gradient Descent: x, y_



Mini-batch Gradient Descent: x, y_



Mini-batch Gradient Descent: x, y_



Mini-batch Gradient Descent

One feature, house size

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

One output, house price

```
# Prepare all actual house size (x), house price (y_) before hand
all_xs = ...
all_ys = …

for i in range(steps):
  xs = np.array(all_xs[batch_start_idx:batch_end_idx])
  ys = np.array(all_ys[batch_start_idx:batch_end_idx])
  feed = { x: xs, y_: ys }
  sess.run(train_step, feed_dict=feed)
```

Code to do data batching

Mini-batch Gradient Descent

One feature, house size

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

One output, house price

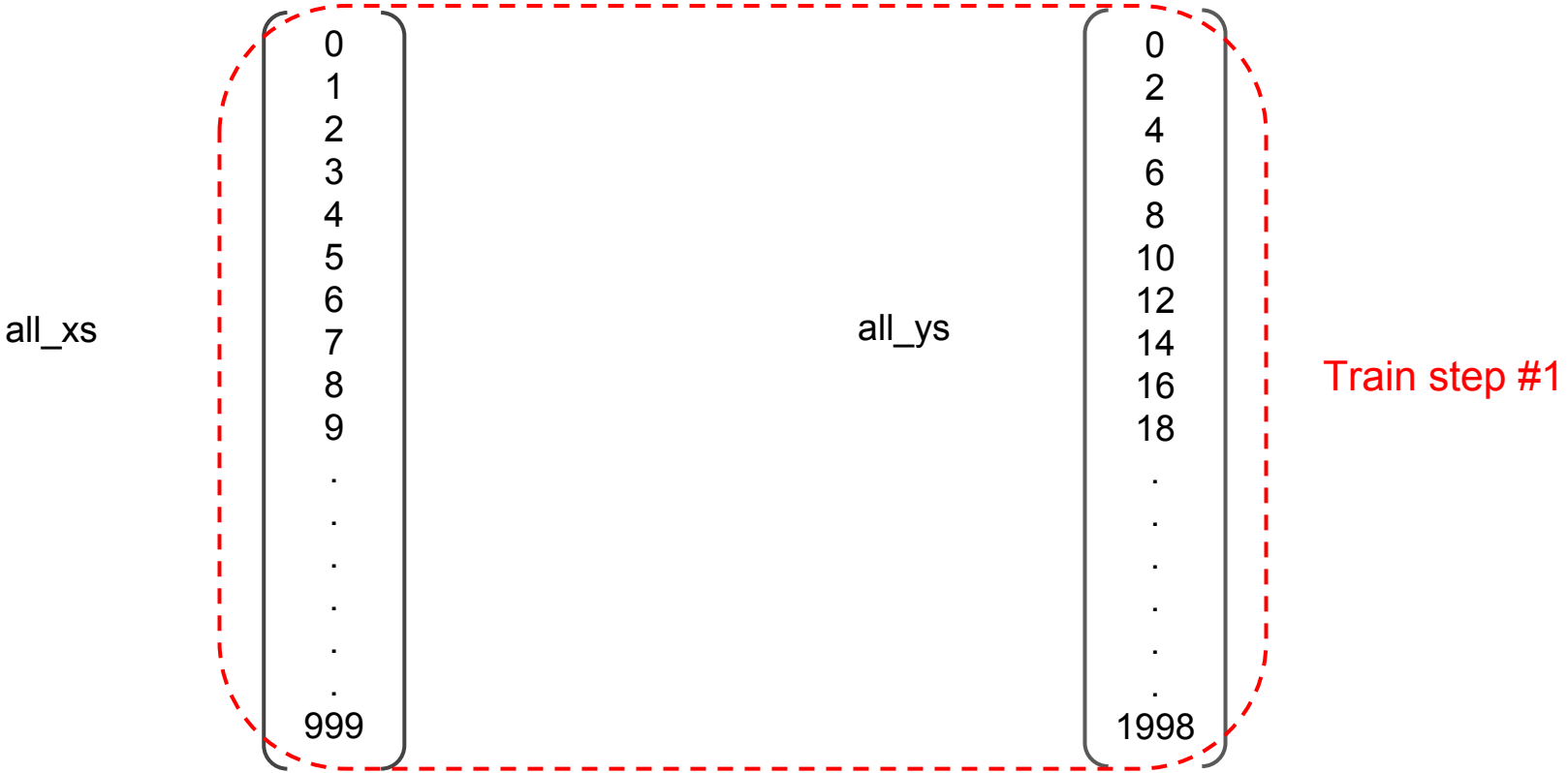
```
# Prepare all actual house size (x), house price (y_) before hand
all_xs = ...
all_ys = …

for i in range(steps):
  xs = np.array(all_xs[batch_start_idx:batch_end_idx])
  ys = np.array(all_ys[batch_start_idx:batch_end_idx])
  feed = { x: xs, y_: ys }
  sess.run(train_step, feed_dict=feed)
```

'None' in placeholder means determined at run-time

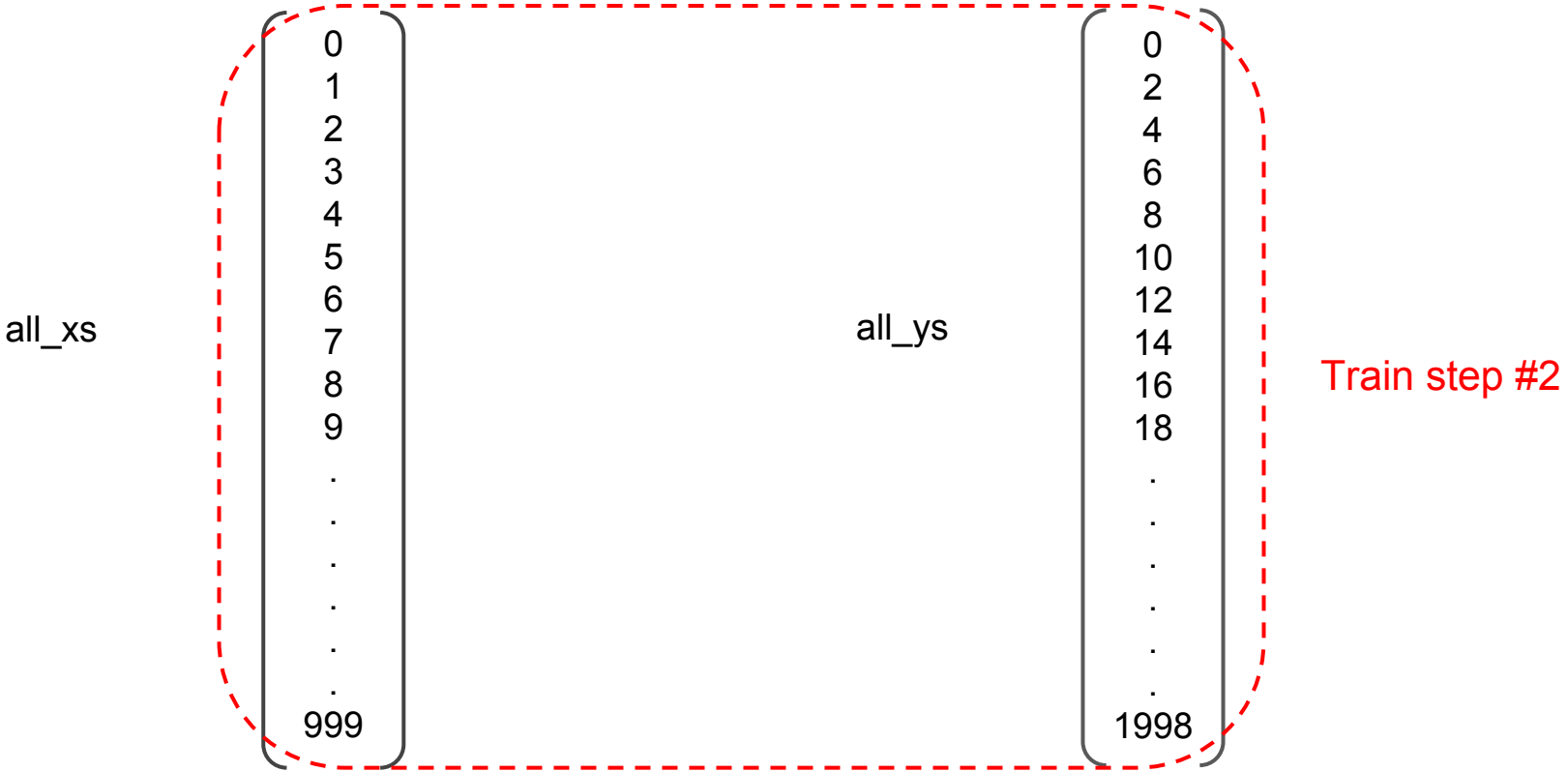
Code to do data batching

Batch Gradient Descent

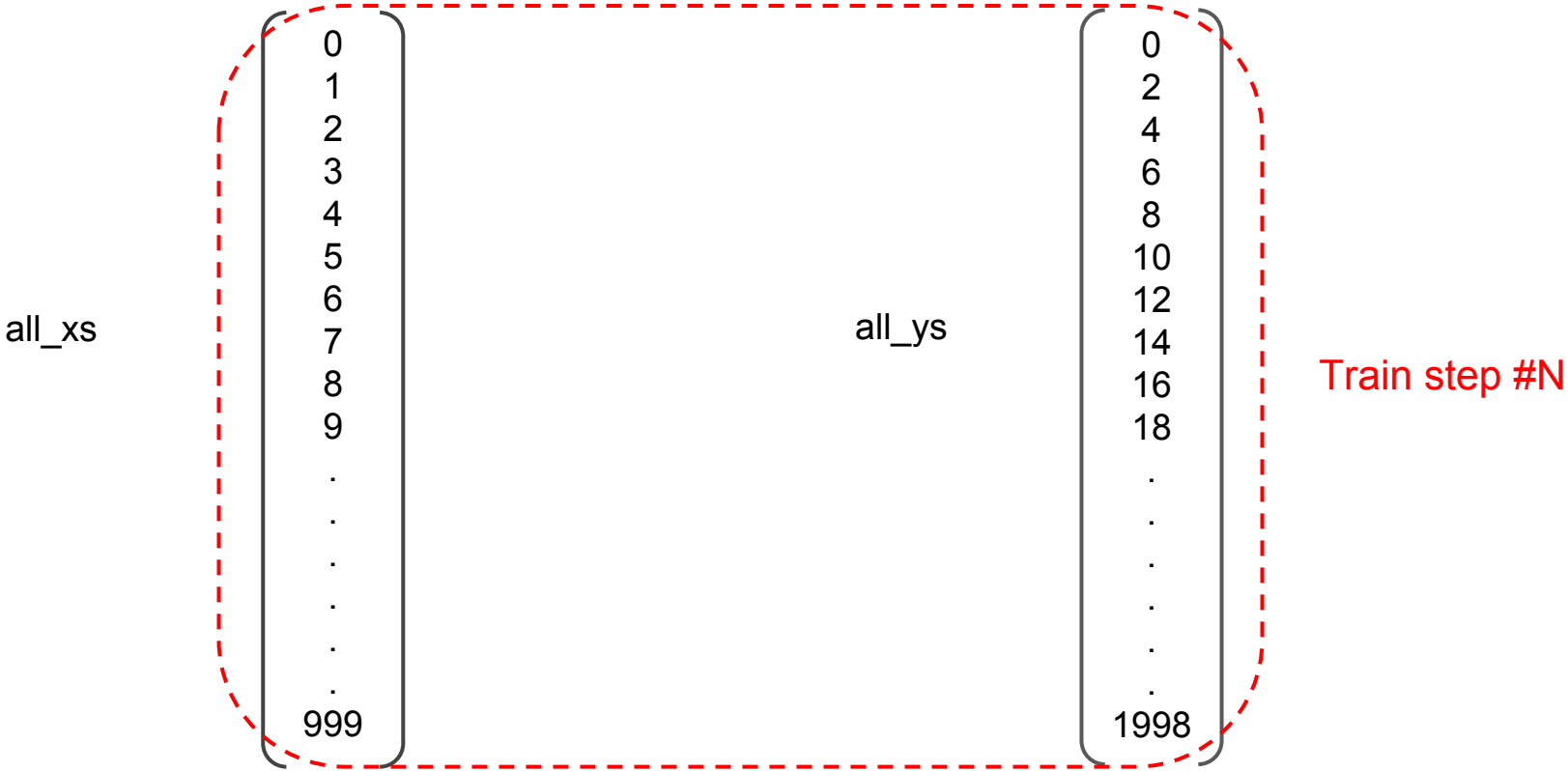
Batch Gradient Descent: x, y_



Batch Gradient Descent: x, y_



Batch Gradient Descent: x, y_



Batch Gradient Descent

One feature, house size

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

One output, house price

```
# Prepare all actual house size (x), house price (y_) before hand
all_xs = ...
all_ys = …

for i in range(steps):
  xs = all_xs
  ys = all_ys
  feed = { x: xs, y_: ys }
  sess.run(train_step, feed_dict=feed)
```

What is the Significance of Batch Size?

Find steepest gradient descent (train_step) from the viewpoint of the points in the batch

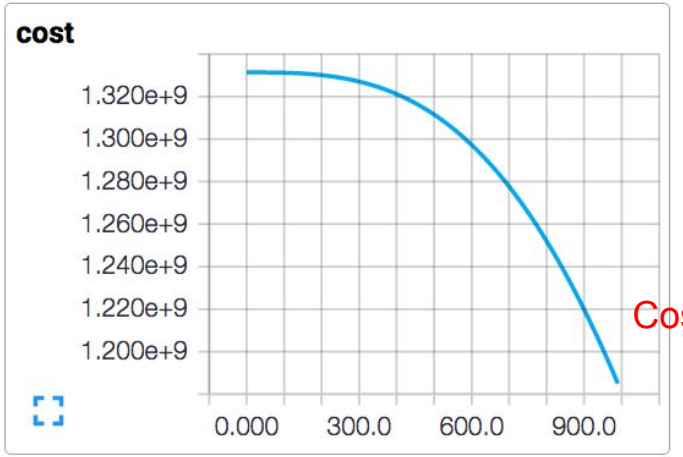
Resource to train each step

Less More

[Batch Size 1] [Batch Size 100] [Full Batch]

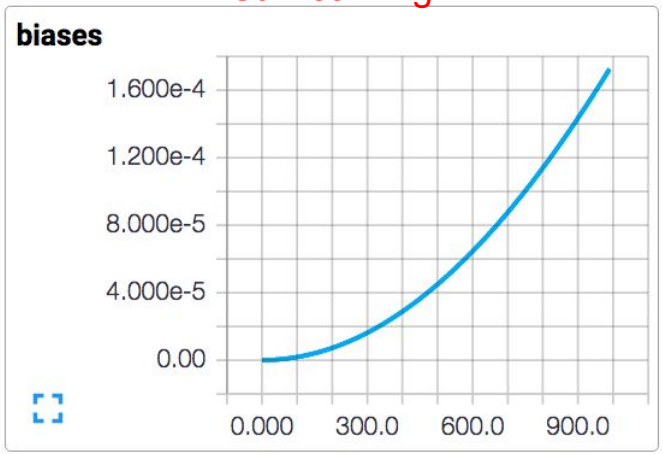
Outcome: With same Gradient Descent learning rate ...

Batch Size = 1, Train Steps = 1000

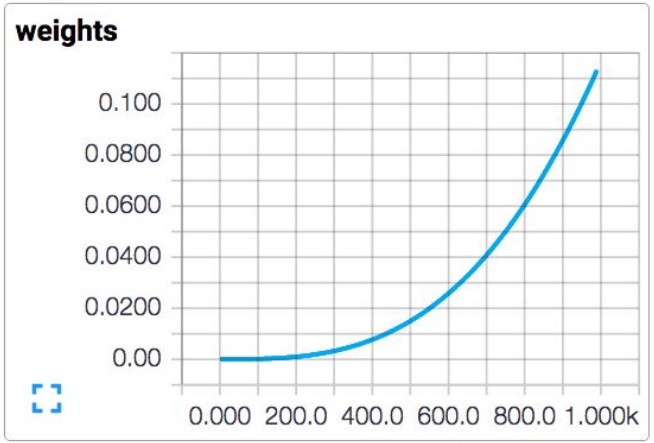


Cost still decreasing towards 0

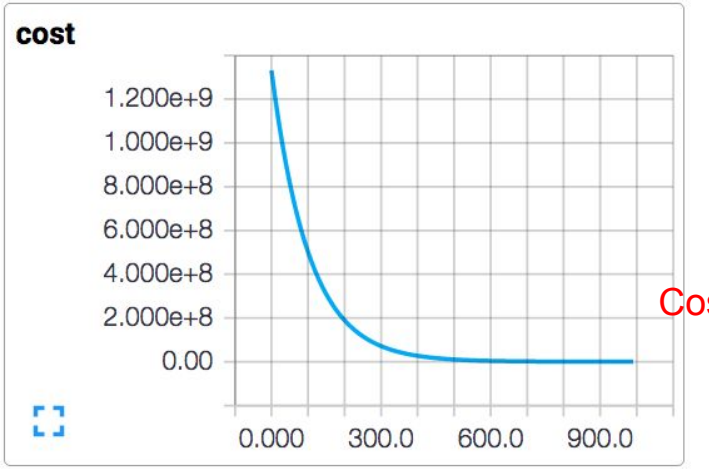
Still learning ...



Still learning ...



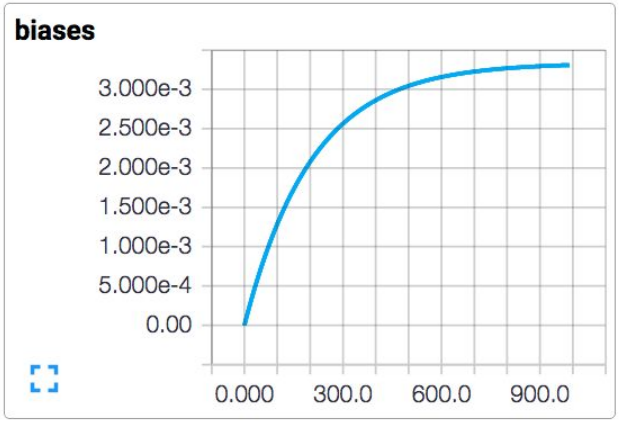
Batch Size = 100, Train Steps = 1000

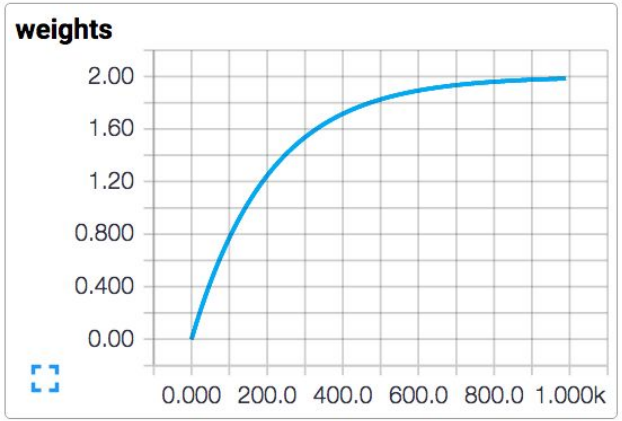


Cost close to 0 = good model fit

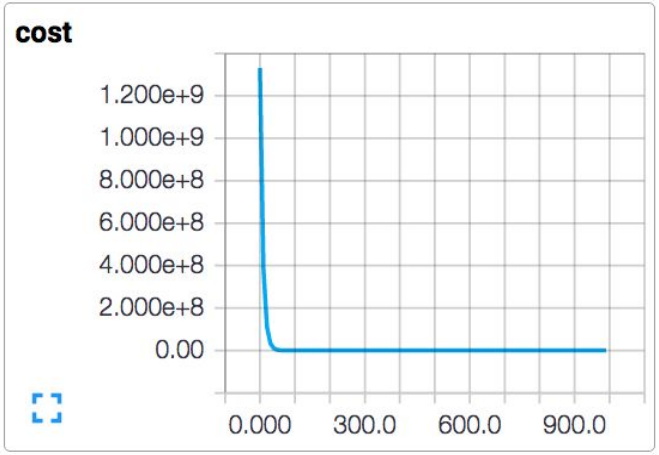
b ~ 0.0

W ~ 2.0





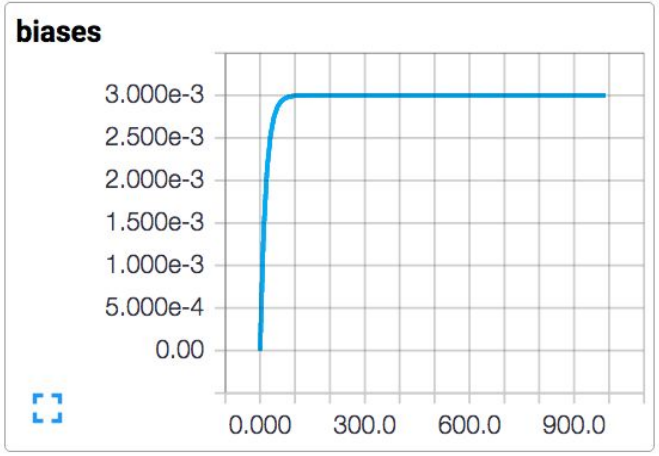
Batch Size = 1000 (Full), Train Steps = 1000

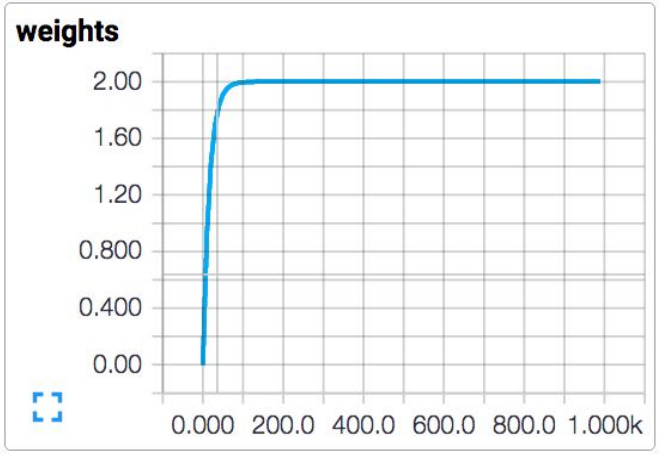


Cost close to 0 = good model fit

b ~ 0.0

W ~ 2.0





Resource to train each step

Less More

[Batch Size 1] [Batch Size 100] [Full Batch]

Many Few

Steps to reach good W, b values

References

Code:

- Using Tensorboard for visualization:
  - https://github.com/nethsix/gentle_tensorflow/blob/master/code/linear_regression_one_feature_with_tensorboard.py
- Performing stochastic/mini-batch/batch Gradient Descent using Tensorflow
  - https://github.com/nethsix/gentle_tensorflow/blob/master/code/linear_regression_one_feature_using_mini_batch_with_tensorboard.py