

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

Deep Learning with TensorFlow

Deep Learning — Units 7 & 8

Dr. Jon Krohn

`jon@untapt.com`

Slides available at `jonkrohn.com/talks`

November 17th, 2018

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

- Symbolic Programming
- Graphs
- Neurons

Fitting Models

- Eight Data Points
- Eight Million Points

Dense Nets

ConvNets

Project Improvement

- Where We Are
- Ten Tunings

Up Next

Assessing Your Deep Learning Project III



Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Assessing

Your Deep Learning Project III

Where are you at with respect to the following?

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries**
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Leading DL Libraries

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

	Caffe	Torch	MXNet	TensorFlow
<i>Language</i>	Python, Matlab	Lua, C	Python, R, C++ Julia, Matlab JavaScript, Go Scala, Perl	Python, R, C++ C, Java, Go
<i>Programming Style</i>	Symbolic	Imperative	Imperative	Symbolic
<i>Parallel GPUs: Data</i>	Yes	Yes	Yes	Yes
<i>Parallel GPUs: Model</i>		Yes	Yes	Yes
<i>Pre-Trained Models</i>	Model Zoo	ModelZoo	Model Zoo	github.com/tensorflow/ models
<i>For RNNs</i>				Best
<i>High-Level APIs</i>		PyTorch	in-built	Keras, TFLearn

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow**
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow**
 - Symbolic Programming**
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

TensorFlow Graphs

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs

Neurons

Fitting Models

Eight Data Points

Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are

Ten Tunings

Up Next

- 1 build graph
- 2 initialize session
- 3 fetch and feed data

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

TensorFlow Graphs

- 1 build graph
- 2 initialize session
- 3 fetch and feed data

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

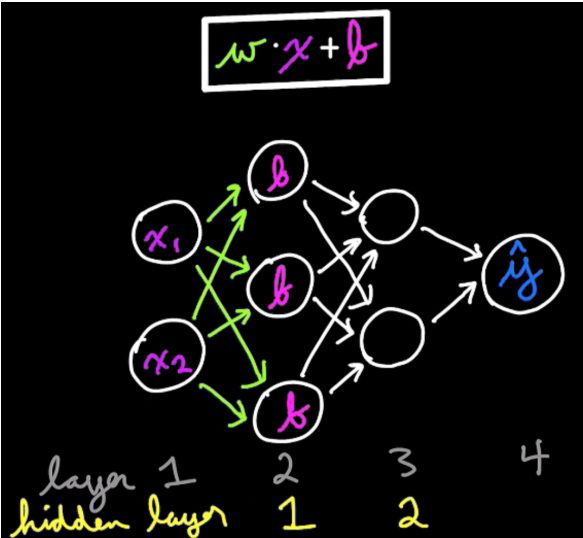
Up Next

TensorFlow Graphs

- 1 build graph
- 2 initialize session
- 3 fetch and feed data

A Familiar Equation

$$w \cdot x + b$$

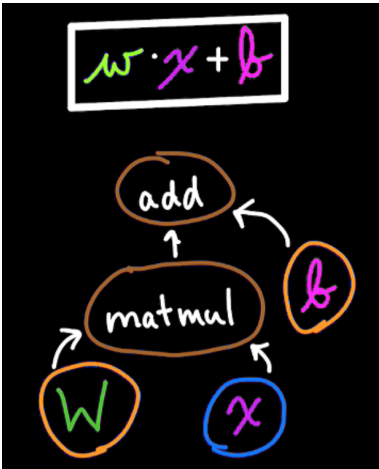


©2018 Pearson, Inc.

- Review
- DL Libraries
- Introduction
 - Symbolic Programming
 - Graphs
 - Neurons
- Fitting Models
 - Eight Data Points
 - Eight Million Points
- Dense Nets
- ConvNets
- Project Improvement
 - Where We Are
 - Ten Tunings
- Up Next

TensorFlow Graphs

- Review
- DL Libraries
- Introduction
 - Symbolic Programming
 - Graphs
 - Neurons
- Fitting Models
 - Eight Data Points
 - Eight Million Points
- Dense Nets
- ConvNets
- Project Improvement
 - Where We Are
 - Ten Tunings
- Up Next



©2018 Pearson, Inc.

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow**
 - Symbolic Programming
 - Programming TensorFlow Graphs**
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs

Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

TensorFlow Graph Programming

[*first TensorFlow graphs notebook*]

Outline

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow**
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow**
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs

Neurons

Fitting Models

Eight Data Points

Eight Million Points

Dense Nets

ConvNets

Project
Improvement

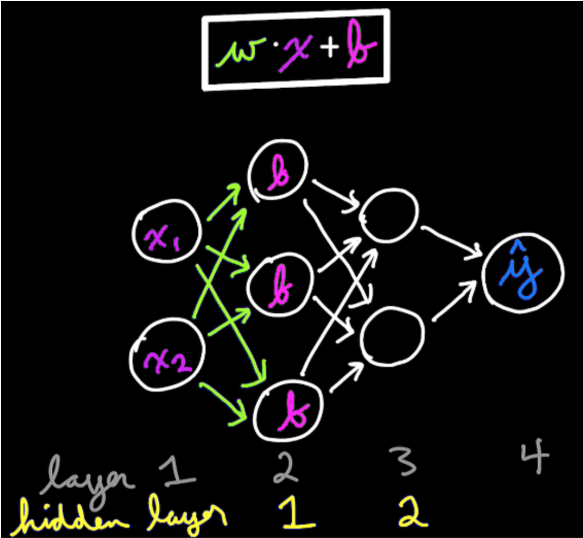
Where We Are

Ten Tunings

Up Next

A Familiar Equation

$$w \cdot x + b$$



©2018 Pearson, Inc.

Neurons in TensorFlow

Programming

Review

DL Libraries

Introduction

Symbolic
Programming

Graphs

Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

[*first TensorFlow neurons notebook*]

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models**
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models**
 - Eight Data Points**
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

Fitting Eight Points

[*point by point intro to TensorFlow notebook*]

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

Fitting Eight Points

with Tensors

[*tensor-fied intro to TensorFlow* notebook]

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models**
 - Eight Data Points
 - Eight Million Points**
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Fitting Eight Million Points

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

[*intro to TensorFlow times a million notebook*]

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets**
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

Dense Nets

[*intermediate net in TensorFlow* notebook]

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

Dense Nets

[*deep net in TensorFlow* notebook]

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

LeNet-5

LeCun et al. (1998)

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

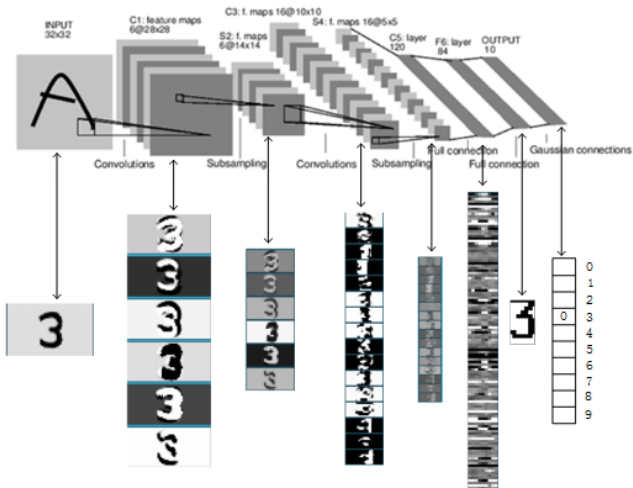
Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next



Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

LeNet-5

LeCun et al. (1998)

[*LeNet in TensorFlow* notebook]

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 **Deep Learning Project IV: Improving Where We Are**
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

Improving Your Deep Learning Project IV



Improving Your Deep Learning Project IV

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

3 Improving performance & tuning hyperparameters in ten steps...

Improving Your Deep Learning Project IV

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

3 Improving performance & tuning hyperparameters in ten steps...

Improving

Your Deep Learning Project IV

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

3 Improving performance & tuning hyperparameters in ten steps...

Improving

Your Deep Learning Project IV

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

3 Improving performance & tuning hyperparameters in ten steps...

Improving

Your Deep Learning Project IV

1 Splitting your data

- training set (80% — for optimizing parameters)
- validation set (10% — for hyperparameters)
- test set (10% — don't touch yet!)

2 Building and assessing architecture

- get above chance (simplifying problem, if necessary)
- do existing performance benchmarks exist?
- if not, use a simple architecture as benchmark

3 Improving performance & tuning hyperparameters in ten steps...

Improving

Your Deep Learning Project IV

- 1 Splitting your data
 - training set (80% — for optimizing parameters)
 - validation set (10% — for hyperparameters)
 - test set (10% — don't touch yet!)
- 2 Building and assessing architecture
 - get above chance (simplifying problem, if necessary)
 - do existing performance benchmarks exist?
 - if not, use a simple architecture as benchmark
- 3 Improving performance & tuning hyperparameters in ten steps...

Improving

Your Deep Learning Project IV

- 1 Splitting your data
 - training set (80% — for optimizing parameters)
 - validation set (10% — for hyperparameters)
 - test set (10% — don't touch yet!)
- 2 Building and assessing architecture
 - get above chance (simplifying problem, if necessary)
 - do existing performance benchmarks exist?
 - if not, use a simple architecture as benchmark
- 3 Improving performance & tuning hyperparameters in ten steps...

Improving

Your Deep Learning Project IV

- 1 Splitting your data
 - training set (80% — for optimizing parameters)
 - validation set (10% — for hyperparameters)
 - test set (10% — don't touch yet!)
- 2 Building and assessing architecture
 - get above chance (simplifying problem, if necessary)
 - do existing performance benchmarks exist?
 - if not, use a simple architecture as benchmark
- 3 Improving performance & tuning hyperparameters in ten steps...

Improving

Your Deep Learning Project IV

- 1 Splitting your data
 - training set (80% — for optimizing parameters)
 - validation set (10% — for hyperparameters)
 - test set (10% — don't touch yet!)
- 2 Building and assessing architecture
 - get above chance (simplifying problem, if necessary)
 - do existing performance benchmarks exist?
 - if not, use a simple architecture as benchmark
- 3 Improving performance & tuning hyperparameters in ten steps...

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

1. Initialization

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

...in `lenet_in_tensorflow.ipynb`:

Set neural network hyperparameters

```
epochs = 20
batch_size = 128
display_progress = 40 # after this many batches, output progress to screen
wt_init = tf.contrib.layers.xavier_initializer() # weight initializer
```

```
weight_dict = {
    'W_c1': tf.get_variable('W_c1',
                            [k_conv_1, k_conv_1, 1, n_conv_1], initializer=wt_init),
    'W_c2': tf.get_variable('W_c2',
                            [k_conv_2, k_conv_2, n_conv_1, n_conv_2], initializer=wt_init),
    'W_d1': tf.get_variable('W_d1',
                            [dense_inputs, n_dense], initializer=wt_init),
    'W_out': tf.get_variable('W_out',
                             [n_dense, n_classes], initializer=wt_init)
}
```

2. Get Above Chance

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

If your accuracy is below chance, try:

- **simplifying the problem**
- simplifying the network architecture
- reducing your training set size (to iterate more quickly)

2. Get Above Chance

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

If your accuracy is below chance, try:

- simplifying the problem
- simplifying the network architecture
- reducing your training set size (to iterate more quickly)

2. Get Above Chance

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

If your accuracy is below chance, try:

- simplifying the problem
- simplifying the network architecture
- reducing your training set size (to iterate more quickly)

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

3. Layers

Experiment with varying:

- number of layers
- type of layers
- layer width (by powers of two)

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

3. Layers

Experiment with varying:

- number of layers
- type of layers
- layer width (by powers of two)

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

3. Layers

Experiment with varying:

- number of layers
- type of layers
- layer width (by powers of two)

4. Cost

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

...in lenet_in_keras.ipynb:

Configure model

```
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
```

...in lenet_in_tensorflow.ipynb:

Define model's loss and its optimizer

```
cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(logits=predictions, labels=y))  
optimizer = tf.train.AdamOptimizer().minimize(cost)
```

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

5. Avoid Overfitting

If validation cost begins to increase or validation accuracy begins to decrease, consider:

- stopping training earlier
- dropout

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

5. Avoid Overfitting

If validation cost begins to increase or validation accuracy begins to decrease, consider:

- stopping training earlier
- dropout

5. Avoid Overfitting

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

...in lenet_in_keras.ipynb:

```
model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3), activation='relu', input_shape=(28, 28, 1)))
model.add(Conv2D(64, kernel_size=(3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(n_classes, activation='softmax'))
```

...in lenet_in_tensorflow.ipynb:

```
# max pooling layer:
pool_size = 2
mp_layer_dropout = 0.25

# dense layer:
n_dense = 128
dense_layer_dropout = 0.5
```

```
# convolutional and max-pooling layers:
conv_1 = conv2d(square_x, weights['W_c1'], biases['b_c1'])
conv_2 = conv2d(conv_1, weights['W_c2'], biases['b_c2'])
pool_1 = maxpooling2d(conv_2, mp_size)
pool_1 = tf.nn.dropout(pool_1, 1-mp_dropout)

# dense layer:
flat = tf.reshape(pool_1, [-1, weights['W_d1'].get_shape().as_list()[0]])
dense_1 = dense(flat, weights['W_d1'], biases['b_d1'])
dense_1 = tf.nn.dropout(dense_1, 1-dense_dropout)
```

6. Learning Rate

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

...in lenet_in_keras.ipynb:

Configure model

```
model.compile(loss='categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
```

...in lenet_in_tensorflow.ipynb:

Define model's loss and its optimizer

```
cost = tf.reduce_mean(tf.nn.softmax_cross_entropy_with_logits(logits=predictions, labels=y))  
optimizer = tf.train.AdamOptimizer().minimize(cost)
```

7. Epochs

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

...in lenet_in_keras.ipynb:

Train!

```
model.fit(X_train, y_train, batch_size=128, epochs=20, verbose=1, validation_data=(X_test, y_test))
```

...in lenet_in_tensorflow.ipynb:

Set neural network hyperparameters

```
epochs = 20  
batch_size = 128  
display_progress = 40 # after this many batches, output progress to screen  
wt_init = tf.contrib.layers.xavier_initializer() # weight initializer
```

```
with tf.Session() as session:  
    session.run(initializer_op)  
  
    print("Training for", epochs, "epochs.")  
  
    # loop over epochs:  
    for epoch in range(epochs):
```

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

8. Regularization λ

If using L1 or L2 regularization, consider:

- adjusting λ by orders of magnitude

9. Batch Size

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

...in lenet_in_keras.ipynb:

Train!

```
model.fit(X_train, y_train, batch_size=128, epochs=20, verbose=1, validation_data=(X_test, y_test))
```

...in lenet_in_tensorflow.ipynb:

Set neural network hyperparameters

```
epochs = 20  
batch_size = 128  
display_progress = 40 # after this i  
wt_init = tf.contrib.layers.xavier_
```

```
# loop over all batches of the epoch:  
n_batches = int(mnist.train.num_examples / batch_size)  
for i in range(n_batches):  
  
    # to reassure you something's happening!  
    if i % display_progress == 0:  
        print("Step ", i+1, " of ", n_batches, " in epoch ", epoch+1, ".", sep='')  
  
    batch_x, batch_y = mnist.train.next_batch(batch_size)
```

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

10. Automation

For grid search of hyperparameters, consider:

- sampling values instead of looping over fixed values
- using [[Spearmint](#)]

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

10. Automation

For grid search of hyperparameters, consider:

- sampling values instead of looping over fixed values
- using [`Spearmint`]

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

All together now...

- 1 Initialization
- 2 Get Above Chance
- 3 Layers
- 4 Cost
- 5 Avoid Overfitting
- 6 Learning Rate
- 7 Epochs
- 8 Regularization λ
- 9 Batch Size
- 10 Automation

Outline

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

- 1 Review Take-Home Exercise
- 2 Comparison of the Leading Deep Learning Libraries
- 3 Introduction to TensorFlow
 - Symbolic Programming
 - Programming TensorFlow Graphs
 - Neurons in TensorFlow
- 4 Fitting Models
 - Eight Data Points
 - Eight Million Points
- 5 Dense Nets
- 6 Convolutional Nets
- 7 Deep Learning Project IV: Improving Where We Are
 - Ten Hyperparameter-Tuning Steps
- 8 Up Next: Advanced Topics

Generative Adversarial Networks

Review

DL Libraries

Introduction

- Symbolic Programming
- Graphs
- Neurons

Fitting Models

- Eight Data Points
- Eight Million Points

Dense Nets

ConvNets

Project Improvement

- Where We Are
- Ten Tunings

Up Next



Reinforcement Learning

Review

DL Libraries

Introduction

Symbolic
Programming
Graphs
Neurons

Fitting Models

Eight Data Points
Eight Million Points

Dense Nets

ConvNets

Project
Improvement

Where We Are
Ten Tunings

Up Next

