

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF

Playground

Hardware

Software

Shallow Net

# The Unreasonable Effectiveness of Deep Learning

Deep Learning — Unit 1

Dr. Jon Krohn

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Slides available at [jonkrohn.com/talks](http://jonkrohn.com/talks)

July 21st, 2018

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

## ① Name

- ② Relevant background, e.g., programming, stats, machine learning
- ③ Interest in Deep Learning
- ④ What you'd like to take away from this course

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

- ① Name
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Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

- ① Name
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- ④ What you'd like to take away from this course

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

- ① Name
- ② Relevant background, e.g., programming, stats, machine learning
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- ④ What you'd like to take away from this course

# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

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## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

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## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

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## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

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Introductory Units (1-3)

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## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

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Intermediate Units (4-6)

Advanced Units (7-10)

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## 6 A Shallow Artificial Neural Network



Introduction

Course  
Survey

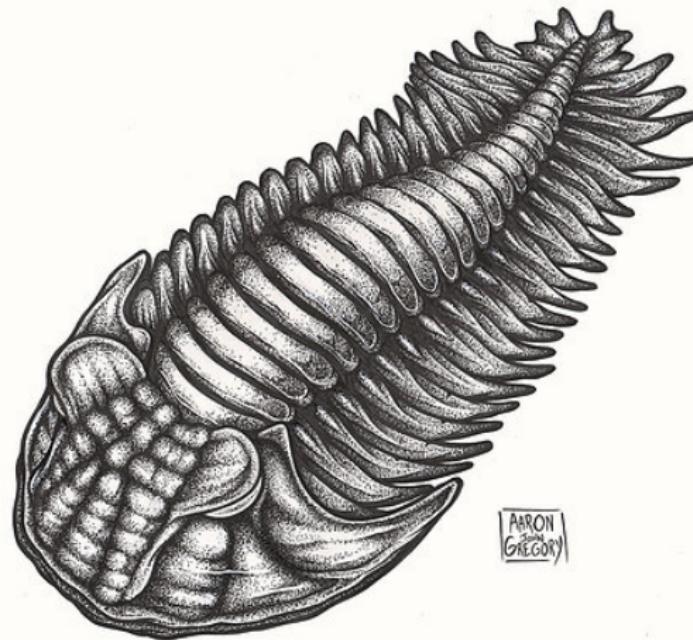
Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

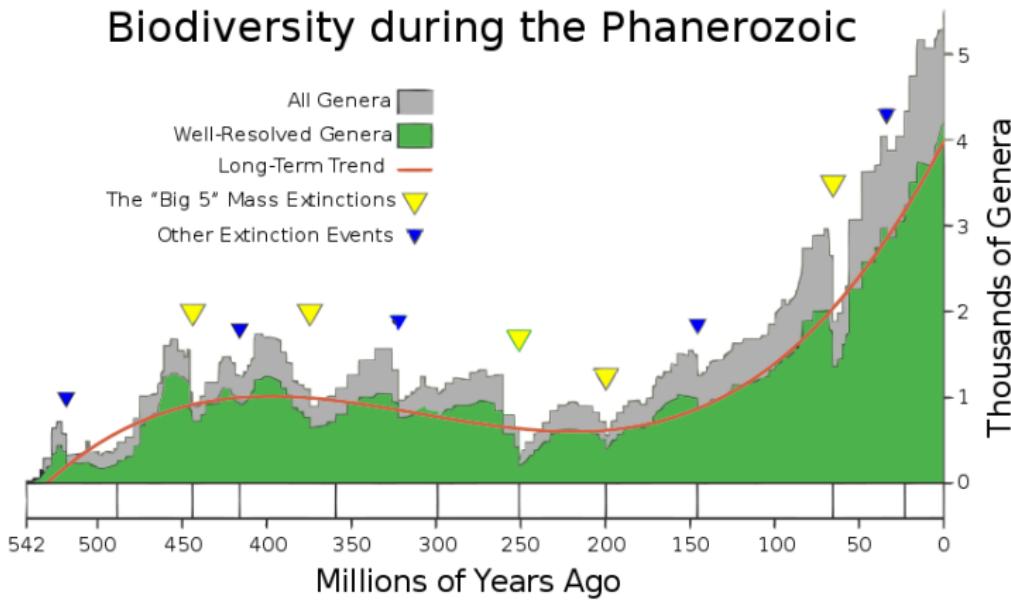
Software

Shallow Net



[Introduction](#)[Course Survey](#)[Introductory](#)[Intermediate](#)[Advanced](#)[TF Playground](#)[Hardware](#)[Software](#)[Shallow Net](#)

# Biodiversity during the Phanerozoic



# Hubel & Wiesel (1959)

Introduction

Course  
Survey

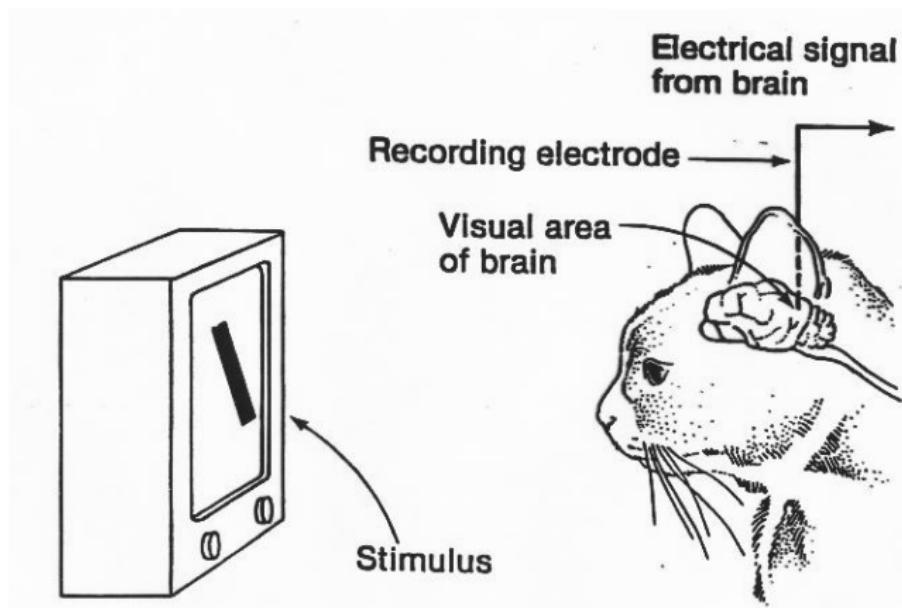
Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



## Introduction

## Course Survey

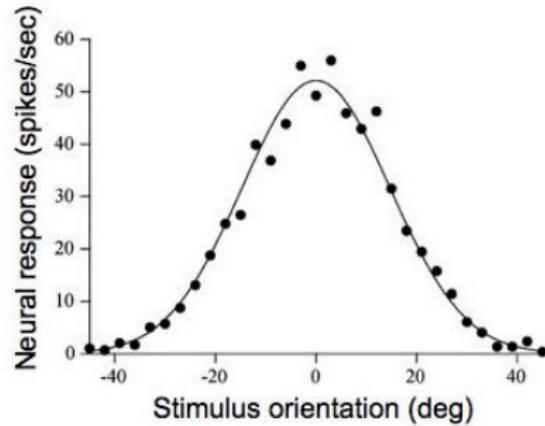
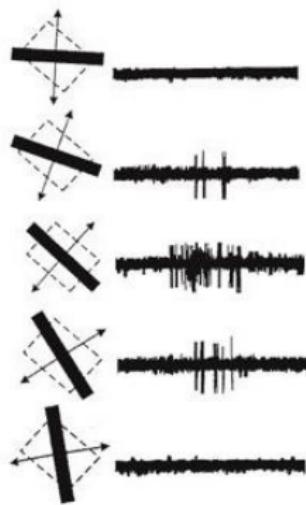
Introductory  
Intermediate  
Advanced

## TF Playground

## Hardware

## Software

## Shallow Net



Hubel &amp; Wiesel, 1968

Introduction

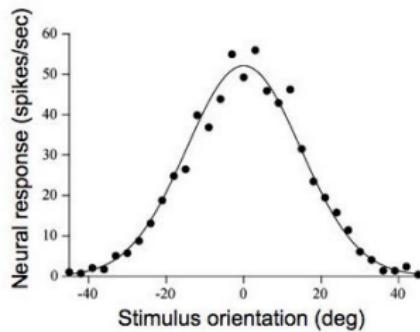
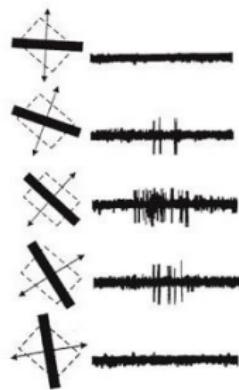
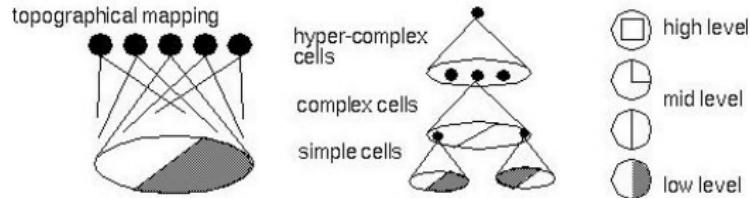
Course Survey

Introductory  
Intermediate  
AdvancedTF  
Playground

Hardware

Software

Shallow Net



Hubel &amp; Wiesel, 1968

## Introduction

## Hardware

The diagram illustrates the visual pathway and the locations of various visual cortex areas:

- LGN**: Lateral Geniculate Nucleus, located in the thalamus.
- Light**: Represented by a beam entering the eye.
- Temporal Lobe**: Located on the side of the brain.
- Visual Radiation**: A bundle of fibers connecting the LGN to the occipital lobe.
- Parietal Lobe**: Located at the top back of the brain.
- Occipital Lobe**: Located at the back of the brain, containing several visual areas.
- V5 (Motion)**: Located in the posterior parietal-occipital region.
- V7**: Located in the lateral occipital region.
- V3a (Motion)**: Located in the lateral occipital region.
- V3 (Form)**: Located in the lateral occipital region.
- LO**: Lateral Occipital area.
- V2 (Relays signals)**: Located in the lateral occipital region.
- V1 (Catalogs Input)**: Located in the lateral occipital region, part of the striate cortex.
- VP (Relays signals)**: Located in the lateral occipital region.
- V4 (Color and Form)**: Located in the lateral occipital region.
- V8**: Located in the lateral occipital region.

**Extrastrate Cortex** (labeled on the right side of the diagram):

- V5 (Motion), V7, V3a (Motion), V3 (Form), V2 (Relays signals), V4 (Color and Form), V8

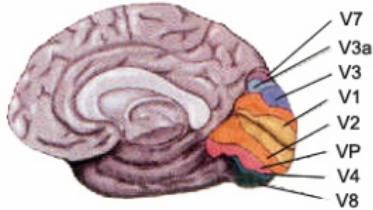
**Striate Cortex** (labeled on the right side of the diagram):

- V1 (Catalogs Input)

**Extrastrate Cortex** (labeled on the right side of the diagram):

- V3 (Form)

## Sagittal Section



Introduction

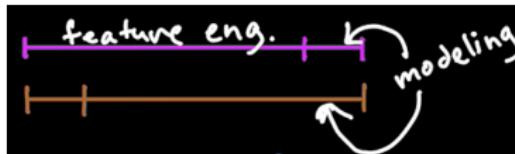
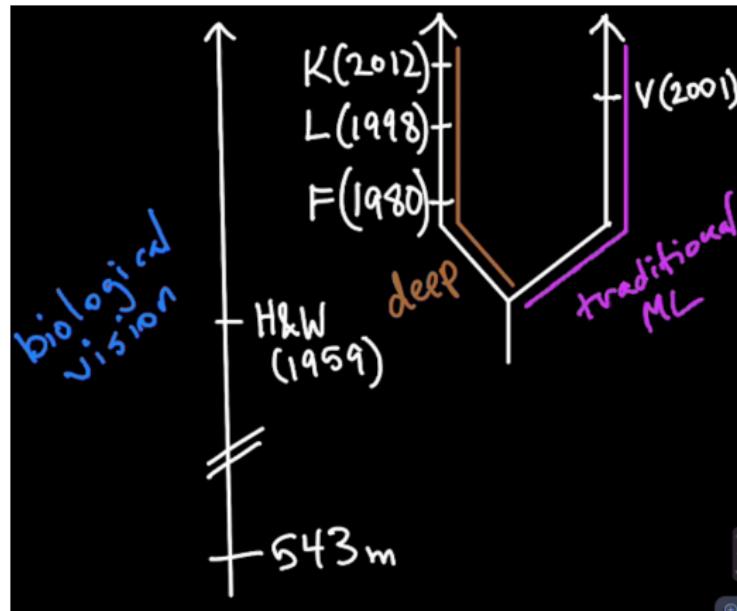
Course Survey

Introductory  
Intermediate  
AdvancedTF  
Playground

Hardware

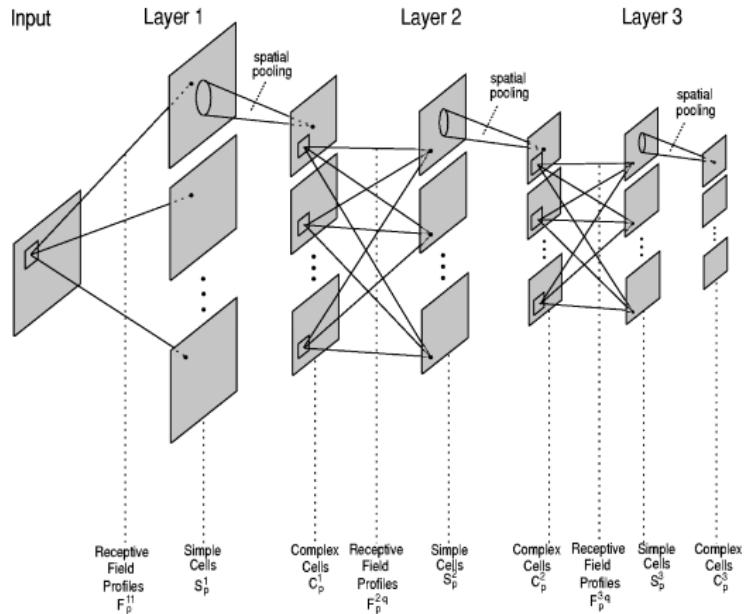
Software

Shallow Net



# Neocognitron

## Fukushima (1980)



Introduction

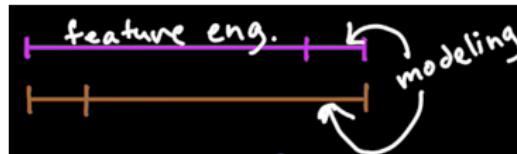
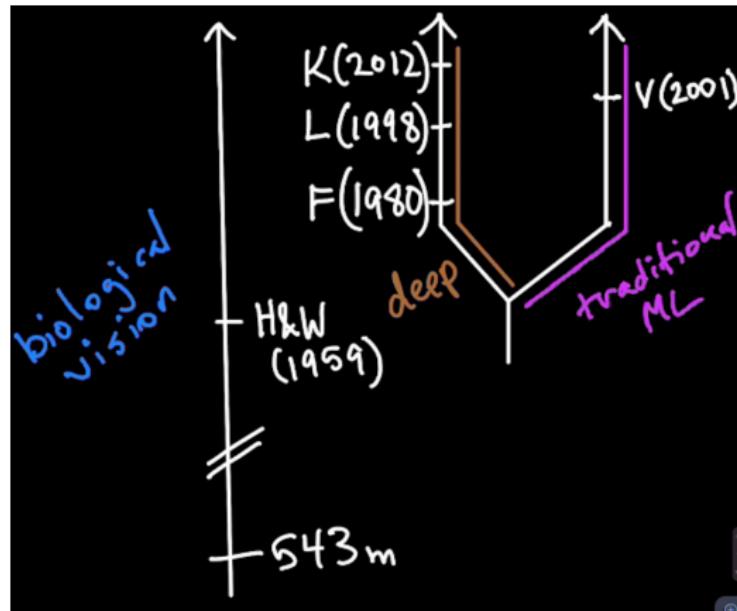
Course Survey

Introductory  
Intermediate  
AdvancedTF  
Playground

Hardware

Software

Shallow Net



# MNIST Digits & LeNet-5

LeCun, Boutou, Bengio & Haffner (1998)



PROC. OF THE IEEE, NOVEMBER 1998

7

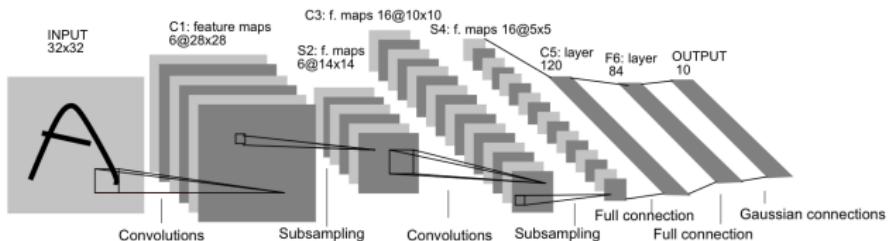
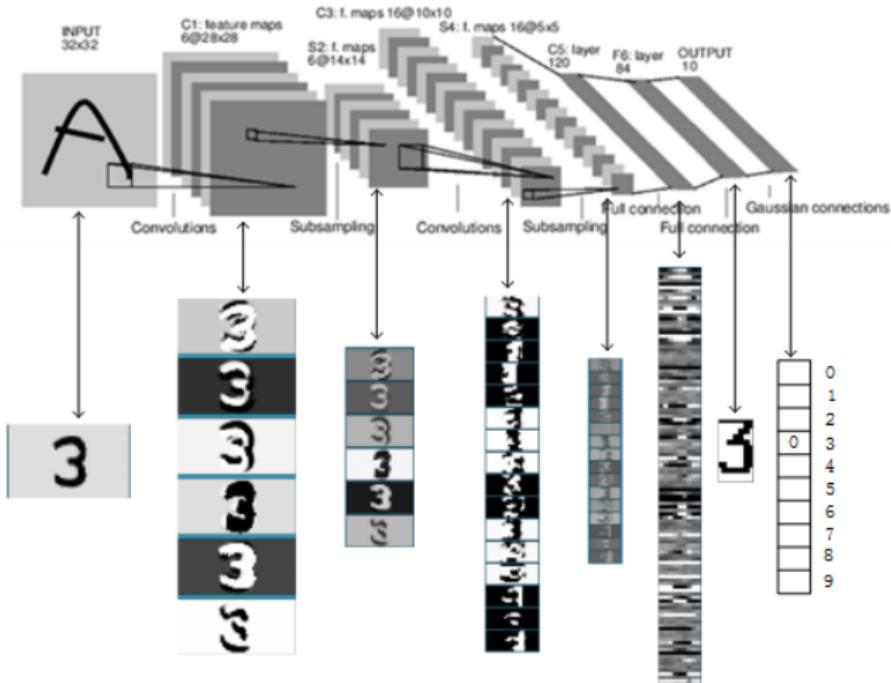


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

# LeNet-5

LeCun, Boutou, Bengio & Haffner (1998)



Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



Introduction

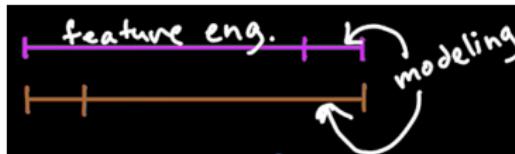
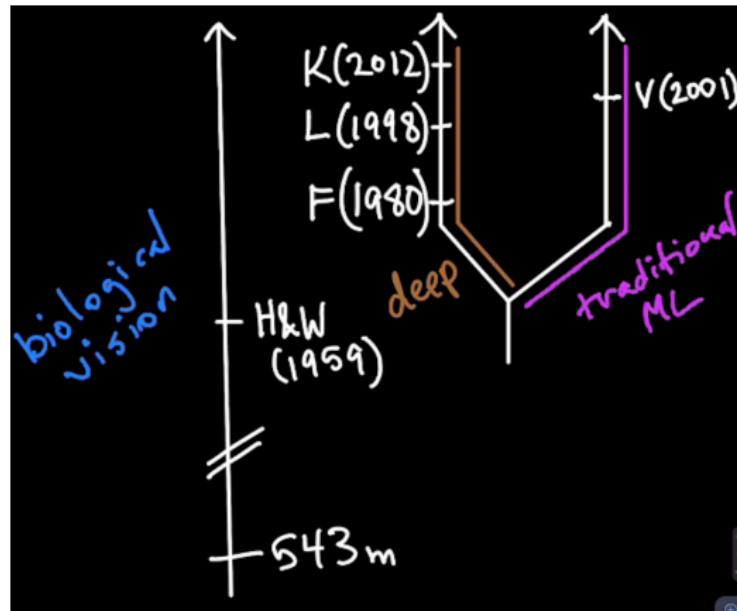
Course Survey

Introductory  
Intermediate  
AdvancedTF  
Playground

Hardware

Software

Shallow Net



# Viola & Jones (2001)

Introduction

Course  
Survey

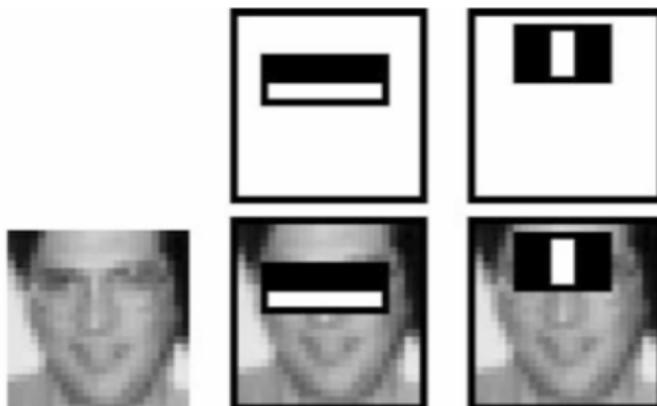
Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



Introduction

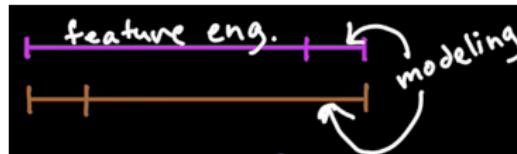
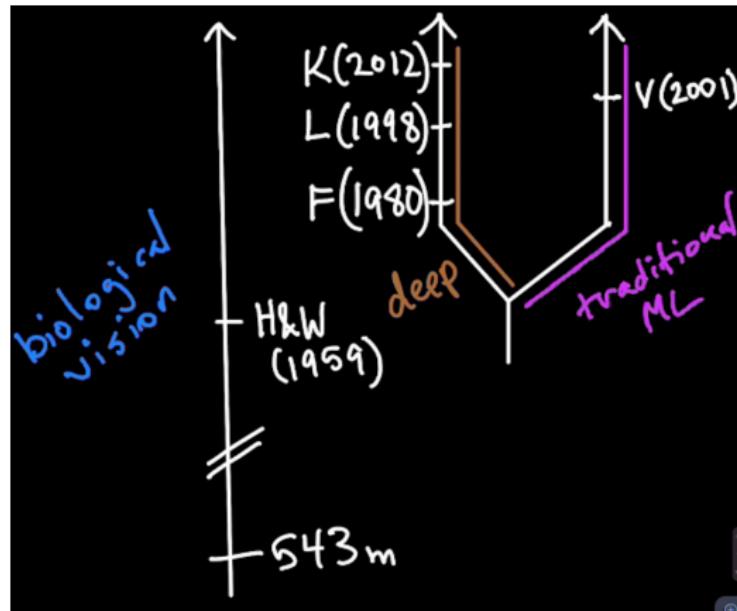
Course Survey

Introductory  
Intermediate  
AdvancedTF  
Playground

Hardware

Software

Shallow Net



# ImageNet

Fei-Fei Li et al. (2009), 14m images, 22k categories

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

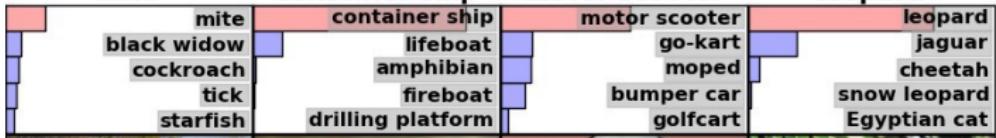


**mite**

**container ship**

**motor scooter**

**leopard**



**grille**

**mushroom**

**cherry**

**Madagascar cat**



# ImageNet Classification Error

ILSVRC: 1.4m, 1k object classes

Introduction

Course Survey

Introductory

Intermediate

Advanced

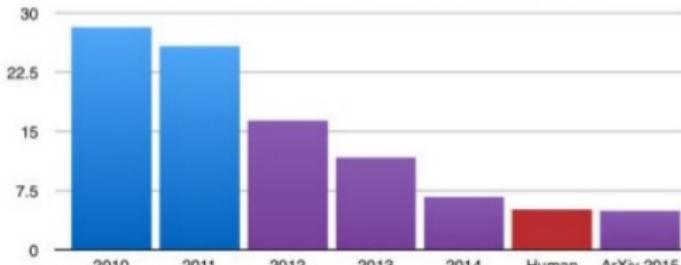
TF Playground

Hardware

Software

Shallow Net

ILSVRC top-5 error on ImageNet



- Blue: Traditional CV
- Purple: Deep Learning
- Red: Human



# AlexNet

Krizhevsky, Sutskever & Hinton (2012)

Introduction

Course Survey

Introductory

Intermediate

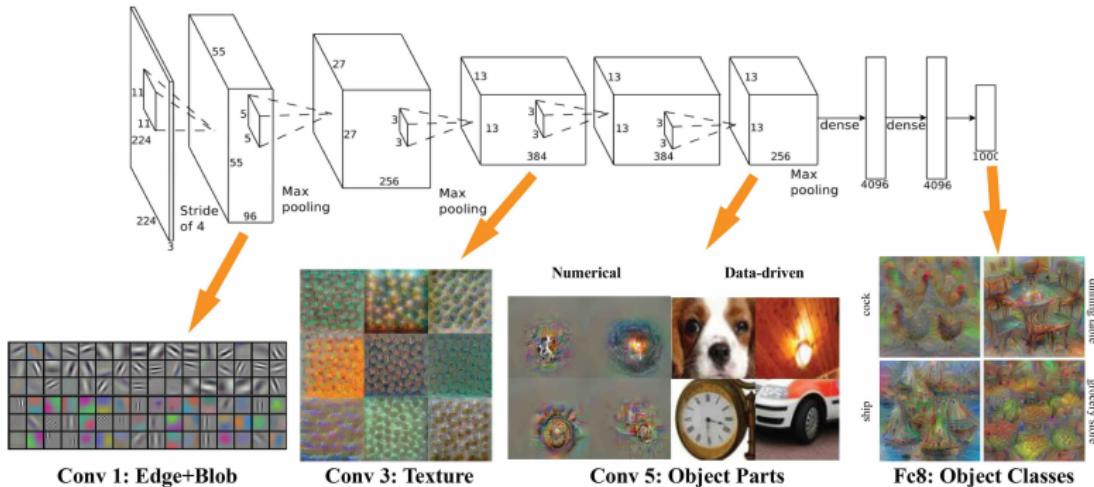
Advanced

TF Playground

Hardware

Software

Shallow Net



Introduction

Course Survey

Introductory

Intermediate

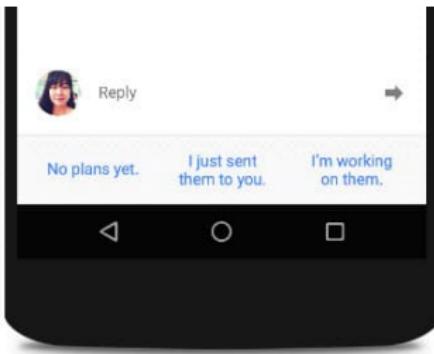
Advanced

TF Playground

Hardware

Software

Shallow Net



Introduction

Course Survey

Introductory

Intermediate

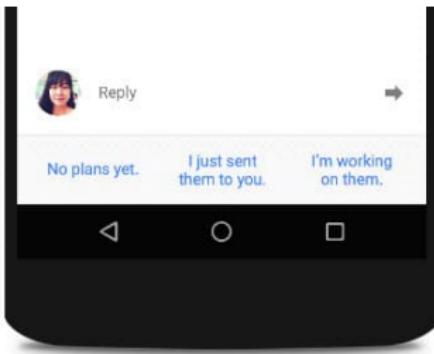
Advanced

TF Playground

Hardware

Software

Shallow Net



Introduction

Course Survey

Introductory

Intermediate

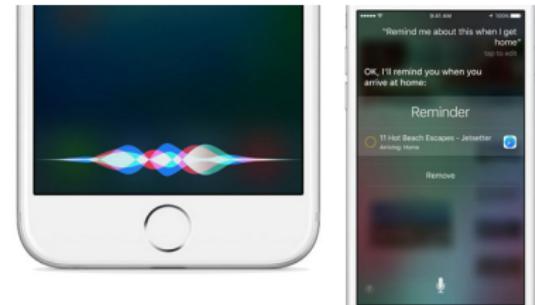
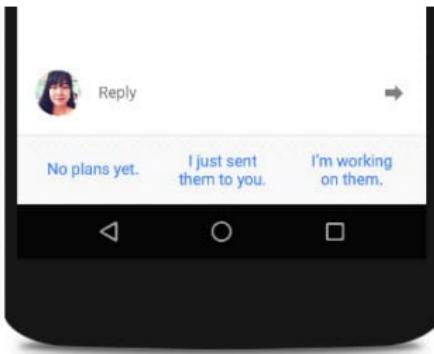
Advanced

TF Playground

Hardware

Software

Shallow Net



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF

Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

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## 6 A Shallow Artificial Neural Network

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF

Playground

Hardware

Software

Shallow Net

← → ⌂ [nycdatascience.com/courses/deep-learning/](https://nycdatascience.com/courses/deep-learning/)

## Syllabus

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### Unit 1: The Unreasonable Effectiveness of Deep Learning

- An Introduction to Neural Networks and Deep Learning
- Course Survey
- Interactive Visualization of an Artificial Neural Network
- Hardware Options for Deep Learning, including How to Build a Deep Learning Server
- Running a TensorFlow Jupyter Notebook within a Docker Container
- A Shallow Artificial Neural Network

### Unit 2: How Deep Learning Works

- Essential Theory I: Neural Units
- Interactive Visualization of Neural Units
- Essential Theory II: Cost Functions, Gradient Descent, and Backpropagation
- Interactive Visualization of a Deep Neural Network
- An Intermediate Neural Network
- Data Sets for Deep Learning
- Your Deep Learning Project: Ideating

Unit 3: Building and Training a Deep Learning Network

# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



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# The Unreasonable Effectiveness of Deep Learning

Unit 1: right now!

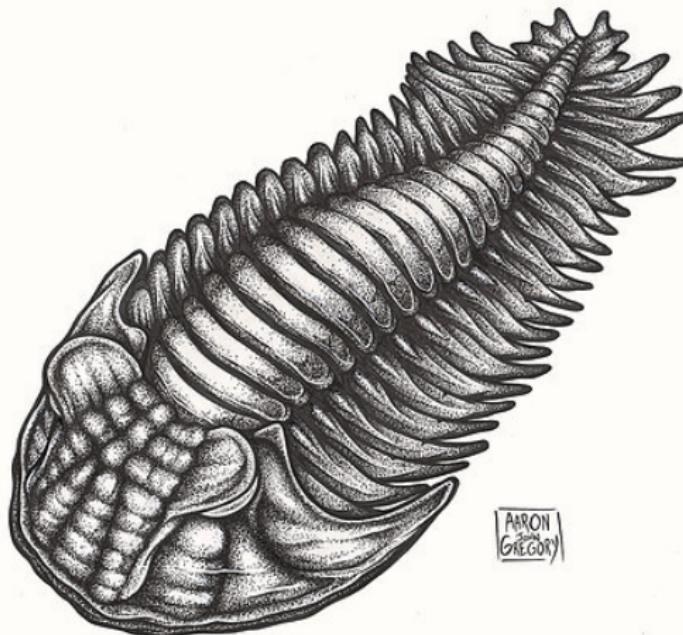
Introduction  
Course Survey

Introductory

Intermediate

Advanced

TF  
Playground  
Hardware  
Software  
Shallow Net



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GREGORY

# Hardware Options for DL

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net



Unit 1

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Jupyter Notebooks

## + Docker + Nvidia GPU + TensorFlow



# A Shallow Neural Network

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

0	4	1	9	2	1	3	1	4	3
5	3	6	1	7	2	8	6	9	4
0	9	1	1	2	4	3	2	7	3
8	6	9	0	5	6	0	7	6	1
8	7	9	3	9	8	5	9	3	3
0	7	4	9	8	0	9	4	1	4
4	6	0	4	5	6	1	0	0	1
7	1	6	3	0	2	1	1	7	9
0	3	6	7	8	3	9	0	4	6
7	4	6	8	0	7	8	3	1	5

# How Deep Learning Works

Unit 2: This Afternoon

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net



Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

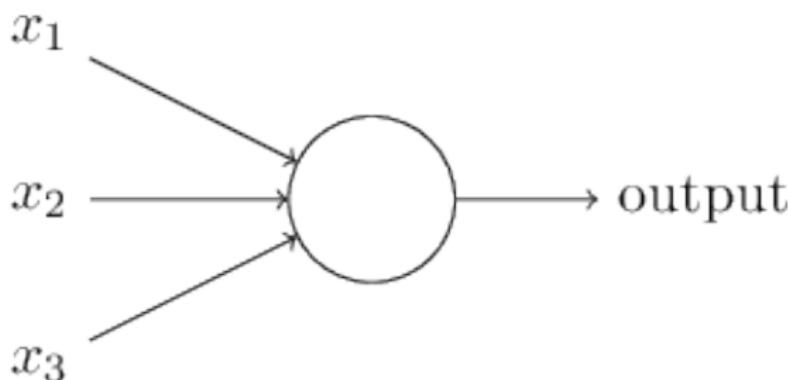
Hardware

Software

Shallow Net

# Essential Theory I

## Neural Units



Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

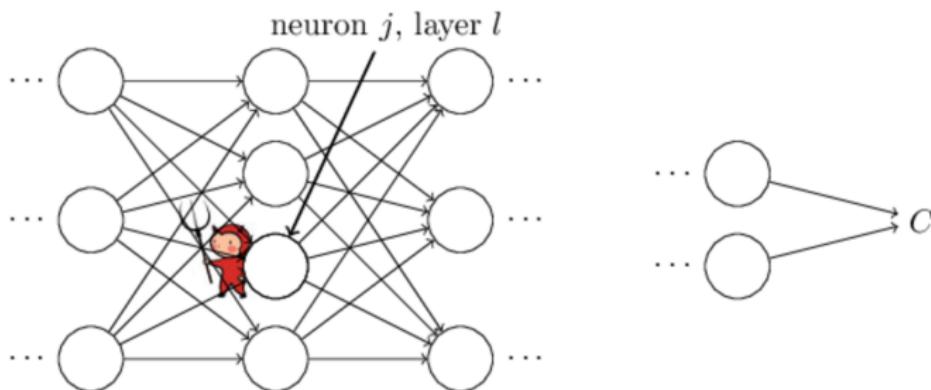
Hardware

Software

Shallow Net

# Essential Theory II

## Cost Functions, Gradient Descent, and Backpropagation



# An Intermediate Neural Network

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF

Playground

Hardware

Software

Shallow Net

[intermediate notebook]

# Data Sets for Deep Learning

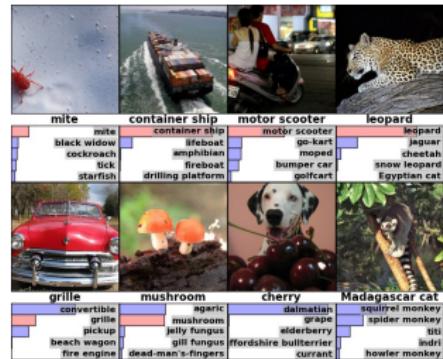
Introduction  
 Course Survey  
 Introductory  
 Intermediate  
 Advanced  
 TF Playground  
 Hardware  
 Software  
 Shallow Net



Dataset	Classes	Train Samples
AG's News	4	120,000
Sogou News	5	450,000
DBPedia	14	560,000
Yelp Review Polarity	2	560,000
Yelp Review Full	5	650,000
Yahoo! Answers	10	1,400,000
Amazon Review Full	5	3,000,000
Amazon Review Polarity	2	3,600,000

# Data Sets for Deep Learning

Introduction  
 Course Survey  
 Introductory  
 Intermediate  
 Advanced  
 TF Playground  
 Hardware  
 Software  
 Shallow Net



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# Data Sets for Deep Learning

Introduction  
 Course Survey  
 Introductory  
 Intermediate  
 Advanced  
 TF Playground  
 Hardware  
 Software  
 Shallow Net



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Introduction

Course Survey

Introductory

Intermediate

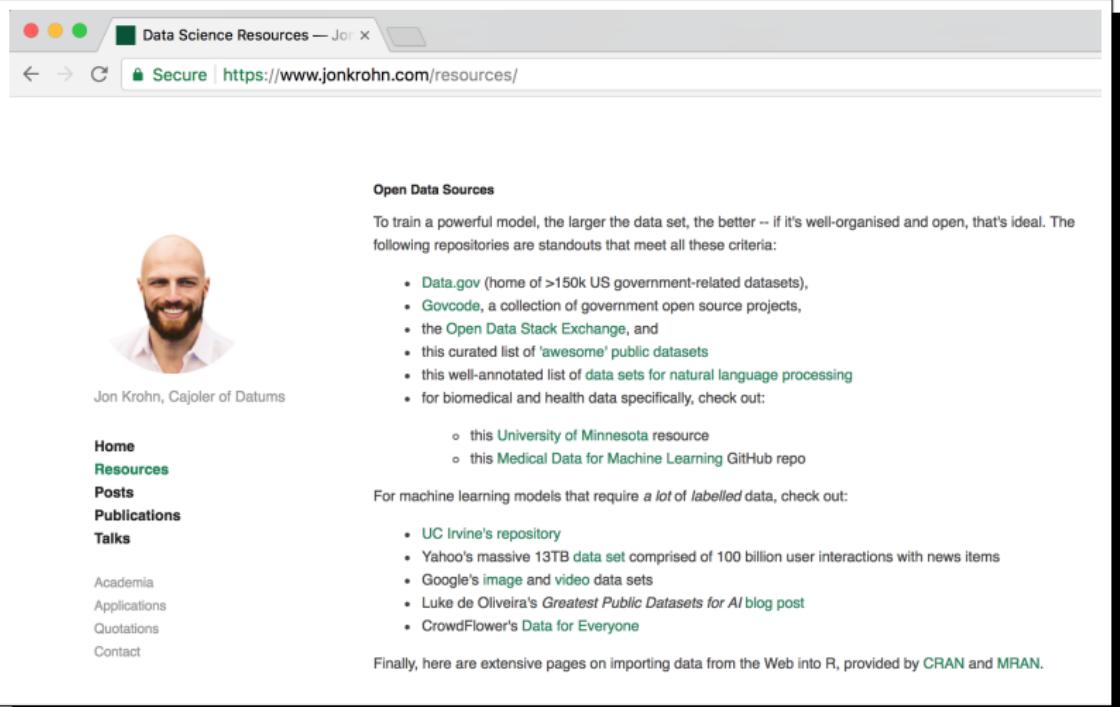
Advanced

TF  
Playground

Hardware

Software

Shallow Net



The screenshot shows a web browser window with the title "Data Science Resources — Jon x". The address bar indicates a secure connection to <https://www.jonkrohn.com/resources/>. The main content area features a portrait of a man with a beard and short hair, identified as Jon Krohn, Cajoler of Datums. Below the portrait is a bio: "Jon Krohn, Cajoler of Datums". To the left of the bio is a sidebar with navigation links: Home, Resources (which is bolded), Posts, Publications, and Talks. Under Publications, there are links to Academia, Applications, Quotations, and Contact. The main content area has a section titled "Open Data Sources" with a sub-section header "To train a powerful model, the larger the data set, the better -- if it's well-organized and open, that's ideal. The following repositories are standouts that meet all these criteria:". A bulleted list follows, including links to Data.gov, Govcode, the Open Data Stack Exchange, an curated list of 'awesome' public datasets, a well-annotated list of data sets for natural language processing, and biomedical and health data resources from the University of Minnesota and Medical Data for Machine Learning. Below this is another section: "For machine learning models that require a lot of labelled data, check out:" followed by a bulleted list of UC Irvine's repository, Yahoo's massive 13TB data set, Google's image and video data sets, Luke de Oliveira's Greatest Public Datasets for AI blog post, and CrowdFlower's Data for Everyone. At the bottom, a note states: "Finally, here are extensive pages on importing data from the Web into R, provided by CRAN and MRAN."

# Your Deep Learning Project I

Ideating

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

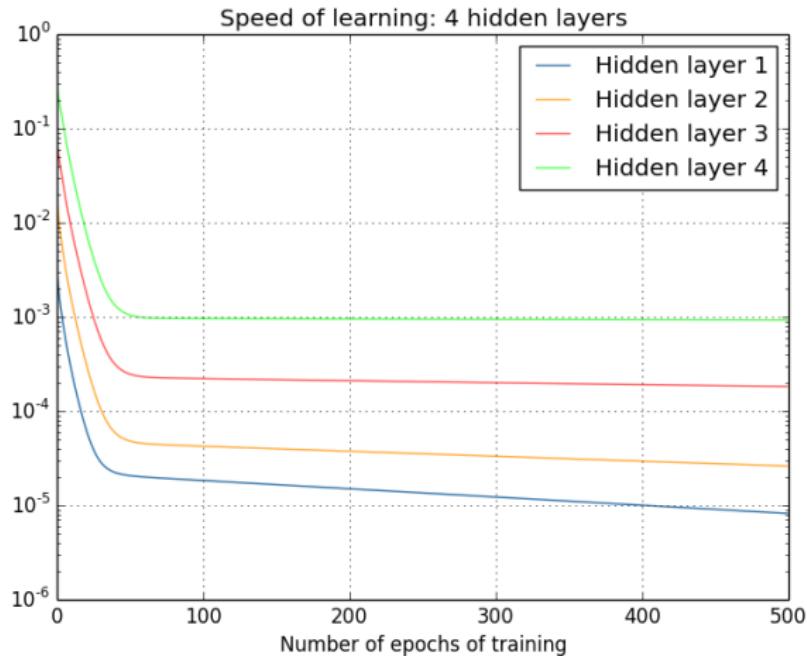
Shallow Net



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# Building & Training a Deep Network

Unit 3: March 10th AM



Unit 1

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Essential Theory III

## Weight Initialization and Mini-Batches

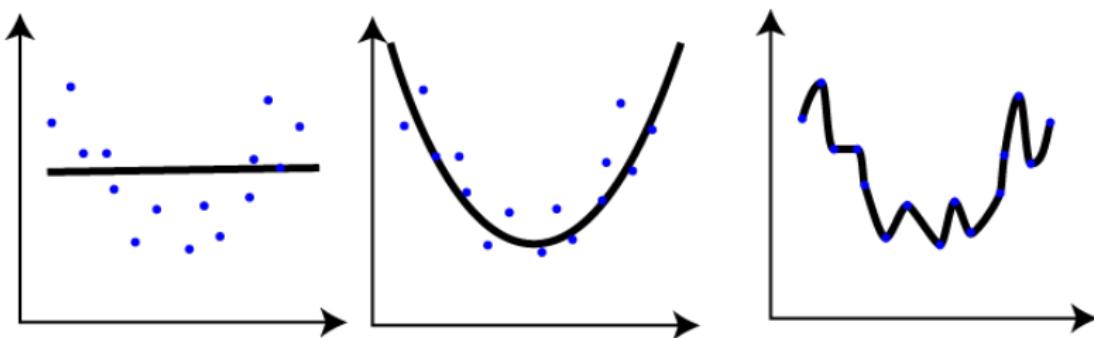
[neurons notebook]



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# Essential Theory IV

## Unstable Gradients and Avoiding Overfitting



# A Deep Neural Network

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

[deep notebook]

# TensorBoard

## and the Interpretation of Model Outputs

Introduction

Course  
Survey

Introductory

Intermediate

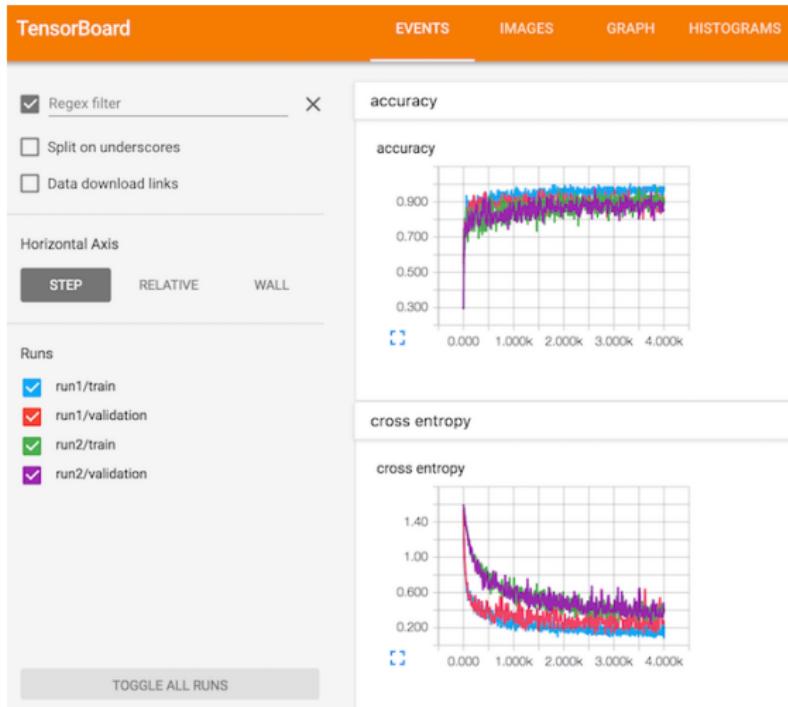
Advanced

TF  
Playground

Hardware

Software

Shallow Net



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



NYC DATA SCIENCE  
ACADEMY

Unit 1

Introduction

Course  
Survey

Introductory

**Intermediate**

Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Machine Vision

Unit 4: March 10th PM



Unit 1

Introduction

Course  
Survey

Introductory

**Intermediate**

Advanced

TF

Playground

Hardware

Software

Shallow Net

# Intro to ConvNets

for Visual Recognition

[deepvis]



NYC DATA SCIENCE  
**ACADEMY**

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

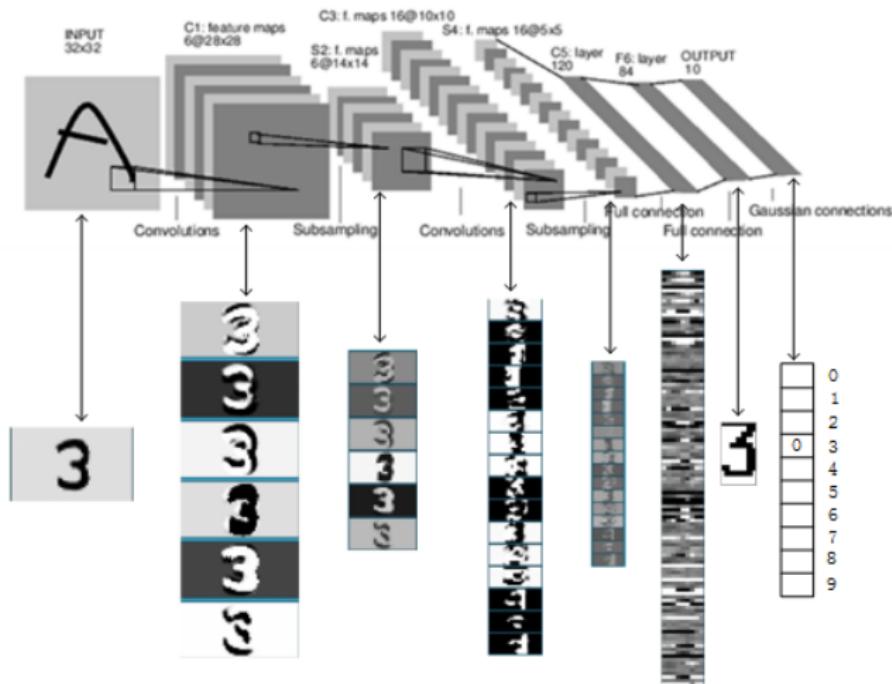
Hardware

Software

Shallow Net

# LeNet-5

## Classic ConvNet Architecture I



[notebook]

# AlexNet

## Classic ConvNet Architecture II

Introduction

Course Survey

Introductory

Intermediate

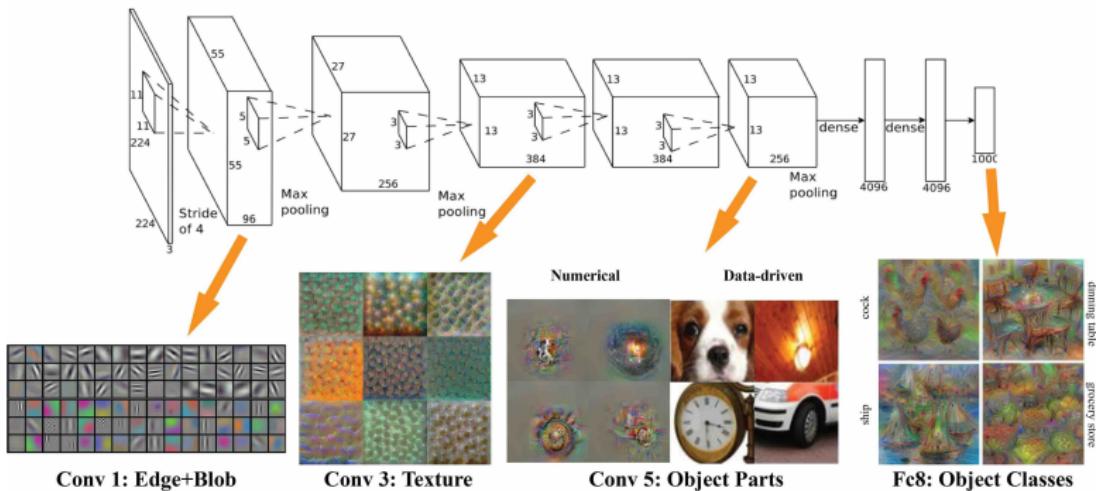
Advanced

TF Playground

Hardware

Software

Shallow Net



[notebook]

# Transfer Learning

Introduction

Course Survey

Introductory

Intermediate

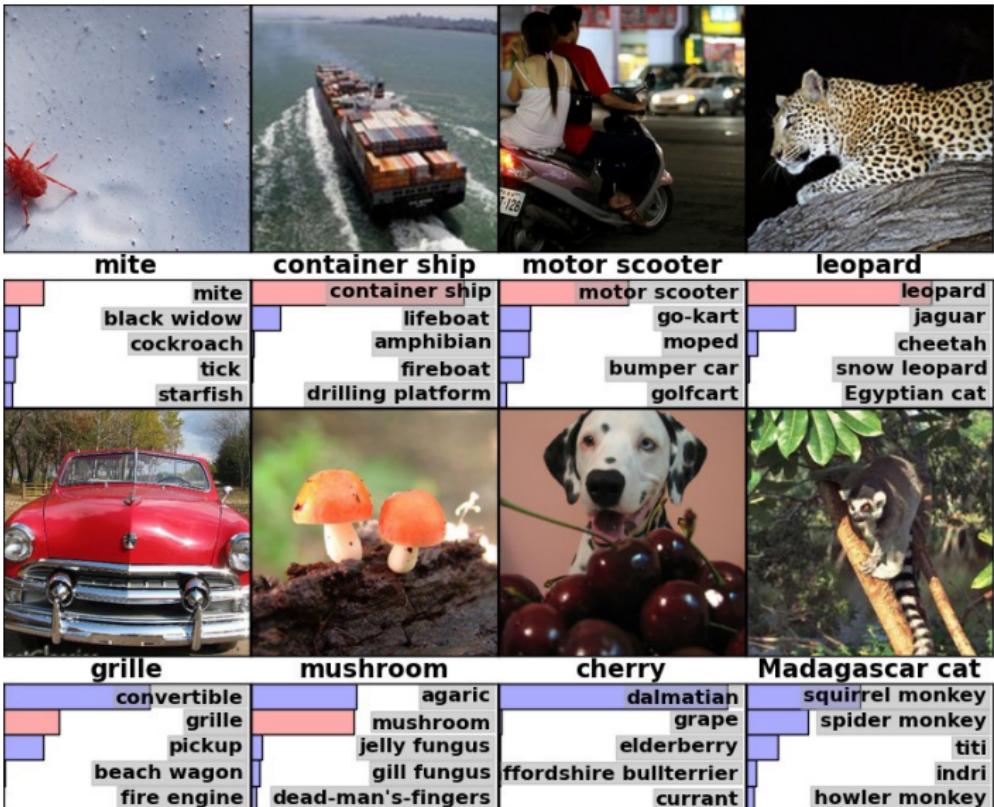
Advanced

TF Playground

Hardware

Software

Shallow Net



# Your Deep Learning Project II

## Formulating

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net



NYC DATA SCIENCE  
ACADEMY

# Natural Language Processing

Units 5 & 6: March 17th

Introduction

Course  
Survey

Introductory

**Intermediate**

Advanced

TF  
Playground

Hardware

Software

Shallow Net



NYC DATA SCIENCE  
**ACADEMY**

## Introduction

## Course Survey

Introductory

Intermediate

Advanced

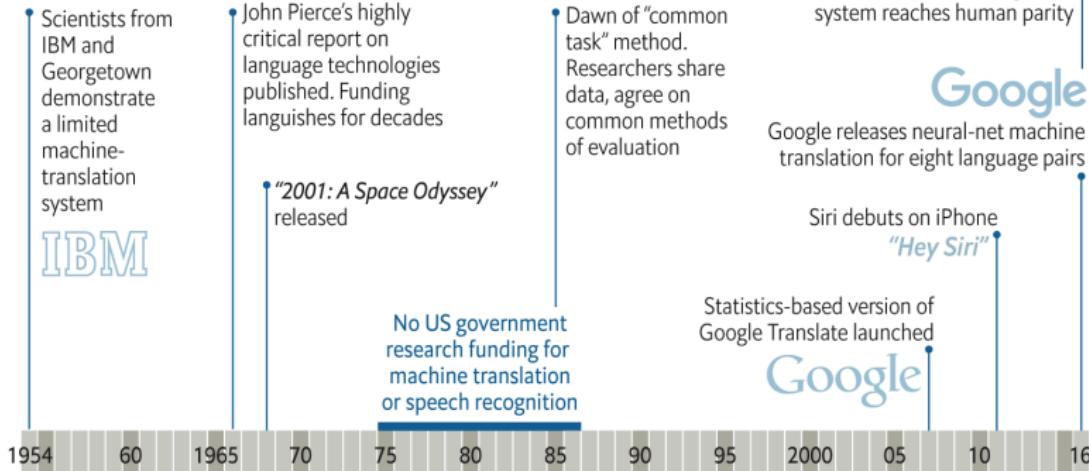
## TF Playground

## Hardware

## Software

## Shallow Net

## A history of language technologies



Introduction

Course  
Survey

Introductory

Intermediate

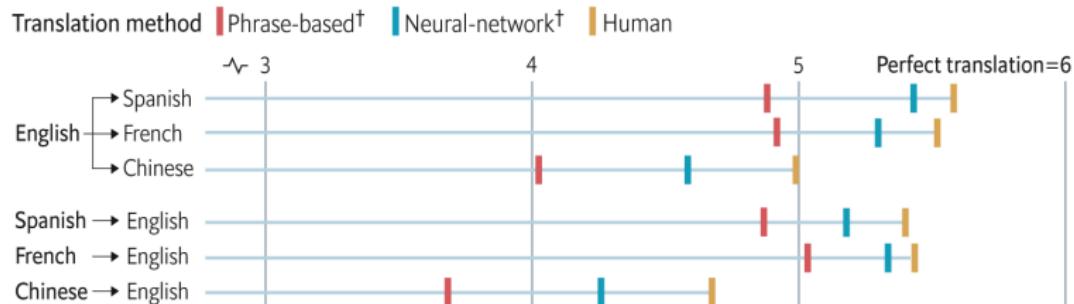
Advanced

TF  
Playground

Hardware

Software

Shallow Net



# Sunspring

Introduction

Course  
Survey

Introductory

**Intermediate**

Advanced

TF  
Playground

Hardware

Software

Shallow Net



NYC DATA SCIENCE  
**ACADEMY**

# Sunspring

## Introduction

### Course Survey

Introductory

Intermediate

Advanced

### TF Playground

### Hardware

### Software

### Shallow Net

INT. SHIP

We see H pull a book from a shelf, flip through it while speaking, and then put it back.

H  
In a future with base unemployment, young people are forced to sell blood. That's the first thing I can do.

H  
You should see the boys and shut up. I was the one who was going to be a hundred years old.

I saw him again. The way you were sent to me... that was a big honest idea. I am not a bright light.

H  
Well, I have to go to the skull. I don't know.

He picks up a light screen and fights the security force of the particles of a transmission on his face.

H  
(continuing)  
What do you mean?

C  
(smiles)  
I don't know anything about any of this.

H  
(to Hask, taking his eyes from his mouth)  
Then what?

H  
There's no answer.

C  
(frowning)  
We're going to see the money.

H  
(reading)  
"All right, you can't tell me that."

Steps back. Coffey is still going through.

C  
I was coming to that thing because you were so pretty.

H  
I don't know. I don't know what you're talking about.

C  
That's right.

H  
So what are you doing?

H  
I don't want to be honest with you.

H  
He looks at him for a moment, then smiles at him.

H  
You don't have to be a doctor.

H  
I am not sure. I don't know what you're talking about.

H  
I want to see you too.

H  
It would be a good time. I think I could have been my life.

H  
He starts to shake.

H (CONT'D)  
It may never be found, but that is just too bad. I have to leave, but I'm not free of the world.

C  
Yes. Perhaps I should take it from here. I'm not going to do something.

H  
You can't afford to take this money. You can't afford to stay. But I've got a good time to stay there.

C  
Well, I think you can still be back on the table.

Mm. It's a damn thing scared to say. Nothing is going to be a child. Then he got it on this rock with a child and then I left the other two.

He is standing in the stars and sitting on the floor. He takes off the stars and pulls the covers over to his back. He stares at it. He is on the phone. He cuts the signal from the ship and puts it in his pocket. He makes a hole in the floor leading to the sea on the roof.

He comes up behind him to protect him. He is still standing next to him.

He looks through the door and the door closes. He looks at the key from his backpack, and starts to cry.

Well, there's the situation with me and the light on the ship. The guy was trying to stop me. He was like a hero. I wanted to tell him I was worried about him. Not even if he would have stopped me, I didn't think he would come any more. I didn't mean to be a virgin. I mean, he was weak. And I thought I'd just sit there and be crazy to take it out. It was a long night. I got home at 2 AM. I was late. I was going to be a moment. I just wanted to tell you that I was such a fool. I was so stupid. I wanted to stop him and I couldn't even tell. I did it. I did it. I did it. I'm sorry, I know I don't like him. I can go home and be so bad and I know to go home and be so bad and the way over here and find the square and go to the game with him and the way over there. Then he changes it out. But I'm going to see him when he gets to the end of it at least. He takes me out of his arms. Then he said he'd go to bed with me.

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Word Vectors

## word2vec & Vector-Space Embedding

[vse 2000]

[word2viz]

# Recurrent Neural Networks

## GRUs and LSTMs

Introduction

Course  
Survey

Introductory

**Intermediate**

Advanced

TF  
Playground

Hardware

Software

Shallow Net

[BiLSTM notebook]

# Advanced Architectures

Introduction

Course  
Survey

Introductory  
**Intermediate**  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

[multi-ConvNet notebook]

# Your Deep Learning Project III

Improving

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net



NYC DATA SCIENCE  
ACADEMY

# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



# TensorFlow

Unit 7 & 8: March 24th

Introduction

Course  
Survey

Introductory

Intermediate

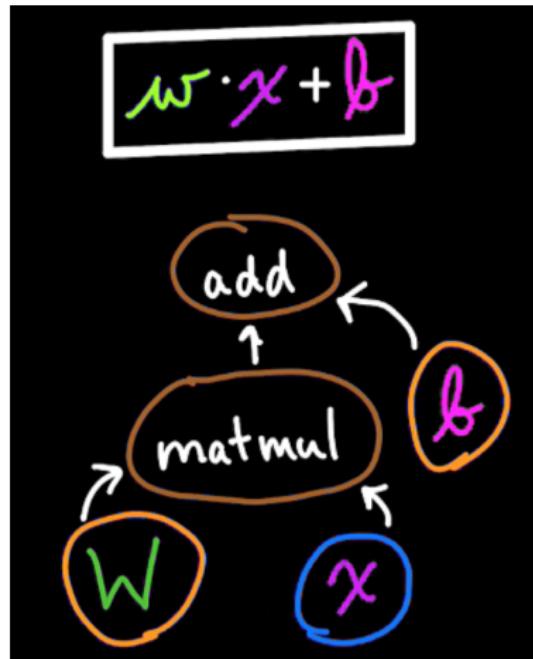
Advanced

TF  
Playground

Hardware

Software

Shallow Net



# Leading DL Libraries

## A Comparison

	Caffe	Torch	Theano	TensorFlow
<i>language</i>	Python, C++	Lua, PyTorch	Python	Python, Java, C, Go
<i>pre-trained models</i>	Model Zoo	ModelZoo	Lasagne	Inception, others
<i>parallel GPUs: data</i>	Yes	Yes	Yes	Yes
<i>parallel GPUs: model</i>		Yes		Yes
<i>source code</i>	Readable	Readable		
<i>for RNNs</i>			Good	Best
<i>high-level APIs</i>			Keras	Keras, TFLearn

# Neurons in TensorFlow

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

[LeNet-5 in TF]

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- ➊ Xavier Glorot initialization
- ➋ problem simplification
- ➌ layer architecture
- ➍ cost function
- ➎ avoid overfitting
- ➏ variable learning rate  $\eta$
- ➐ epochs
- ➑ regularization parameters, e.g.,  $\lambda$
- ➒ mini-batch size
- ➓ grid-search automation

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Improving Model Performance

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

- 1 Xavier Glorot initialization
- 2 problem simplification
- 3 layer architecture
- 4 cost function
- 5 avoid overfitting
- 6 variable learning rate  $\eta$
- 7 epochs
- 8 regularization parameters, e.g.,  $\lambda$
- 9 mini-batch size
- 10 grid-search automation

# Tuning Hyperparameters

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

...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:

```
# 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_layer_dropout)

# dense layer:
n_dense = 128
dense_layer_dropout = 0.5

# 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_layer_dropout)
```

# Your Deep Learning Project IV

## Assessing

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net



NYC DATA SCIENCE  
ACADEMY

Unit 1

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Generative Adversarial Networks

Unit 9: April 7th AM



NYC DATA SCIENCE  
ACADEMY

## Introduction

## Course Survey

Introductory

Intermediate

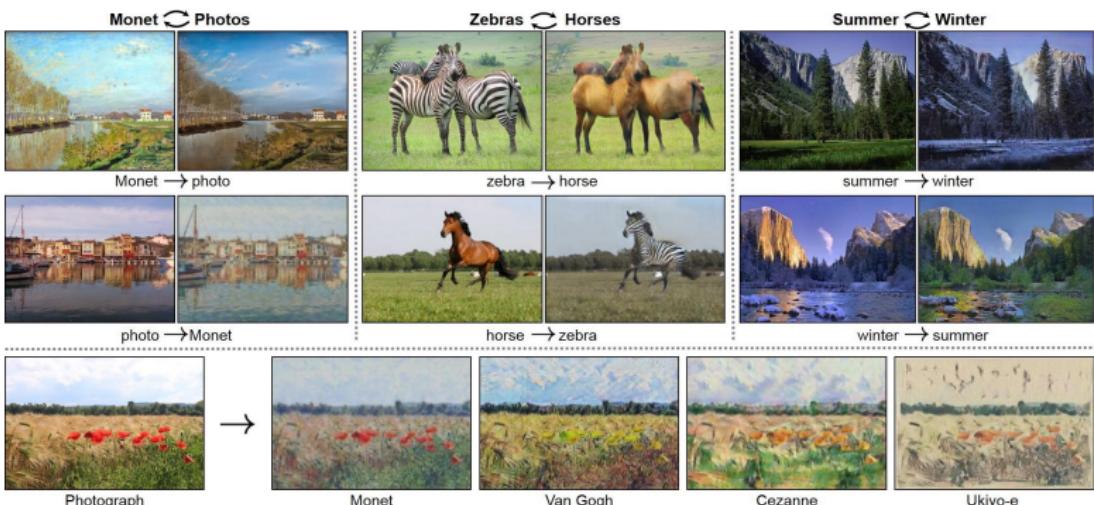
Advanced

## TF Playground

## Hardware

## Software

## Shallow Net



Introduction

Course Survey

Introductory

Intermediate

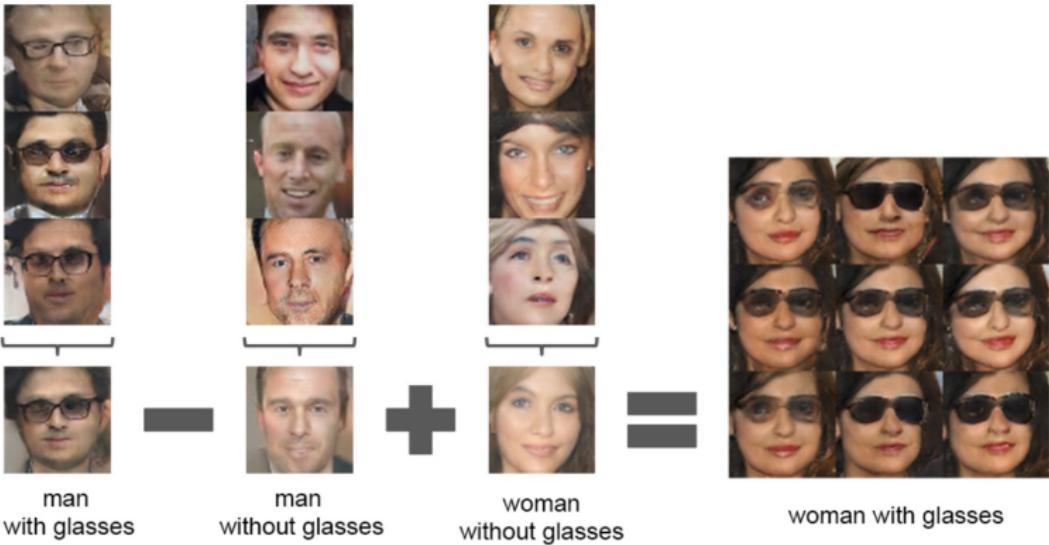
Advanced

TF Playground

Hardware

Software

Shallow Net



## Unit 1

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

# [Quick, Draw!]



NYC DATA SCIENCE  
**ACADEMY**

# Unit 1

Introduction

Course  
Survey

Introductory

Intermediate

**Advanced**

TF  
Playground

Hardware

Software

Shallow Net

## Unit 1

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

[*GAN* notebook]



NYC DATA SCIENCE  
**ACADEMY**

# Deep Reinforcement Learning

Unit 10: April 7th PM

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net



Introduction

Course Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

# AlphaGO

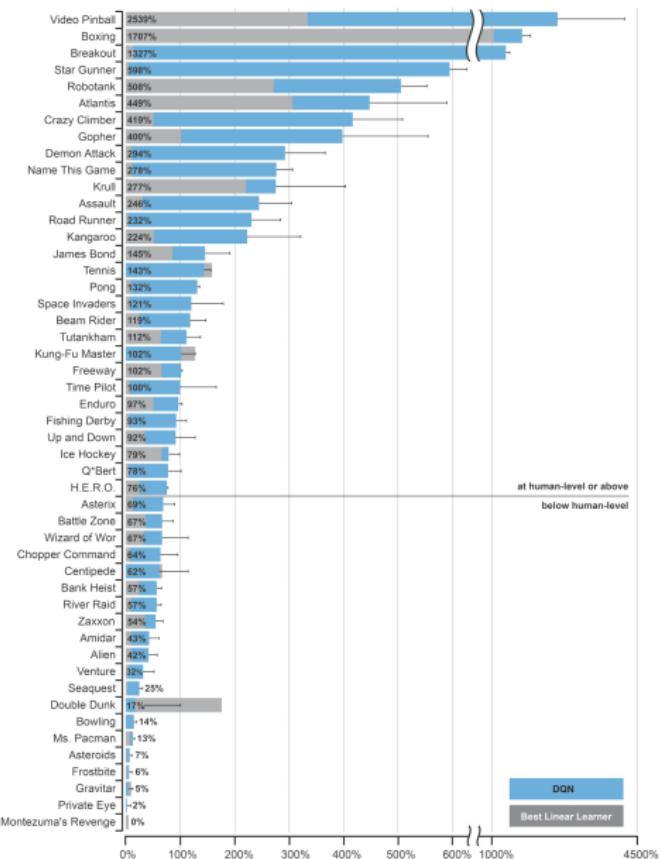
Silver et al. (2016)



# Deep Q-Learning

Mnih et al. (2015)

Introduction  
Course Survey  
Introductory  
Intermediate  
Advanced  
TF Playground  
Hardware  
Software  
Shallow Net

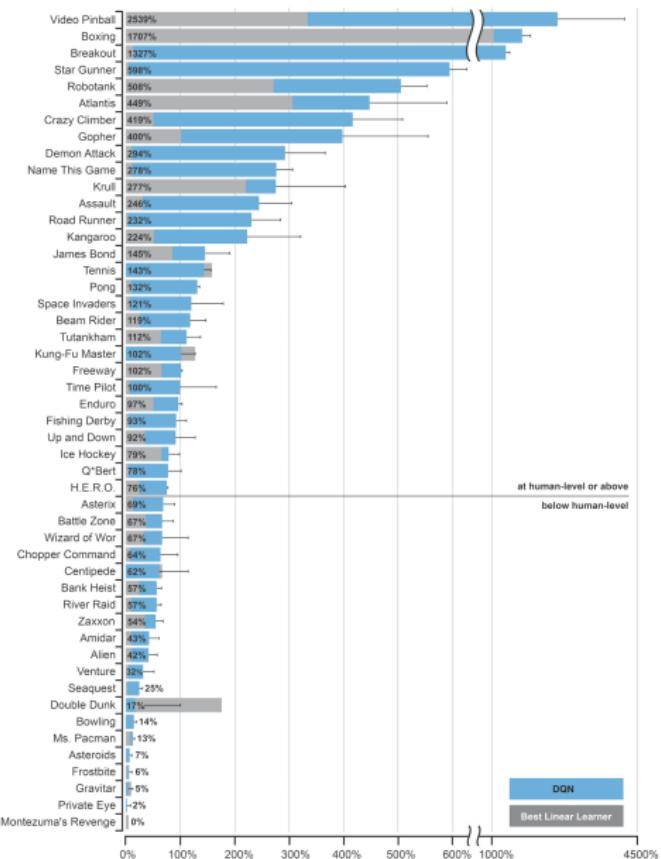


[Atari Games]

# Deep Q-Learning

Mnih et al. (2015)

Introduction  
Course Survey  
Introductory  
Intermediate  
Advanced  
TF Playground  
Hardware  
Software  
Shallow Net

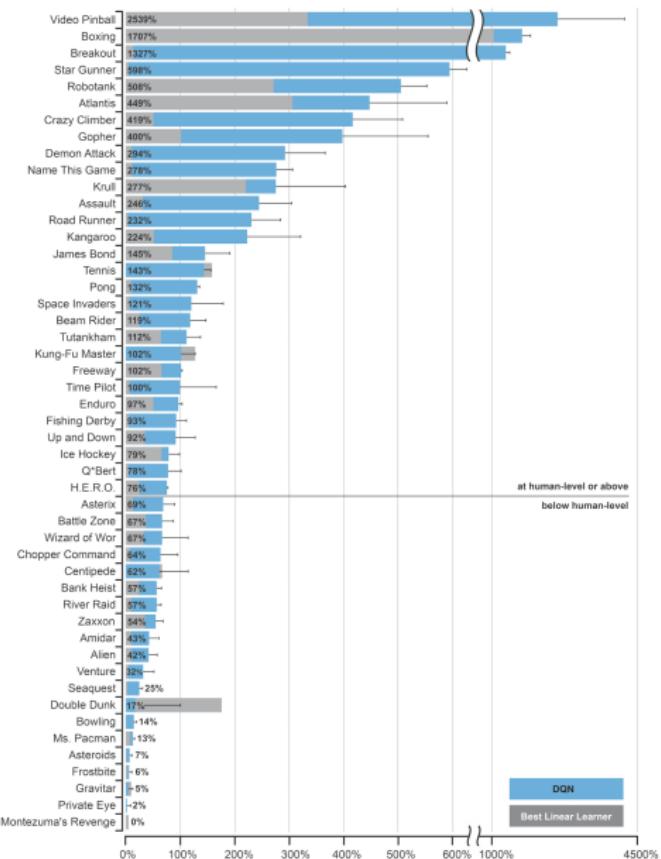


[Atari Games]

# Deep Q-Learning

Mnih et al. (2015)

Introduction  
Course Survey  
Introductory  
Intermediate  
Advanced  
TF Playground  
Hardware  
Software  
Shallow Net



[Atari Games]

Unit 1

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

[*Deep Q-Learning Network* notebook]

[SLM-Lab]



NYC DATA SCIENCE  
ACADEMY

# Your Deep Learning Project V

## Presentations

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net



Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground  
Hardware  
Software  
Shallow Net

# Demand for AI Talent

i.e., *Deep Learning* talent

“Of the ten most valuable quoted companies in the world, seven say they have plans to put deep-learning-based AI at the heart of their operations”

~ *The Economist* (Feb. 17th, 2018)

# Demand for AI Talent

i.e., Deep Learning talent

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

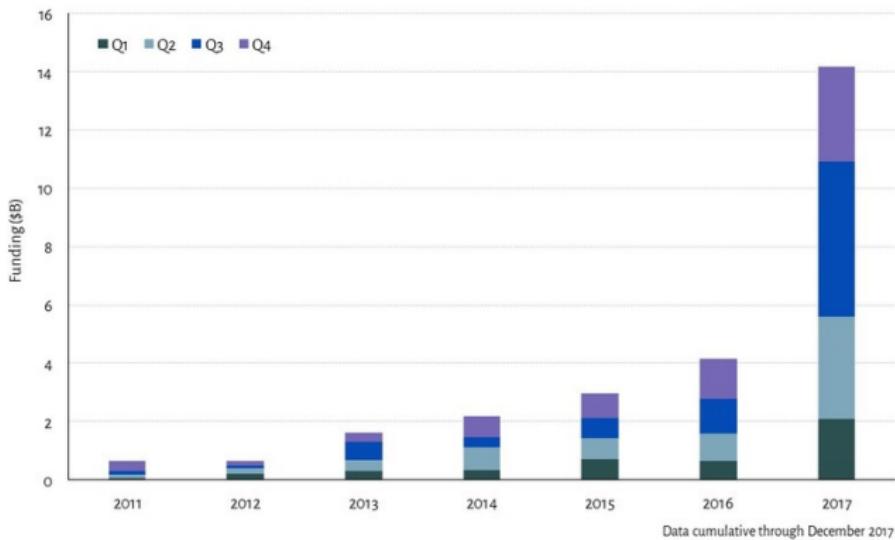
Software

Shallow Net



ARTIFICIAL INTELLIGENCE  
Annual Funding Amount

VS / VENTURE SCANNER



Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

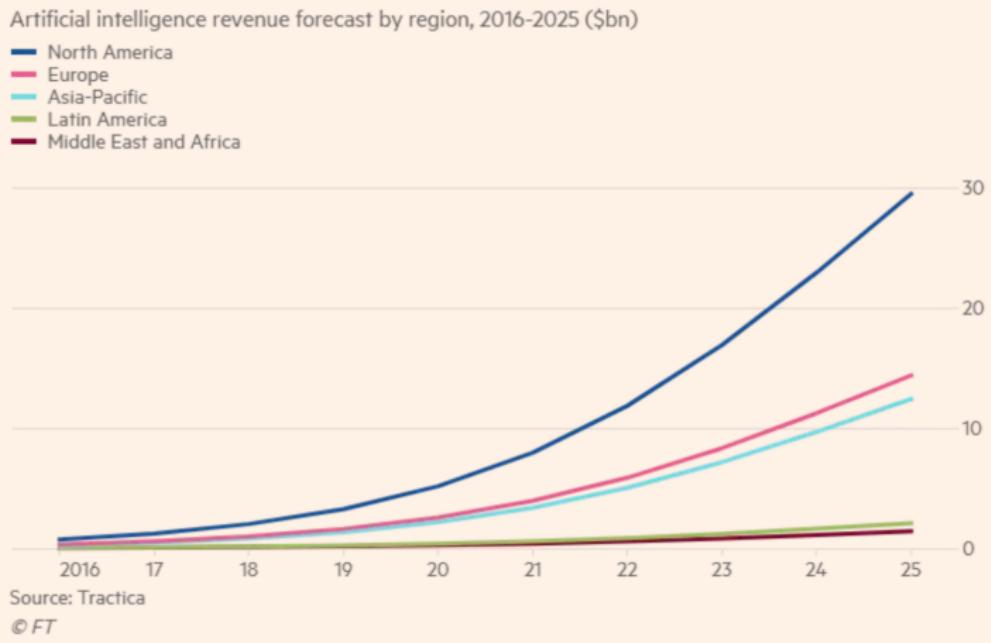
Hardware

Software

Shallow Net

# Demand for AI Talent

i.e., *Deep Learning* talent

NYC DATA SCIENCE  
ACADEMY

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Demand for AI Talent

i.e., *Deep Learning* talent

According to JF Gagne's [Global AI Talent Report 2018]:

- ① 22k Ph.D.-educated researchers globally
- ② 3k of those currently looking
- ③ 5k publishing / presenting at AI conferences

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

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[Introduction](#)[Course Survey](#)[Introductory](#)[Intermediate](#)[Advanced](#)[TF Playground](#)[Hardware](#)[Software](#)[Shallow Net](#)

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i.e., *Deep Learning* talent

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Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

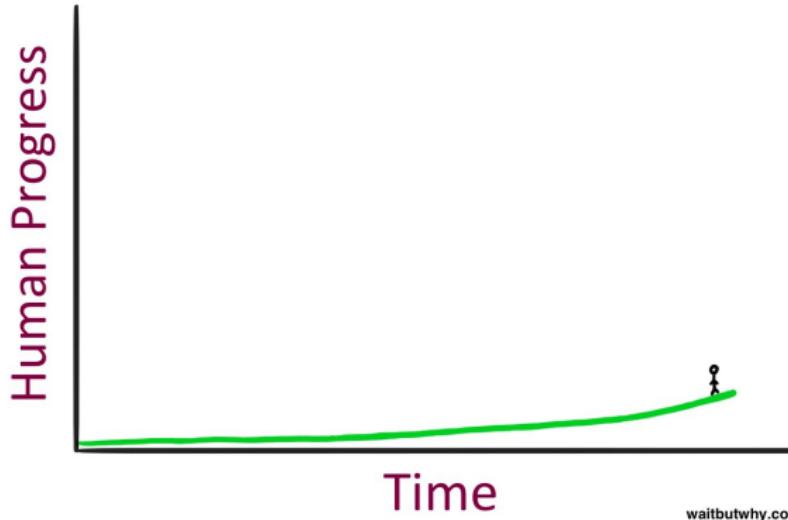
TF  
Playground

Hardware

Software

Shallow Net

# The AI Revolution



[waitbutwhy.com](http://waitbutwhy.com)

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

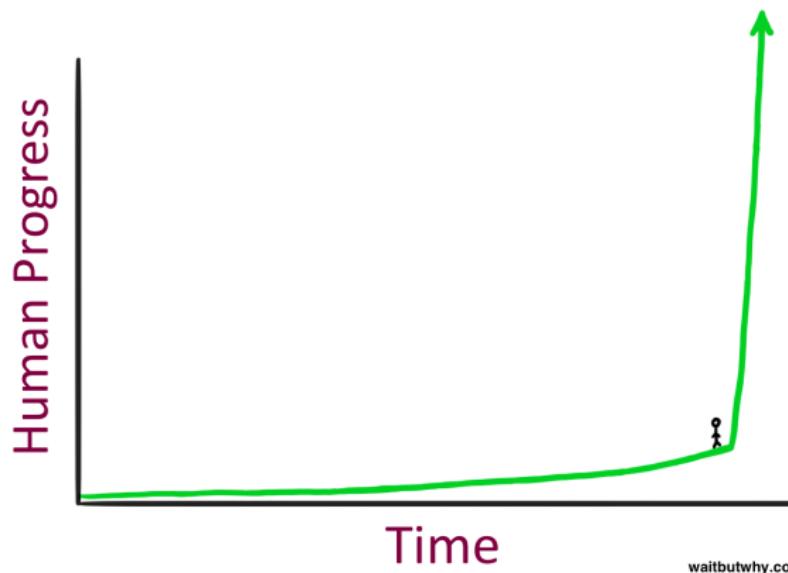
TF  
Playground

Hardware

Software

Shallow Net

# The AI Revolution



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



Unit 1

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# TensorFlow Playground

Interactive ANN Visualization

[TensorFlow Playground]



NYC DATA SCIENCE  
ACADEMY

# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## ① An Introduction to Neural Networks and Deep Learning

## ② Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## ③ Interactive Visualization of an Artificial Neural Network

## ④ Hardware Options for DL

## ⑤ TensorFlow Jupyter Notebooks within a Docker Container

## ⑥ A Shallow Artificial Neural Network



Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Hardware Options for DL

incl. how to build a DL server

- local machine
- eGPU
- (Tesla K80) cloud instance
- (GTX 1080ti) monster box

Introduction

Course  
Survey

Introductory

Intermediate

Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Hardware Options for DL

incl. how to build a DL server

- local machine
- eGPU
  - (Tesla K80) cloud instance
  - (GTX 1080ti) monster box

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Hardware Options for DL

incl. how to build a DL server

- local machine
- eGPU
- (Tesla K80) cloud instance
- (GTX 1080ti) monster box

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Hardware Options for DL

incl. how to build a DL server

- local machine
- eGPU
- (Tesla K80) cloud instance
- (GTX 1080ti) monster box

# Local Machine

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



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ACADEMY

# Remote Cloud Instance

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

[GCP Ubuntu Instance]

# Build Your Own Monster Box

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



[PC Part Picker]  
[Blog Post]

# Unit 1

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



Introduction

Course Survey

Introductory

Intermediate

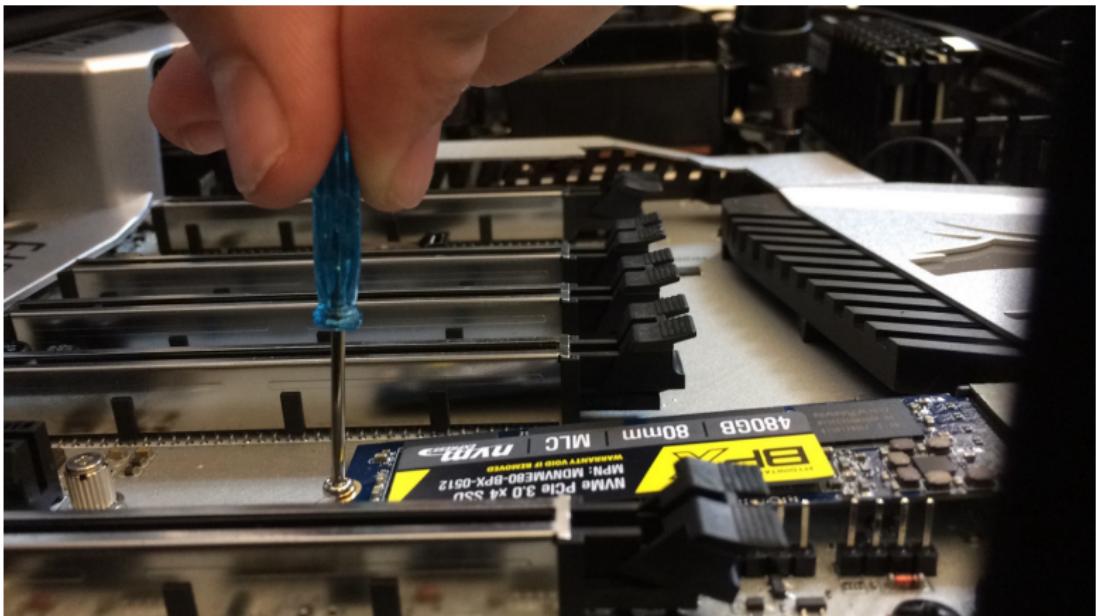
Advanced

TF  
Playground

Hardware

Software

Shallow Net



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Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



NYC DATA SCIENCE  
**ACADEMY**

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



# Unit 1

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net



# Unit 1

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## 1 An Introduction to Neural Networks and Deep Learning

## 2 Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

Advanced Units (7-10)

## 3 Interactive Visualization of an Artificial Neural Network

## 4 Hardware Options for DL

## 5 TensorFlow Jupyter Notebooks within a Docker Container

## 6 A Shallow Artificial Neural Network



NYC DATA SCIENCE  
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Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Software Installation

How did everyone get on?

[installation instructions]

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Jupyter Notebooks

+ Docker + Nvidia GPU

[Dockerfile]



NYC DATA SCIENCE  
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Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

# Jupyter Notebooks

## + Docker + Nvidia GPU + *TensorFlow*

[Dockerfile]

# Outline

Introduction

Course Survey

Introductory

Intermediate

Advanced

TF Playground

Hardware

Software

Shallow Net

## ① An Introduction to Neural Networks and Deep Learning

## ② Course Survey

Introductory Units (1-3)

Intermediate Units (4-6)

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## ③ Interactive Visualization of an Artificial Neural Network

## ④ Hardware Options for DL

## ⑤ TensorFlow Jupyter Notebooks within a Docker Container

## ⑥ A Shallow Artificial Neural Network



# A Shallow Neural Network

Introduction

Course  
Survey

Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net

0	4	1	9	2	1	3	1	4	3
5	3	6	1	7	2	8	6	9	4
0	9	1	1	2	4	3	2	7	3
8	6	9	0	5	6	0	7	6	1
8	7	9	3	9	8	5	9	3	3
0	7	4	9	8	0	9	4	1	4
4	6	0	4	5	6	1	0	0	1
7	1	6	3	0	2	1	1	7	9
0	3	6	7	8	3	9	0	4	6
7	4	6	8	0	7	8	3	1	5

# A Shallow Neural Network

Introduction

Course  
Survey

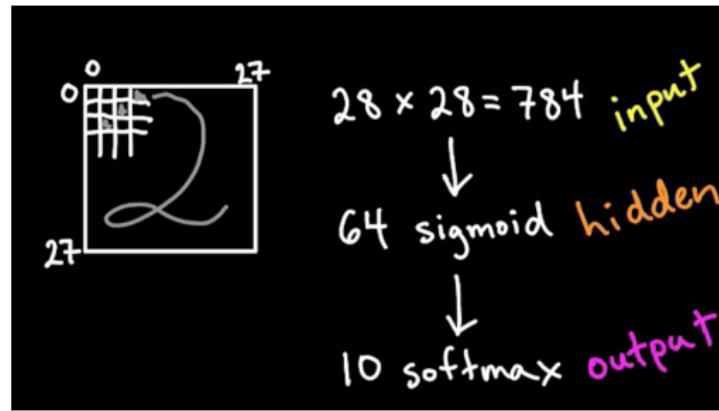
Introductory  
Intermediate  
Advanced

TF  
Playground

Hardware

Software

Shallow Net



[shallow notebook]