

# The Unreasonable Effectiveness of Deep Learning

## Deep Learning — Unit 1

Dr. Jon Krohn

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March 3rd, 2018

- 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

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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

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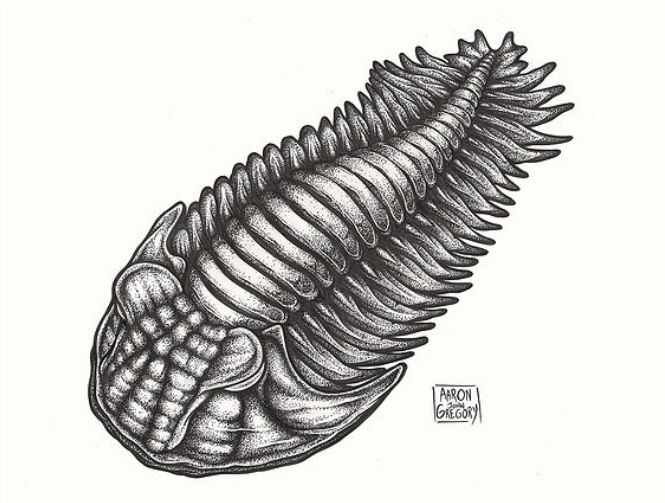
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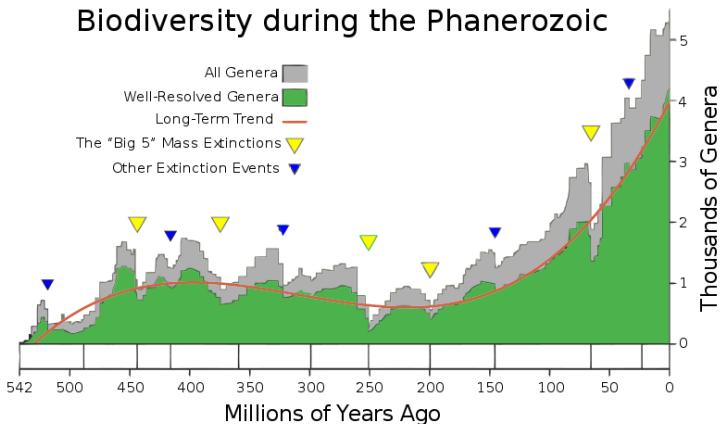
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## Biodiversity during the Phanerozoic



# Hubel & Wiesel (1959)

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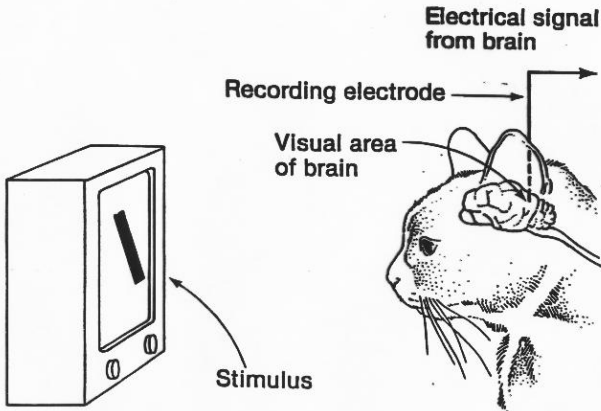
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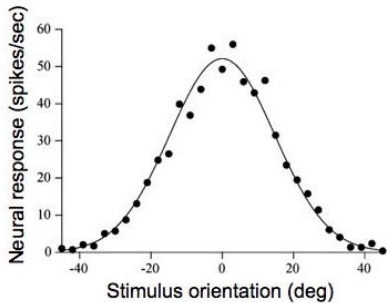
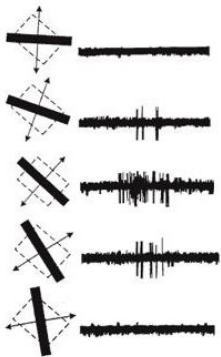
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Hubel &amp; Wiesel, 1968



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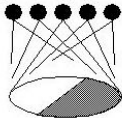
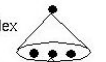
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topographical mapping

hyper-complex  
cells

complex cells



simple cells

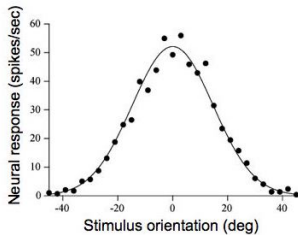
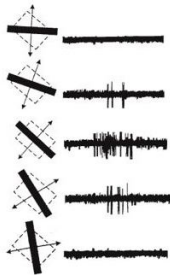


high level

mid level

low level

low level



Hubel &amp; Wiesel, 1968

## Introduction

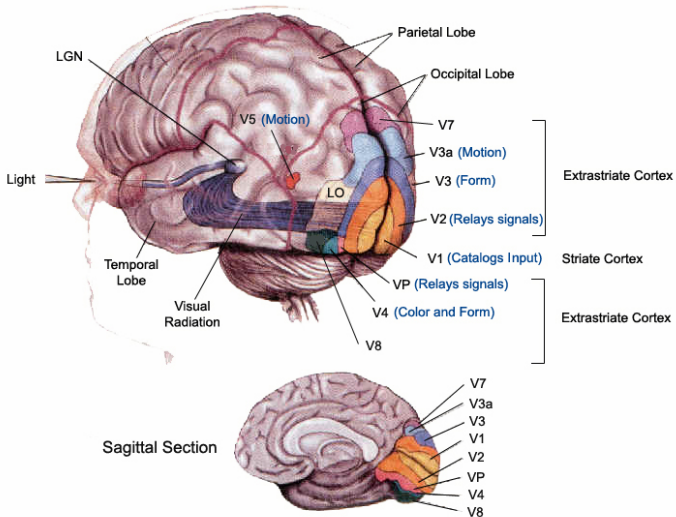
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## Visual Cortices



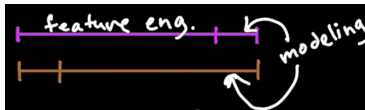
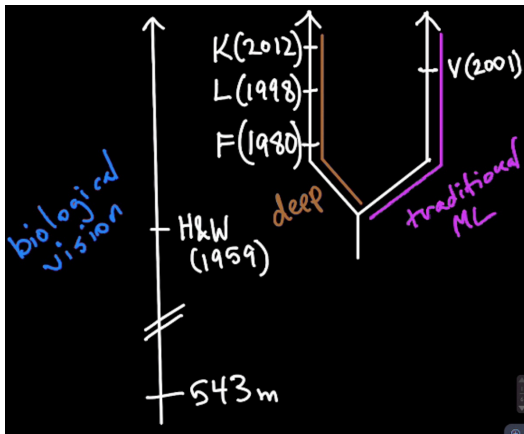
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# Neocognitron

Fukushima (1980)

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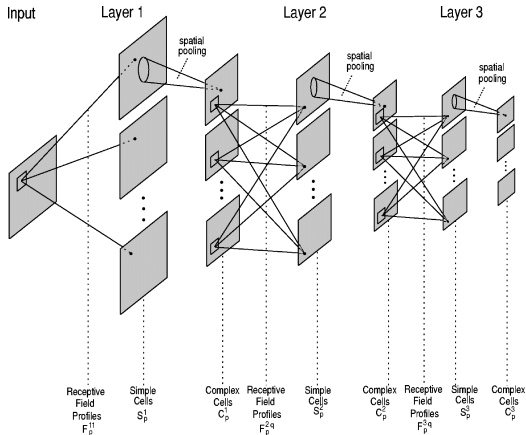
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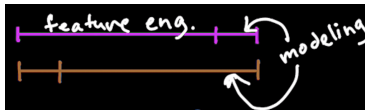
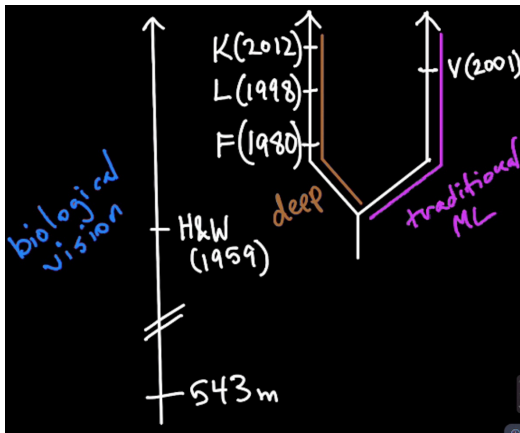
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# MNIST Digits & LeNet-5

LeCun, Boutou, Bengio & Haffner (1998)



PROC. OF THE IEEE, NOVEMBER 1998

7

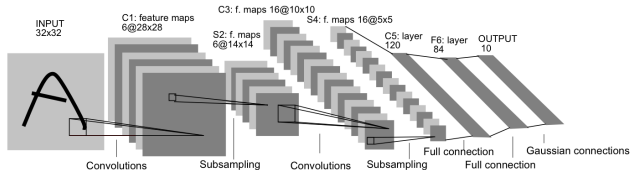


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

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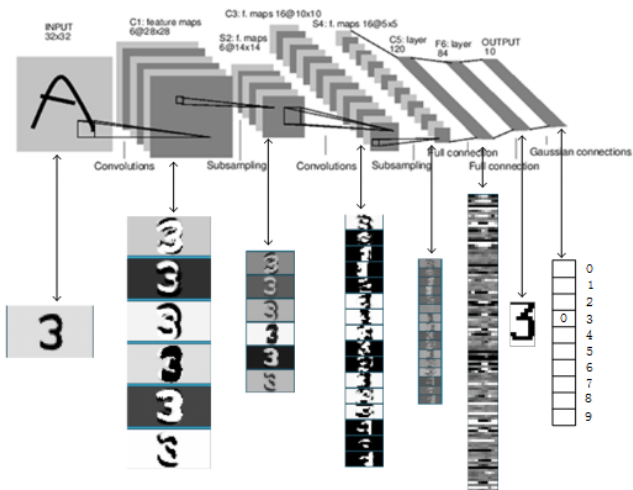
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## LeNet-5

LeCun, Boutou, Bengio &amp; Haffner (1998)



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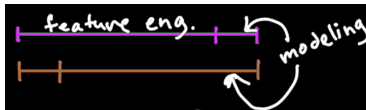
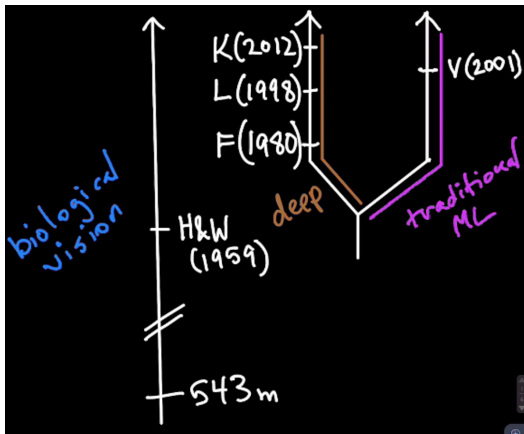
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# Viola & Jones (2001)

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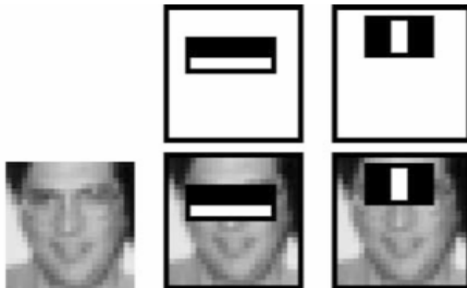
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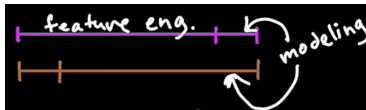
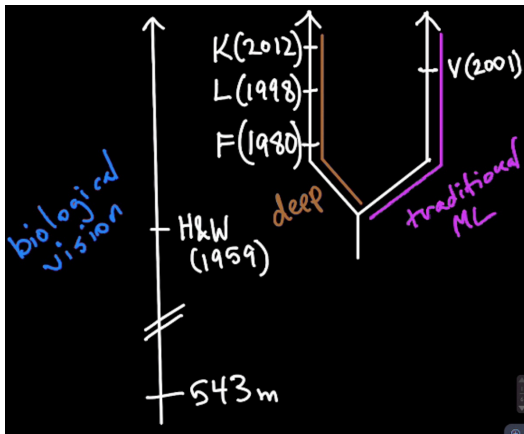
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## ImageNet

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

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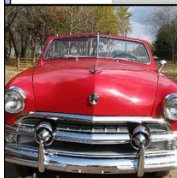
mite

container ship

motor scooter

leopard

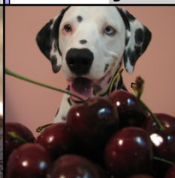
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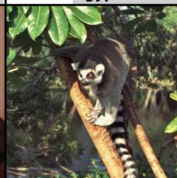
grille



mushroom



cherry



Madagascar cat

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# ImageNet Classification Error

ILSVRC: 1.4m, 1k object classes

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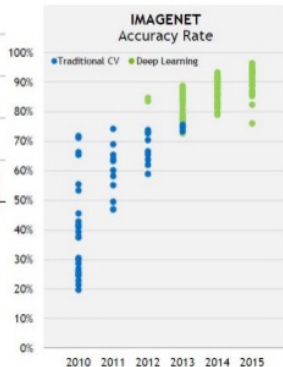
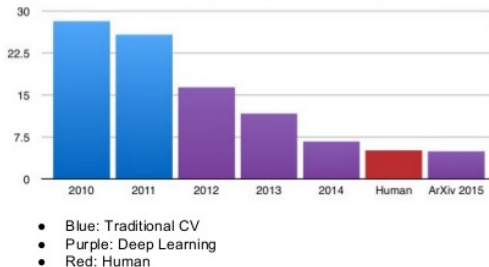
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ILSVRC top-5 error on ImageNet



## AlexNet

Krizhevsky, Sutskever &amp; Hinton (2012)

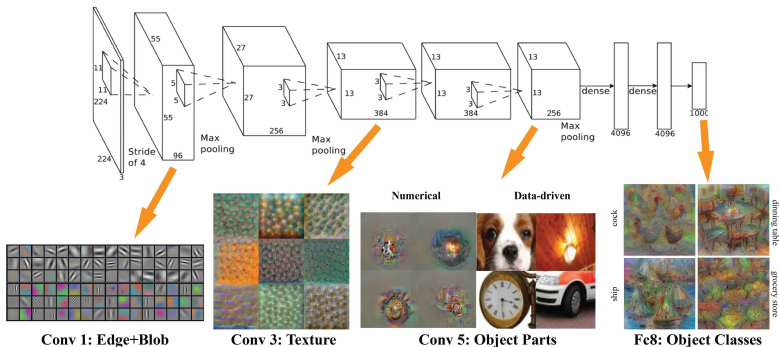
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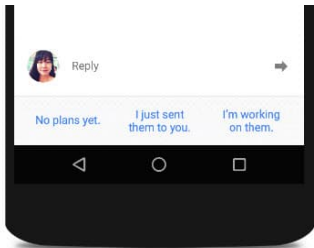
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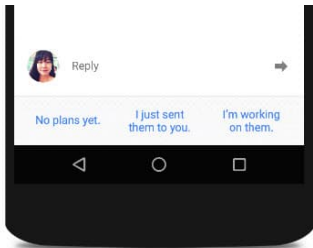
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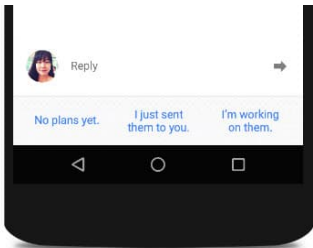
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← → ↻ [nycdatascience.com/courses/deep-learning/](https://nycdatascience.com/courses/deep-learning/)

## 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**

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# Jupyter Notebooks

## + Docker + Nvidia GPU + TensorFlow

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# A Shallow Neural Network

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# How Deep Learning Works

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# Essential Theory I

## Neural Units

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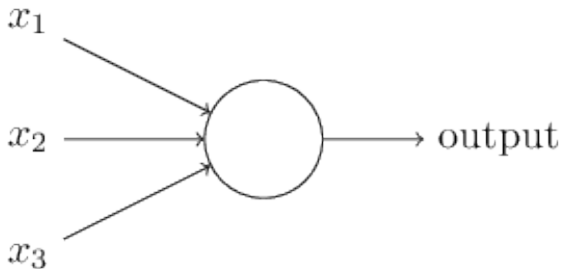
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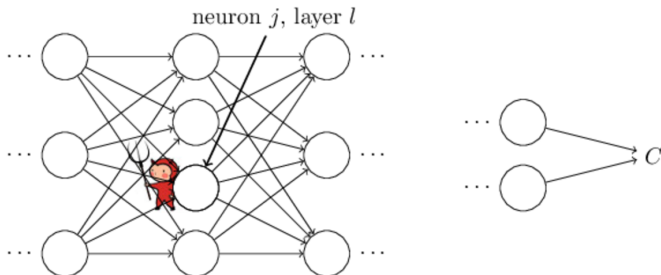
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# Essential Theory II

## Cost Functions, Gradient Descent, and Backpropagation



# An Intermediate Neural Network

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[intermediate notebook]

# Data Sets for Deep Learning

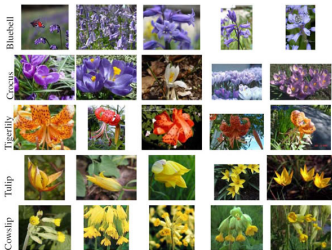
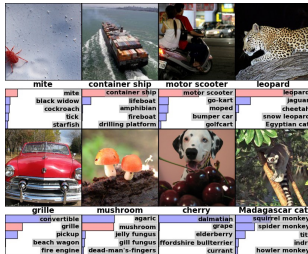
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Dataset	Classes	Train Samples
AG's News	4	120,000
Sogou News	5	450,000
DBpedia	14	560,000
Yelp Review Polarity	2	560,000
Yelp Review Full	5	650,000
Yahoo! Answers	10	1,400,000
Amazon Review Full	5	3,000,000
Amazon Review Polarity	2	3,600,000

# Data Sets for Deep Learning

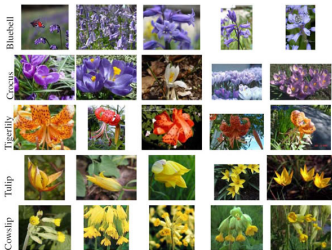
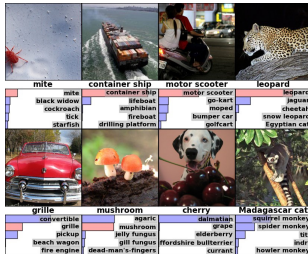
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Yahoo! Answers	10	1,400,000
Amazon Review Full	5	3,000,000
Amazon Review Polarity	2	3,600,000

# Data Sets for Deep Learning

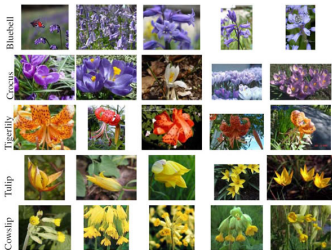
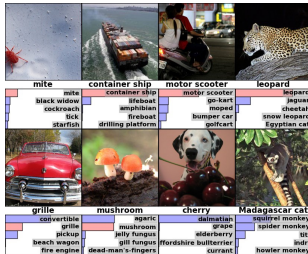
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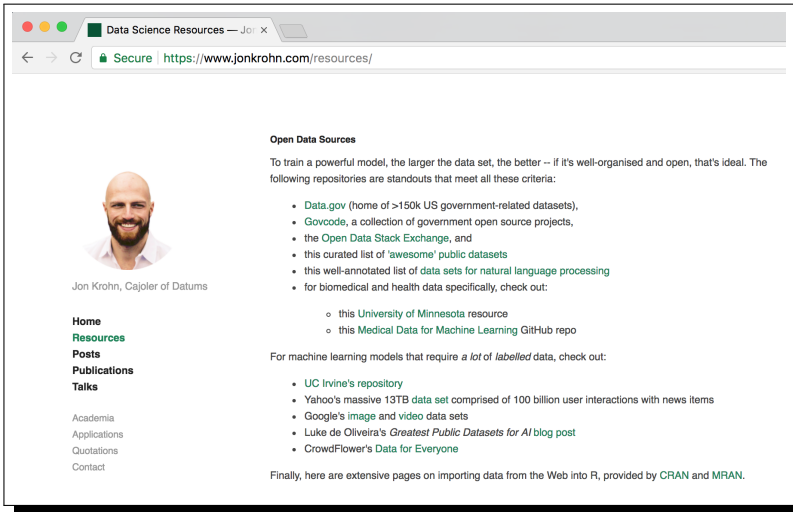
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DBpedia	14	560,000
Yelp Review Polarity	2	560,000
Yelp Review Full	5	650,000
Yahoo! Answers	10	1,400,000
Amazon Review Full	5	3,000,000
Amazon Review Polarity	2	3,600,000



Data Science Resources — Jon x

Secure | <https://www.jonkrohn.com/resources/>



Jon Krohn, Cajoler of Datums

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**Open Data Sources**

To train a powerful model, the larger the data set, the better -- if it's well-organised and open, that's ideal. The following repositories are standouts that meet all these criteria:

- [Data.gov](#) (home of >150k US government-related datasets),
- [Govcode](#), a collection of government open source projects,
- the [Open Data Stack Exchange](#), and
- this curated list of 'awesome' [public datasets](#)
- this well-annotated list of [data sets for natural language processing](#)
- for biomedical and health data specifically, check out:
  - this [University of Minnesota](#) resource
  - this [Medical Data for Machine Learning](#) GitHub repo

For machine learning models that require a *lot* of *labelled* data, check out:

- [UC Irvine's repository](#)
- Yahoo's massive 13TB [data set](#) comprised of 100 billion user interactions with news items
- Google's [image](#) and [video](#) data sets
- Luke de Oliveira's [Greatest Public Datasets for AI](#) blog post
- CrowdFlower's [Data for Everyone](#)

Finally, here are extensive pages on importing data from the Web into R, provided by [CRAN](#) and [MRAN](#).



# Your Deep Learning Project I

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# Building & Training a Deep Network

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# Essential Theory III

## Weight Initialization and Mini-Batches

[neurons notebook]

# Essential Theory IV

## Unstable Gradients and Avoiding Overfitting

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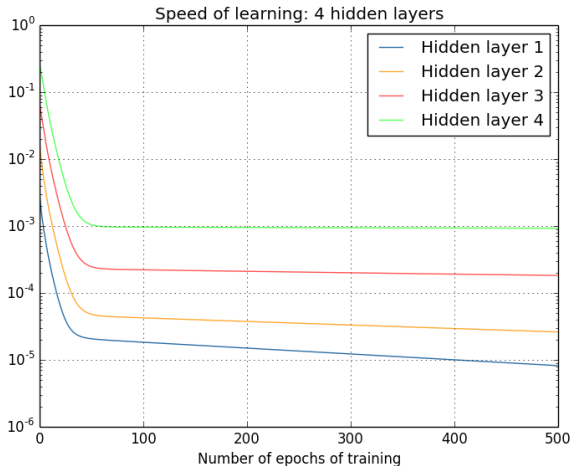
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# Essential Theory IV

## Unstable Gradients and Avoiding Overfitting

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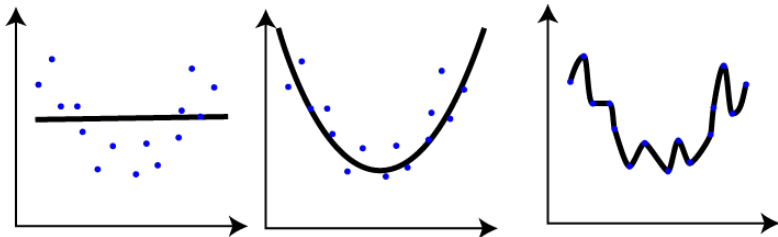
Advanced

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# A Deep Neural Network

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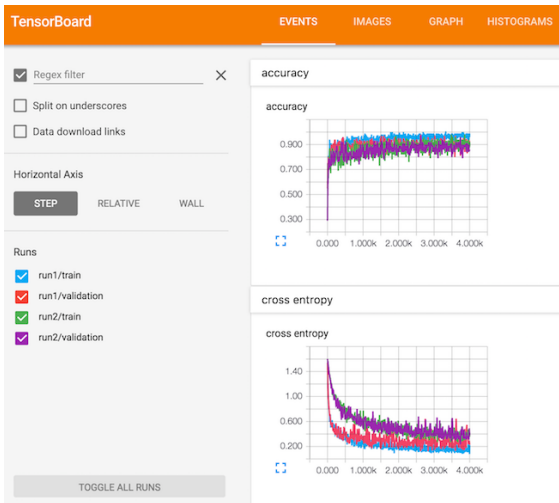
Software

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[deep notebook]

# TensorBoard

## and the Interpretation of Model Outputs



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① An Introduction to Neural Networks and Deep Learning

② **Course Survey**

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**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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# Machine Vision

Unit 4: March 10th PM

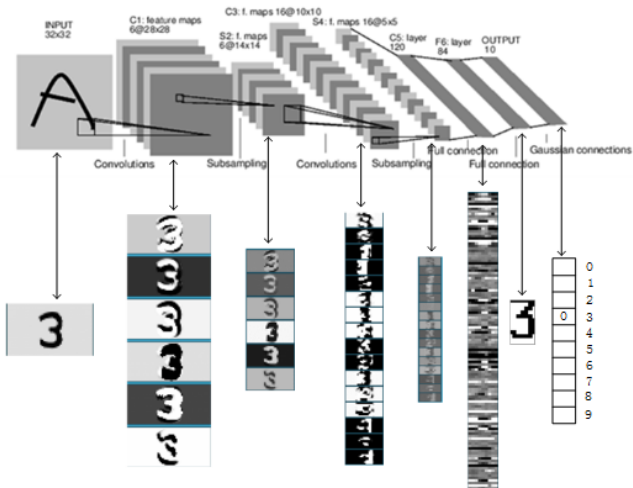
# Intro to ConvNets

## for Visual Recognition

[deepvis]

# LeNet-5

## Classic ConvNet Architecture I



[notebook]

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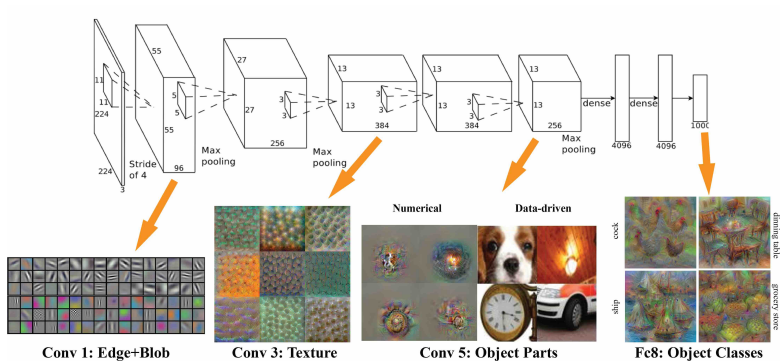
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[notebook]

## Transfer Learning

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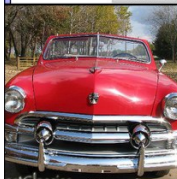
mite

container ship

motor scooter

leopard

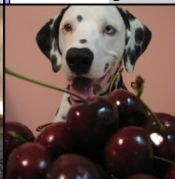
	<b>mite</b>		<b>container ship</b>		<b>motor scooter</b>		<b>leopard</b>
	black widow		lifeboat		go-kart		jaguar
	cockroach		amphibian		moped		cheetah
	tick		fireboat		bumper car		snow leopard
	starfish		drilling platform		golfcart		Egyptian cat



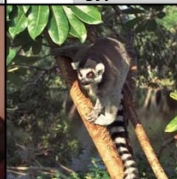
grille



mushroom



cherry



Madagascar cat

	<b>convertible</b>		<b>agaric</b>		<b>dalmatian</b>		<b>squirrel monkey</b>
	grille		mushroom		grape		spider monkey
	pickup		jelly fungus		elderberry		titi
	beach wagon		gill fungus		ffordshire bullterrier		indri
	fire engine		dead-man's-fingers		currant		howler monkey

# Your Deep Learning Project II

## Formulating

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# Natural Language Processing

Units 5 & 6: March 17th

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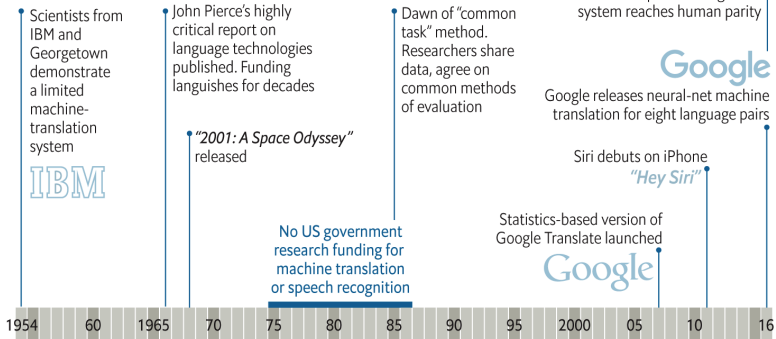
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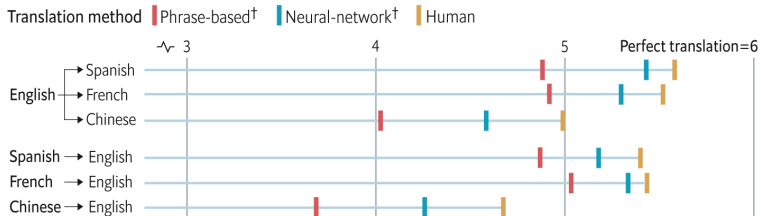
Software

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## A history of language technologies







# Sunspring

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## Sunspring

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TNT. GRIP

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

H

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

H2

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

H

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

C

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

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

H

(continuing)  
What do you mean?

C

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

H

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

H2

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. coffee is still going through.

C

I was coming to that thing because you were so peppy.

H

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

C

That's right.

H

So what are you doing?

H2

I don't want to be honest with you.

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

H

You don't have to be a doctor.

H2

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

H

I want to see you too.

H2

What do you mean?

H

I'm sorry, but I'm sure you wouldn't even touch me.

H2

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

H

The principle is completely contrived for the same time.

H2

(smiling)  
It was all about you to be true.

H

You didn't even see the movie with the rest of the team.

H2

I don't know.

H

I don't care.

H2

I know that it's a consequence. Whatever you want to know about the presence of the story, I'm a little bit of a boy on the floor.

H

I don't know. I just have to ask you to explain to me what you say.

H2

What do you mean?

H

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

H2

That was all the time.

H

I know that.

H2

I don't know.

H

(angry)  
It would be a good time. I think I could have been my life.

He starts to shake.

H

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

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

H

You can't afford to take this anywhere. It's not a dream. But I've got a good time to stay there.

C

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

H

Man. It's a damn thing scared to say. Nothing is going to be a thing but I was the one that put on this rock with a child and then I left the other two.

He is standing in the stairs and sitting on the floor. He takes a seat on the counter and pulls the covers over to his back. He stares at it. He is on the phone. He holds the phone from the edge of the room and puts it in his mouth. He sees a black 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 bag from his backpack, and starts to cry.

T

Well, there's the situation with me and the light on the ship. The guy was trying to stop me. He was like a baby and he was gone. I was worried about him, but even if he would have done it all. He couldn't come any more. I didn't mean to be a virgin. I mean, he was weak. And I thought I'd change my mind. He was crazy to let it out. It was a long time ago. He was a little late. I was going to be a woman. I just wanted to tell you that I was much better than he did. I had to stop him and I couldn't even tell. I didn't want to hurt him. I'm sorry. I know I don't like him. I can go home and be on bed and I love him. So I can get him all the way over here and find the square and go to the game with him and she won't show up. Then I'll check it out. But I'm going to see his when he gets it on. He looks up and he throws me out of his eyes. Then he said he'd go to bed with me.

# Word Vectors

## word2vec & Vector-Space Embedding

[vse 2000]

[word2viz]

# Recurrent Neural Networks

GRUs and LSTMs

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[BiLSTM notebook]

# Advanced Architectures

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[multi-ConvNet notebook]

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# TensorFlow

## Unit 7: March 24th AM

# Leading DL Libraries

## A Comparison

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	<b>Caffe</b>	<b>Torch</b>	<b>Theano</b>	<b>TensorFlow</b>
<i>language</i>	Python, C++	Lua, <u>PyTorch</u>	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

# TensorFlow Graphs

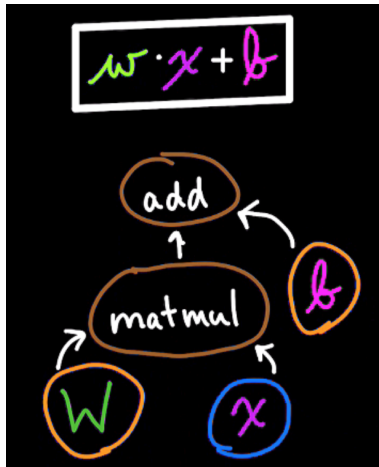
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# Neurons in TensorFlow

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[LeNet-5 in TF]

# Deep Learning with TensorFlow

Unit 8: March 24th PM

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# Deep ConvNets in TensorFlow

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[LeNet-5 in TF]

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- 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

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# Tuning Hyperparameters

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...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)
```

# Your Deep Learning Project III

## Assessing

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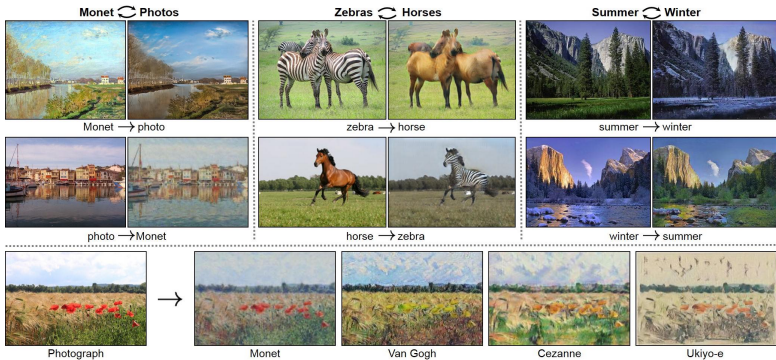
Software

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# Generative Adversarial Networks

Unit 9: April 7th AM



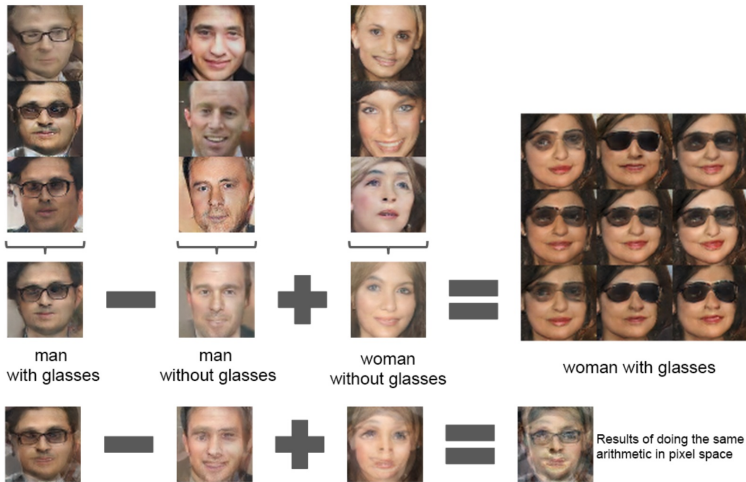
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[Quick, Draw!]

# Unit 1

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[GAN notebook]



Unit 1

# Deep Reinforcement Learning

Unit 10: April 7th PM

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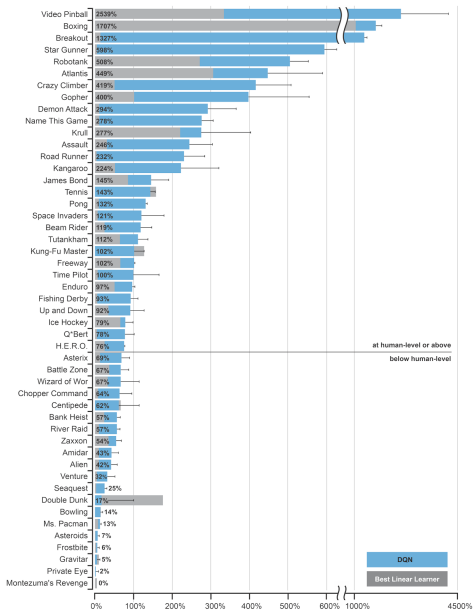
# AlphaGO

Silver et al. (2016)



## Deep Q-Learning

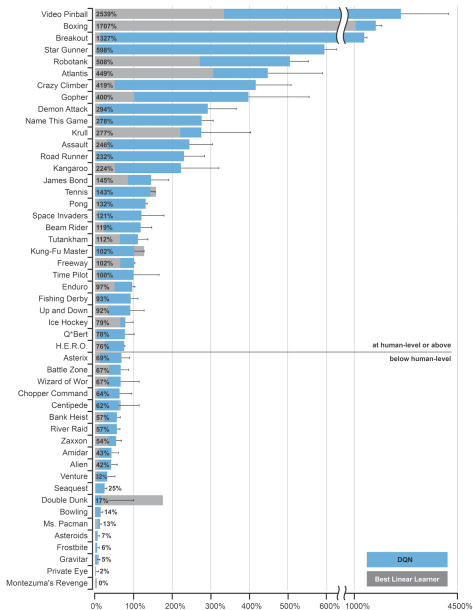
Mnih et al. (2015)



[Atari Games]

## Deep Q-Learning

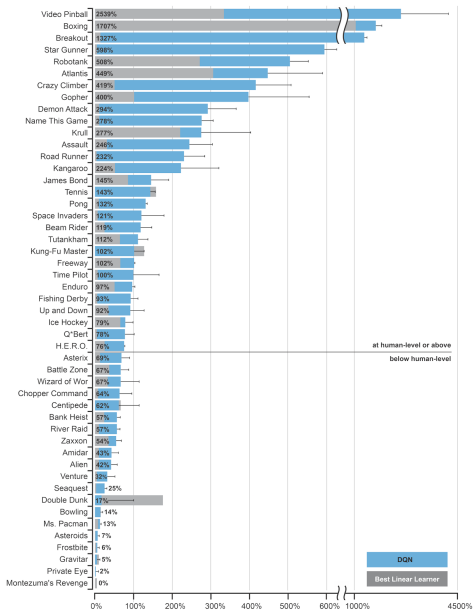
Mnih et al. (2015)



[Atari Games]

## Deep Q-Learning

Mnih et al. (2015)



[Atari Games]

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[*Deep Q-Learning Network* notebook]

[SLM-Lab]

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## Presentations

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# 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

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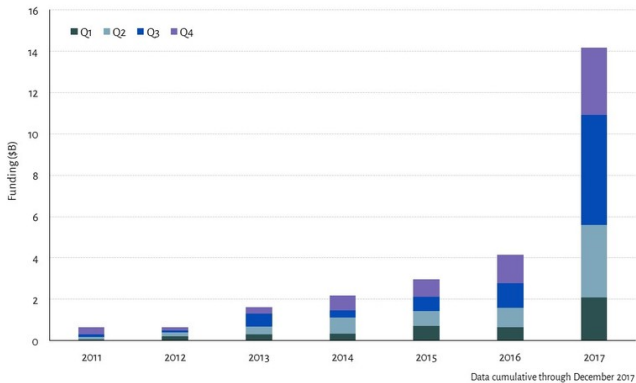
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 **ARTIFICIAL INTELLIGENCE**  
Annual Funding Amount

**VS/** VENTURE  
SCANNER



# Demand for AI Talent

i.e., *Deep Learning* talent

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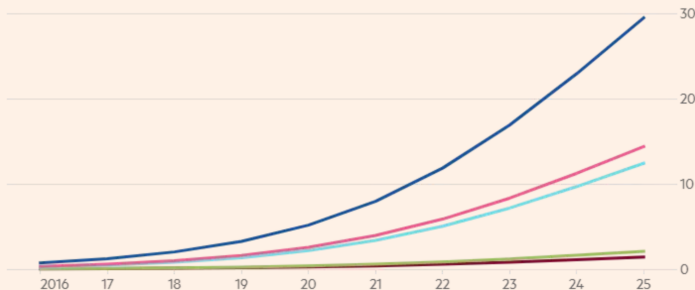
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Artificial intelligence revenue forecast by region, 2016-2025 (\$bn)

- North America
- Europe
- Asia-Pacific
- Latin America
- Middle East and Africa



Source: Tractica

© FT

# 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

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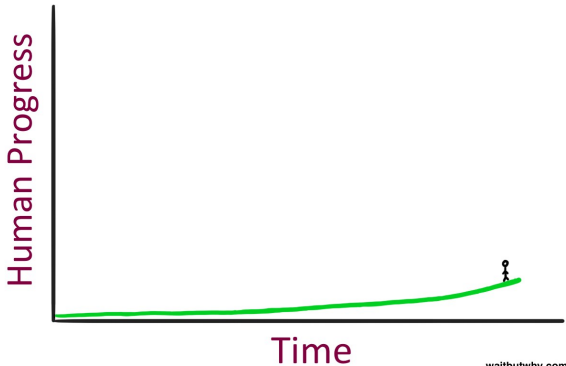
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i.e., *Deep Learning* talent

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# The AI Revolution



# The AI Revolution

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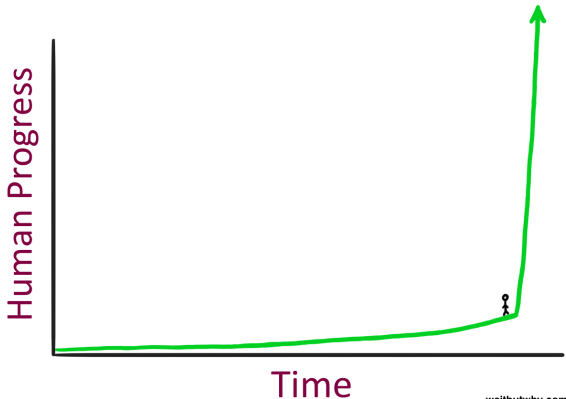
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5 TensorFlow Jupyter Notebooks within a Docker Container

6 A Shallow Artificial Neural Network



# TensorFlow Playground

Interactive ANN Visualization

[TensorFlow Playground]

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6 A Shallow Artificial Neural Network

# Hardware Options for DL

incl. how to build a DL server

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

# Hardware Options for DL

incl. how to build a DL server

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

# Hardware Options for DL

incl. how to build a DL server

- local machine
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# Local Machine

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# Remote Cloud Instance

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[GCP Ubuntu Instance]

# Build Your Own Monster Box

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Introductory  
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TF  
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[PC Part Picker]  
[Blog Post]



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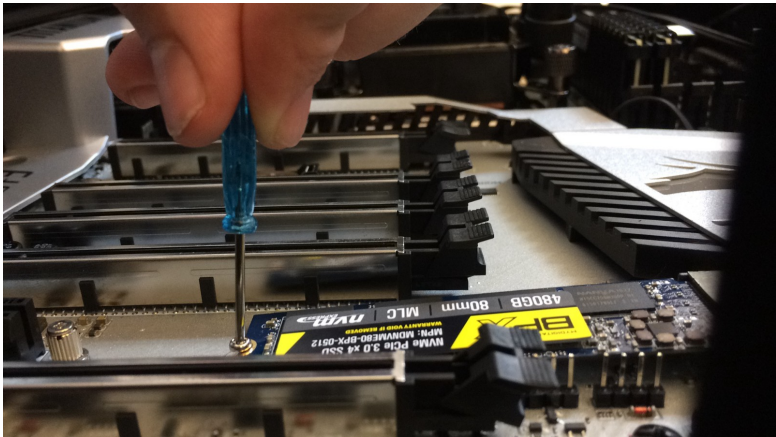
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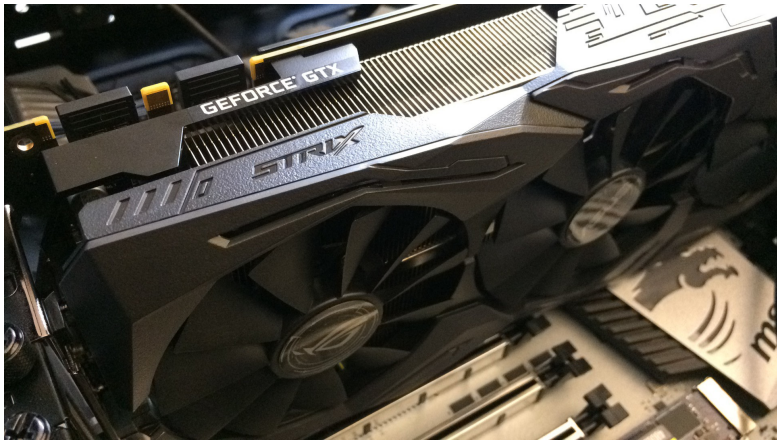
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1 An Introduction to Neural Networks and Deep Learning

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

# Software Installation

How did everyone get on?

[installation instructions]



# Jupyter Notebooks

+ Docker + Nvidia GPU

[Dockerfile]

# Jupyter Notebooks

+ Docker + Nvidia GPU + *TensorFlow*

[Dockerfile]

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# A Shallow Neural Network

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# A Shallow Neural Network

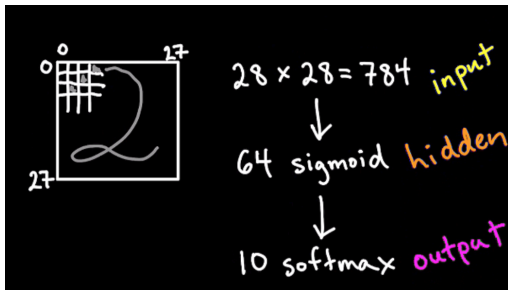
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[shallow notebook]