The Fundamentals of Deep Learning

with Applications

Jon Krohn

`jon@untapt.com`

Chief Data Scientist at untapt

New York Open Statistical Programming Meetup
January 17th, 2017
(slides available at `jonkrohn.com/talks`)

Outline

Outline

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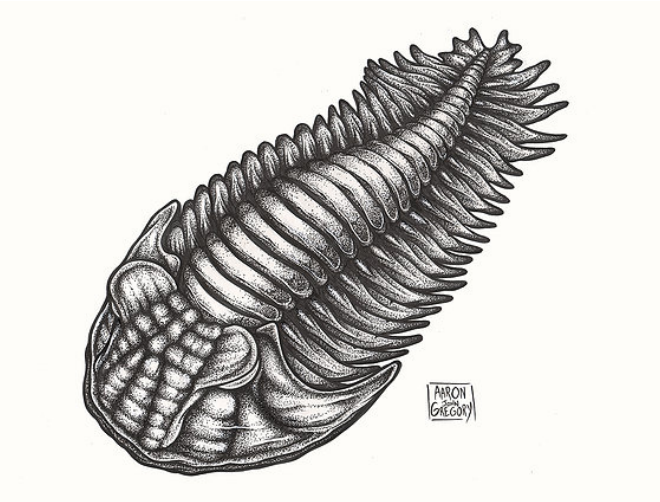
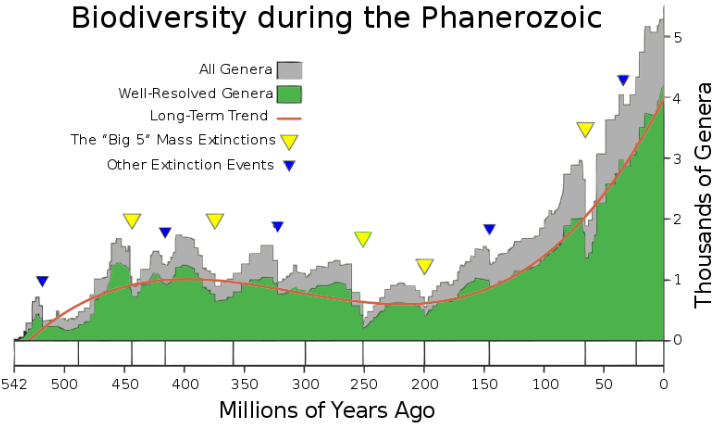
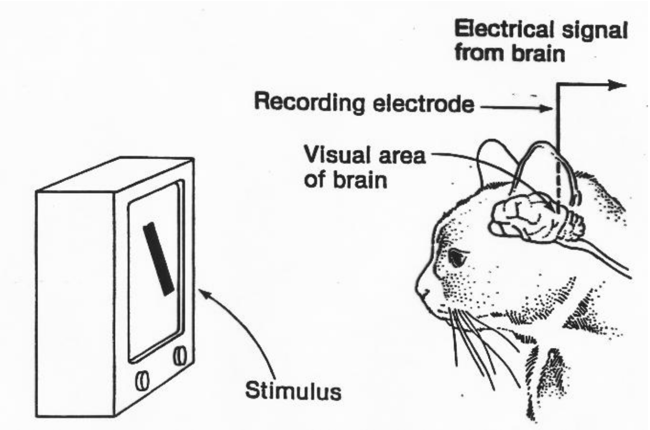
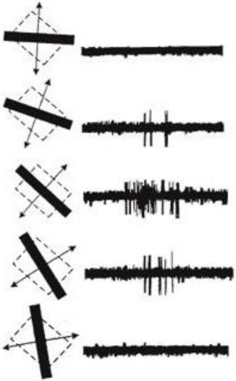
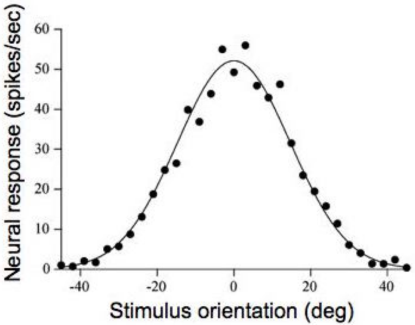

AARON JOHN GREGORY


Biodiversity during the Phanerozoic
All Genera
Well-Resolved Genera
Long-Term Trend
The "Big 5" Mass Extinctions
Other Extinction Events
Thousands of Genera
0
1
2
3
4
5
542
500
450
400
350
300
250
200
150
100
50
0
Millions of Years Ago

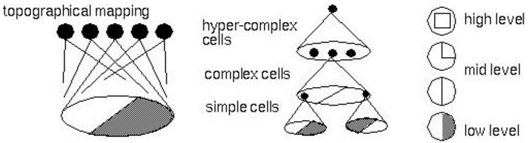
Hubel & Wiesel (1959)

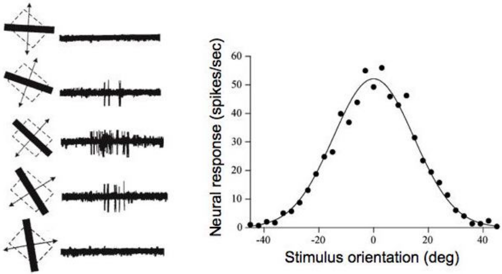




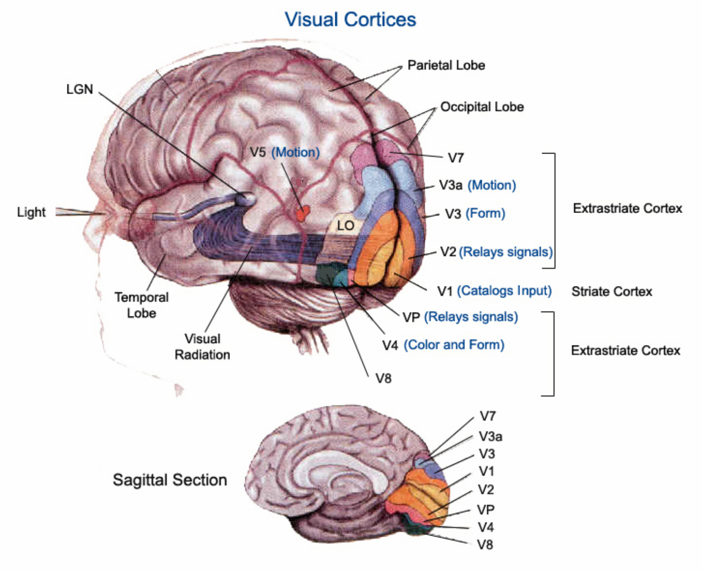


Hubel & Wiesel, 1968



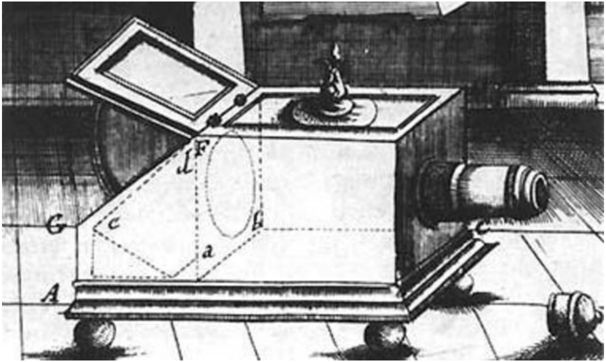


Hubel & Wiesel, 1968


Visual Cortices
Parietal Lobe
Occipital Lobe
LGN
V7
V5 (Motion)
V3a (Motion)
Light
LO
V3 (Form)
Extrastriate Cortex
V2 (Relays signals)
V1 (Catalogs Input)
Striate Cortex
Temporal Lobe
VP (Relays signals)
Visual Radiation
V4 (Color and Form)
Extrastriate Cortex
V8
Sagittal Section
V7
V3a
V3
V1
V2
VP
V4
V8

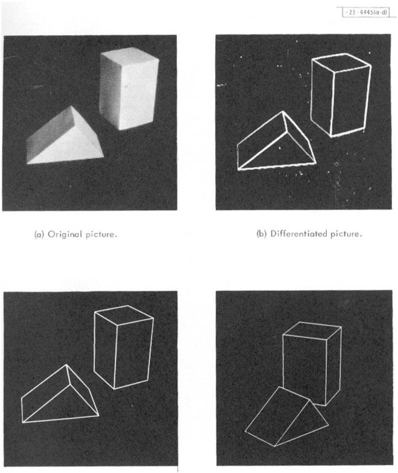
Camera Obscura

da Vinci (15th Century)



Block World

Larry Roberts (1965)



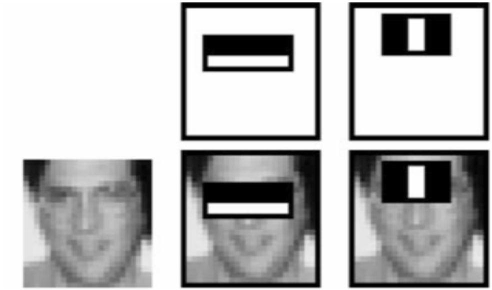
(a) Original picture.

(b) Differentiated picture.

(c) Line drawing.

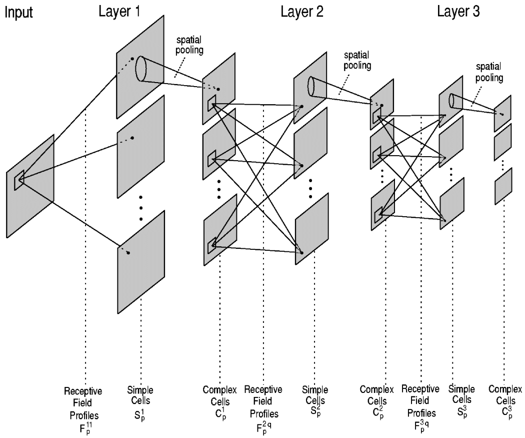
(d) Rotated view.

Viola & Jones (2001)



Neurocognitron

Fukushima (1980)



MNIST Digits & LeNet-5

LeCun, Boutou, Bengio & Haffner (1998)

PROC. OF THE IEEE, NOVEMBER 1998 7

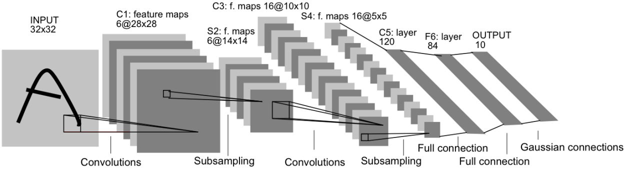
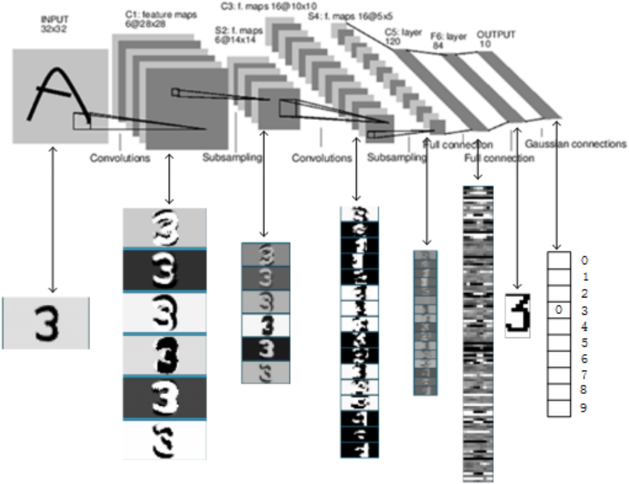


Fig. 2. Architecture of LeNet-5, a Convolutional Neural Network, here for digits recognition. Each plane is a feature map, i.e. a set of units whose weights are constrained to be identical.

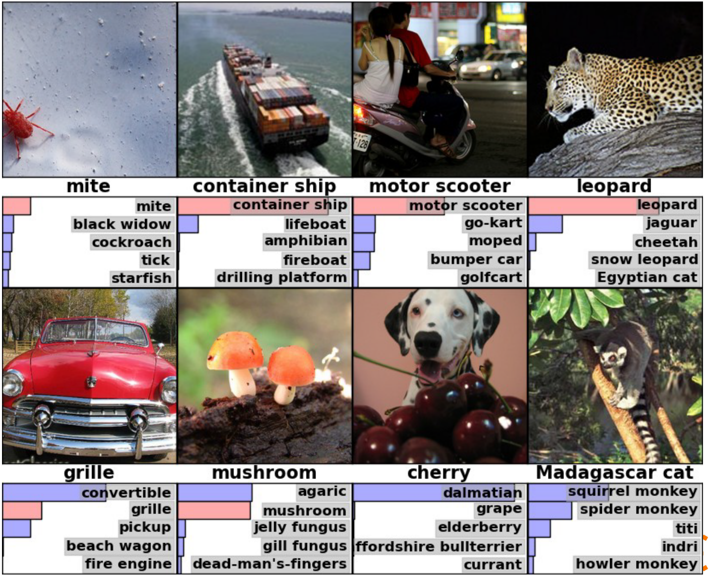
LeNet-5

LeCun, Boutou, Bengio & Haffner (1998)



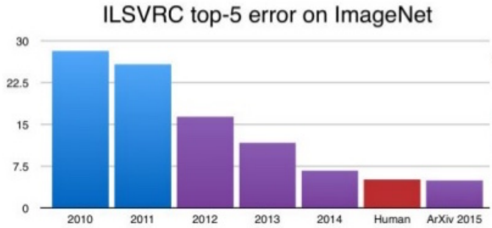
ImageNet

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

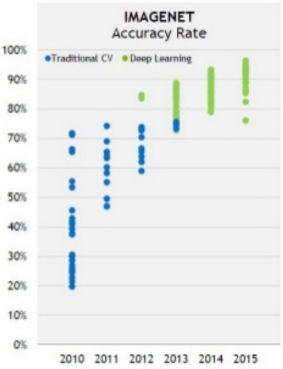


ImageNet Classification Error

ILSVRC: 1.4m, 1k object classes

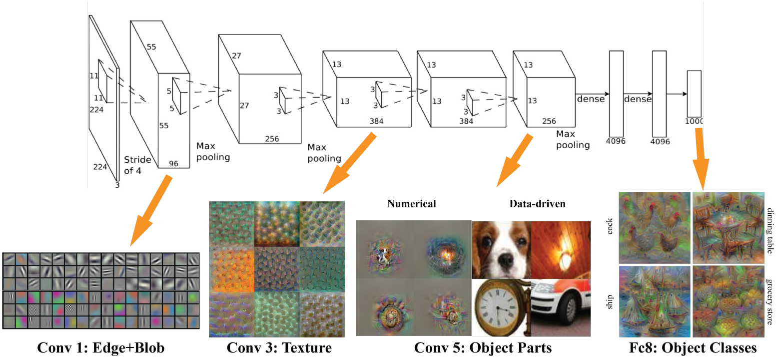


- Blue: Traditional CV
- Purple: Deep Learning
- Red: Human

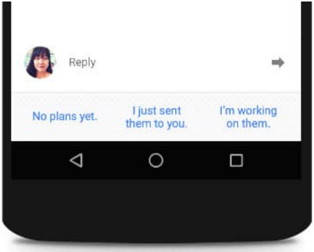


AlexNet

Krizhevsky, Sutskever & Hinton (2012)




mark zuckerberg
Mark Zuckerberg
11,814 like this. · Business P...


Reply
No plans yet.
I just sent them to you.
I'm working on them.


"Remind me about this when I get home"
tap to edit
OK, I'll remind you when you arrive at home:
Reminder
11 Hot Beach Escapes - Jetsetter
Arriving: Home
Remove

Sunspring

Sharp & Goodwin (2016)

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 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 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 Hauk, 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. 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?

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 constructed 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 base.

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 (CONT'D)
It may never be forgiven, 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 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
Mmm. It's a damn thing scared to say. Nothing is going to be a thing but I was the one that got 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 a seat on the counter and pulls the camera over to his back. He stares at it. He is on the phone. He cuts the shotgun from the edge of the room and puts it in his mouth. He sees a black hole in the floor leading to the man 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 take it out. It was a long time ago. He was a little late. I was going to be a moment. 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 so bad 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 him when he gets to me. He looks at me and he throws me out of his eyes. Then he said he'd go to bed with me.

Sunspring

Sharp & Goodwin (2016)

[video]

Outline

Hardware

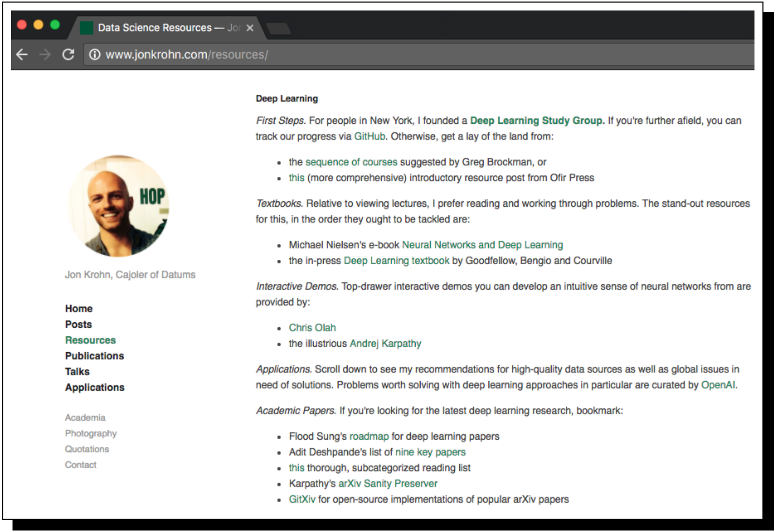
- local machine
- build your own server
- AWS / Google Cloud Platform
- GPU(s) / TPU(s)

Popular Libraries

based on Johnson (2016) in Stanford *CS231n* l.12

	Caffe	**Torch**	**Theano**	**TensorFlow**
Language	C++, Python	Lua	Python	Python
Pretrained	Yes++	Yes++	Yes (Lasagne)	Inception
Parallel GPUs: Data	Yes	Yes	Yes	Yes
Parallel GPUs: Model	No	Yes	Experimental	Yes (best)
Readable Source Code	Yes (C++)	Yes	No	No
Good at RNN	No	Mediocre	Yes	Yes (best)
Higher-Level APIs	No	No	Keras	Keras and TFLearn

[Human Learning Resources]



Data Science Resources — Jor ×

www.jonkrohn.com/resources/

Jon Krohn, Cajoler of Datums

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Contact

Deep Learning

First Steps. For people in New York, I founded a **Deep Learning Study Group.** If you're further afield, you can track our progress via GitHub. Otherwise, get a lay of the land from:

- the sequence of courses suggested by Greg Brockman, or
- this (more comprehensive) introductory resource post from Ofir Press

Textbooks. Relative to viewing lectures, I prefer reading and working through problems. The stand-out resources for this, in the order they ought to be tackled are:

- Michael Nielsen's e-book Neural Networks and Deep Learning
- the in-press Deep Learning textbook by Goodfellow, Bengio and Courville

Interactive Demos. Top-drawer interactive demos you can develop an intuitive sense of neural networks from are provided by:

- Chris Olah
- the illustrious Andrej Karpathy

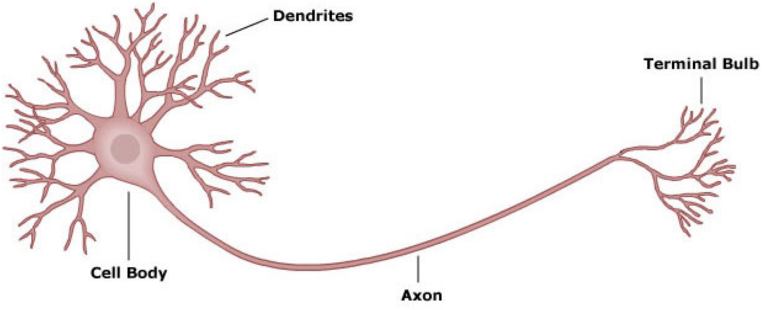
Applications. Scroll down to see my recommendations for high-quality data sources as well as global issues in need of solutions. Problems worth solving with deep learning approaches in particular are curated by OpenAI.

Academic Papers. If you're looking for the latest deep learning research, bookmark:

- Flood Sung's roadmap for deep learning papers
- Adit Deshpande's list of nine key papers
- this thorough, subcategorized reading list
- Karpathy's arXiv Sanity Preserver
- GitXiv for open-source implementations of popular arXiv papers

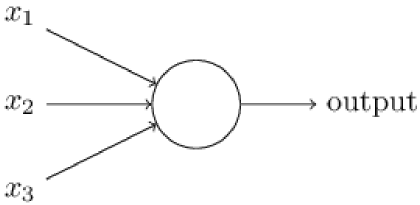
Outline

Biological Neuron Morphology



Perceptron

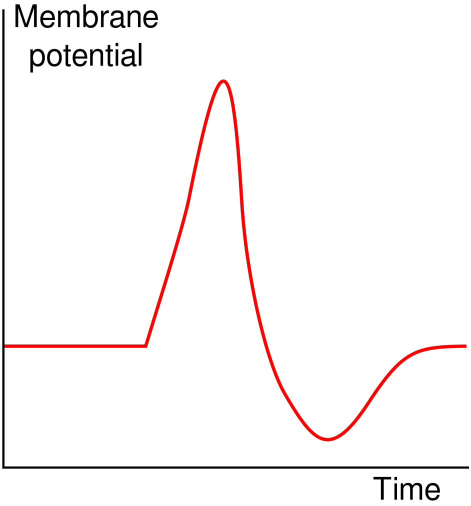
Rosenblatt (1957)



$$\text{output} = \begin{cases} 0 & \text{if } \sum_j w_j x_j \leq \text{ threshold} \\ 1 & \text{if } \sum_j w_j x_j > \text{ threshold} \end{cases}$$

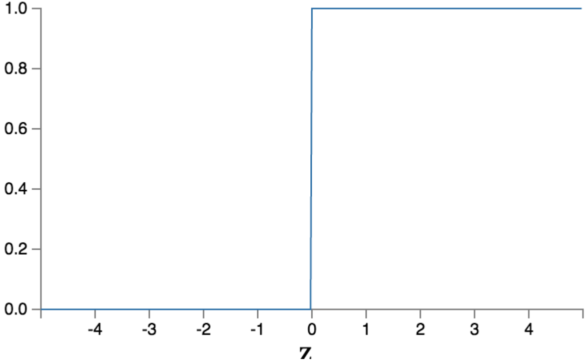
Biological Neuron Physiology

The *Binary* Action Potential

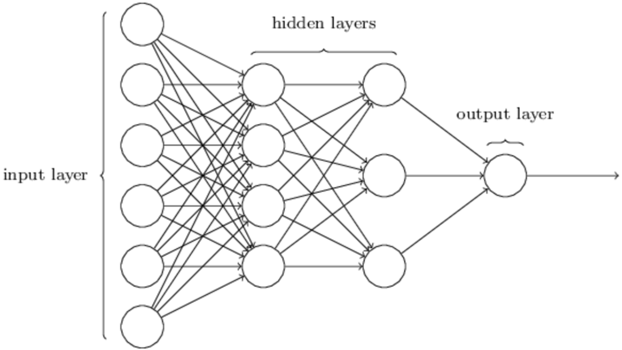


Perceptron

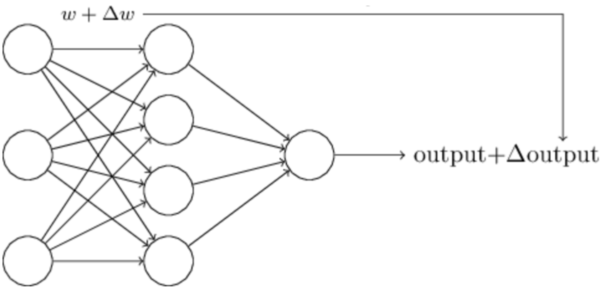
Rosenblatt (1957)



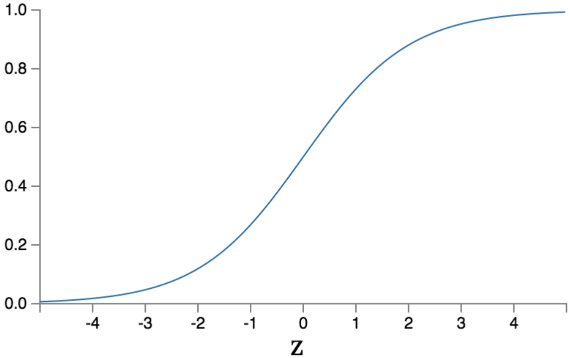
Multi-Layer Perceptron



Multi-Layer Perceptron

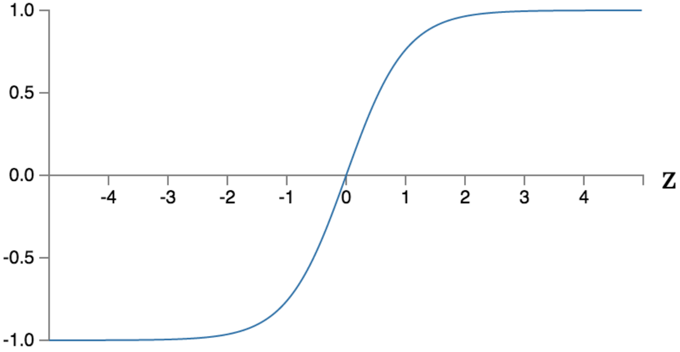


Sigmoid Neuron



$$\frac{1}{1 + \exp(-\sum_j w_j x_j - b)}$$

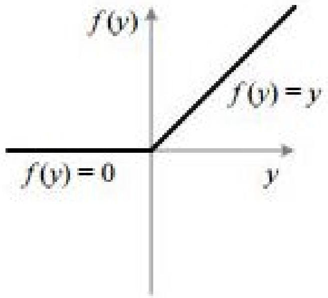
tanh Neuron

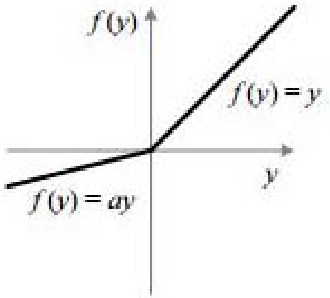


$$\sigma(z) = \frac{1 + \tanh(z/2)}{2}$$

ReLU: Rectified Linear Units

Nair & Hinton (2010); Maas, Hannun & Ng (2014)

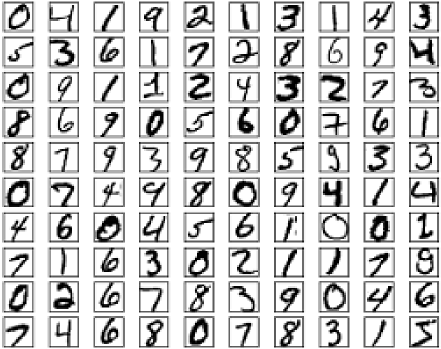




Outline

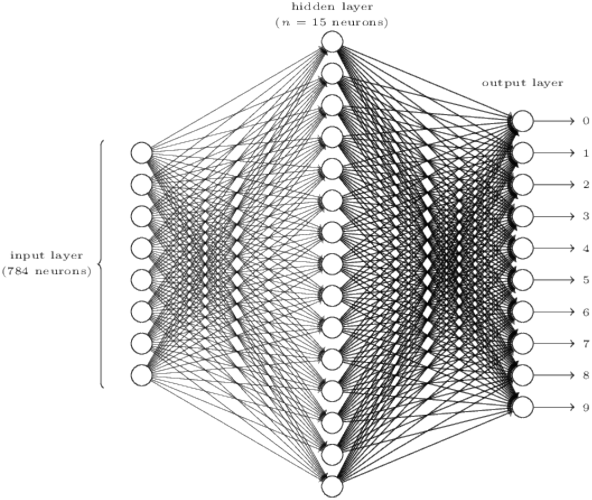
MNIST

LeCun, Cortes & Burges



Fully-Connected Neural Net

Single Hidden Layer



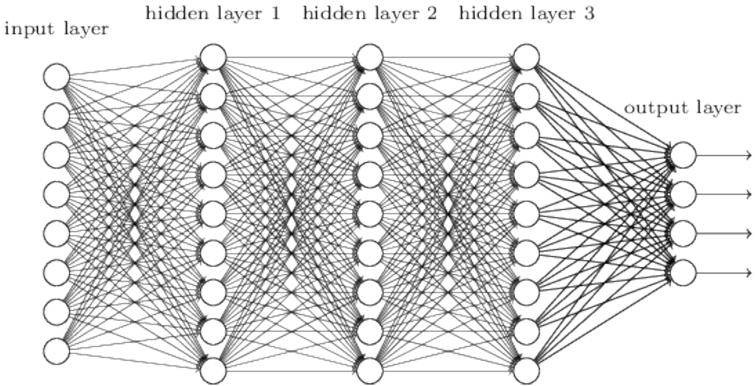
TensorFlow Playground

[demo]

Outline

Deep Fully-Connected Net

3 (or more) Hidden Layers



TFLearn

	Caffe	**Torch**	**Theano**	**TensorFlow**
Language	C++, Python	Lua	Python	Python
Pretrained	Yes++	Yes++	Yes (Lasagne)	Inception
Parallel GPUs: Data	Yes	Yes	Yes	Yes
Parallel GPUs: Model	No	Yes	Experimental	Yes (best)
Readable Source Code	Yes (C++)	Yes	No	No
Good at RNN	No	Mediocre	Yes	Yes (best)
Higher-Level APIs	No	No	Keras	Keras and TFLearn

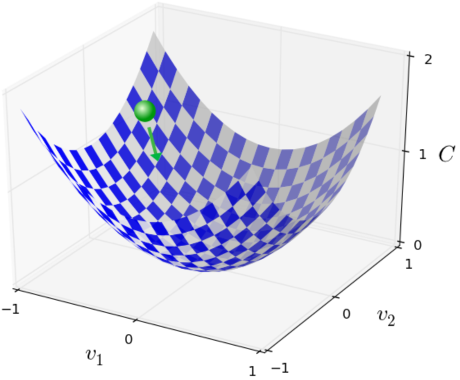
A Simple Deep Net in TFLearn

[notebook]

Synaptic Pruning

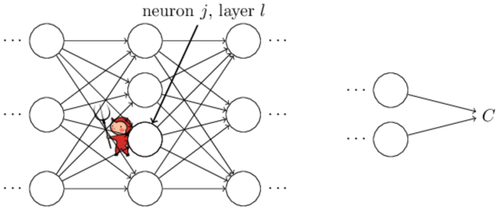
(Stochastic) Gradient Descent

Adam = AdaGrad + RMSprop



Backpropagation

computes error & gradient of cost function



$$\delta^L = \nabla_a C \odot \sigma'(z^L) \tag{BP1}$$

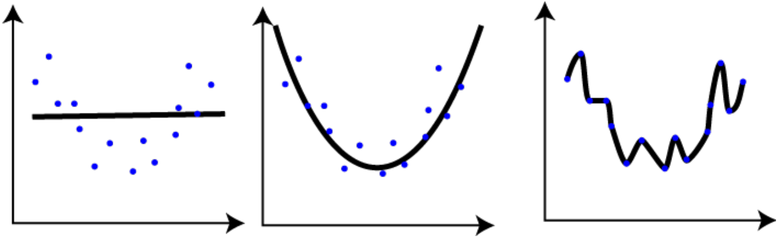
$$\delta^l = ((w^{l+1})^T \delta^{l+1}) \odot \sigma'(z^l) \tag{BP2}$$

$$\frac{\partial C}{\partial b^l_j} = \delta^l_j \tag{BP3}$$

$$\frac{\partial C}{\partial w^l_{jk}} = a^{l-1}_k \delta^l_j \tag{BP4}$$

Overfitting

...and avoiding it



- L1/L2 regularization
- dropout
- artificial data set expansion

Improving Neural Networks

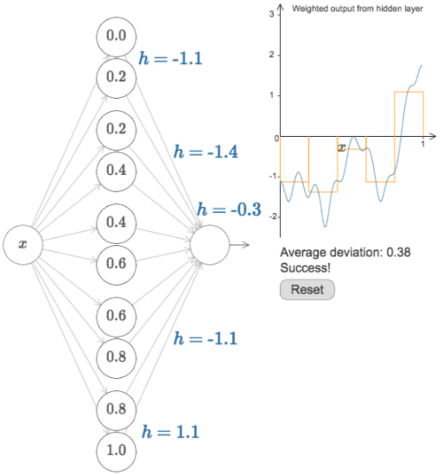
Mostly Hyperparameter Tuning

- problem simplification
- number and width of layers
- cost fxn: quadratic, cross-entropy, log-likelihood, &c.
- more epochs, early stopping
- clever initialization of weights and biases
- learning rate η, variable schedule
- regularization parameter λ
- mini-batch size
- automation, e.g., with Spearmint

[Summary Blog Post]

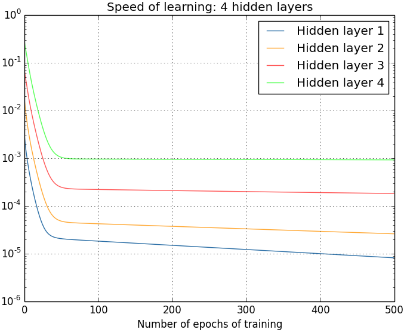
Universality

Solve Any Continuous Function (Nielsen, 2015)

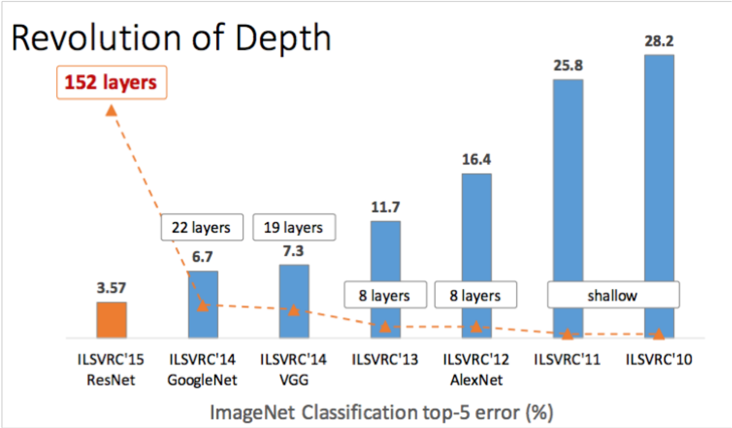


Unstable Gradient

Typically *Vanishes* (but can *Explode*)

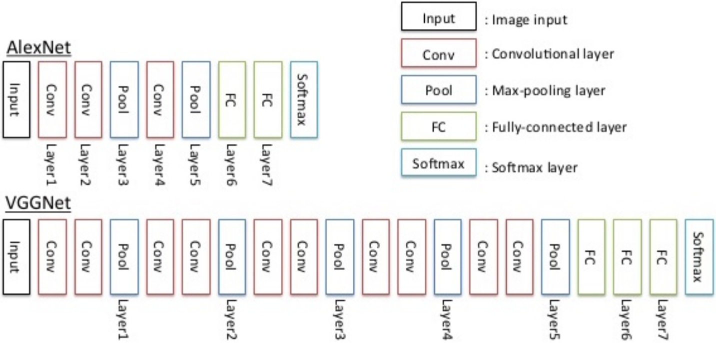


$$\frac{\partial C}{\partial b_1} = \sigma'(z_1) \times w_2 \times \sigma'(z_2) \times w_3 \times \sigma'(z_3) \times w_4 \times \sigma'(z_4) \times \frac{\partial C}{\partial a_4}$$


Revolution of Depth
152 layers
22 layers
19 layers
8 layers
8 layers
shallow
3.57
6.7
7.3
11.7
16.4
25.8
28.2
ILSVRC'15 ResNet
ILSVRC'14 GoogleNet
ILSVRC'14 VGG
ILSVRC'13
ILSVRC'12 AlexNet
ILSVRC'11
ILSVRC'10
ImageNet Classification top-5 error (%)

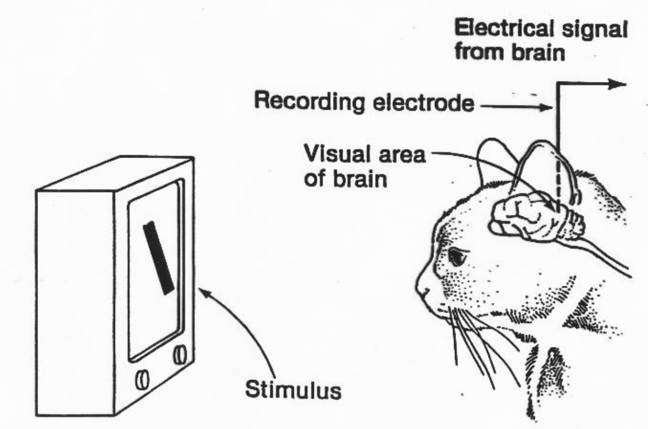
Classic Deep Architectures

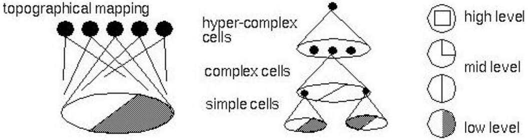
...introducing *Convolutional Layers*

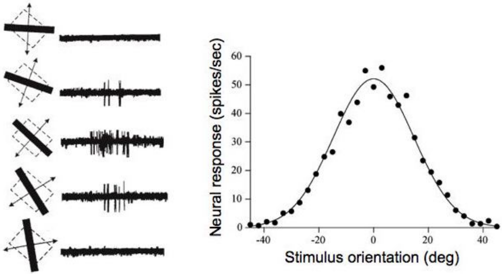


Outline

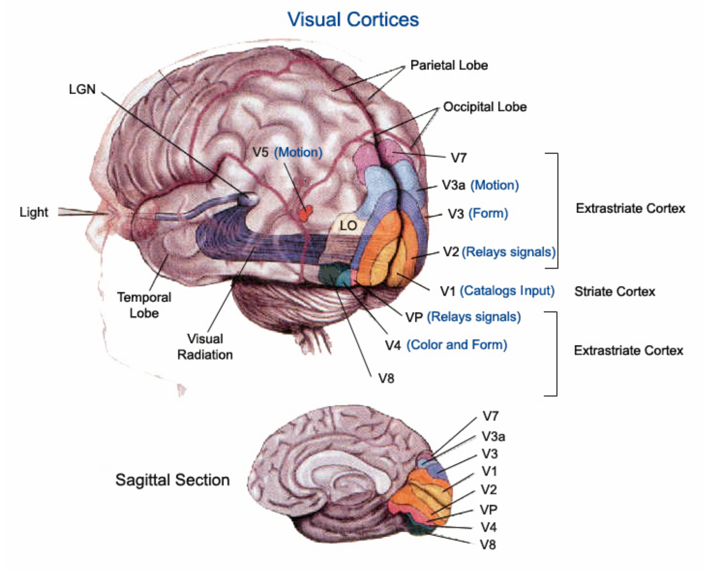
Hubel & Wiesel (1959)





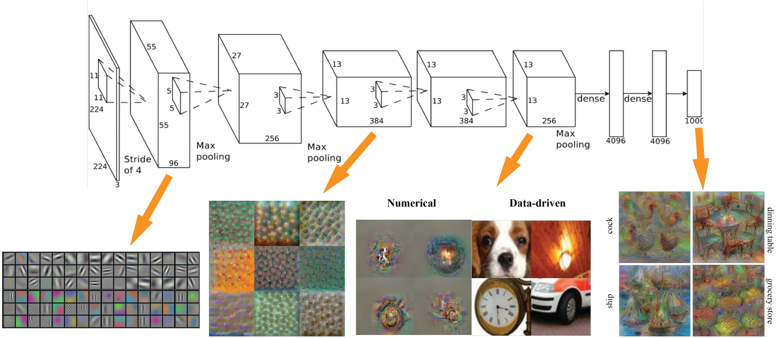


Hubel & Wiesel, 1968

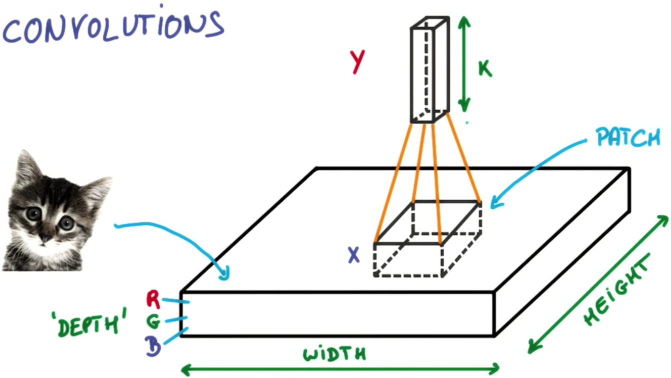

Visual Cortices
Parietal Lobe
LGN
Occipital Lobe
V7
V5 (Motion)
V3a (Motion)
Light
V3 (Form)
Extrastriate Cortex
LO
V2 (Relays signals)
V1 (Catalogs Input)
Striate Cortex
Temporal Lobe
VP (Relays signals)
Visual Radiation
V4 (Color and Form)
Extrastriate Cortex
V8
Sagittal Section
V7
V3a
V3
V1
V2
VP
V4
V8

AlexNet

Krizhevsky, Sutskever & Hinton (2012)



Conv 1: Edge+Blob Conv 3: Texture Conv 5: Object Parts Fc8: Object Classes

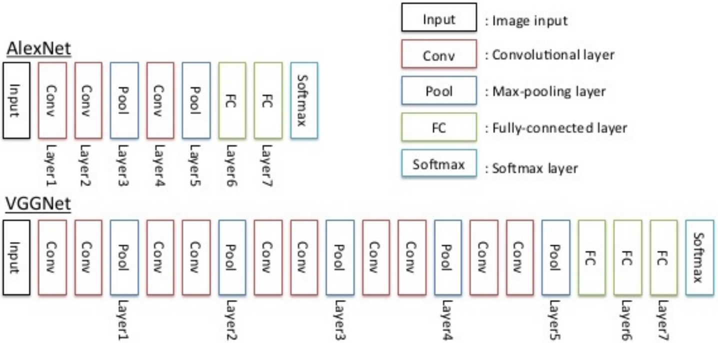

CONVOLUTIONS
Y
K
PATCH
X
'DEPTH'
R
G
B
WIDTH
HEIGHT

ConvNet Visualisation

Yosinski et al. (2015)

[video]

Network Architectures



AlexNet: ILSVRC '12 winner

Krizhevsky et al. (2012)

[TFLearn notebook]

VGGNet: ILSVRC '14 runner-up

Simonyan & Zisserman (2015)

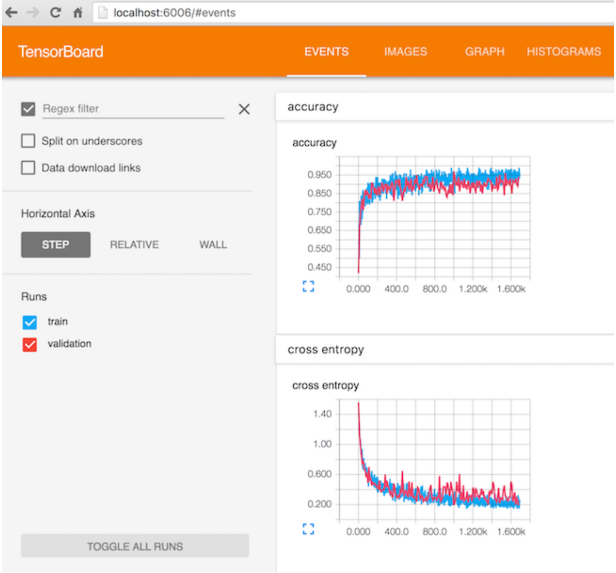
[TFLearn notebook]

ConvNet in TensorFlow

	Caffe	**Torch**	**Theano**	**TensorFlow**
Language	C++, Python	Lua	Python	Python
Pretrained	Yes++	Yes++	Yes (Lasagne)	Inception
Parallel GPUs: Data	Yes	Yes	Yes	Yes
Parallel GPUs: Model	No	Yes	Experimental	Yes (best)
Readable Source Code	Yes (C++)	Yes	No	No
Good at RNN	No	Mediocre	Yes	Yes (best)
Higher-Level APIs	No	No	Keras	Keras and TFLearn

ConvNet in TensorFlow

[notebook]


localhost:6006/#events
TensorBoard
EVENTS
IMAGES
GRAPH
HISTOGRAMS
Regex filter
Split on underscores
Data download links
Horizontal Axis
STEP
RELATIVE
WALL
Runs
train
validation
TOGGLE ALL RUNS
accuracy
accuracy
0.950
0.850
0.750
0.650
0.550
0.450
0.000
400.0
800.0
1.200k
1.600k
cross entropy
cross entropy
1.40
1.00
0.600
0.200
0.000
400.0
800.0
1.200k
1.600k

ConvNet in Theano

	Caffe	**Torch**	**Theano**	**TensorFlow**
Language	C++, Python	Lua	Python	Python
Pretrained	Yes++	Yes++	Yes (Lasagne)	Inception
Parallel GPUs: Data	Yes	Yes	Yes	Yes
Parallel GPUs: Model	No	Yes	Experimental	Yes (best)
Readable Source Code	Yes (C++)	Yes	No	No
Good at RNN	No	Mediocre	Yes	Yes (best)
Higher-Level APIs	No	No	Keras	Keras and TFLearn

ConvNet in Theano

[demo]

ConvNet in Keras

calls TensorFlow or Theano

	Caffe	**Torch**	**Theano**	**TensorFlow**
Language	C++, Python	Lua	Python	Python
Pretrained	Yes++	Yes++	Yes (Lasagne)	Inception
Parallel GPUs: Data	Yes	Yes	Yes	Yes
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Good at RNN	No	Mediocre	Yes	Yes (best)
Higher-Level APIs	No	No	Keras	Keras and TFLearn

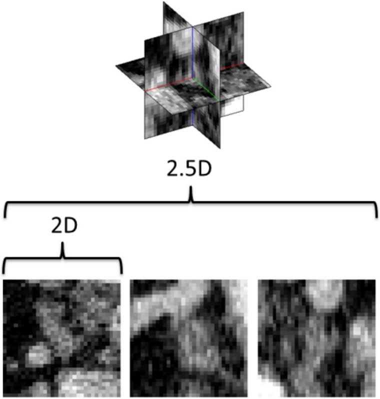
ConvNet in Keras

calls TensorFlow or Theano

[notebook]

"2.5-dimension" CT Scans

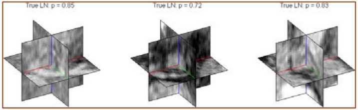
Roth et al. (2015)

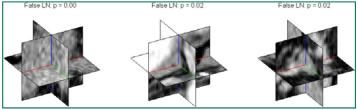


Computer-Aided Detection

Shin et al. (2016); Roth et al. (2016)

Experimental Results (~100% sensitivity but ~40 FPs/patient at candidate generation step; then 3-fold CV with data augmentation)

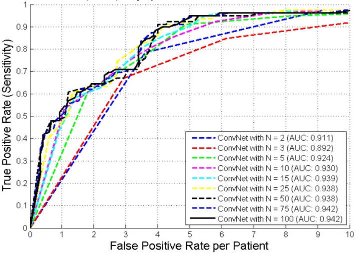




- Mediastinum

71% @ 3 FPs (was 55%)

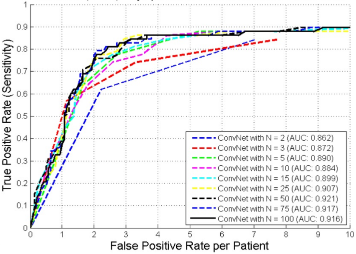
Distance (<=15) - Lymph Node FROC Curve for 15 Patients

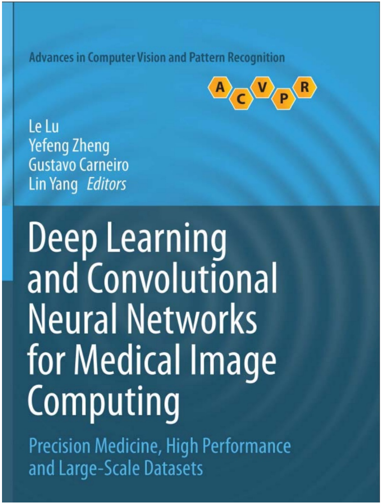


- Abdomen

83% @ 3 FPs (was 30%)

Distance (<=15) - Lymph Node FROC Curve for 14 Patients




Advances in Computer Vision and Pattern Recognition
ACVPR
Le Lu
Yefeng Zheng
Gustavo Carneiro
Lin Yang Editors
Deep Learning and Convolutional Neural Networks for Medical Image Computing
Precision Medicine, High Performance and Large-Scale Datasets

Kaggle

Data Science Bowl 2017

[link]

Transfer Learning

Caffe

	Caffe	**Torch**	**Theano**	**TensorFlow**
Language	C++, Python	Lua	Python	Python
Pretrained	Yes++	Yes++	Yes (Lasagne)	Inception
Parallel GPUs: Data	Yes	Yes	Yes	Yes
Parallel GPUs: Model	No	Yes	Experimental	Yes (best)
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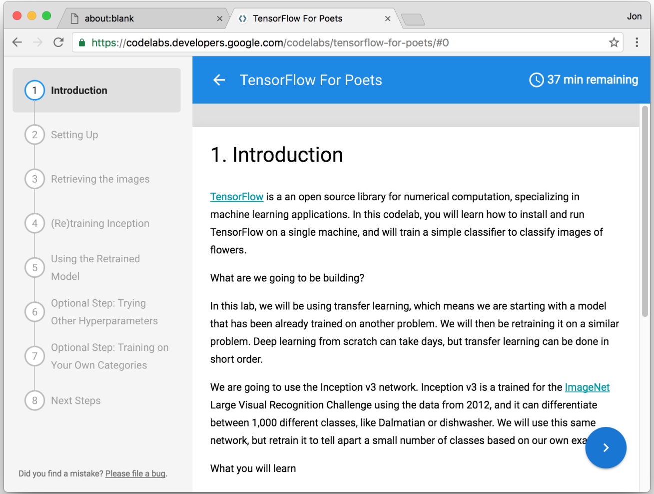
Transfer Learning

Caffe

[Model Zoo]

Transfer Learning



Video Classification

[video]

Outline

Sunspring

Sunspring

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 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 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 Hauk, 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. 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?

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 constructed 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 base.

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 (CONT'D)
It may never be forgiven, 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 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.

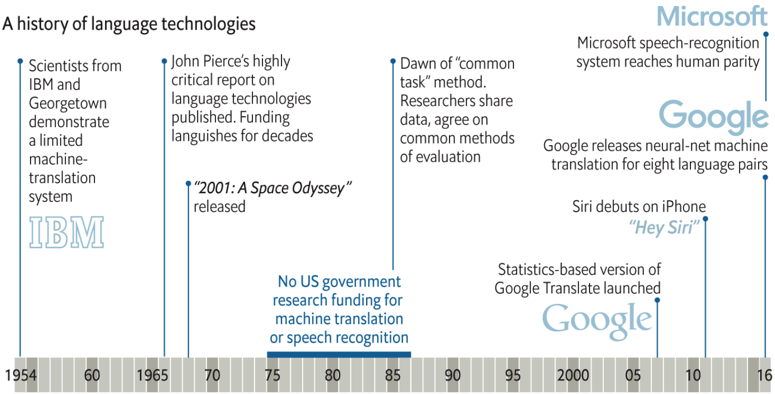
H
Mmm. It's a damn thing scared to say. Nothing is going to be a thing but I was the one that got on this rock with a child and then I left the other two.

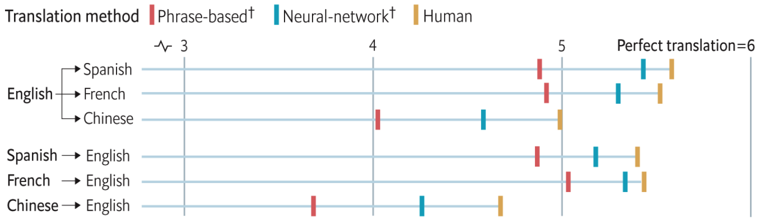
He is standing in the stars and sitting on the floor. He takes a seat on the counter and pulls the camera over to his back. He stares at it. He is on the phone. He cuts the shotgun from the edge of the room and puts it in his mouth. He sees a black hole in the floor leading to the man on the roof.

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.

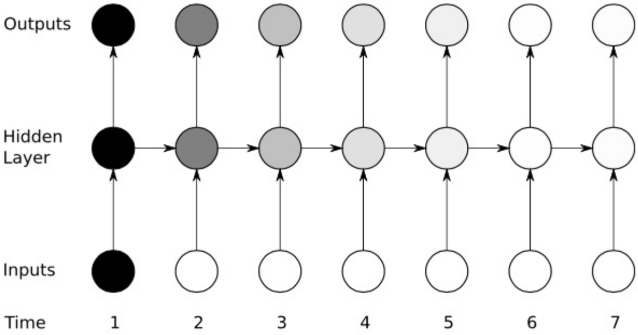
T
Well, there's the situation with me and the light on the ship. The guy was trying to stop me. He was like a baby and he was gone. I was worried about him. But even if he would have done it all. He couldn't come any more. I didn't mean to be a virgin. I mean, he was weak. And I thought I'd change my mind. He was crazy to take it out. It was a long time ago. He was a little late. I was going to be a moment. 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 so bad 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 him when he gets to me. He looks at me and he throws me out of his eyes. Then he said he'd go to bed with me.


A history of language technologies
Scientists from IBM and Georgetown demonstrate a limited machine-translation system
IBM
John Pierce's highly critical report on language technologies published. Funding languishes for decades
"2001: A Space Odyssey" released
No US government research funding for machine translation or speech recognition
Dawn of "common task" method. Researchers share data, agree on common methods of evaluation
Statistics-based version of Google Translate launched
Google
Siri debuts on iPhone
"Hey Siri"
Microsoft
Microsoft speech-recognition system reaches human parity
Google
Google releases neural-net machine translation for eight language pairs
1954
60
1965
70
75
80
85
90
95
2000
05
10
16


Translation method
Phrase-based†
Neural-network†
Human
3
4
5
Perfect translation=6
English
Spanish
French
Chinese
Spanish → English
French → English
Chinese → English

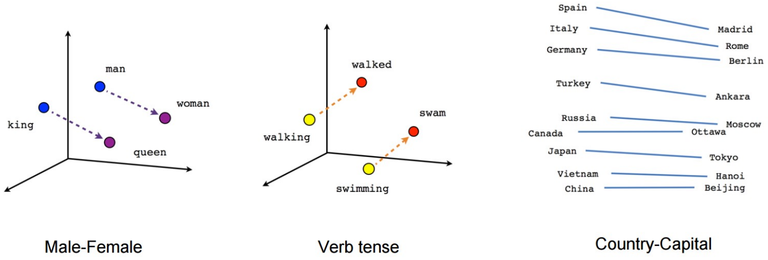
RNNs; *LSTM* RNNs

Hochreiter & Schmidhuber (1997)
Graves, ... & Schmidhuber (2009)



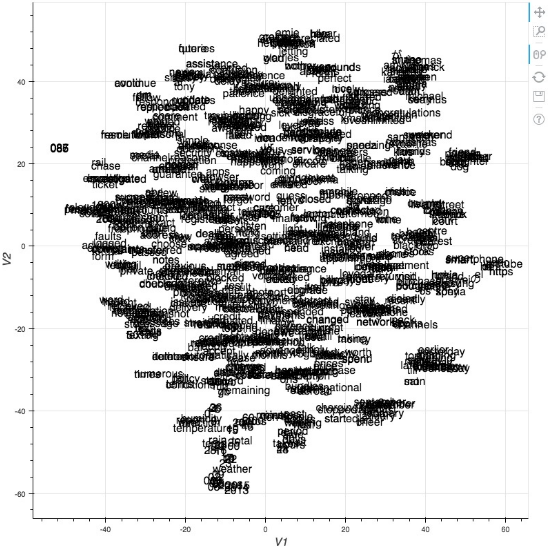
Vector Space Embedding

Word2Vec: Mikolov, ... & Dean (2013)

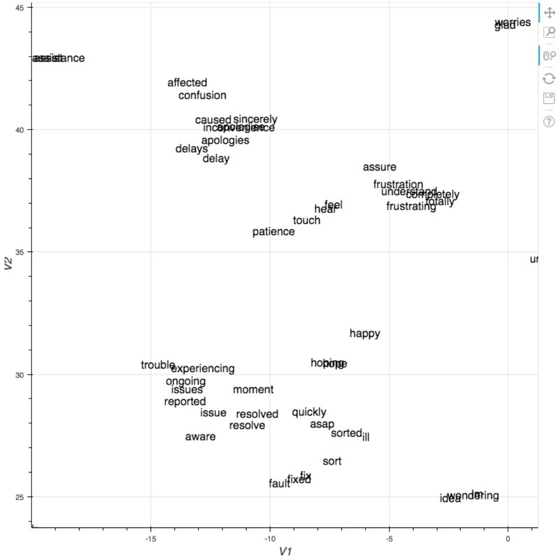


t-SNE

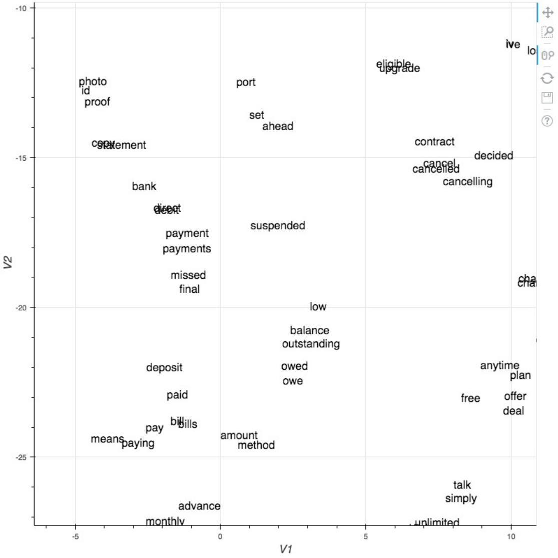
Hinton & van der Maaten (2008)



Word2Vec + t-SNE



Word2Vec + t-SNE



‘Understand’ Language

with Word2Vec features in your model

```
model.most_similar(positive=['angular'])

[('angularjs', 0.9534549117088318),
 ('backbonejs', 0.9315043687820435),
 ('ember', 0.905410647392273),
 ('emberjs', 0.9029799103736877),
 ('reactjs', 0.896049439907074),
 ('requirejs', 0.8759748339653015),
 ('coffeescript', 0.8645504713058472),
 ('bootstrap', 0.8554328083992004),
 ('nodejs', 0.8515532612800598),
 ('backbone', 0.8443130254745483)]
```

```
model.most_similar(positive=['managed'])

[('oversaw', 0.8659406900405884),
 ('directed', 0.8491166234016418),
 ('supervised', 0.8058902621269226),
 ('coordinated', 0.7858685851097107),
 ('led', 0.7539615035057068),
 ('orchestrated', 0.7211644649505615),
 ('supported', 0.7198437452316284),
 ('comanaged', 0.6774874925613403),
 ('encompassing', 0.6726169586181641),
 ('administered', 0.6706464886665344)]
```

[even with small corpora]

Quick, Draw!

ConvNet + LSTM

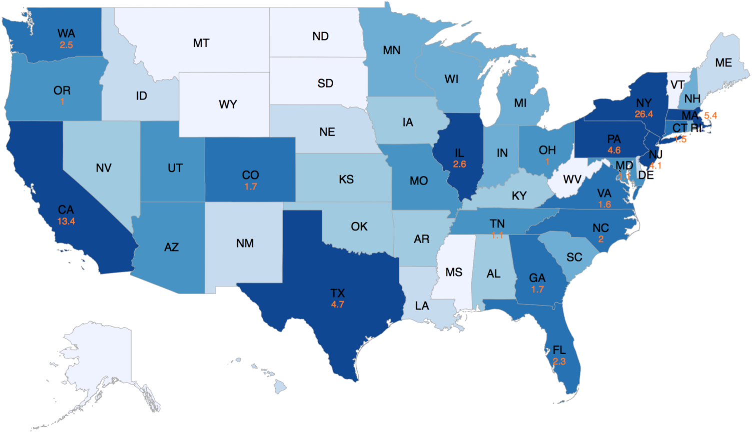
[link]

Outline

untapt

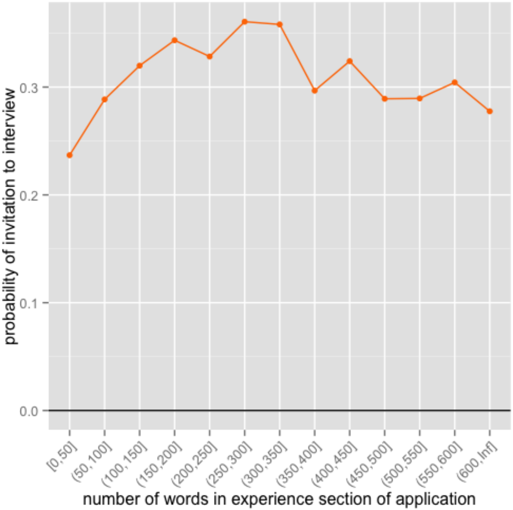
Digital Recruitment Platform

untapt


WA
2.5
MT
ND
MN
ME
OR
1
ID
SD
WI
VT
NH
WY
MI
NY
26.4
MA
5.4
IA
CT
RI
1.5
NE
PA
4.6
NV
UT
IL
2.6
IN
OH
1
NJ
4.1
CO
1.7
KS
MO
MD
1.1
DE
WV
KY
VA
1.6
CA
13.4
OK
TN
1.1
NC
2
AR
AZ
NM
SC
MS
AL
GA
1.7
TX
4.7
LA
FL
2.3

untapt

Candidate-Side Feedback

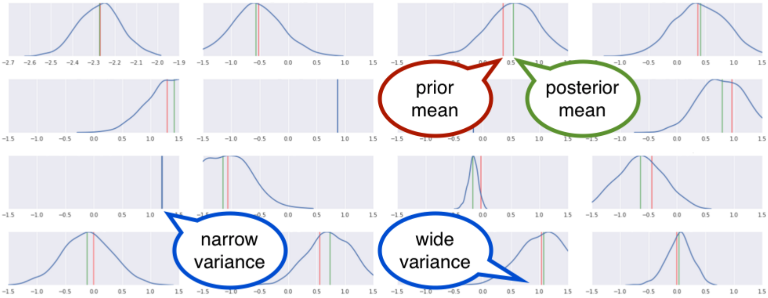


untapt

Client-Side Feedback

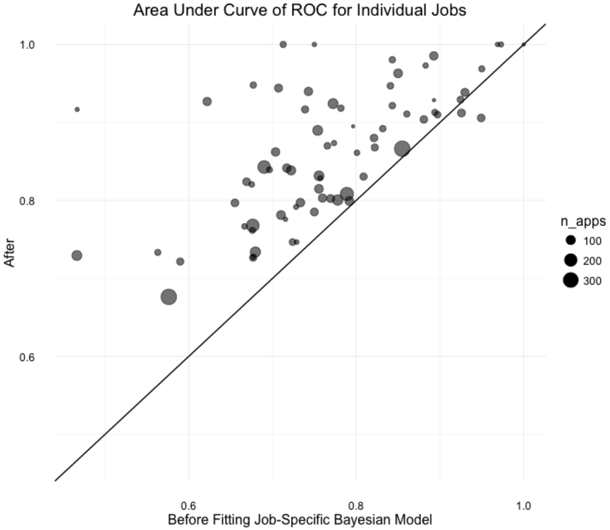
untapt

Multi-Stage Bayesian Regression with PyMC3



Krohn, Rives-Corbett & Donner (2016)

untapt



Krohn, Rives-Corbett & Donner (2016)

untapt

Ensemble with Deep Neural Net

```
Give me one bullet-point from your resume:
>> • Sat around all day checking my Facebook feed
I predict a 0.0% chance of interview
```

```
Give me one bullet-point from your resume:
>> • Developed trading applications in Python
I predict a 24.6% chance of interview
```

```
Give me one bullet-point from your resume:
>> • Developed python solution for Monte Carlo risk calculation using numpy,
 scipy and pandas, with a Javascript frontend in AngularJS and React
I predict a 98.1% chance of interview
```

deep-orange.untapt.com


ye olde Hosmer-Lemeshow test
proportion of applications connected
model yhat
0.00
0.25
0.50
0.75
1.00

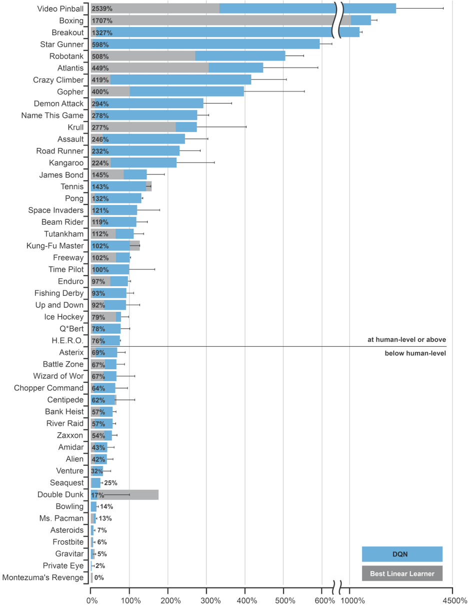
Outline

AlphaGO

Silver et al. (2016)

Deep Q-Learning

Mnih et al. (2015)



[Atari Games]

[OpenAI Universe]

[Google DeepMind Lab]


CHEERS