UNIVERSITAT DE BARCELONA

Deep Learning

Jordi Vitrià

Barcelona, 2018

What

1. Describe how a (deep) neural network works and combine different types of layers and activation functions. Deep Learning is not magic.
2. Describe how these models can be applied in computer vision, text analytics, time series analysis, etc. Deep Learning is not the final machine learning method.
3. Develop your own models in **Tensorflow, Keras** and derivates. You can train (small) deep models in your laptop.

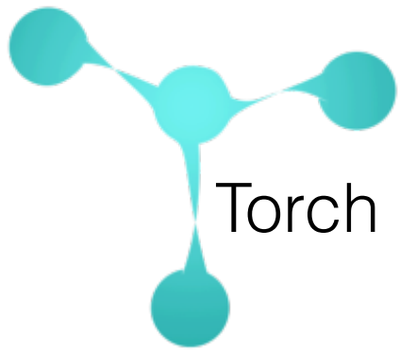
Library	Rank	Overall	Github	Stack Overflow	Google Results
tensorflow	1	10.87	4.25	4.37	2.24
keras	2	1.93	0.61	0.83	0.48
caffe	3	1.86	1.00	0.30	0.55
theano	4	0.76	-0.16	0.36	0.55
pytorch	5	0.48	-0.20	-0.30	0.98
sonnet	6	0.43	-0.33	-0.36	1.12
mxnet	7	0.10	0.12	-0.31	0.28
torch	8	0.01	-0.15	-0.01	0.17
cntk	9	-0.02	0.10	-0.28	0.17
dlib	10	-0.60	-0.40	-0.22	0.02
caffe2	11	-0.67	-0.27	-0.36	-0.04
chainer	12	-0.70	-0.40	-0.23	-0.07
paddlepaddle	13	-0.83	-0.27	-0.37	-0.20
deeplearning4j	14	-0.89	-0.06	-0.32	-0.51
lasagne	15	-1.11	-0.38	-0.29	-0.44
bigdl	16	-1.13	-0.46	-0.37	-0.30
dynet	17	-1.25	-0.47	-0.37	-0.42
apache singa	18	-1.34	-0.50	-0.37	-0.47
nvidia digits	19	-1.39	-0.41	-0.35	-0.64
matconvnet	20	-1.41	-0.49	-0.35	-0.58
tflearn	21	-1.45	-0.23	-0.28	-0.94
nervana neon	22	-1.65	-0.39	-0.37	-0.89
opennn	23	-1.97	-0.53	-0.37	-1.07

BackEnds

Python, C++, Java

MultiGPU

Distributed



Lua/Python

MultiGPU

theano

Python

Large amount of sample code

Université de Montréal

2017/09/28:

IMPORTANT: MILA will stop developing Theano and the next release (renamed to 1.0) will be the last main release.

Caffe

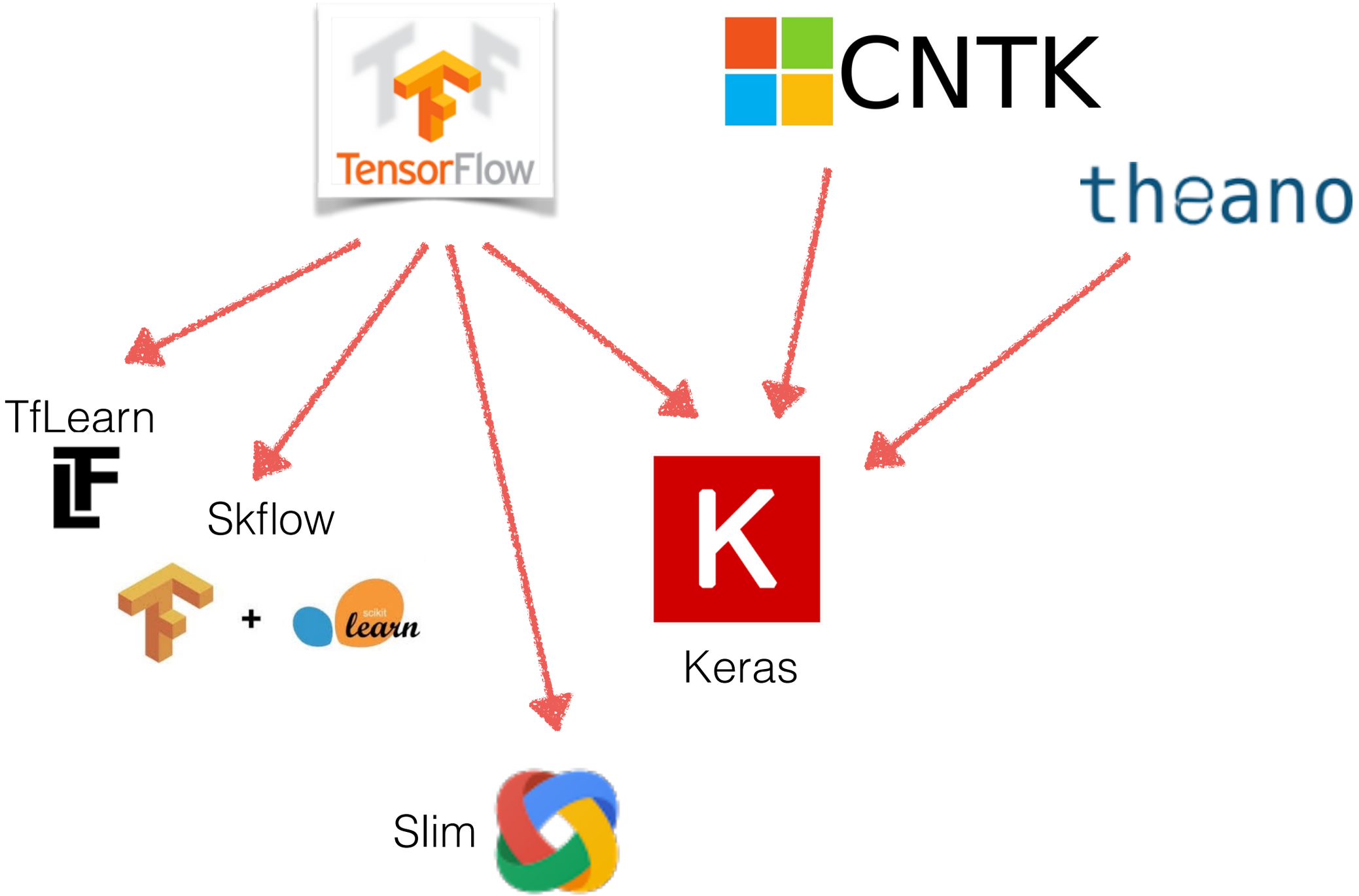
Python, C++

MultiGPU

Berkeley
UNIVERSITY OF CALIFORNIA

Google

Tools


TensorFlow
CNTK
theano
TfLearn
Skflow
scikit learn
Keras
Slim

Other BackEnds

dmlc mxnet

Caffe

Neon

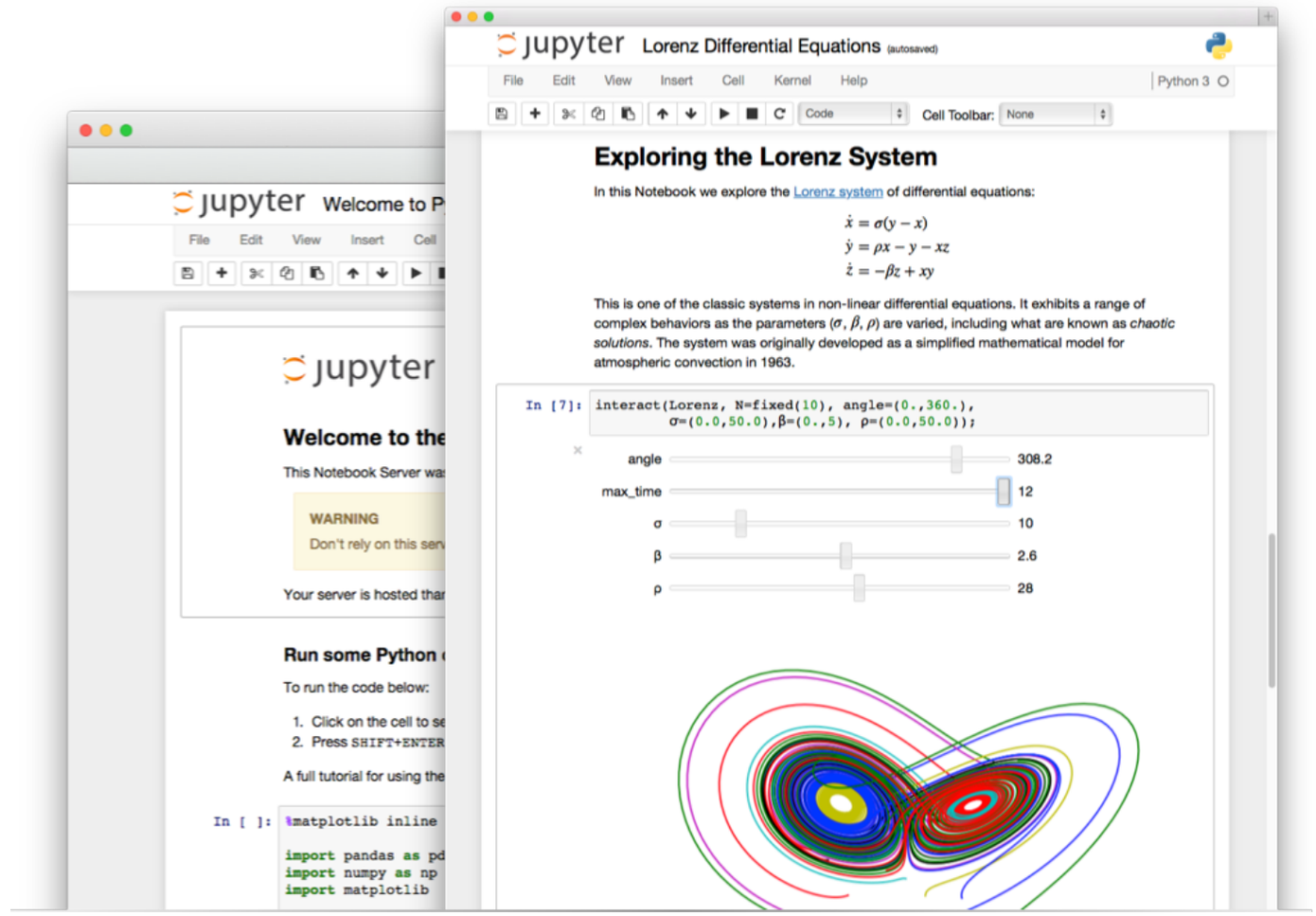
DL4J Deep Learning for Java

ConvNetJS

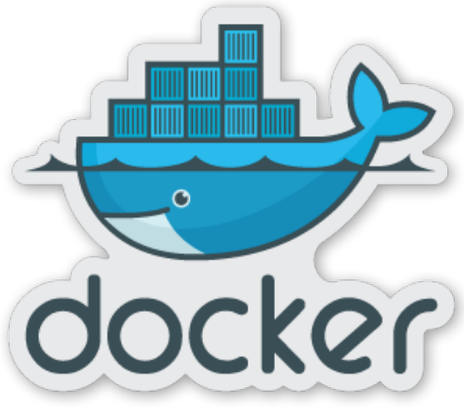
Deep Learning in your browser

Approach

We will illustrate all contents with Jupyter notebooks, a web application that allows you to create and share documents that contain live code, equations, visualizations and explanatory text.

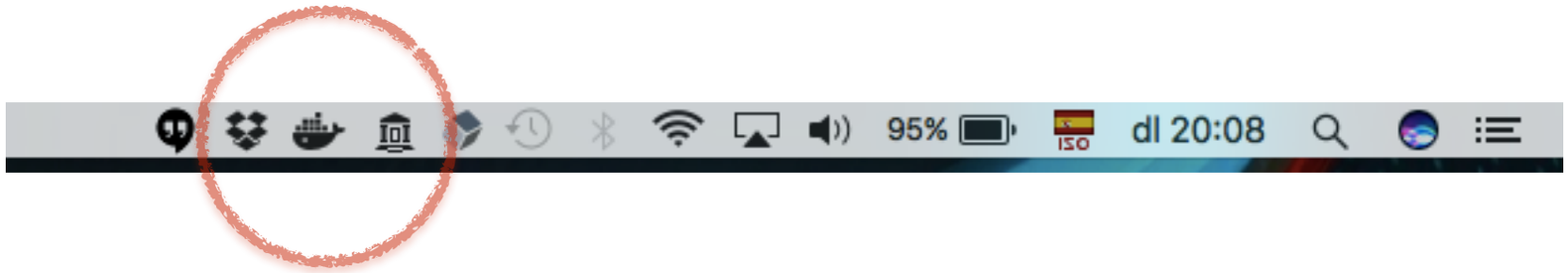


Approach



We will use a **Docker Container**.

Docker provides the ability to build a runtime environment that not only remains isolated from other running containers, but also can be deployed to multiple locations in a repeatable way. Docker also uses a text document – a Dockerfile – that contains all the commands to assemble an image, which will meet our need to document the build environment. Finally, Docker's runtime options enable us to attach GPU devices when deploying on remote servers.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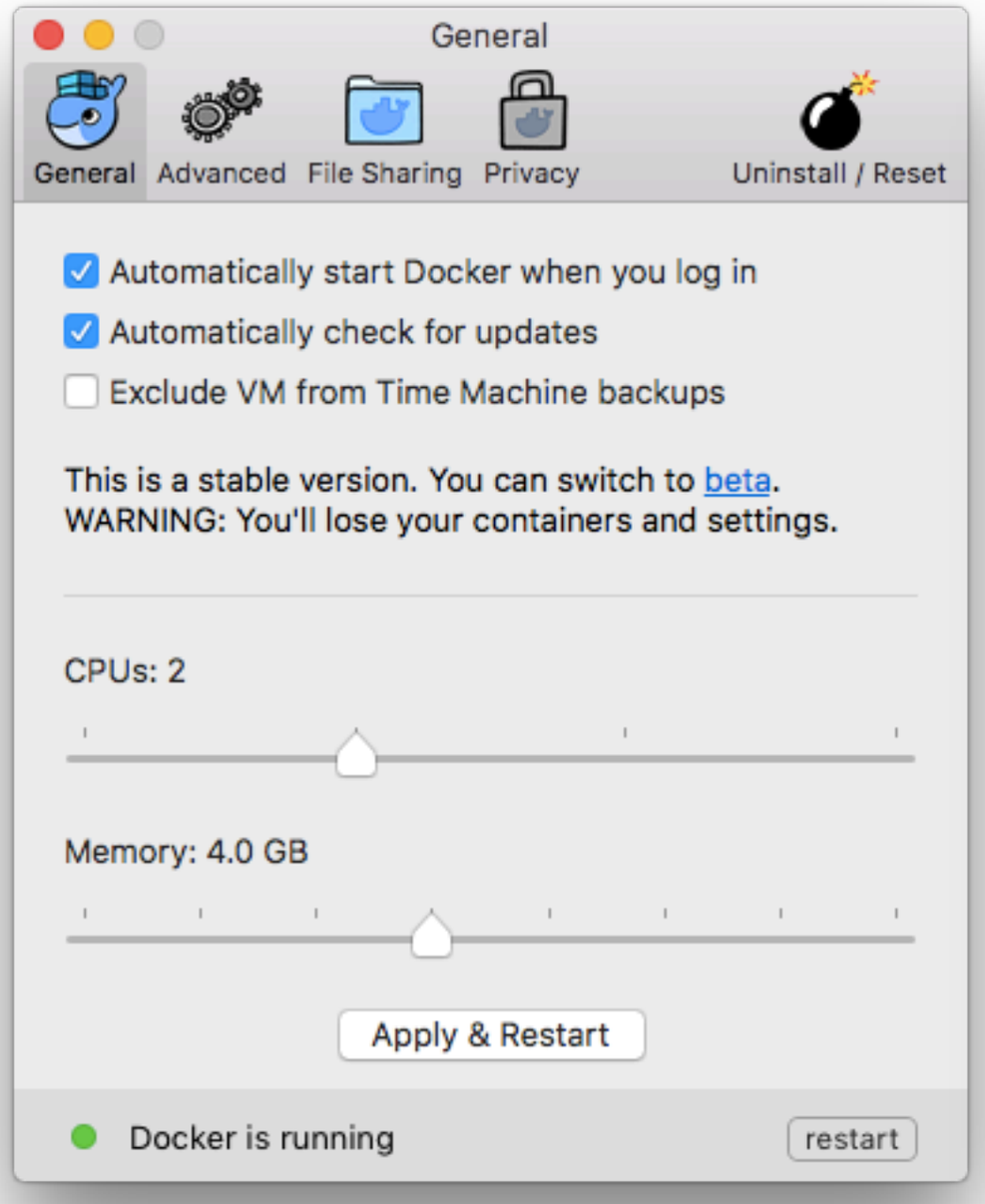
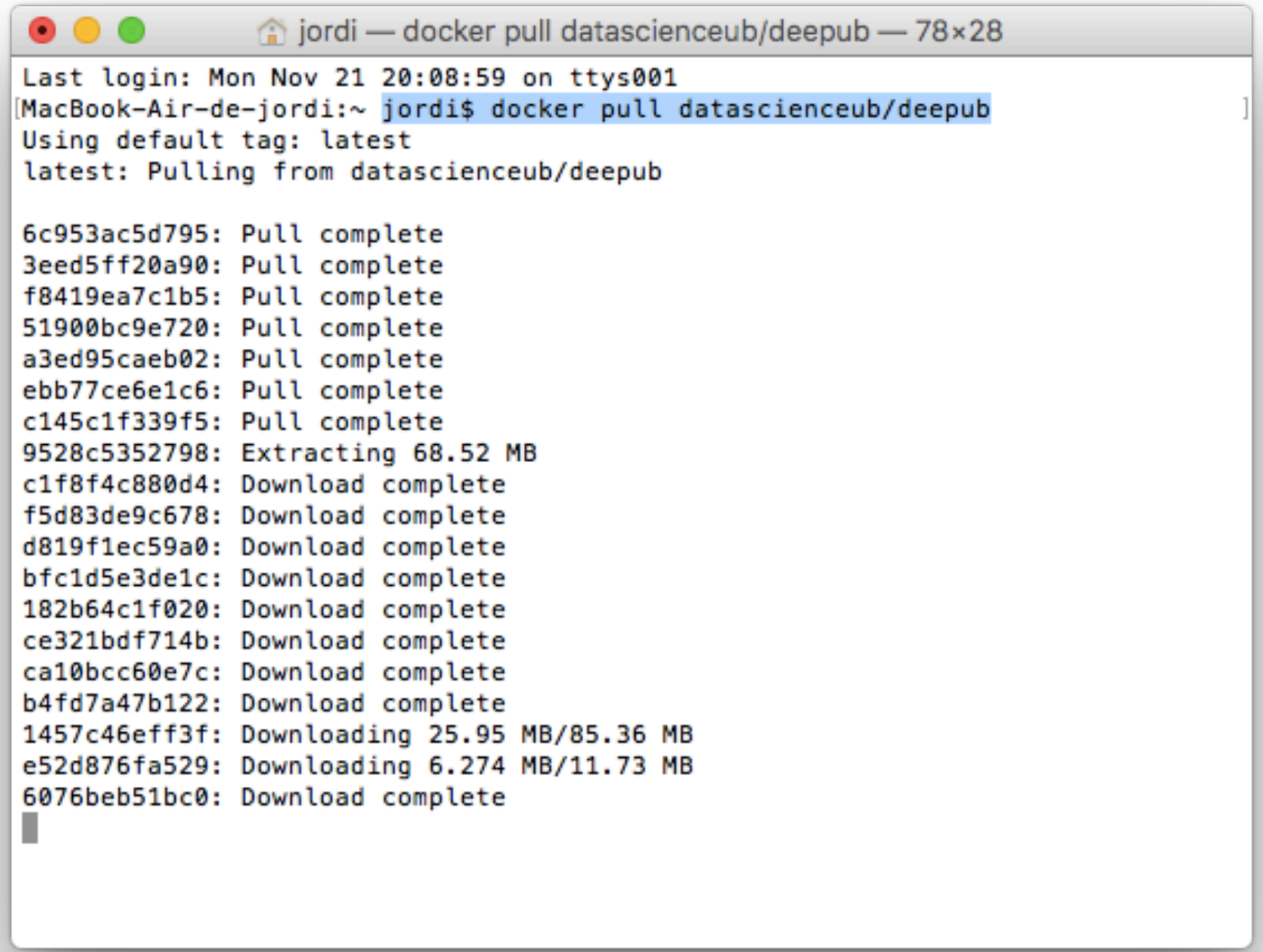

General
General
Advanced
File Sharing
Privacy
Uninstall / Reset
Automatically start Docker when you log in
Automatically check for updates
Exclude VM from Time Machine backups
This is a stable version. You can switch to beta.
WARNING: You'll lose your containers and settings.
CPUs: 2
Memory: 4.0 GB
Apply & Restart
Docker is running
restart


File Sharing
General
Advanced
File Sharing
Privacy
Uninstall / Reset
These OS X directories (and their subdirectories) can be bind mounted into Docker containers. These exported directories cannot overlap.
You can check the documentation for more details.
/Users
/Volumes
/tmp
/private
Apply & Restart
Docker starting...
restart

`tensorflow==1.4.0rc1` `ipython==6.2.1` `Keras==2.1.2`



DeepLearningBBVA2016-master — docker run -it -p 8888:8888 -v ~/Dropbox/Dee...

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Last login: Mon Nov 21 20:17:10 on ttys001
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MacBook-Air-de-jordi:DeepLearningBBVA2016-master jordi$
MacBook-Air-de-jordi:DeepLearningBBVA2016-master jordi$ docker run -it -p 8888:8888
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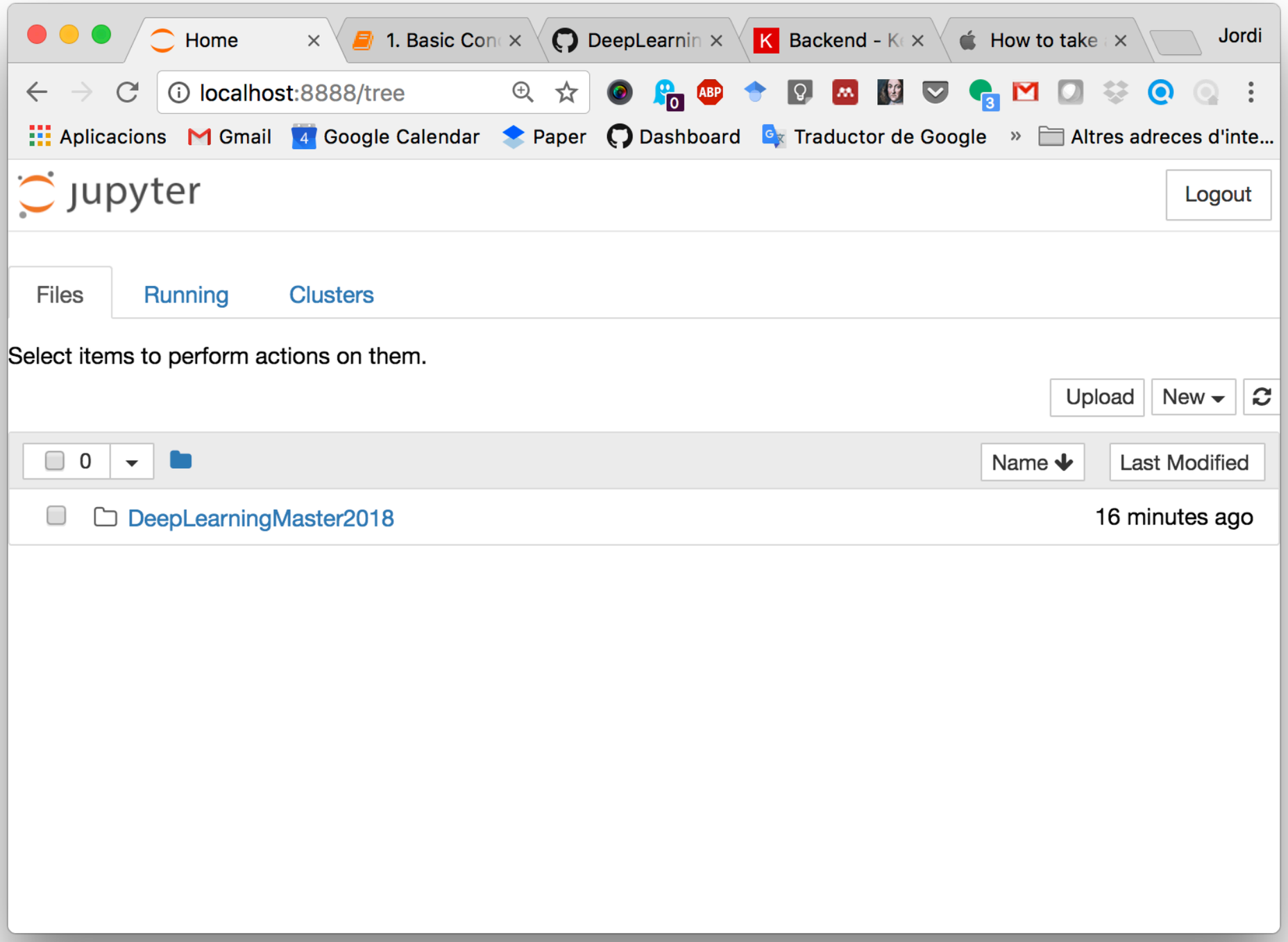
[W 19:18:44.975 NotebookApp] WARNING: The notebook server is listening on all IP add
resses and not using authentication. This is highly insecure and not recommended.
[I 19:18:44.982 NotebookApp] Serving notebooks from local directory: /notebooks
[I 19:18:44.982 NotebookApp] 0 active kernels
[I 19:18:44.982 NotebookApp] The Jupyter Notebook is running at: http://[all ip addr
esses on your system]:8888/
[I 19:18:44.983 NotebookApp] Use Control-C to stop this server and shut down all ker
nels (twice to skip confirmation).
```

docker run -it -p 8888:8888 -p 6006:6006
-v /$(pwd):/notebooks datascienceub/deepub

docker run -it -p 8888:8888 -p 6006:6006 -v
C:\jordi\DeepLearning:/notebooks datascienceub/
deepub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DeepLearningMaster2018
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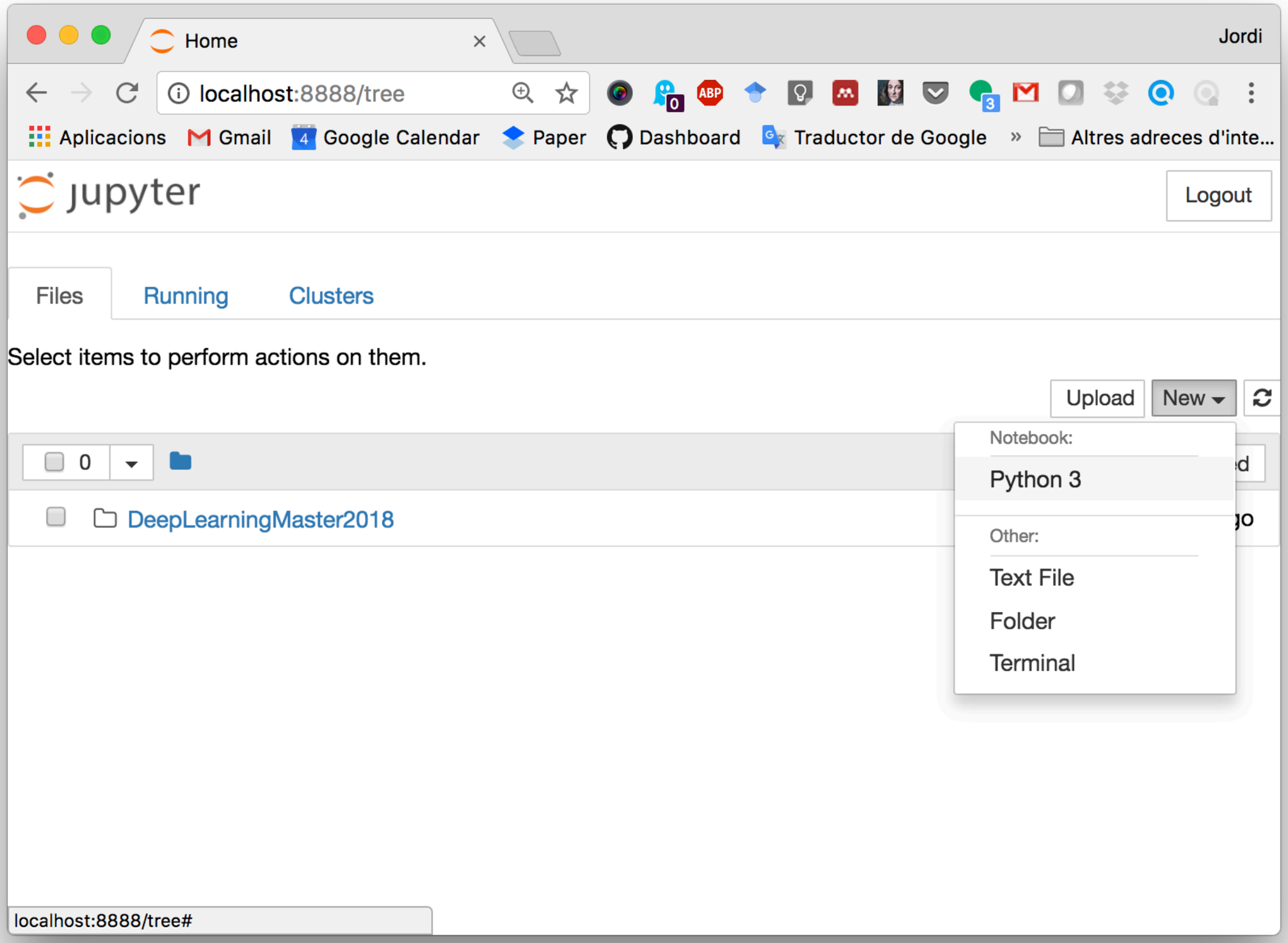
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Logout
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Select items to perform actions on them.
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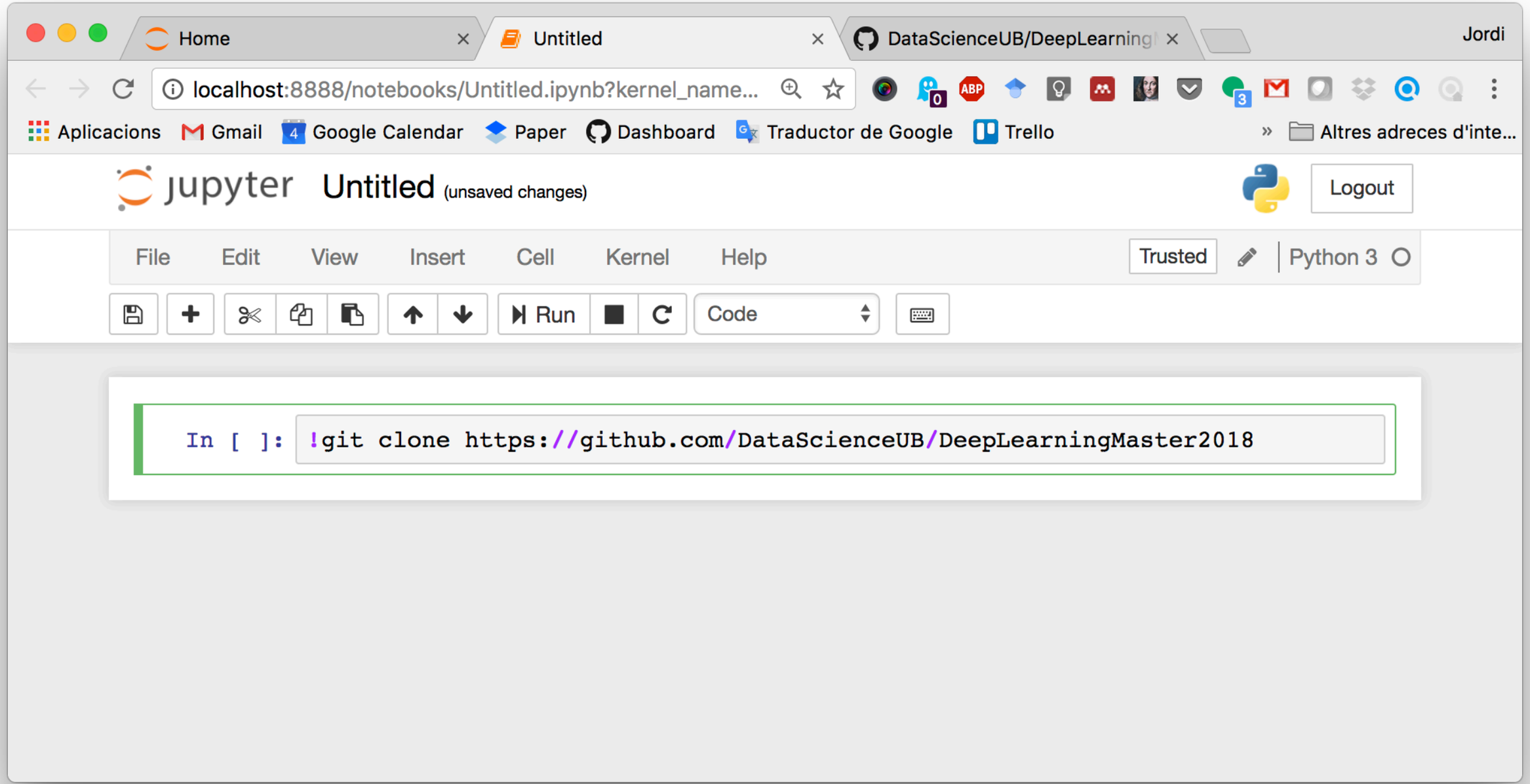
Python 3
Other:
Text File
Folder
Terminal
localhost:8888/tree#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Paper
Dashboard
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View
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Kernel
Help
Trusted
Python 3
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Code
In [ ]:
!git clone https://github.com/DataScienceUB/DeepLearningMaster2018

DeepLearningMaster2018/ | Untitled | DataScienceUB/DeepLearning | Jordi

localhost:8888/tree/DeepLearningMast...

Aplicacions | Gmail | Google Calendar | Paper | Dashboard | Traductor de Google | Trello | Altres adreces d'inte...

jupyter

Logout

Files | Running | Clusters

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11. Non supervised learning I.ipynb	3 hours ago
12. Non supervised learning II.ipynb	3 hours ago
13. Reinforcement learning.ipynb	3 hours ago
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Why Deep Learning?


It’s funny!
It’s not rocket science!
It’s powerful!

- In 1943, neurophysiologist **Warren McCulloch** and mathematician **Walter Pitts** wrote a paper on how neurons might work. In order to describe how neurons in the brain might work, they modeled a simple neural network using electrical circuits.

- In 1949, Donald **Hebb** wrote *The Organization of Behavior*, a work which pointed out the fact that neural pathways are strengthened each time they are used, a concept fundamentally essential to the ways in which humans learn. If two nerves fire at the same time, he argued, the connection between them is enhanced.

- In 1957 **Frank Rosenblatt** attempted to build a kind of mechanical brain called the Perceptron, which was billed as "a machine which senses, recognizes, remembers, and responds like the human mind".


- In 1962, **Widrow & Hoff** developed a learning procedure that examines the value before the weight adjusts it (i.e. 0 or 1) according to the rule: Weight Change = (Pre-Weight line value) * (Error / (Number of Inputs)). It is based on the idea that while one active perceptron may have a big error, one can adjust the weight values to distribute it across the network, or at least to adjacent perceptrons.


- A critical book written in 1969 by **Marvin Minsky** and his collaborator **Seymour Papert** showed that Rosenblatt's original system was painfully limited, literally blind to some simple logical functions like "exclusive-or" (As in, you can have the cake or the pie, but not both). What had become known as the field of "neural networks" all but disappeared.

First neural network winter is coming

- In 1982, interest in the field was renewed. **John Hopfield** of Caltech presented a paper to the National Academy of Sciences. His approach was to create more useful machines by using bidirectional lines. Previously, the connections between neurons was only one way.

- In 1986, the problem was how to extend the Widrow-Hoff rule to multiple layers. Three independent groups of researchers, which included **David E. Rumelhart, Geoffrey E. Hinton** and **Ronald J. Williams**, came up with similar ideas which are now called back-propagation networks because it distributes pattern recognition errors throughout the network.

- From 1986 to mid 90's new developments arised: convolutional neural networks (**Y.LeCun**), unsupervised learning (**Y.Bengio**), RBM (**G.Hinton**), etc. But, by this point **new machine learning methods** had begun to also emerge, and people were again beginning to be skeptical of neural nets since they seemed so intuition-based and since computers were still barely able to meet their computational needs.

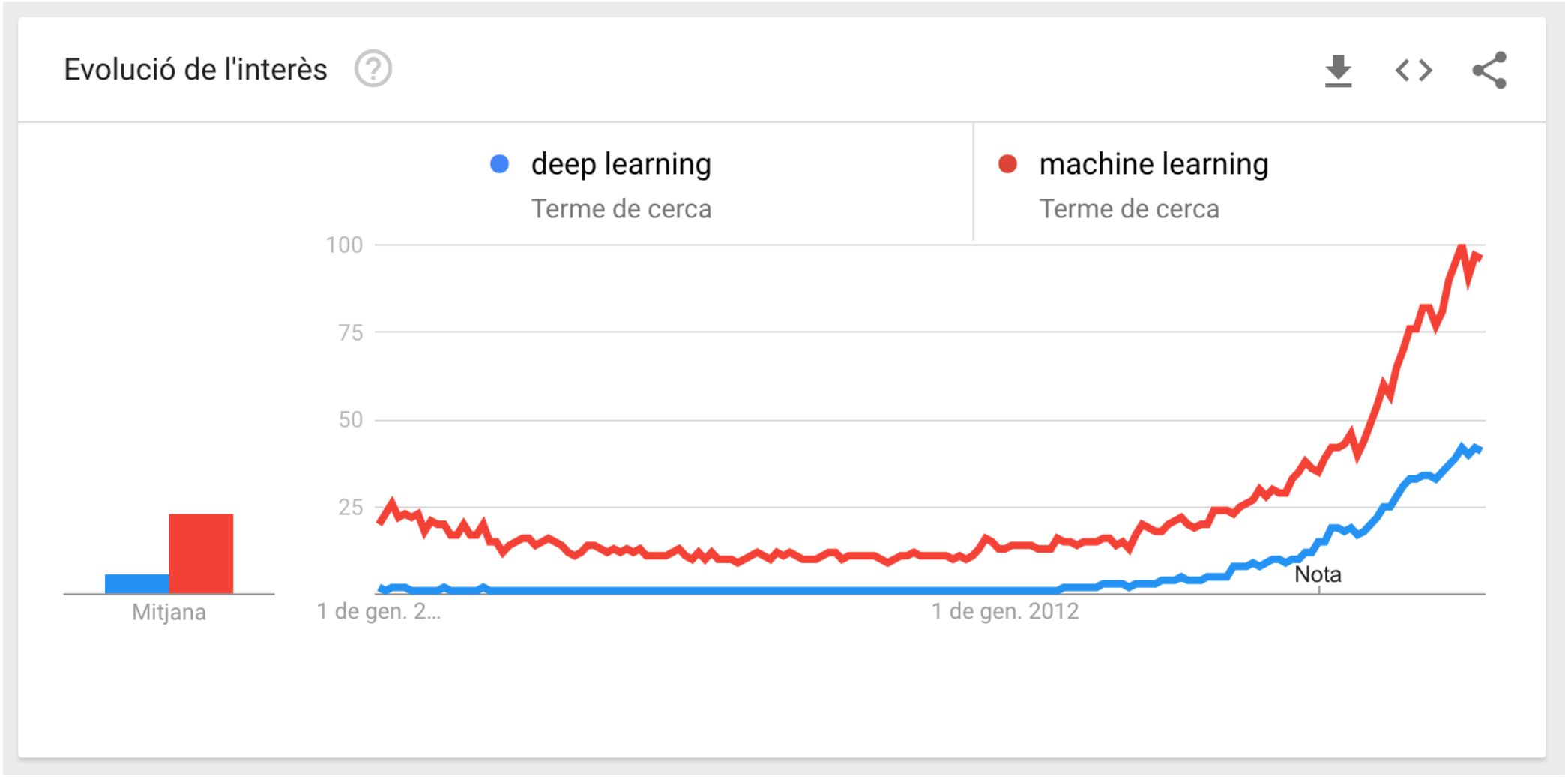
Second neural network winter is coming

- With the ascent of Support Vector Machines and the failure of backpropagation, the early 2000s were a dark time for neural net research.

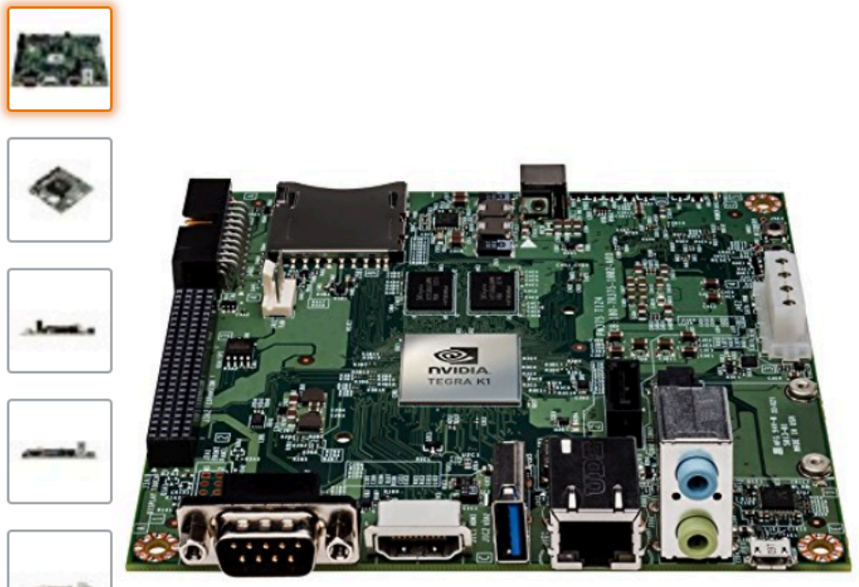
- Then, what every researcher must dream of actually happened: G.Hinton, S.Osindero, and Y.W.Teh published a paper in 2006 that was seen as a breakthrough, a breakthrough significant enough to rekindle interest in neural nets: *A fast learning algorithm for* ***deep*** *belief nets.*

- After that, following Moore's law, computers got dozens of times faster (GPUs) since the slow days of the 90s, making learning with large datasets and many layers much more tractable.

Neural Networks Reborn



Google Trends



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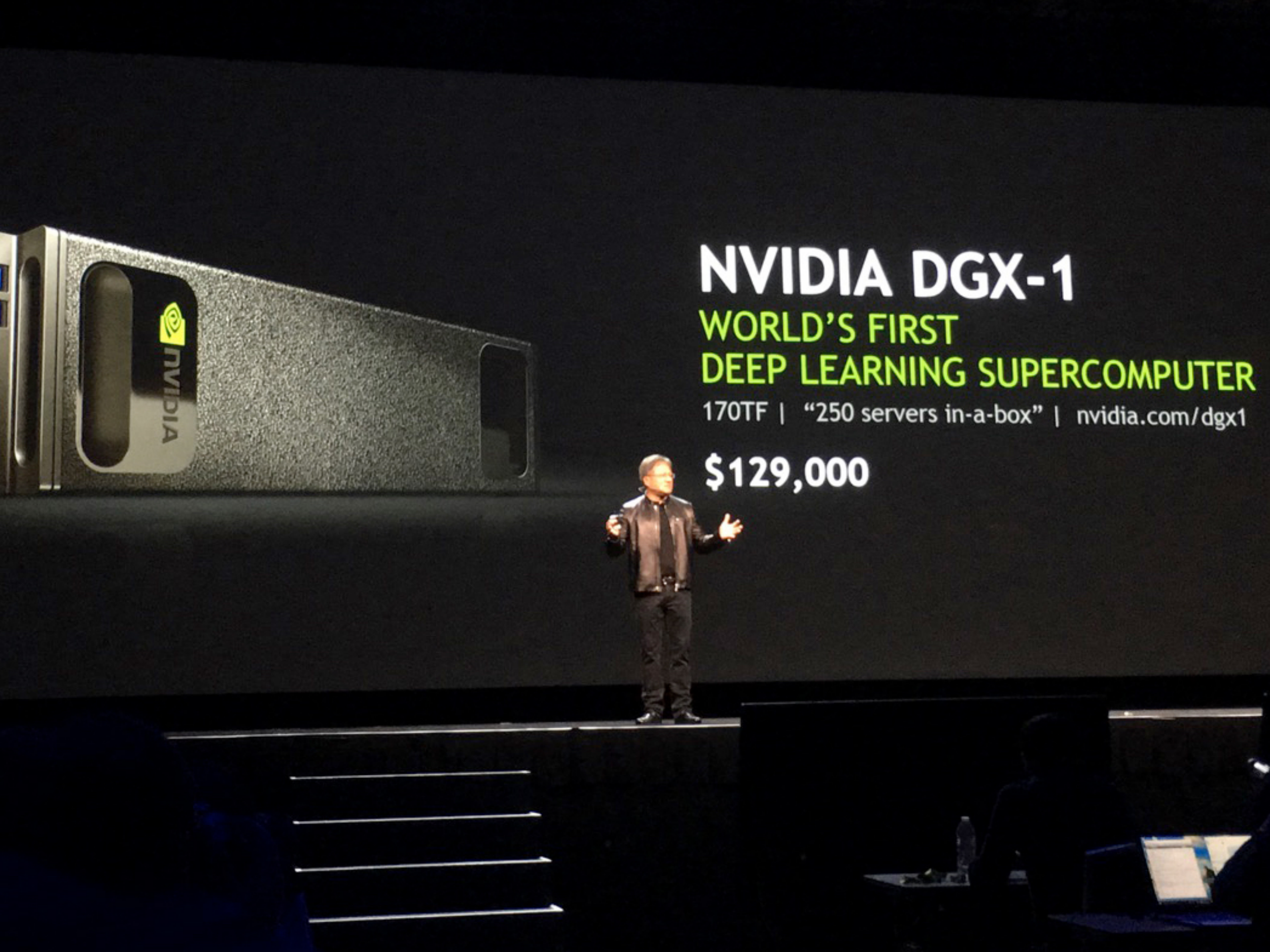
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Definitions

- **Neural Networks (NN)** is a beautiful biologically-inspired programming paradigm which enables a computer to learn from observational data.

- **Deep Learning (DL)** is a powerful set of techniques for learning in neural networks.

- NN and DL currently provide the best solutions to many problems in image recognition, speech recognition, and natural language processing.

“Classical” applications:
object classification, detection and segmentation.

Face recognition.

DeepFace (Facebook): Accuracy of 97.35%

New applications: navigation and mapping.

New applications: Image Upscaling (Flipboard)

http://engineering.flipboard.com/2015/05/scaling-convnets/

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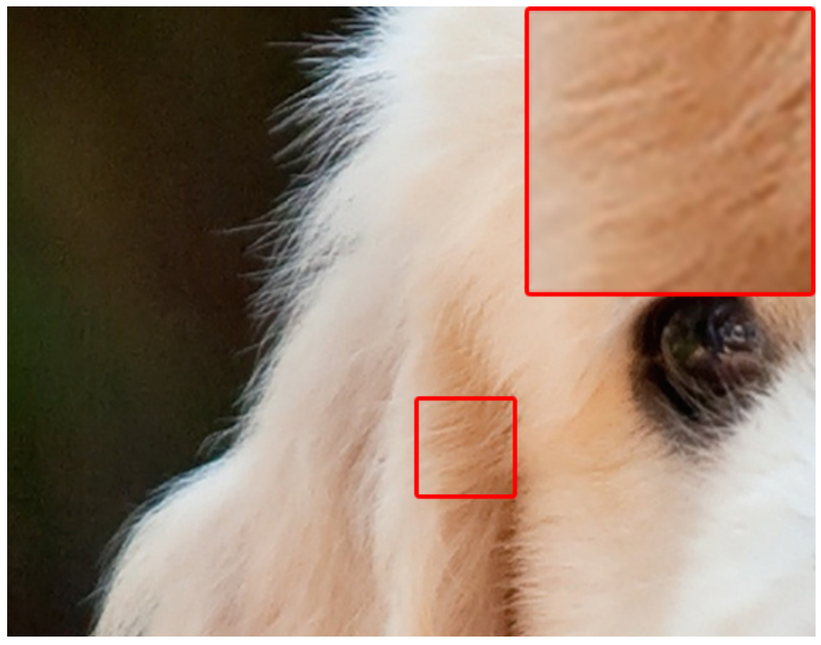
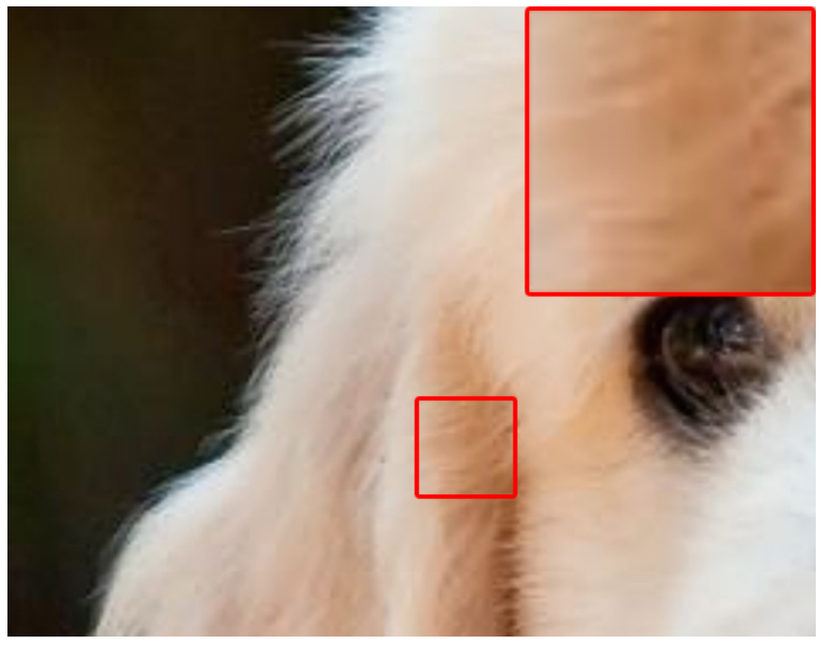
http://engineering.flipboard.com/2015/05/scaling-convnets/

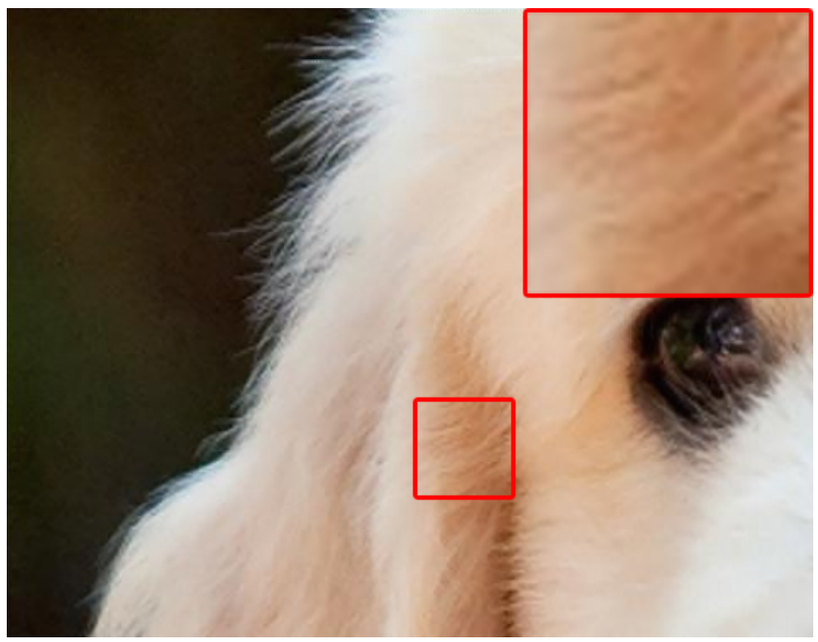
New applications: Image Upscaling (Flipboard)



Original



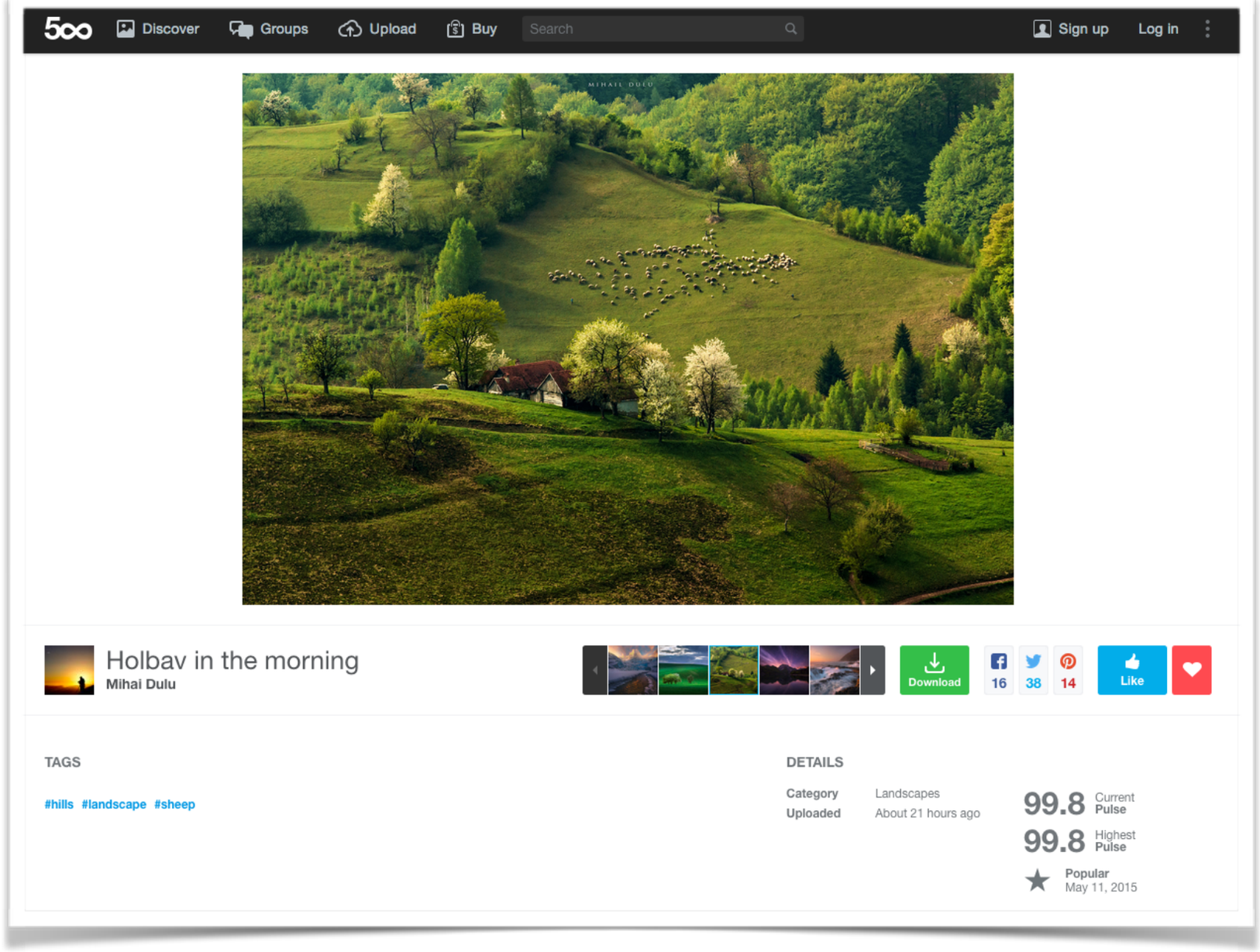
Bicubic



Model

http://engineering.flipboard.com/2015/05/scaling-convnets/

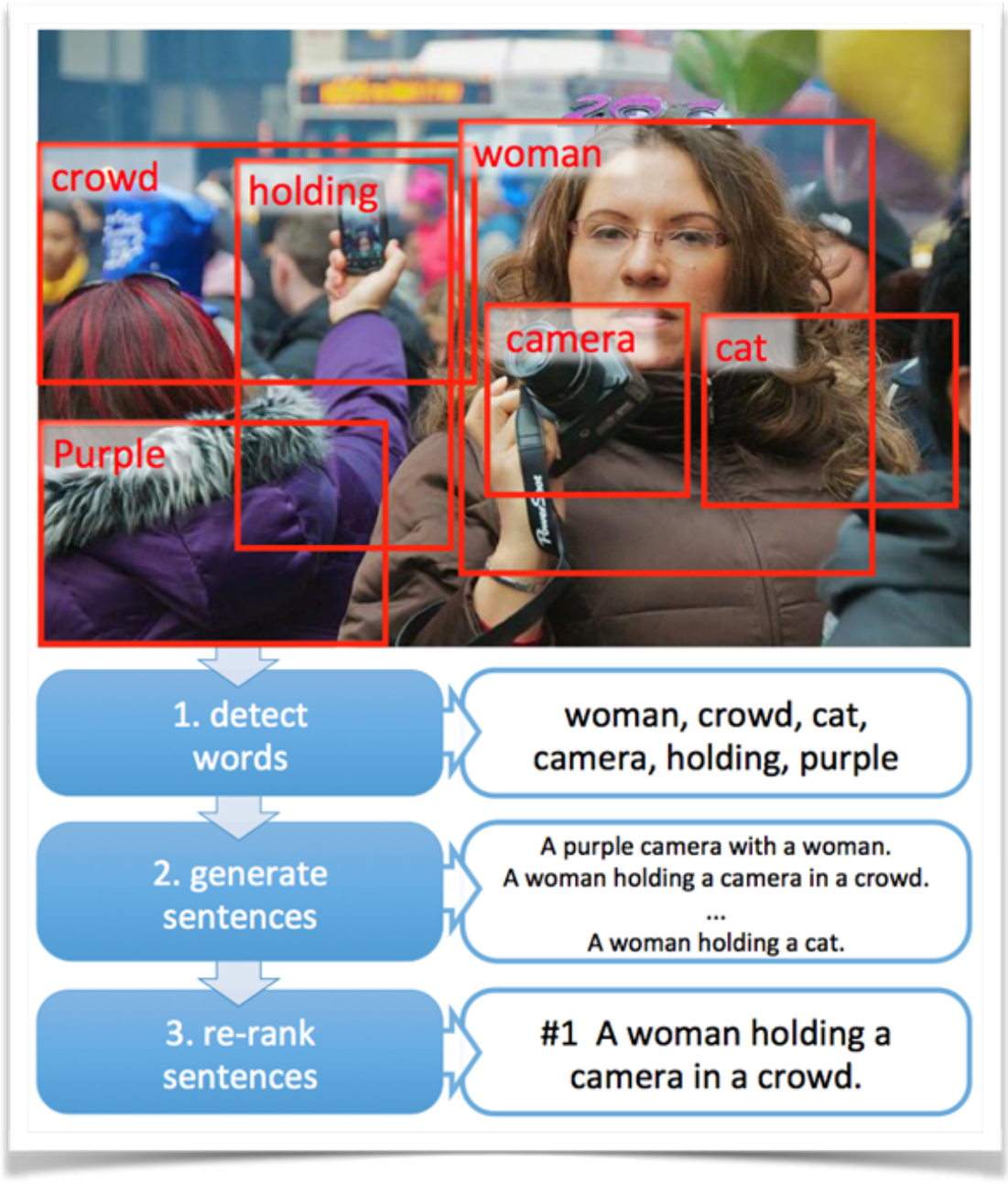
New applications: Non visual data prediction



What is Pulse?

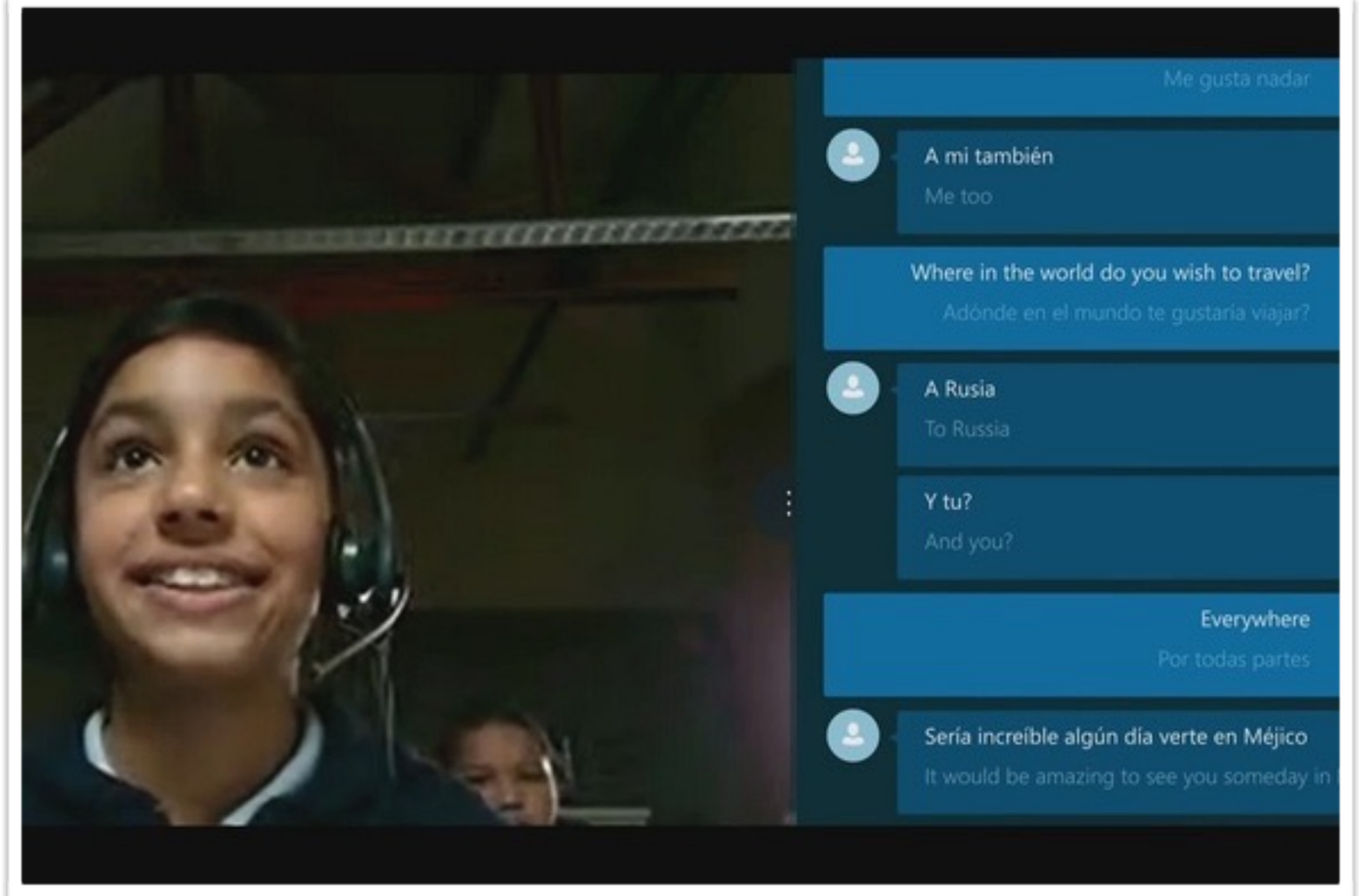
Pulse is a score out of 100 points that measures how **popular** a photo is. Pulse is calculated by an algorithm, which is unique to 500px and is based on votes (Likes & Favorites) on your photo from the community. The Pulse algorithm was designed to promote daily exposure of new photographs and photographers. It is not necessarily a measure of photograph's quality.

New applications: Automatic Image Captioning

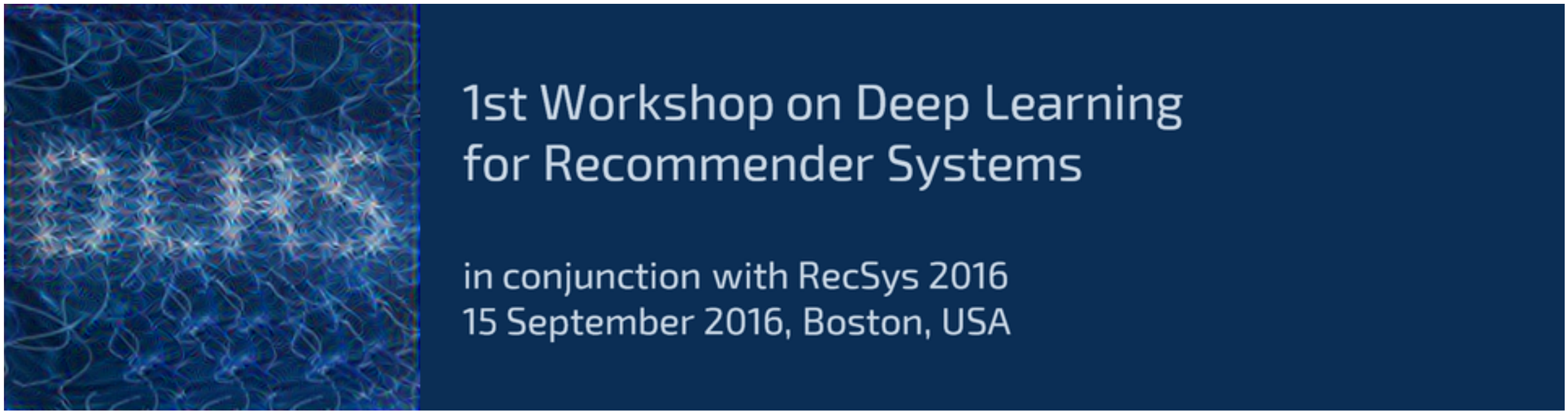


http://blogs.technet.com/b/machinelearning/archive/2014/11/18/rapid-progress-in-automatic-image-captioning.aspx

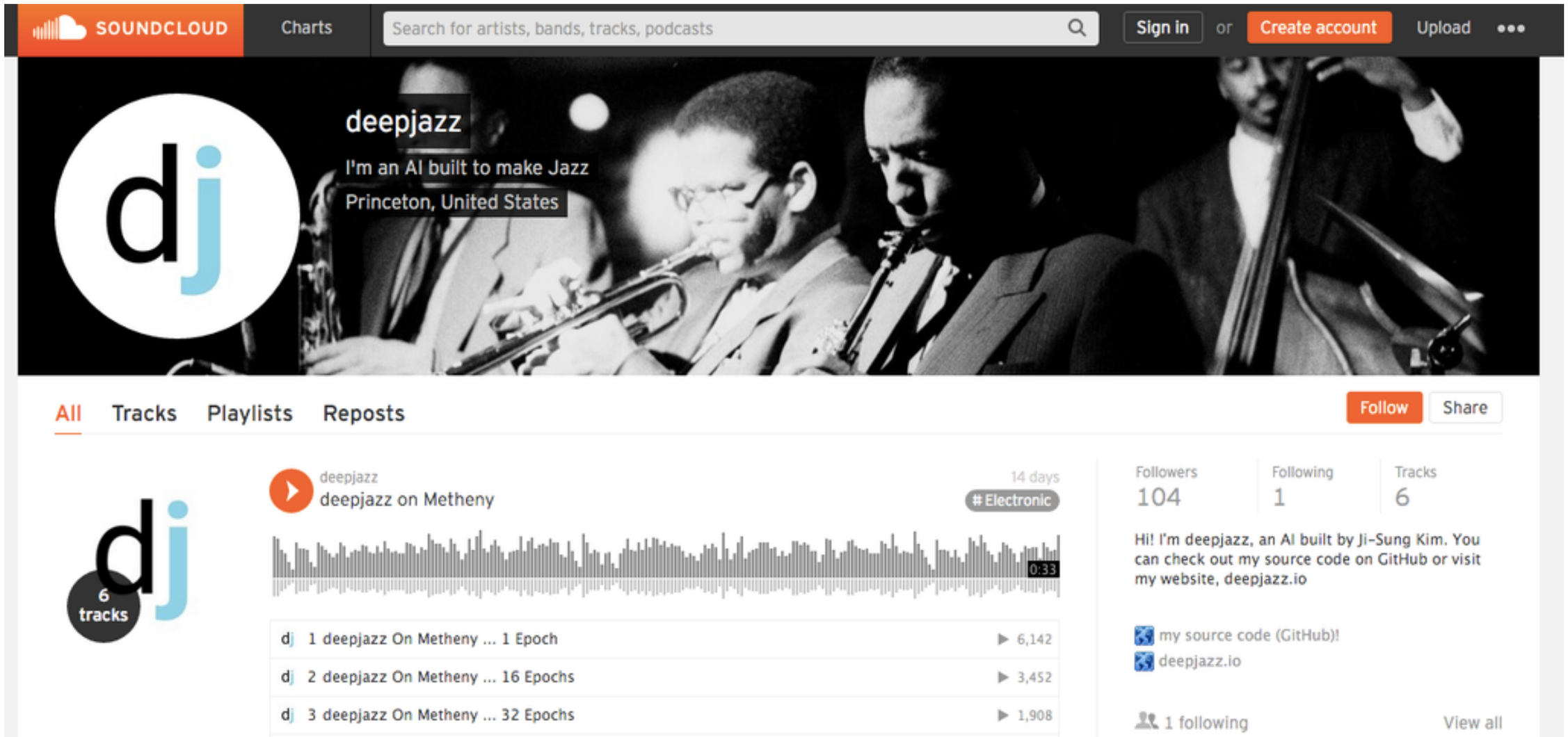
Speech translation



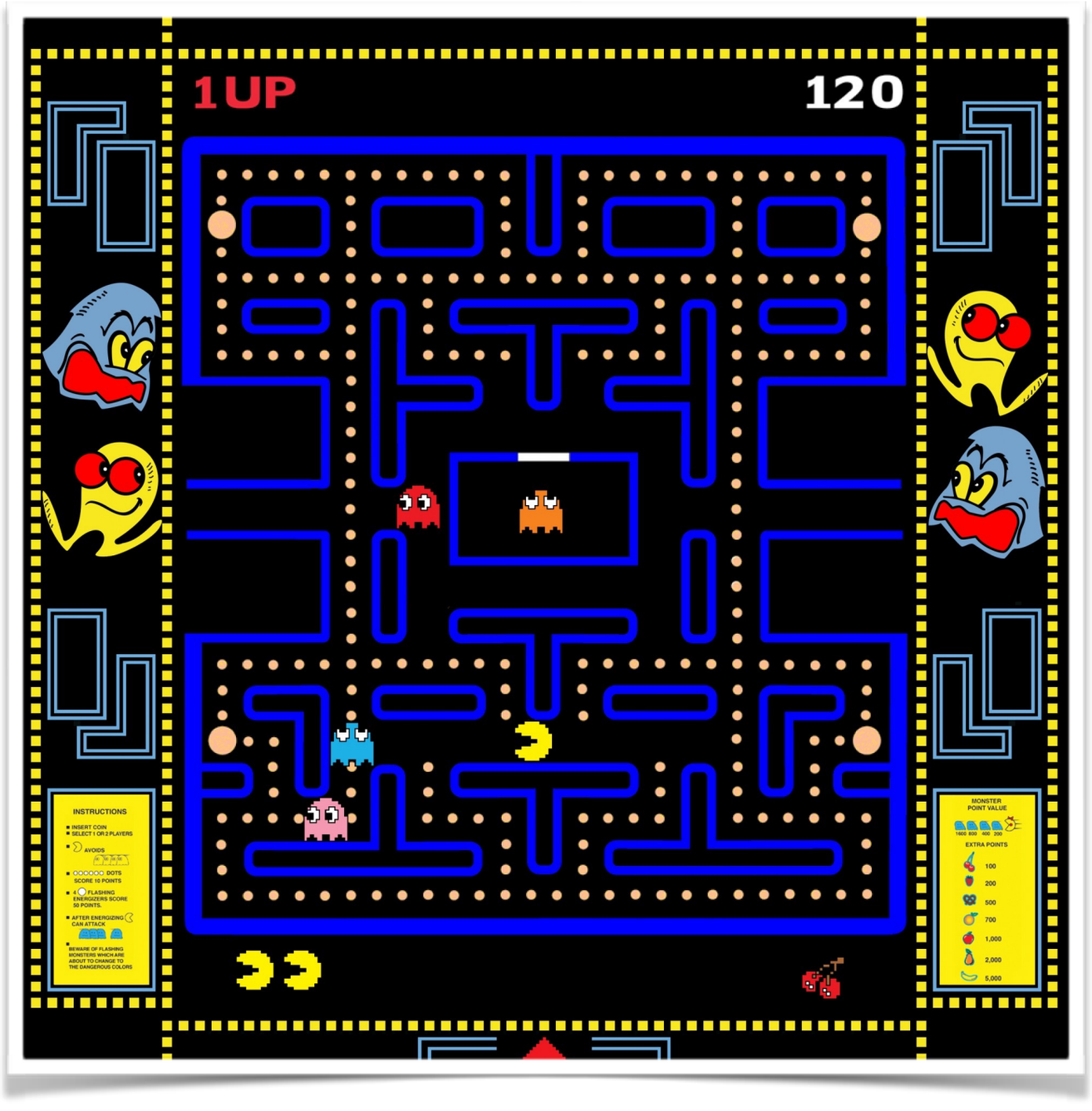
Recommenders



Music Generation



Reinforcement learning.



Go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Illegal harvest of millions of Mediterranean birds
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SAFEGUARD TRANSPARENCY
Don't let openness backfire on individuals
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BI, SALES & CRM

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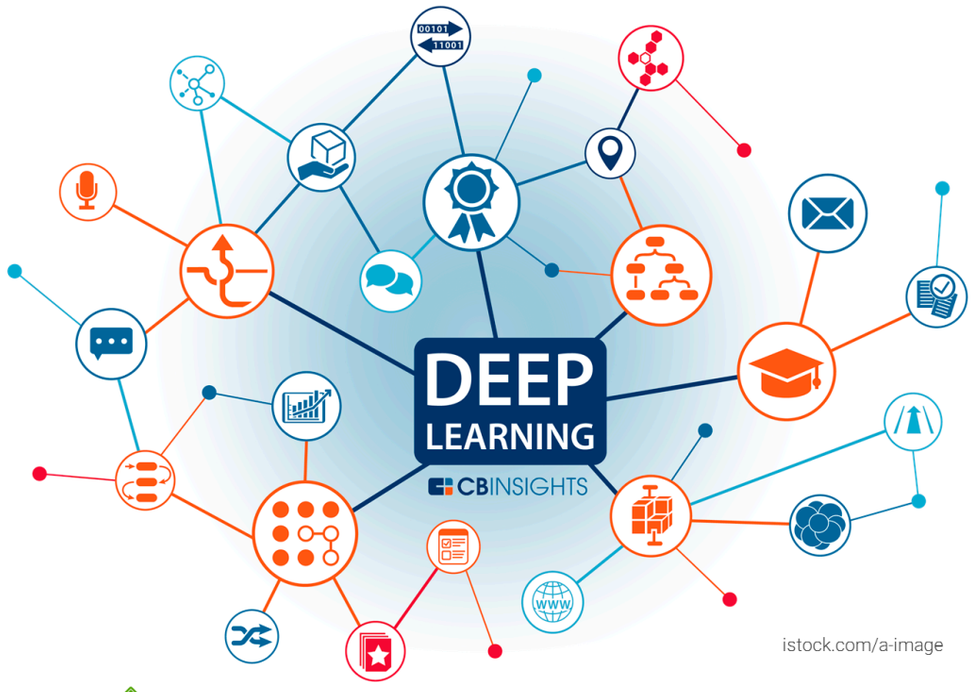
CORE AI: VOICE INTERFACE

VIV · Mobvoi 出门问问 · MaluubA · OBEN



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OTHER

Alpaca · indico · Iris Automation

ACQUIRED

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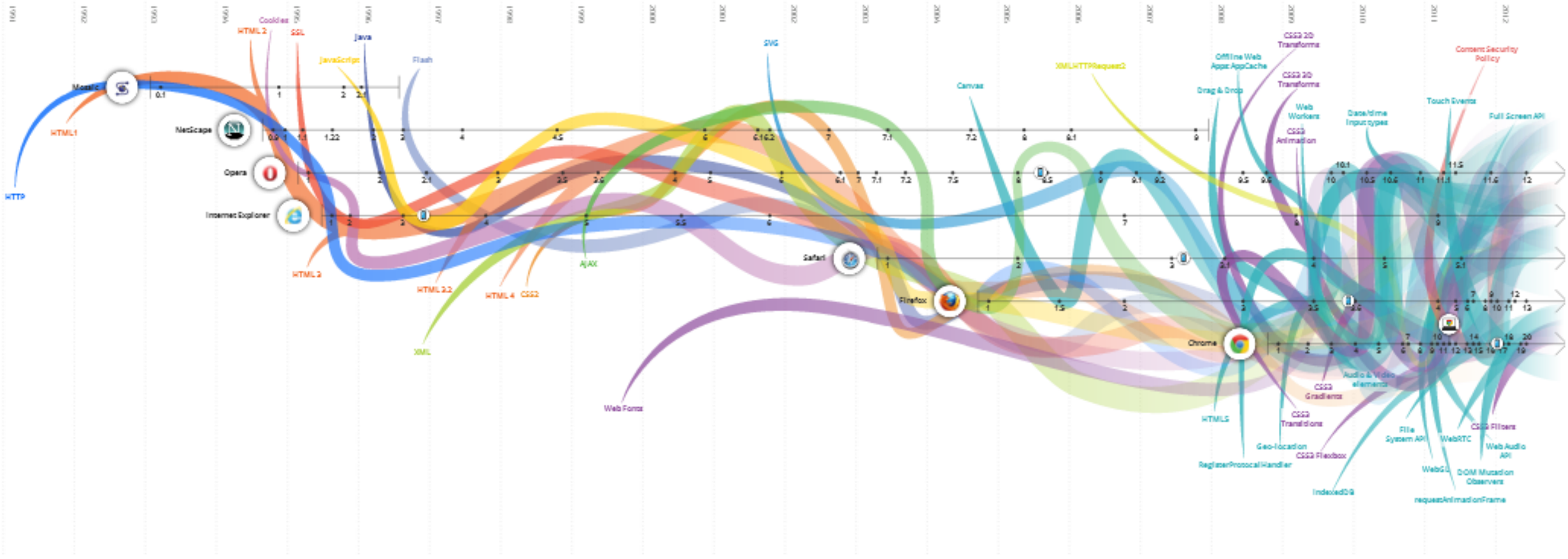


What is Deep Learning?

Learning from Data

Training data: a set of $(x^{(m)}, y^{(m)})$ pairs.
Learn a function $f_w : x \to y$ to predict on new inputs x.

1. Choose a model function family f_w.

2. Optimize parameters w.

1-layer neural net model

Parameters

Weights

Bias

$$f(x) = \sigma(w^T \cdot x + b)$$

Sigmoid Function

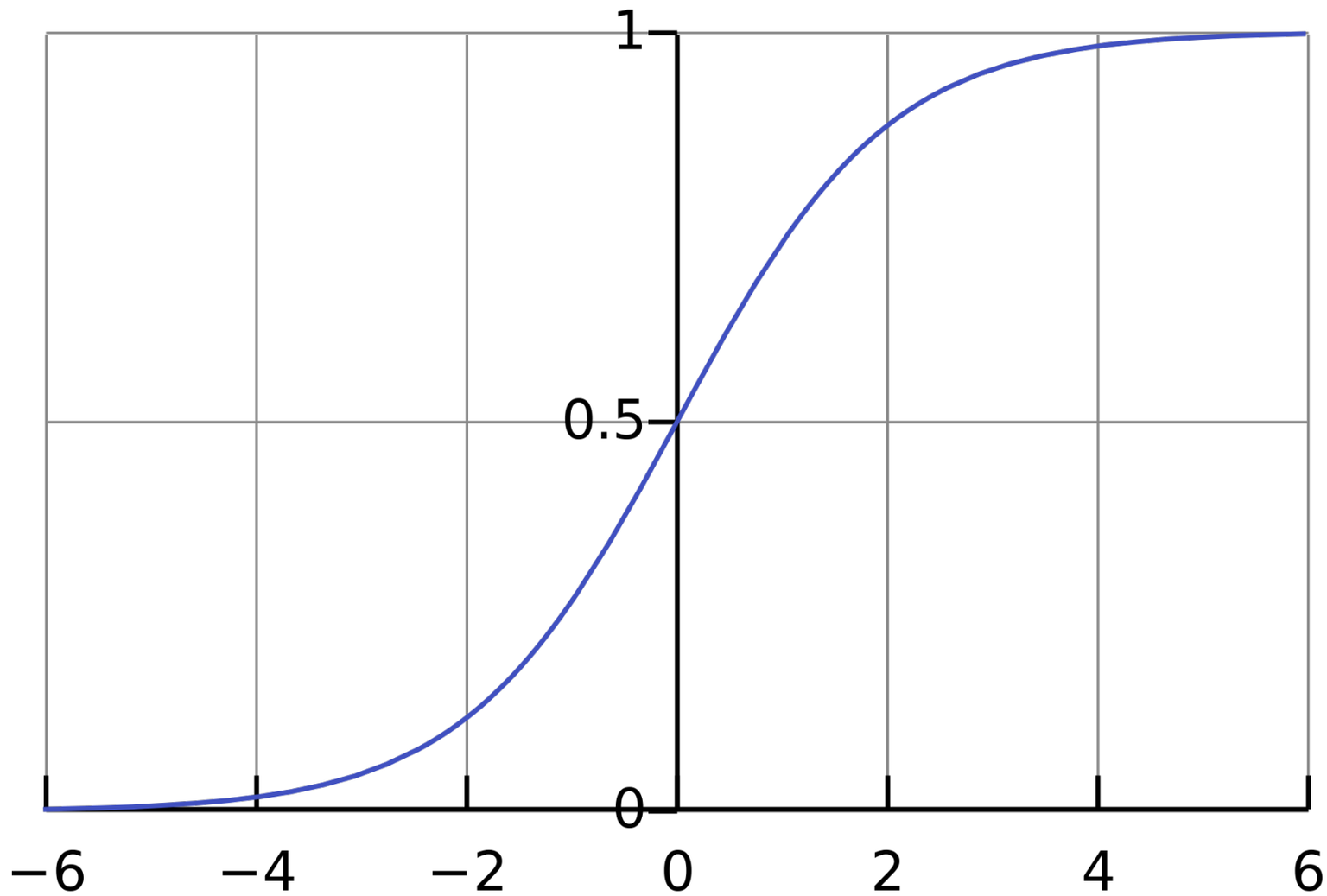
$$\sigma(x) = \frac{1}{(1+e^{-x})}$$

ReLU Function

$$\sigma(x) = max(0, x)$$

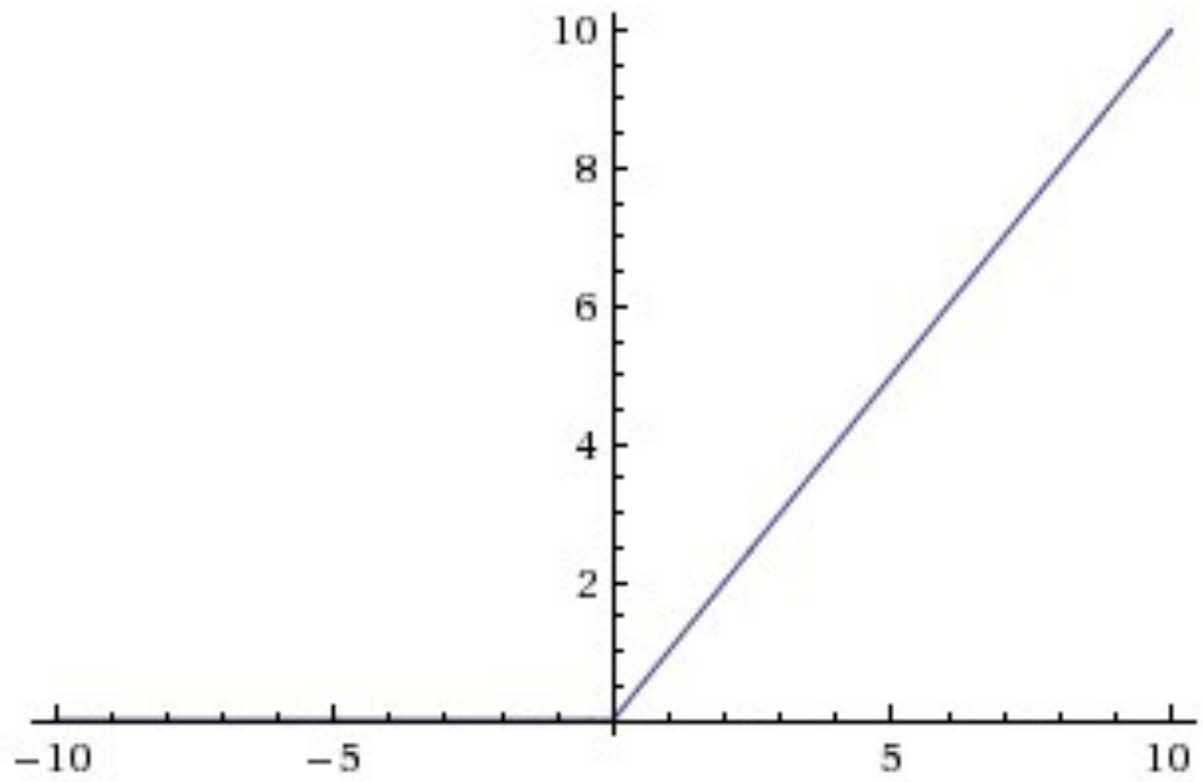
Dot Product

1-layer neural net model



$$\sigma(x) = \frac{1}{(1+e^{-x})}$$

1-layer neural net model



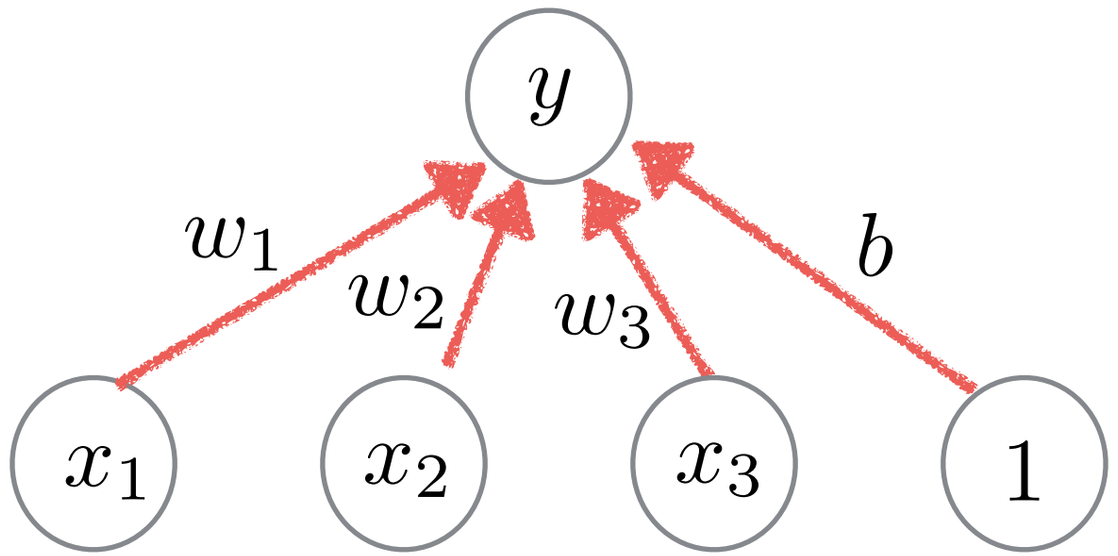
$$\sigma(x) = max(0, x)$$

Table 3: Non-linearities tested.

Name	**Formula**	**Year**
none	$y = x$	-
sigmoid	$y = \frac{1}{1+e^{-x}}$	1986
tanh	$y = \frac{e^{2x}-1}{e^{2x}+1}$	1986
ReLU	$y = \max(x, 0)$	2010
(centered) SoftPlus	$y = \ln(e^x + 1) - \ln 2$	2011
LReLU	$y = \max(x, \alpha x), \alpha \approx 0.01$	2011
maxout	$y = \max(W_1 x + b_1, W_2 x + b_2)$	2013
APL	$y = \max(x,0) + \sum_{s=1}^{S} a_i^s \max(0, -x + b_i^s)$	2014
VLReLU	$y = \max(x, \alpha x), \alpha \in 0.1, 0.5$	2014
RReLU	$y = \max(x, \alpha x), \alpha = \text{random}(0.1, 0.5)$	2015
PReLU	$y = \max(x, \alpha x), \alpha$ is learnable	2015
ELU	$y = x$, if $x \geq 0$, else $\alpha(e^x - 1)$	2015

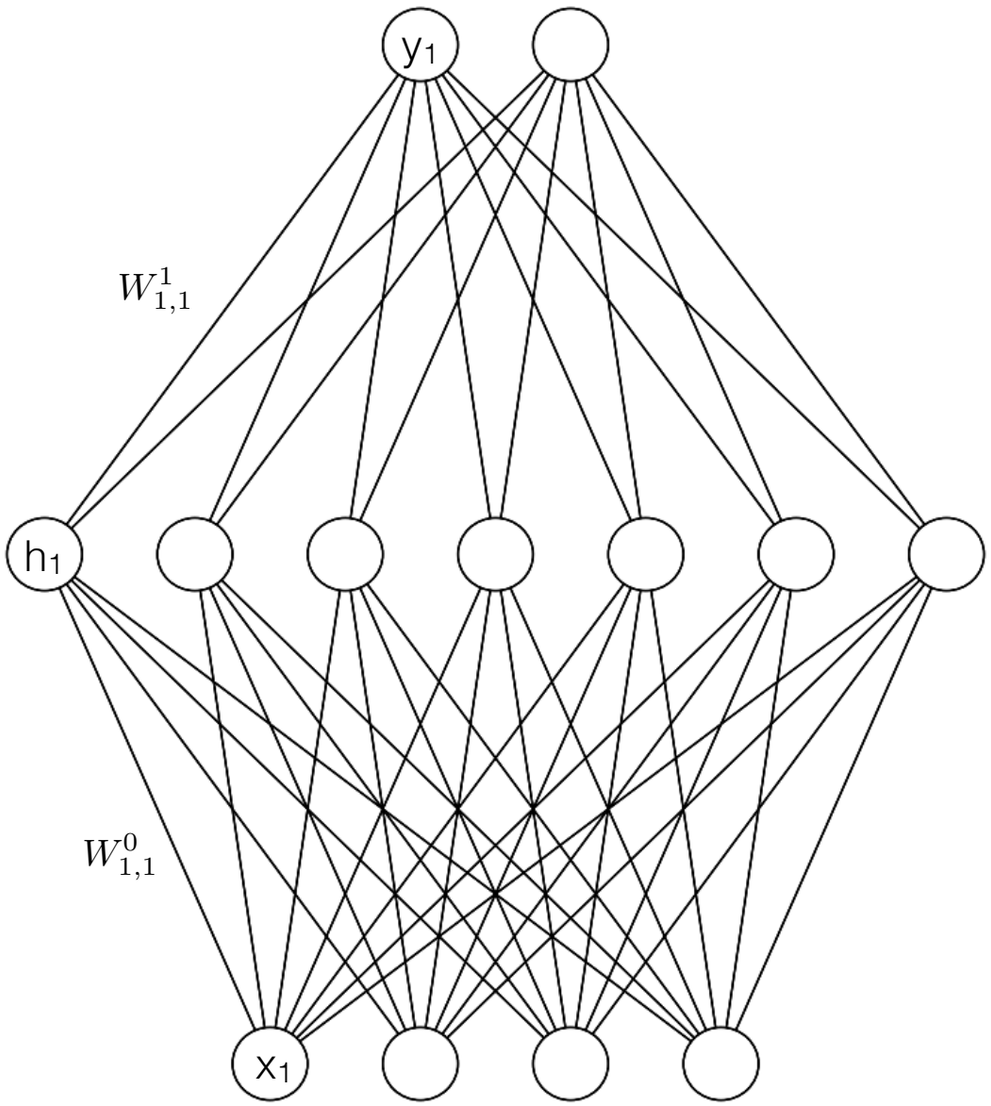
1-layer neural net model

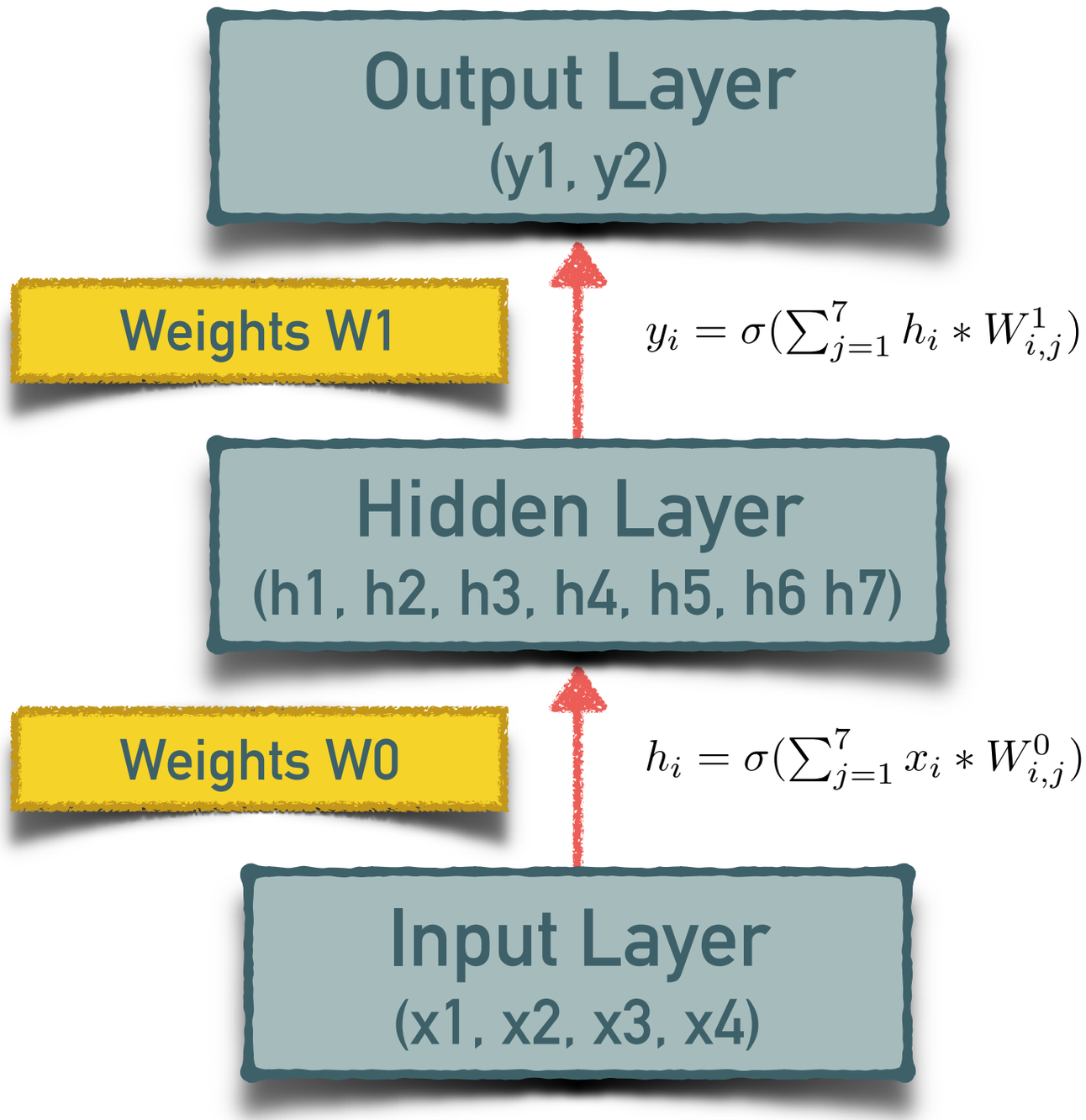
$$f(x) = \sigma(w^T \cdot x + b)$$



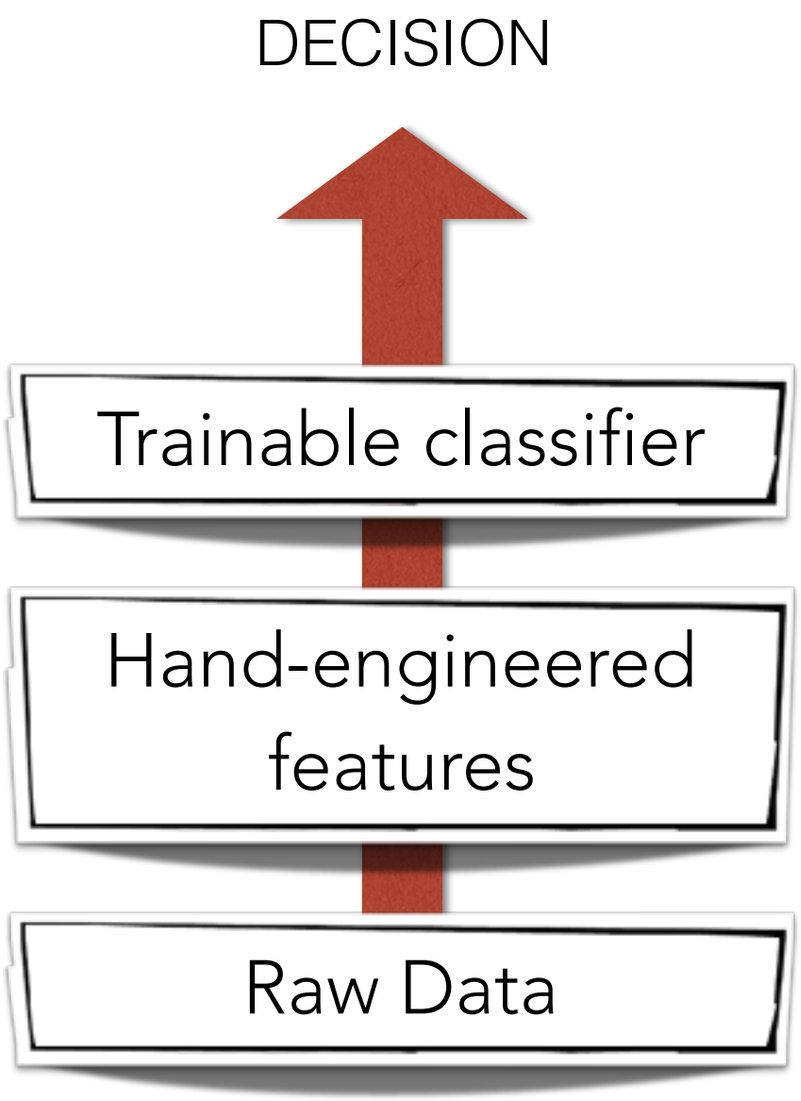
Graphical Representation

2-layer neural net model

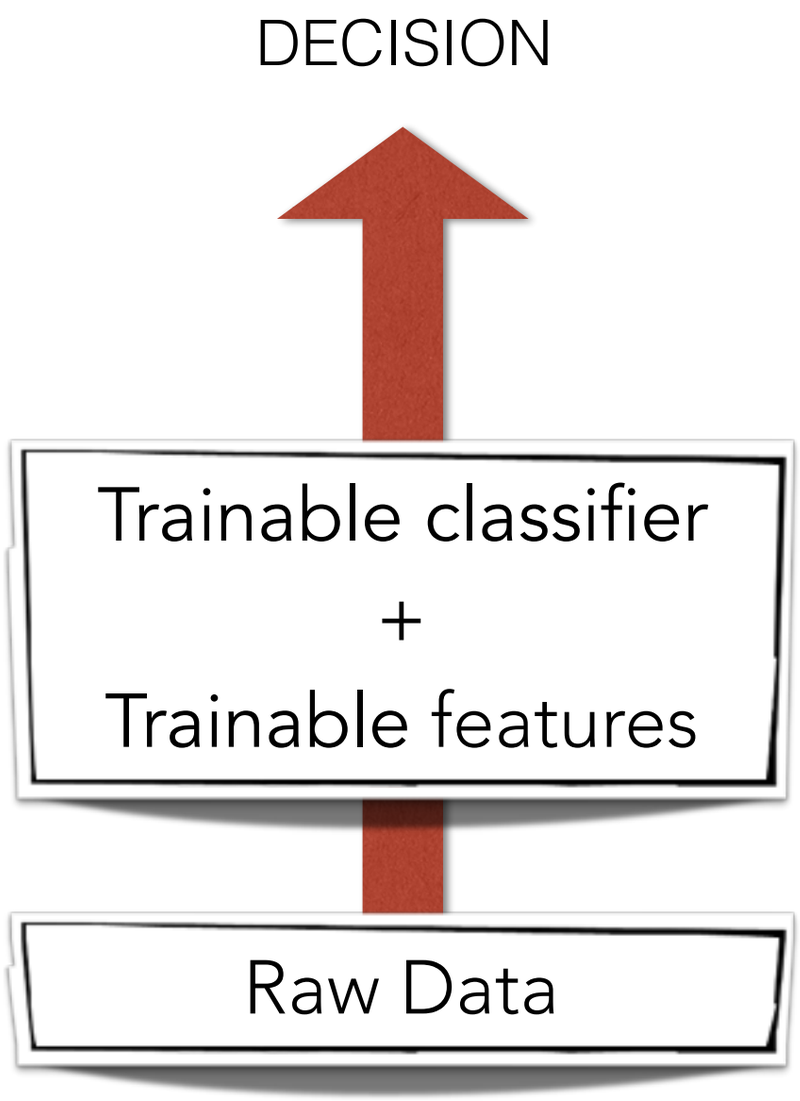




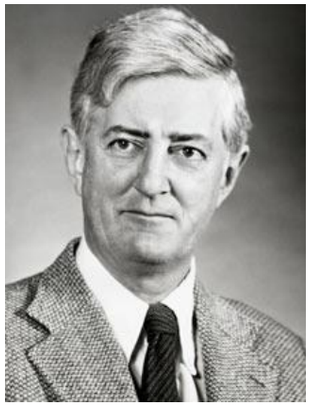
Computing the activation of one layer from the previous one can be written as a matrix-vector multiplication!

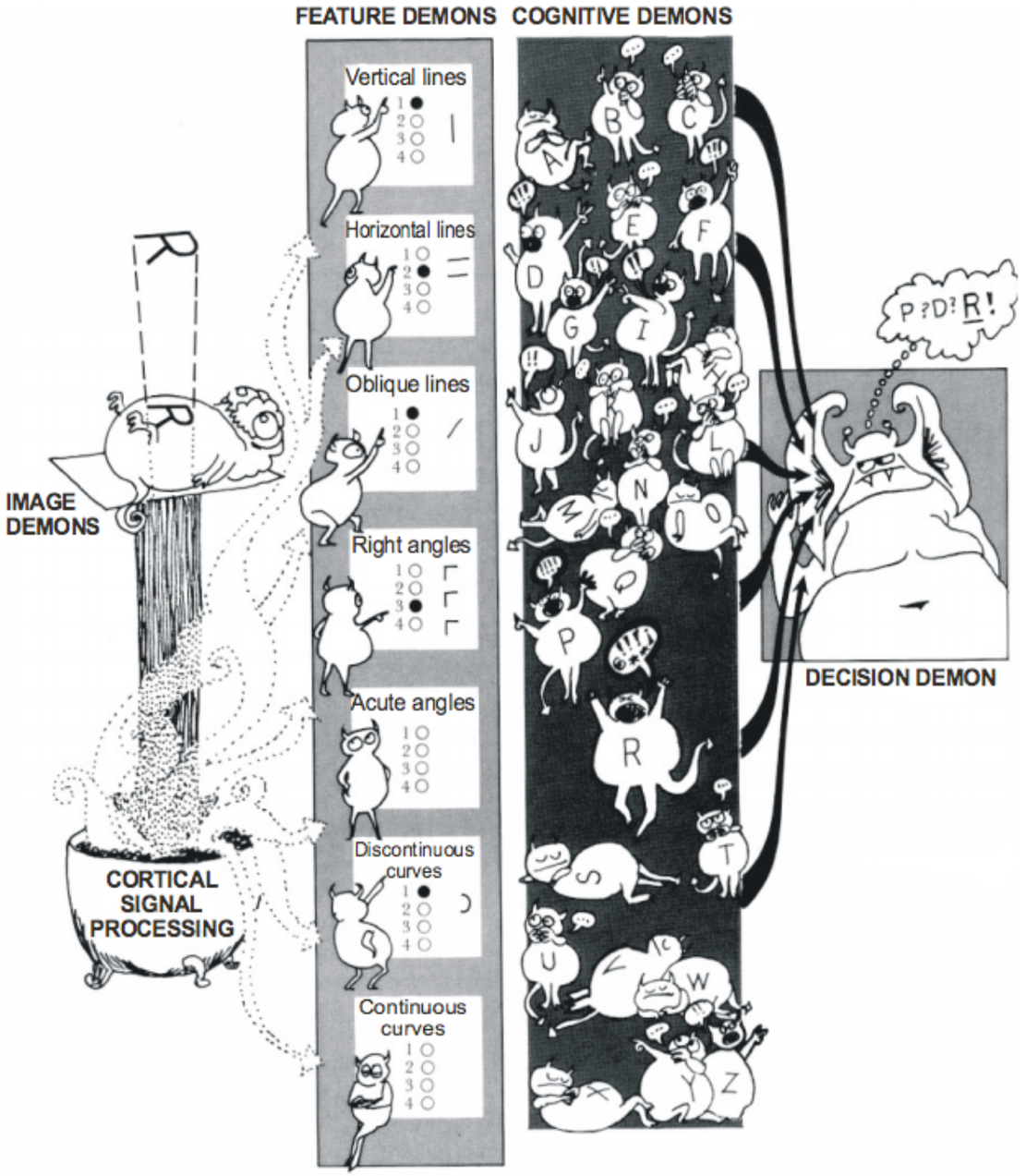


STANDARD MACHINE LEARNING



DEEP LEARNING





Pandemonium

An early architecture of vision, proposed by Oliver Selfridge in 1959.

Hype is not new

1958 New York Times...

NEW NAVY DEVICE LEARNS BY DOING

Psychologist Shows Embryo of Computer Designed to Read and Grow Wiser

WASHINGTON, July 7 (UPI) —The Navy revealed the embryo of an electronic computer today that it expects will be able to walk, talk, see, write, reproduce itself and be conscious of its existence.

The embryo—the Weather Bureau's $2,000,000 "704" computer—learned to differentiate between right and left after fifty attempts in the Navy's demonstration for newsmen.

The service said it would use this principle to build the first of its Perceptron thinking machines that will be able to read and write. It is expected to be finished in about a year at a cost of $100,000.

Dr. Frank Rosenblatt, designer of the Perceptron, conducted the demonstration. He said the machine would be the first device to think as the human brain. As do human beings, Perceptron will make mistakes at first, but will grow wiser as it gains experience, he said.

Dr. Rosenblatt, a research psychologist at the Cornell Aeronautical Laboratory, Buffalo, said Perceptrons might be fired to the planets as mechanical space explorers.

Without Human Controls

The Navy said the perceptron would be the first non-living mechanism "capable of receiving, recognizing and identifying its surroundings without any human training or control."

The "brain" is designed to remember images and information it has perceived itself. Ordinary computers remember only what is fed into them on punch cards or magnetic tape.

Later Perceptrons will be able to recognize people and call out their names and instantly translate speech in one language to speech or writing in another language, it was predicted.

Mr. Rosenblatt said in principle it would be possible to build brains that could reproduce themselves on an assembly line and which would be conscious of their existence.

In today's demonstration, the "704" was fed two cards, one with squares marked on the left side and the other with squares on the right side.

Learns by Doing

In the first fifty trials, the machine made no distinction between them. It then started registering a "Q" for the left squares and "O" for the right squares.

Dr. Rosenblatt said he could explain why the machine learned only in highly technical terms. But he said the computer had undergone a "self-induced change in the wiring diagram."

The first Perceptron will have about 1,000 electronic "association cells" receiving electrical impulses from an eye-like scanning device with 400 photo-cells. The human brain has 10,000,000,000 responsive cells, including 100,000,000 connections with the eyes.