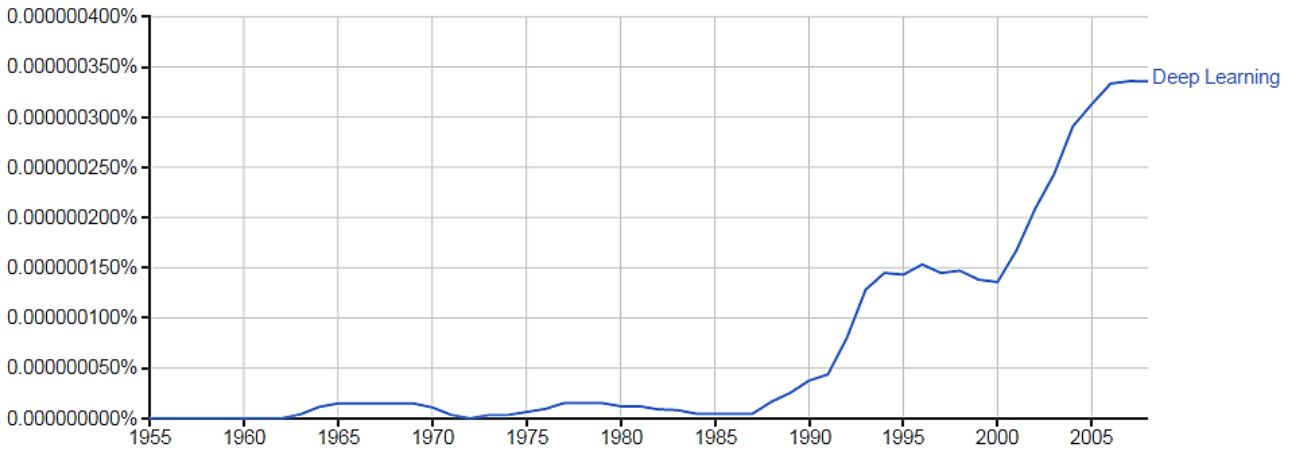
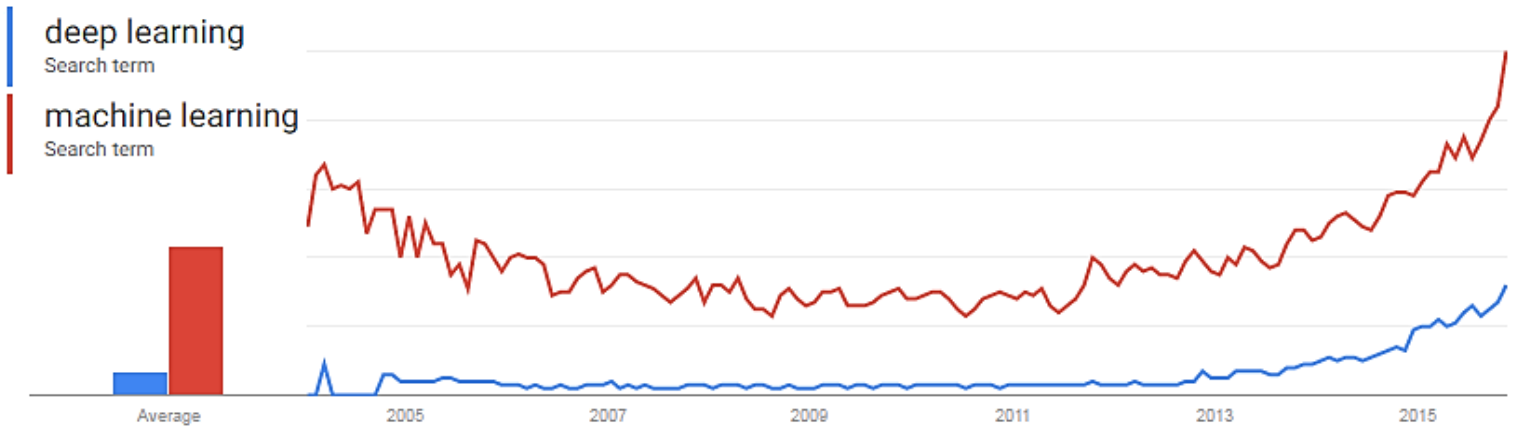
Deep Learning

A Visual Introduction

Interest

Google NGRAM & Google Trends



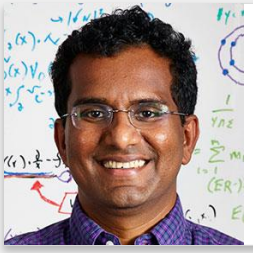


Hype or Reality?

Quotes

I have worked all my life in Machine Learning, and I've never seen one algorithm knock over benchmarks like Deep Learning
– Andrew Ng (Stanford & Baidu)

Deep Learning is an algorithm which has no theoretical limitations of what it can learn; the more data you give and the more computational time you provide, the better it is *– Geoffrey Hinton (Google)*

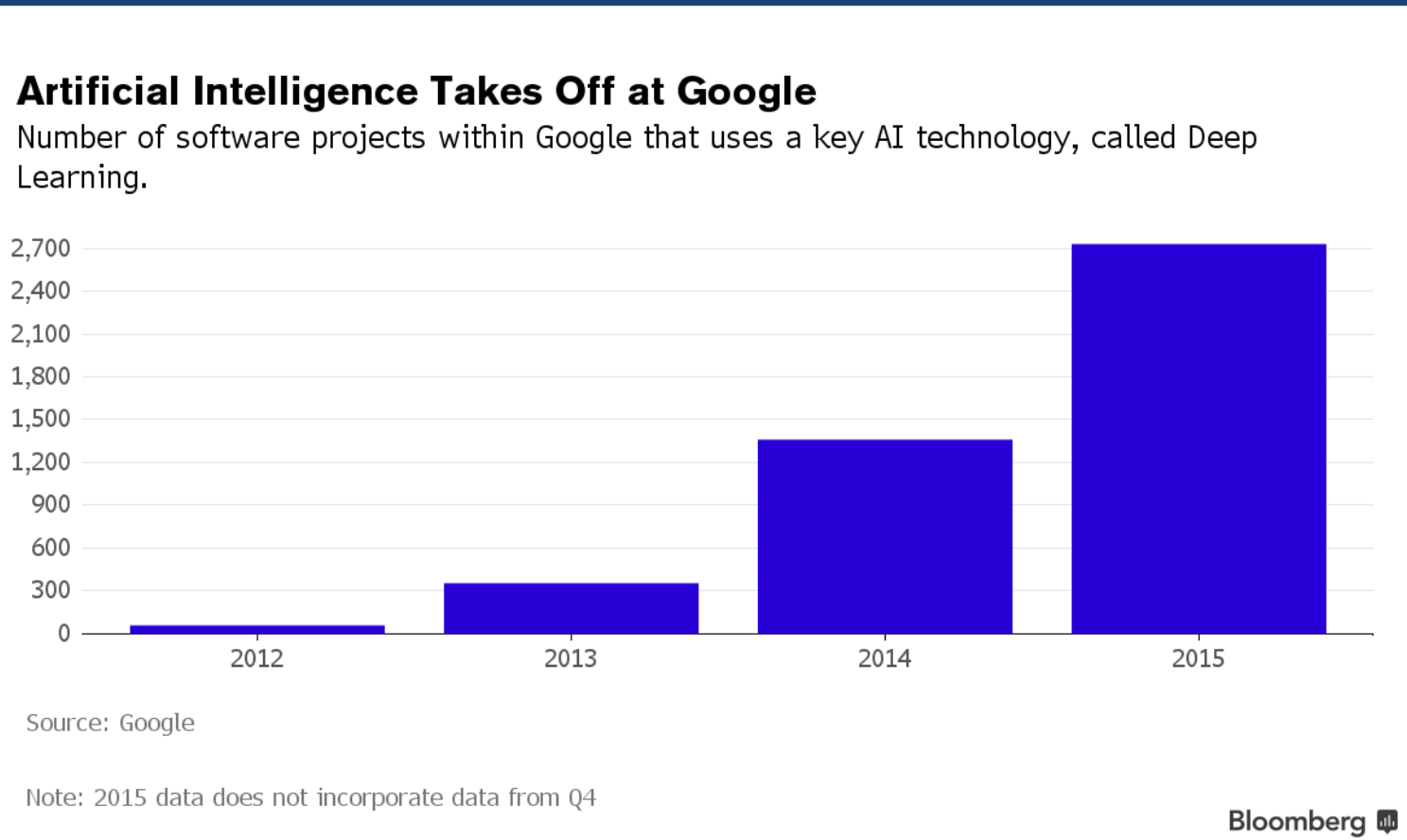


Human-level artificial intelligence has the potential to help humanity thrive more than any invention that has come before it *– Dileep George (Co-Founder Vicarious)*

For a very long time it will be a complementary tool that human scientists and human experts can use to help them with the things that humans are not naturally good *– Demis Hassabis (Co-Founder* DeepMind*)*

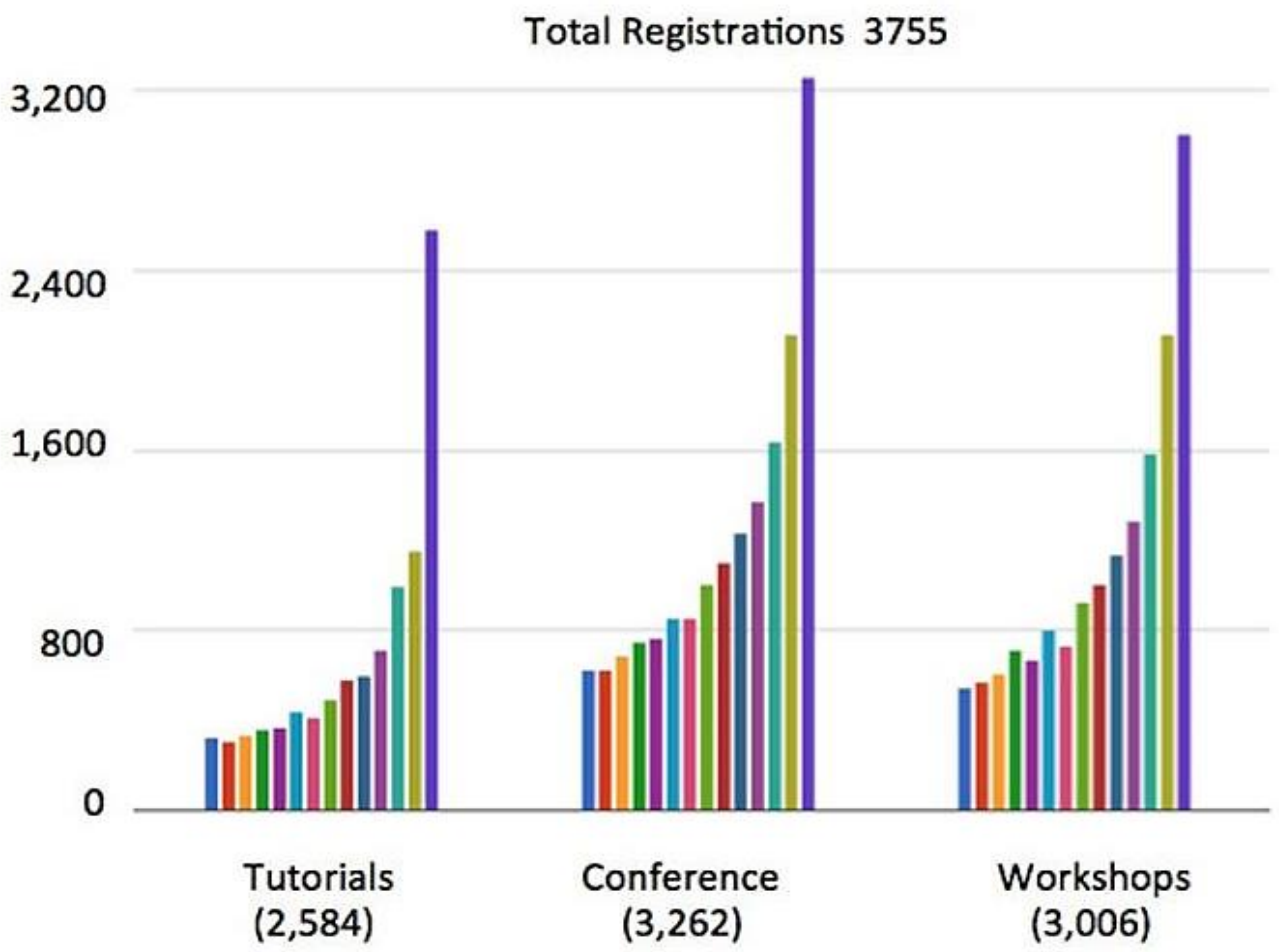
Hype or Reality?

Deep Learning at Google

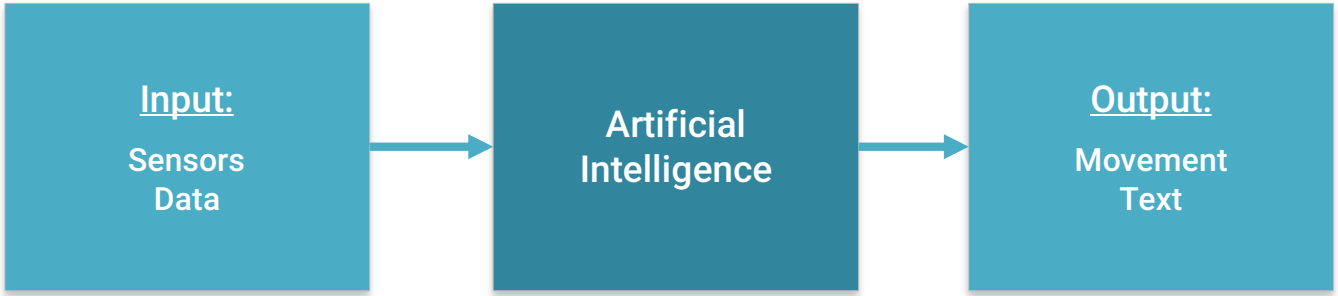


Hype or Reality?

NIPS (Computational Neuroscience Conference) Growth



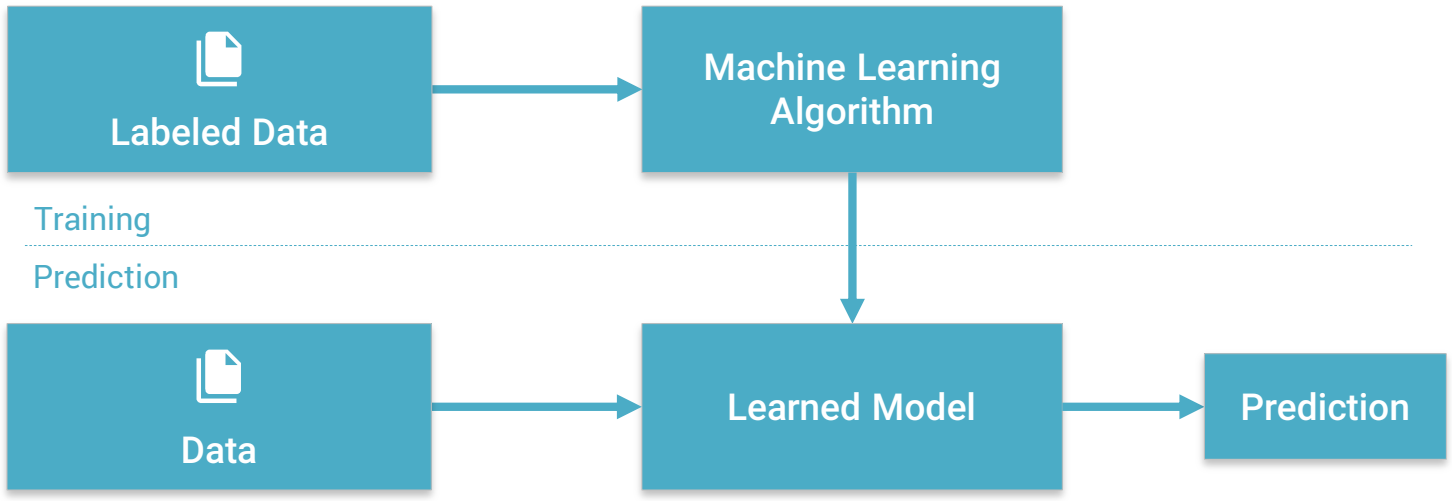
What is Artificial Intelligence?



Machine Learning - Basics

Introduction

Machine Learning is a type of Artificial Intelligence that provides computers with the ability to learn without being explicitly programmed.



Provides various techniques that can learn from and make predictions on data

Machine Learning - Basics

Learning Approaches

Supervised Learning: Learning with a labeled training set
Example: email spam detector with training set of already labeled emails

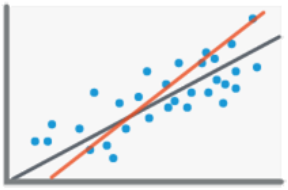
Unsupervised Learning: Discovering patterns in unlabeled data
Example: cluster similar documents based on the text content

Reinforcement Learning: learning based on feedback or reward
Example: learn to play chess by winning or losing

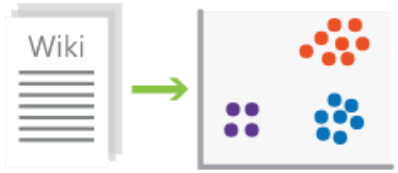
Machine Learning - Basics

Problem Types

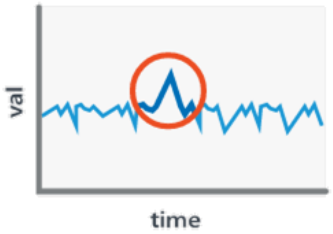
Classification
(supervised – predictive)



Regression
(supervised – predictive)



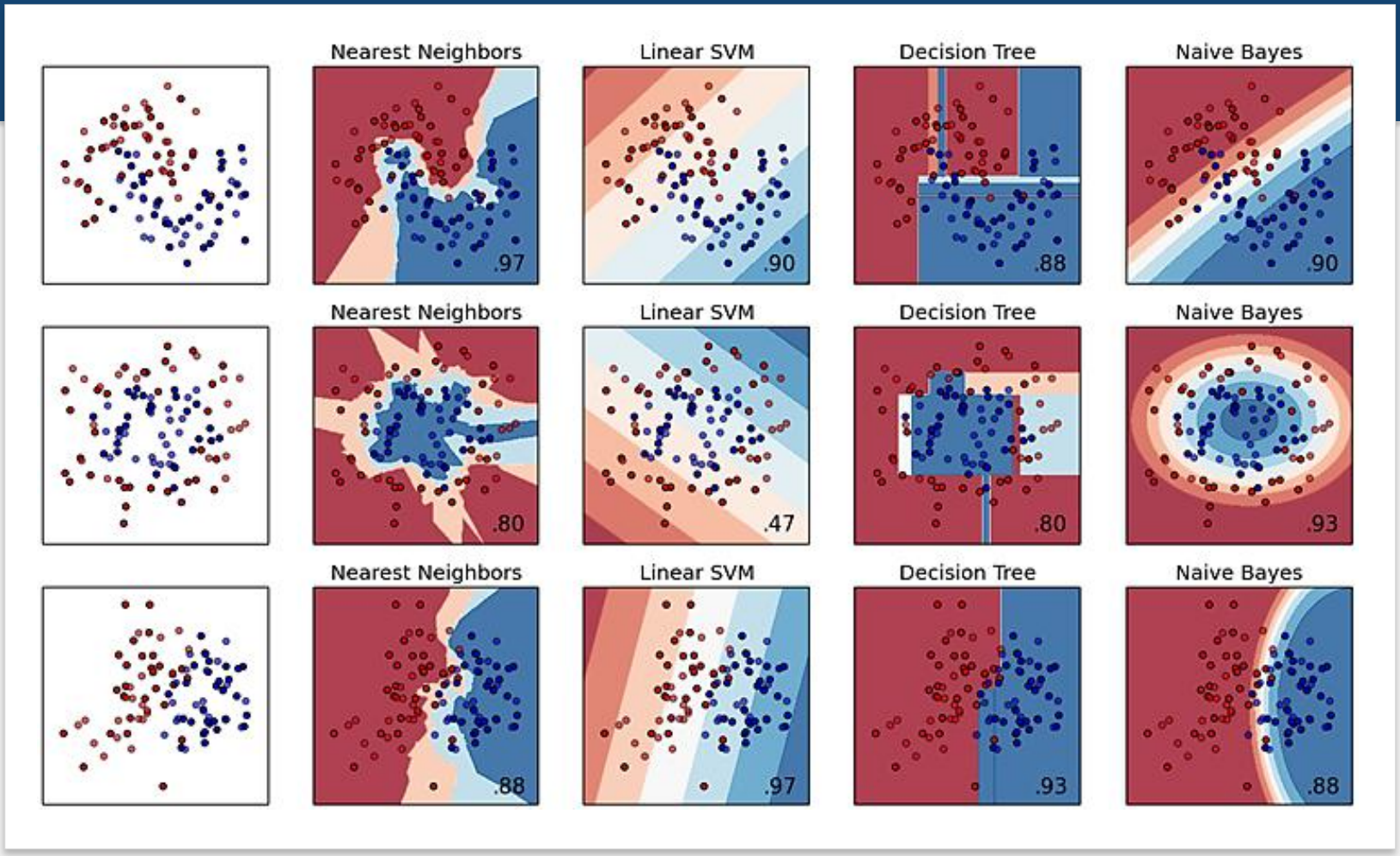
Clustering
(unsupervised – descriptive)



Anomaly Detection
(unsupervised– descriptive)

Machine Learning - Basics

Algorithms Comparison - Classification



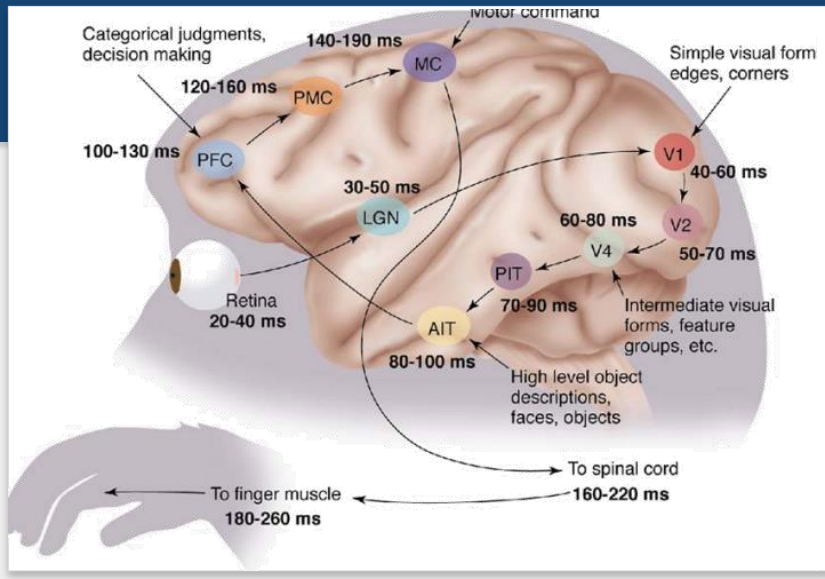
What is Deep Learning?

Part of the machine learning field of learning representations of data. Exceptional effective at learning patterns.

Utilizes learning algorithms that derive meaning out of data by using a hierarchy of multiple layers that mimic the neural networks of our brain.

If you provide the system tons of information, it begins to understand it and respond in useful ways.

Inspired by the Brain



The first hierarchy of neurons that receives information in the visual cortex are sensitive to specific edges while brain regions further down the visual pipeline are sensitive to more complex structures such as faces.

Our brain has lots of neurons connected together and the strength of the connections between neurons represents long term knowledge.

1

One learning algorithm hypothesis: all significant mental algorithms are learned except for the learning and reward machinery itself.

Why Deep Learning?

Applications

Speech Recognition

Computer Vision

Natural Language Processing

A brief History

A long time ago…

1958 Perceptron

1974 Backpropagation

Convolution Neural Networks for Handwritten Recognition

1998

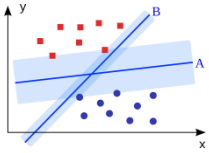
Google Brain Project on 16k Cores

2012

awkward silence (AI Winter)

1969
Perceptron criticized

1995
SVM reigns



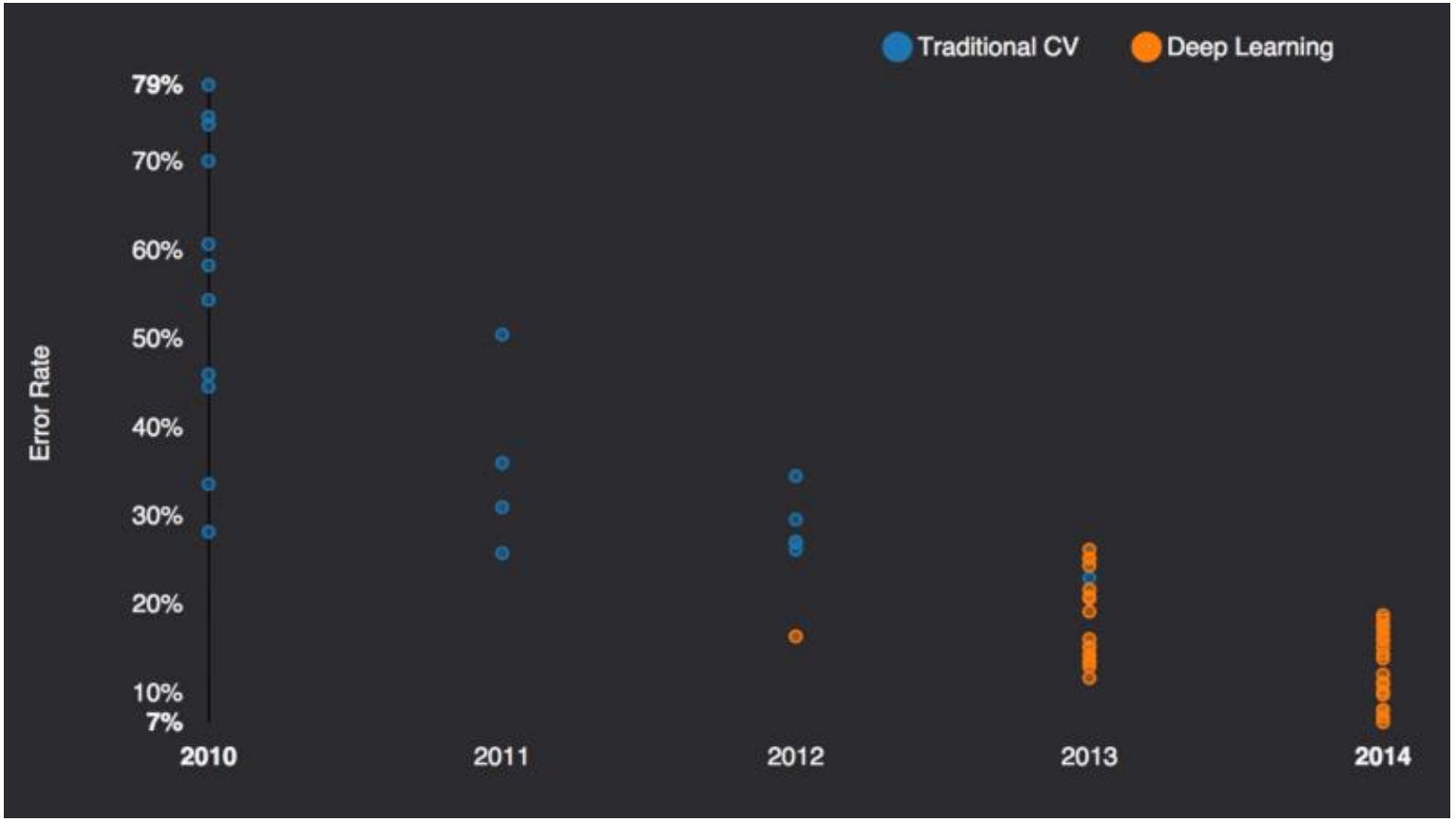
2006
Restricted Boltzmann Machine

2012
AlexNet wins ImageNet

IMAGENET

A brief History

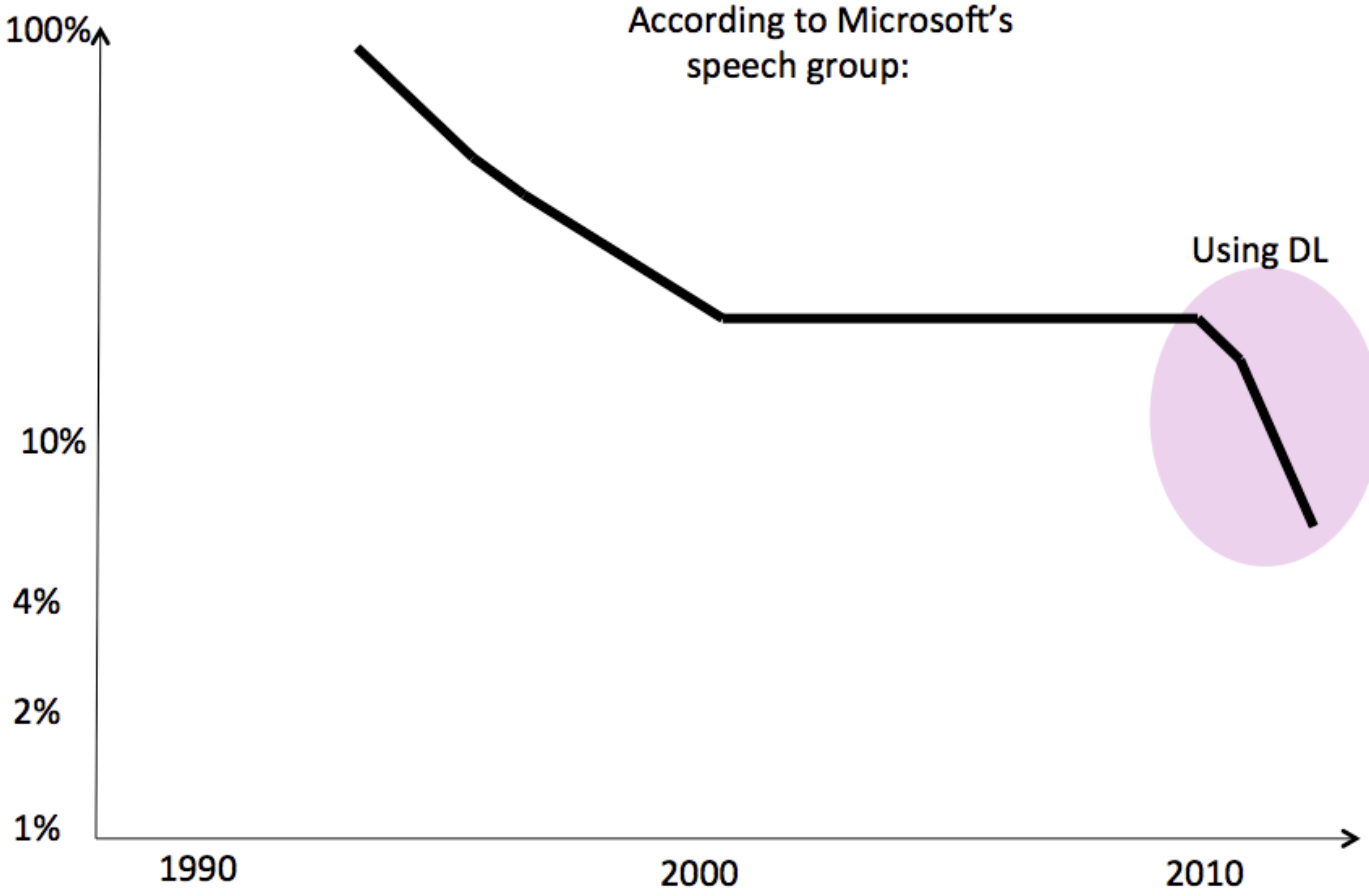
The Big Bang aka “One net to rule them all”



ImageNet: The “computer vision World Cup”

A brief History

The Big Bang aka “One net to rule them all”

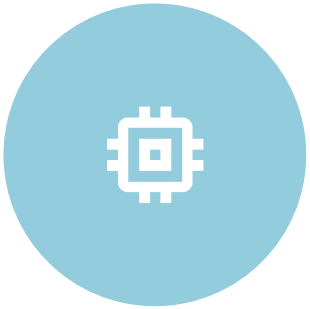


Deep Learning in Speech Recognition

What changed?

Old wine in new bottles

Big Data
(Digitalization)



Computation
(Moore's Law, GPUs)

Algorithmic
Progress

The Big Players

Superstar Researchers

Geoffrey Hinton: University of Toronto & Google

Yann LeCun: New York University & Facebook

Andrew Ng: Stanford & Baidu

Yoshua Bengio: University of Montreal

Jürgen Schmidhuber: Swiss AI Lab & NNAISENSE

The Big Players

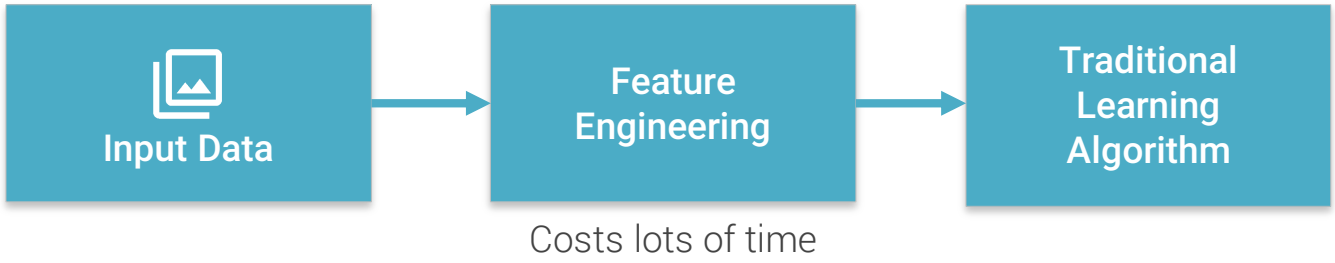
Companies

The Big Players

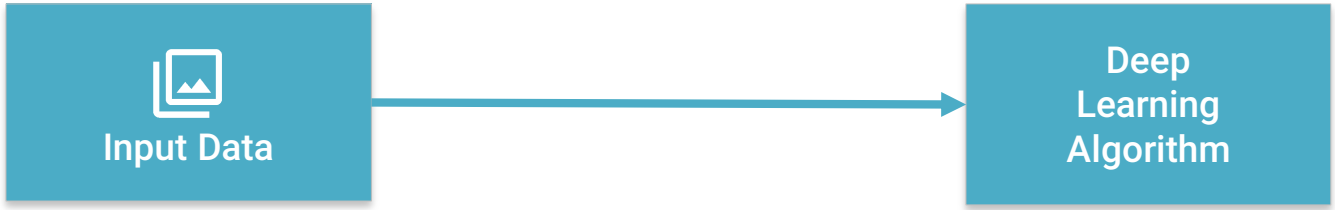
Startups

Deep Learning - Basics

No more feature engineering

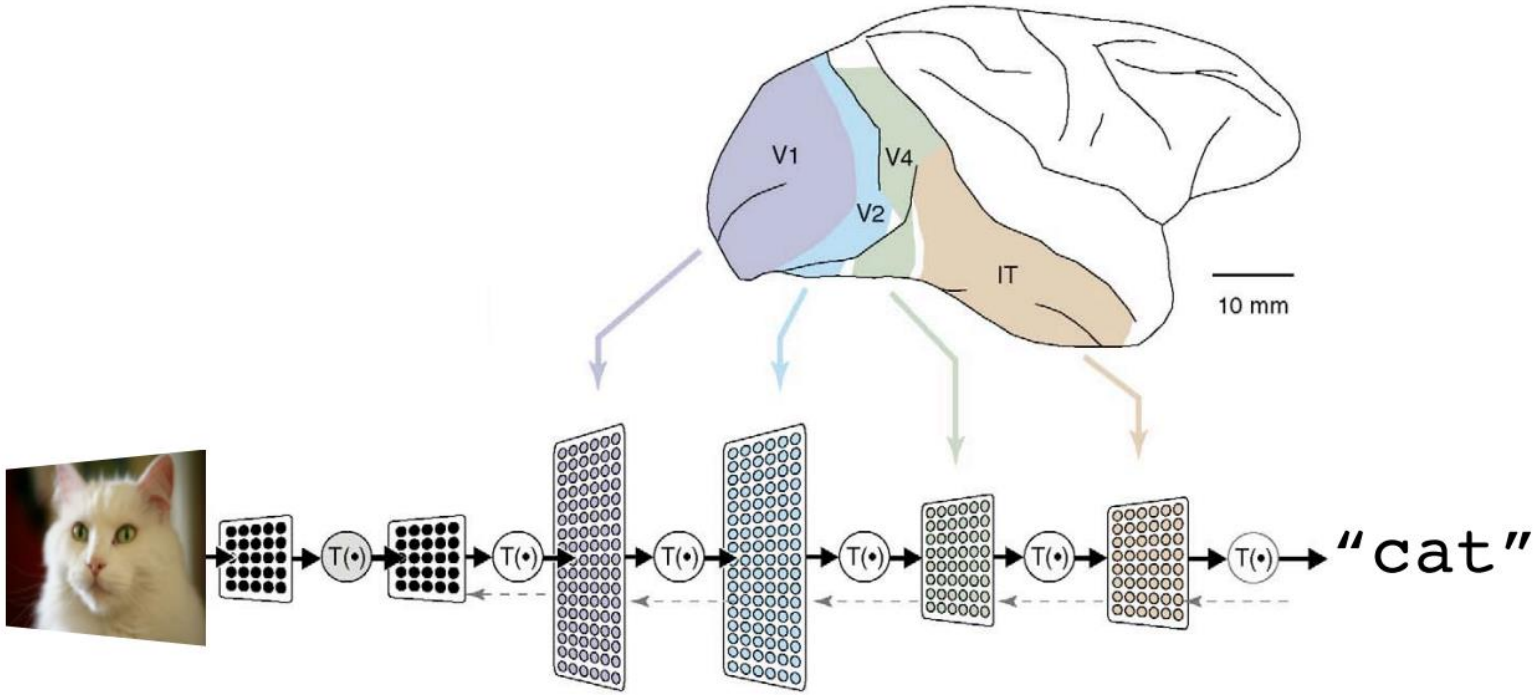


Costs lots of time



Deep Learning - Basics

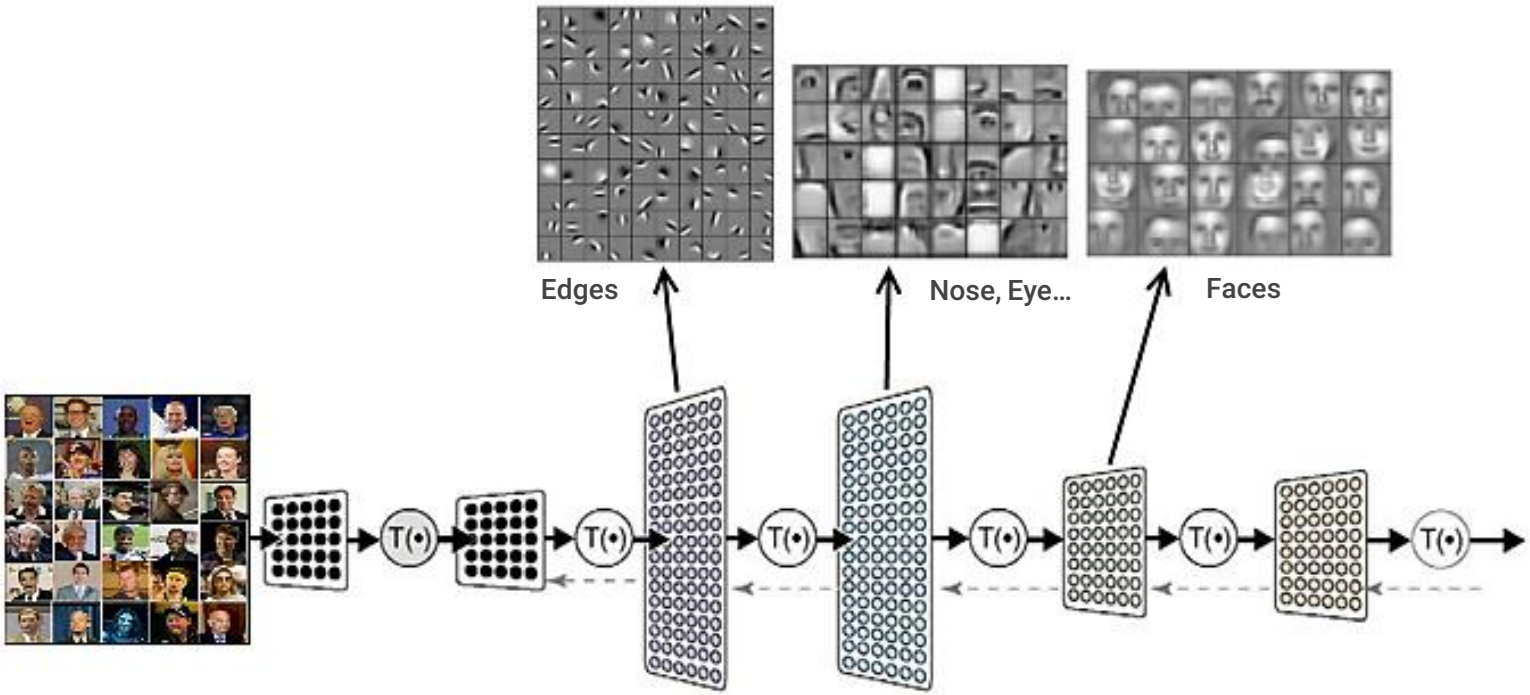
Architecture



A deep neural network consists of a hierarchy of layers, whereby each layer transforms the input data into more abstract representations (e.g. edge -> nose -> face). The output layer combines those features to make predictions.

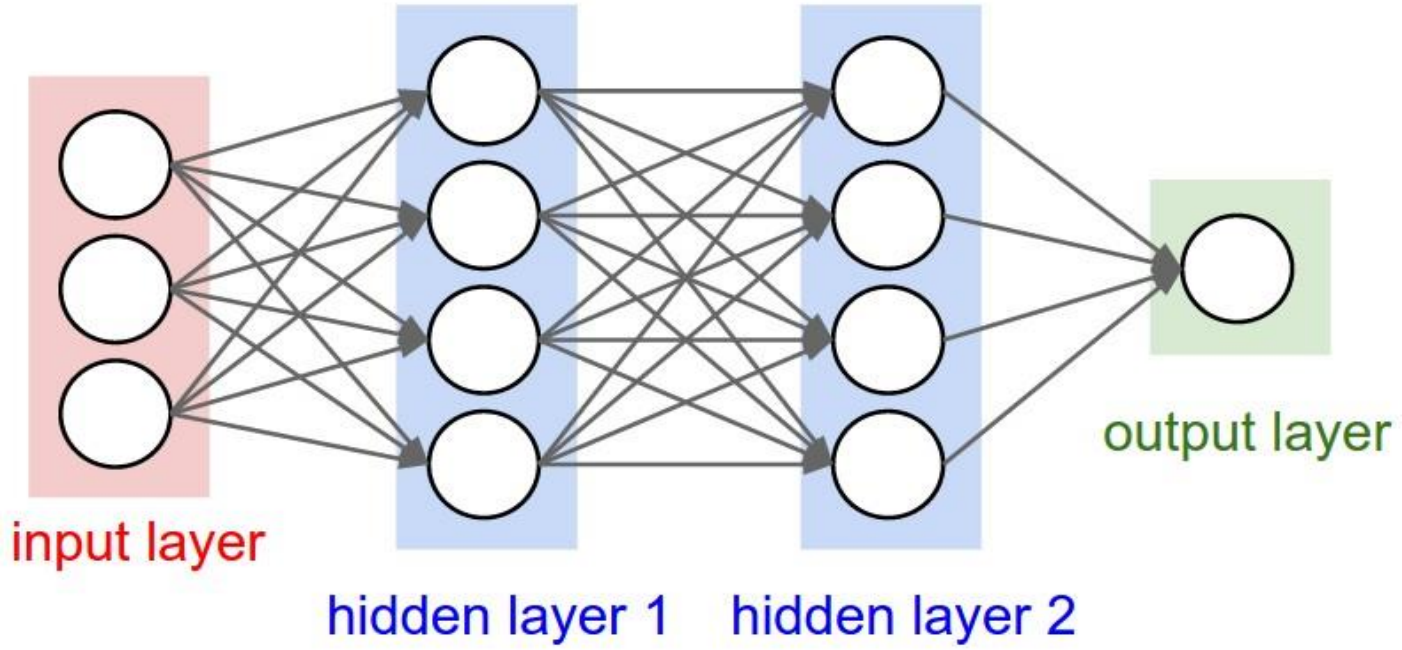
Deep Learning - Basics

What did it learn?



Deep Learning - Basics

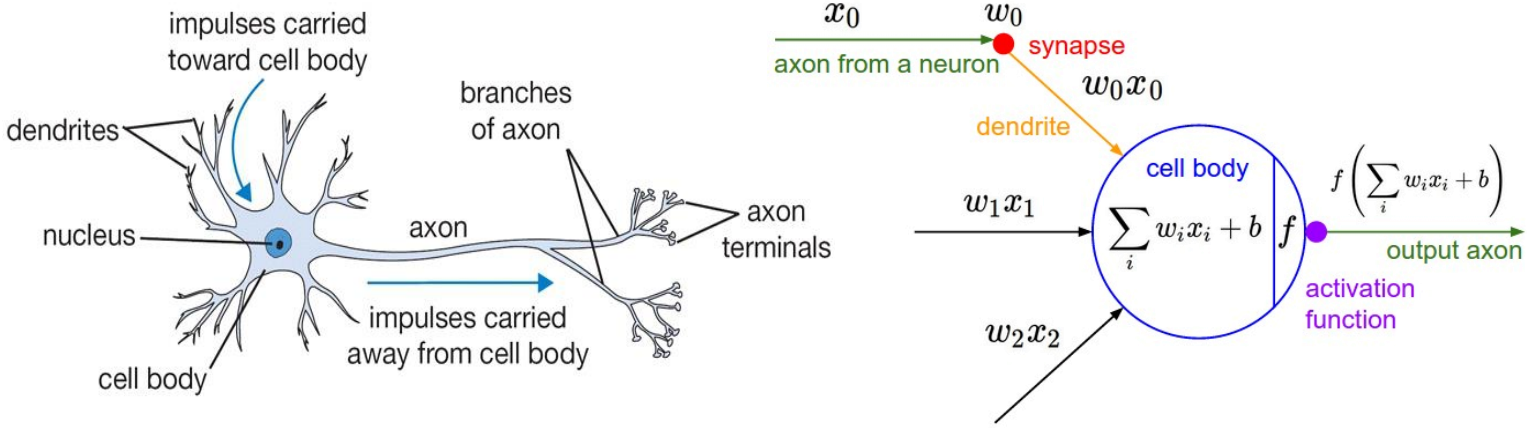
Artificial Neural Networks



Consists of one input, one output and multiple fully-connected hidden layers in-between. Each layer is represented as a series of neurons and progressively extracts higher and higher-level features of the input until the final layer essentially makes a decision about what the input shows. The more layers the network has, the higher-level features it will learn.

Deep Learning - Basics

The Neuron

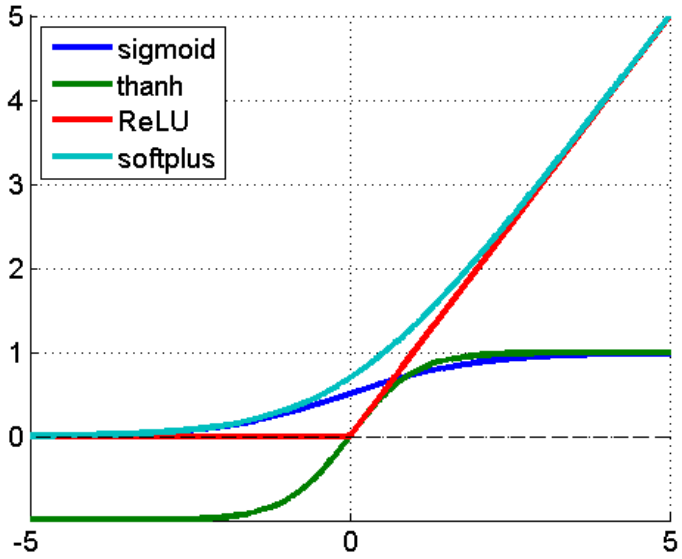


An artificial neuron contains a nonlinear activation function and has several incoming and outgoing weighted connections.

Neurons are trained to filter and detect specific features or patterns (e.g. edge, nose) by receiving weighted input, transforming it with the activation function und passing it to the outgoing connections.

Deep Learning - Basics

Non-linear Activation Function

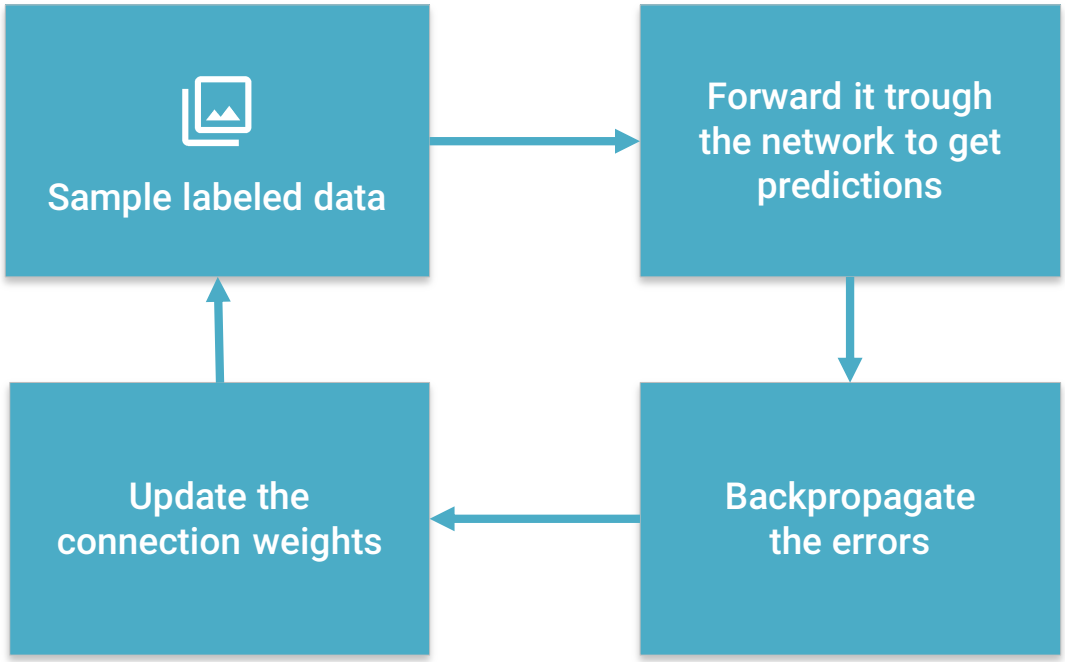


Most deep networks use ReLU - max(0,x) - nowadays for hidden layers, since it trains much faster, is more expressive than logistic function and prevents the gradient vanishing problem.

Non-linearity is needed to learn complex (non-linear) representations of data, otherwise the NN would be just a linear function.

Deep Learning - Basics

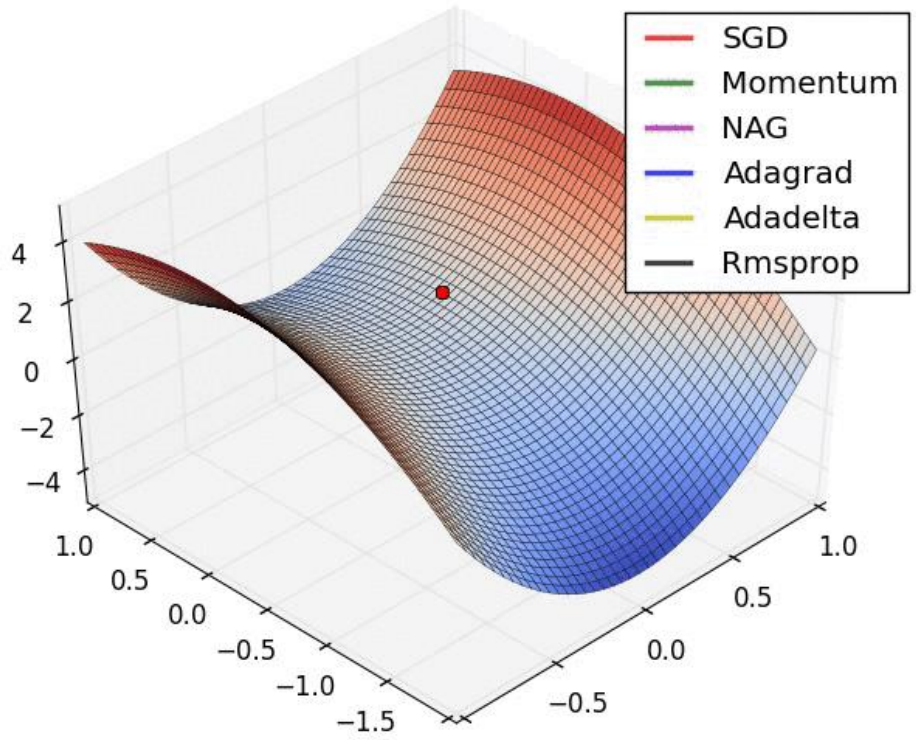
The Training Process



Learns by generating an error signal that measures the difference between the predictions of the network and the desired values and then using this error signal to change the weights (or parameters) so that predictions get more accurate.

Deep Learning - Basics

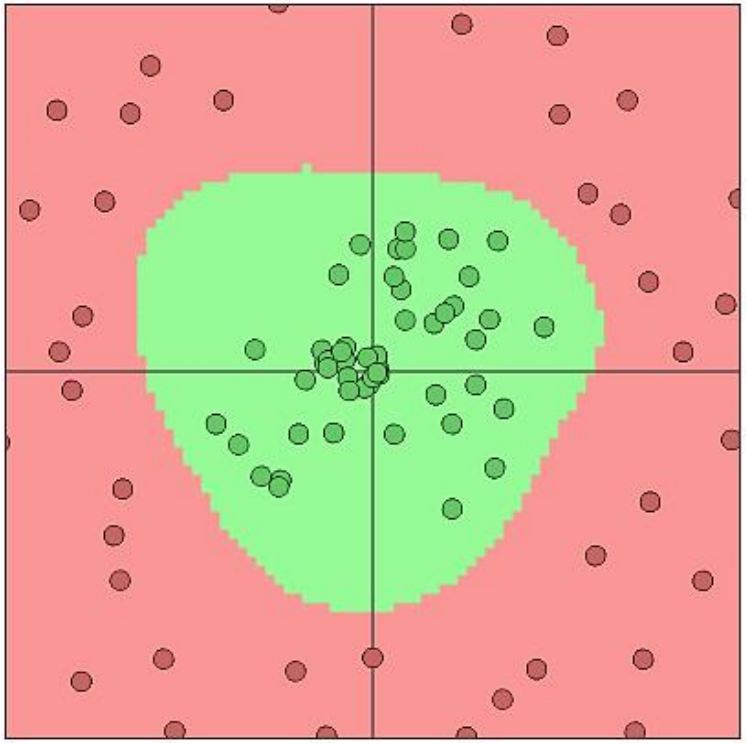
Gradient Descent

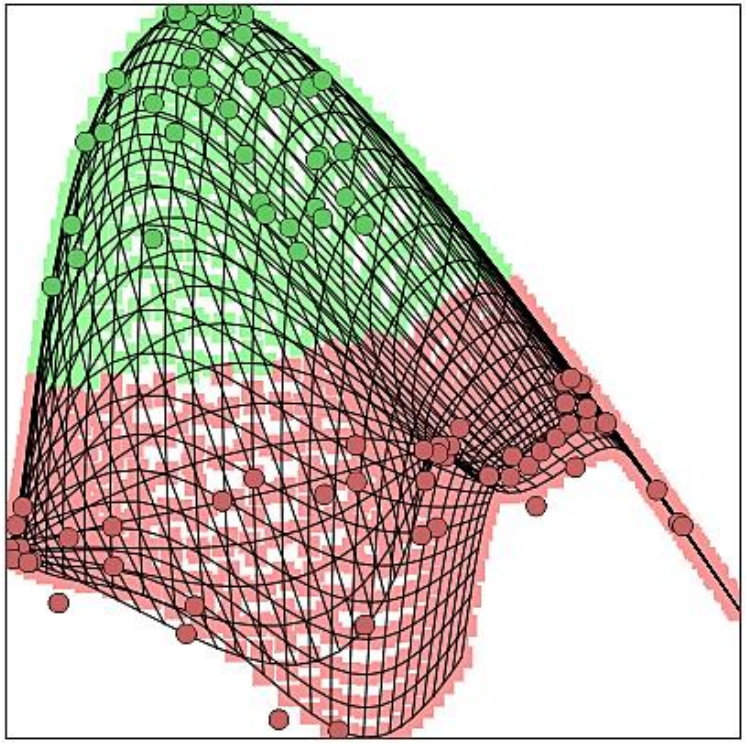


Gradient Descent finds the (local) the minimum of the cost function (used to calculate the output error) and is used to adjust the weights.

Deep Learning - Basics

Data transformation in other dimensions

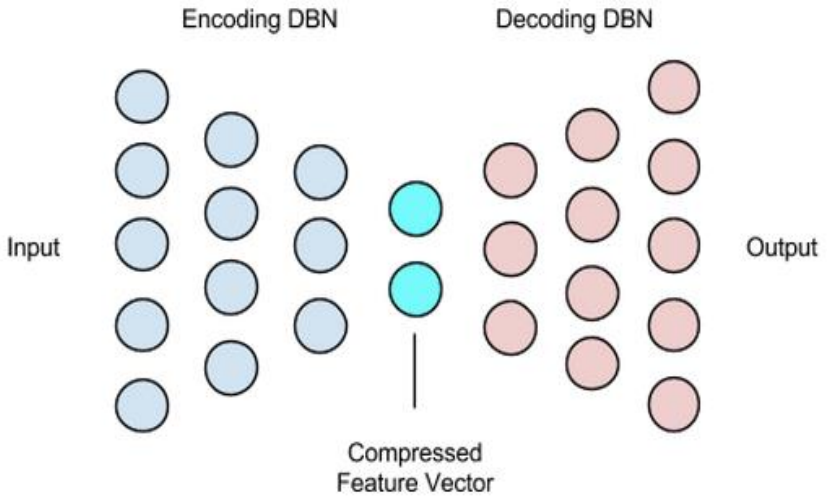




A neural network is transforming the data into other dimensions to solve the specified problem.

Deep Learning - Basics

Deep Autoencoders



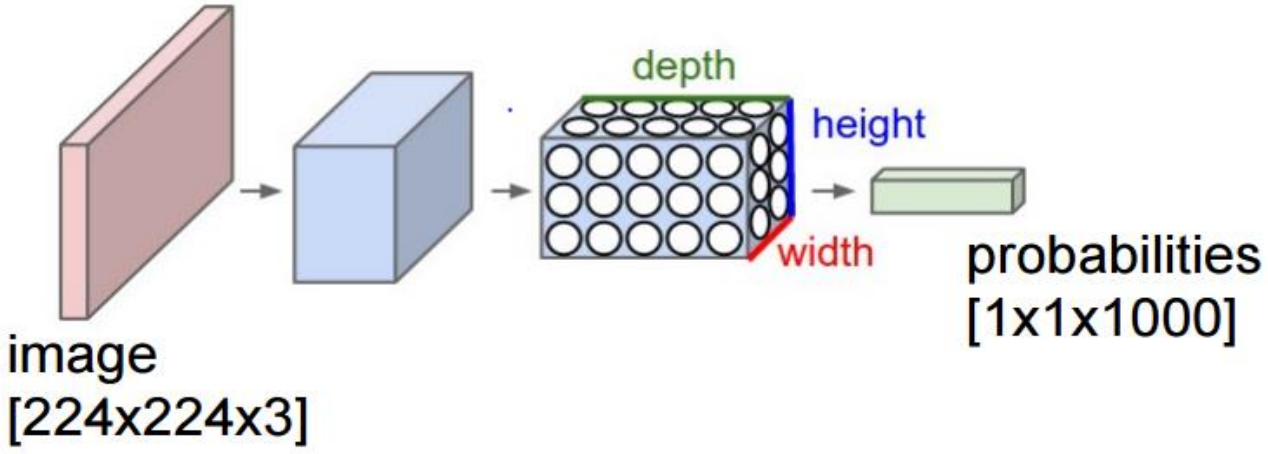
Composed of two symmetrical deep-belief networks. The encoding network learns to compresses the input to a condensed vector (dimensionality reduction). The decoding network can be used to reconstruct the data.

Topic Modeling: Document in a collection is converted to a Bag-of-Words and transformed to a compressed feature vector using an autoencoder. The distance from every other document-vector can be measured and nearby document-vectors fall under the same topic.

Deep Learning - Basics

Convolutional Neural Nets (CNN)

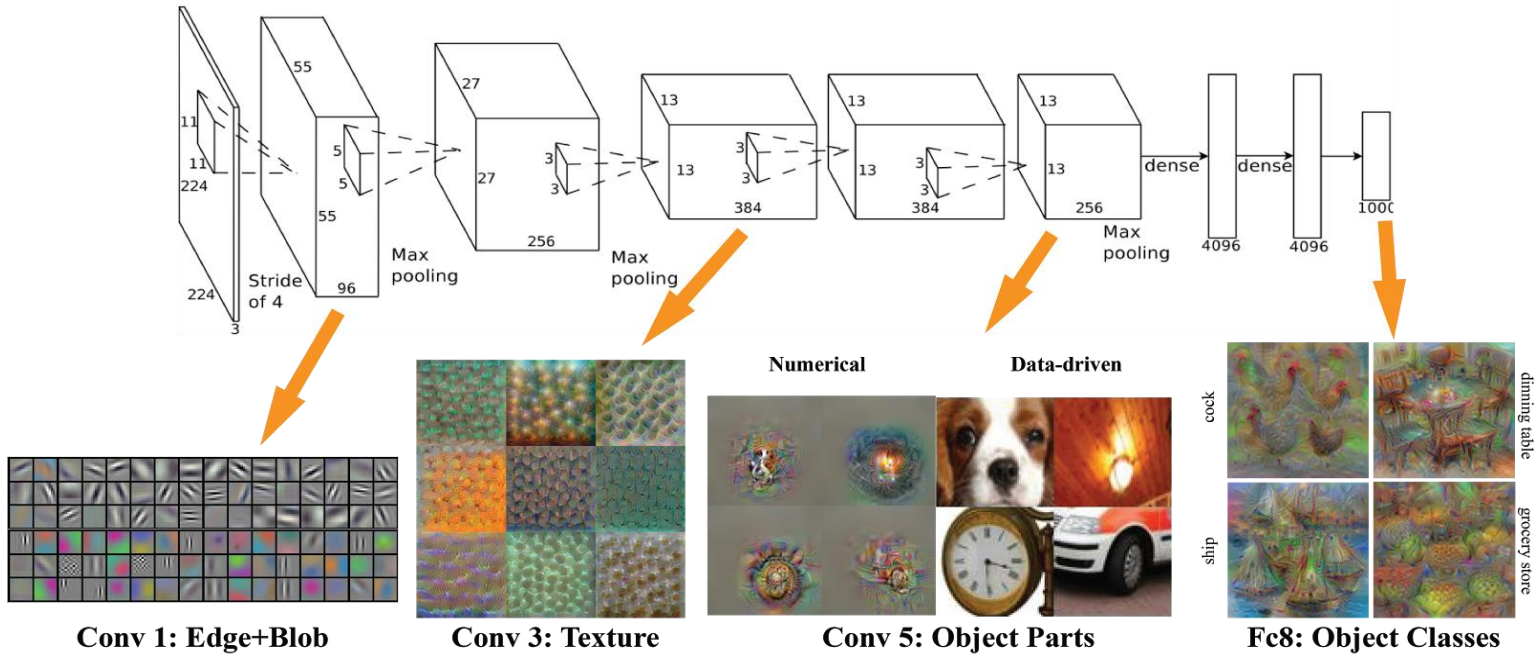
Convolutional Neural Networks learn a complex representation of visual data using vast amounts of data. They are inspired by the human visual system and learn multiple layers of transformations, which are applied on top of each other to extract a progressively more sophisticated representation of the input.



Every layer of a CNN takes a 3D volume of numbers and outputs a 3D volume of numbers. E.g. Image is a 224*224*3 (RGB) cube and will be transformed to 1*1000 vector of probabilities.

Deep Learning - Basics

Convolutional Neural Nets (CNN)

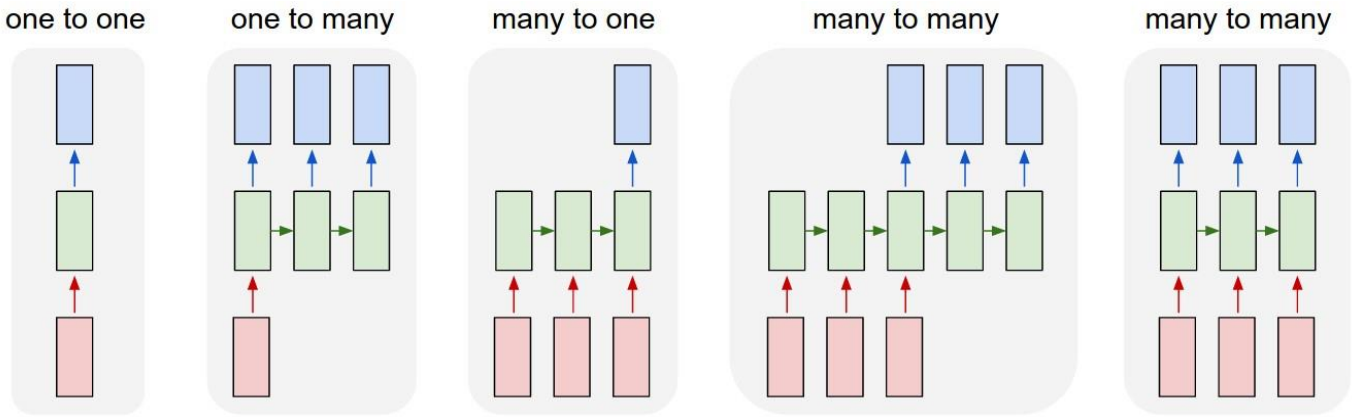


Convolution layer is a feature detector that automagically learns to filter out not needed information from an input by using convolution kernel.

Pooling layers compute the max or average value of a particular feature over a region of the input data *(downsizing of input images).* Also helps to detect objects in some unusual places and reduces memory size.

Deep Learning - Basics

Recurrent Neural Nets (RNN)

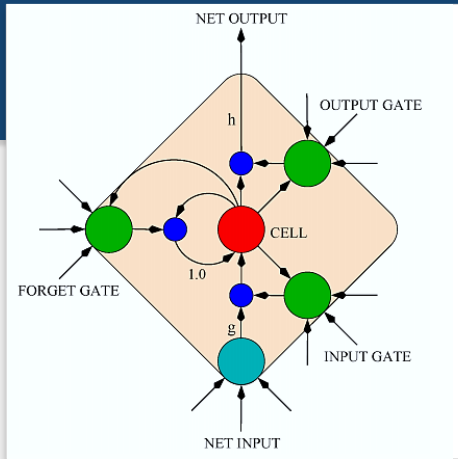


RNNs are general computers which can learn algorithms to map input sequences to output sequences (flexible-sized vectors). The output vector's contents are influenced by the entire history of inputs.

State-of-the-art results in time series prediction, adaptive robotics, handwriting recognition, image classification, speech recognition, stock market prediction, and other sequence learning problems. *Everything can be processed sequentially.*

Deep Learning - Basics

Long Short-Term Memory RNN (LSTM)



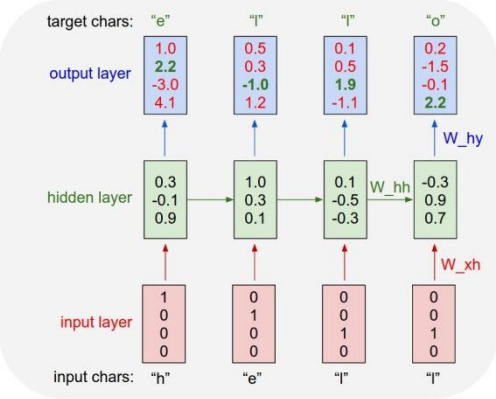
A Long Short-Term Memory (LSTM) network is a particular type of recurrent network that works slightly better in practice, owing to its more powerful update equation and some appealing back propagation dynamics.

The **LSTM units** give the network memory cells with read, write and reset operations. During training, the network can learn when it should remember data and when it should throw it away.

Well-suited to learn from experience to classify, process and predict time series when there are very long time lags of unknown size between important events.

Deep Learning - Basics

Recurrent Neural Nets (RNN) – Generating Text



To train the RNN, insert characters sequentially and predict the probabilities of the next letter. Backpropagate error and update RNN's weights to increase the confidence of the correct letter (green) and decrease the confidence of all other letters (red).

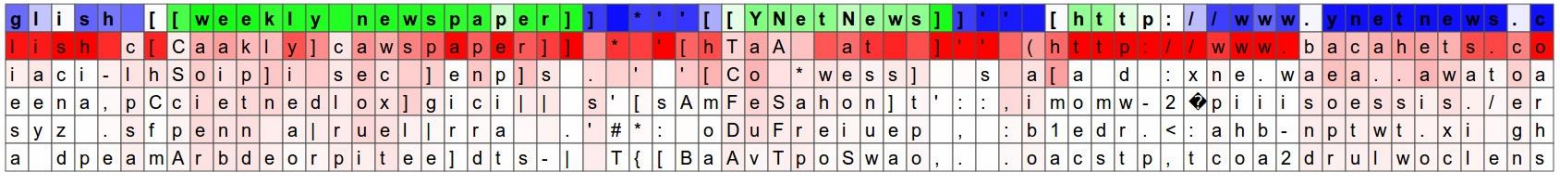
```
The emperor travelled back to [[Antioch, Perth, October 25|21]] to note, the Kingdom
of Costa Rica, unsuccessful fashioned the [[Thrales]], [[Cynth's Dajoard]], known
in western [[Scotland]], near Italy to the conquest of India with the conflict.
Copyright was the succession of independence in the slop of Syrian influence that
was a famous German movement based on a more popular servicious, non-doctrinal
and sexual power post. Many governments recognize the military housing of the
[[Civil Liberalization and Infantry Resolution 265 National Party in Hungary]],
that is sympathetic to be to the [[Punjab Resolution]]
(PJS)[http://www.humah.yahoo.com/guardian.cfm/7754800786d17551963s89.htm]
```

Trained on structured Wikipedia markdown. Network learns to spell English words completely from scratch and copy general syntactic structures.

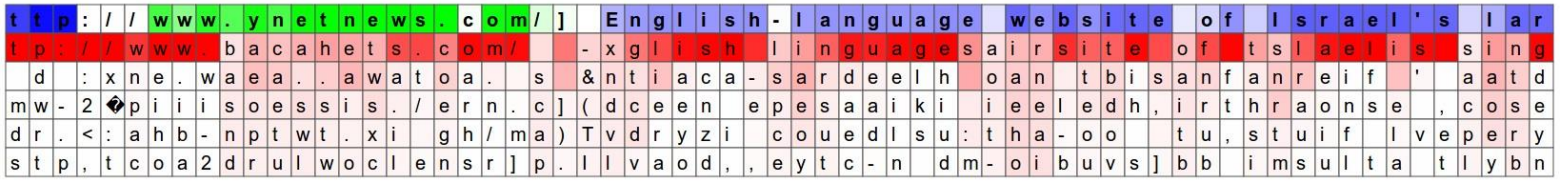
Deep Learning - Basics

Recurrent Neural Nets (RNN) – Generating Text

To generate text, we feed a character into the trained RNN and get a distribution over what characters are likely to come next *(red = likely)*. We sample from this distribution, and feed it right back in to get the next letter.



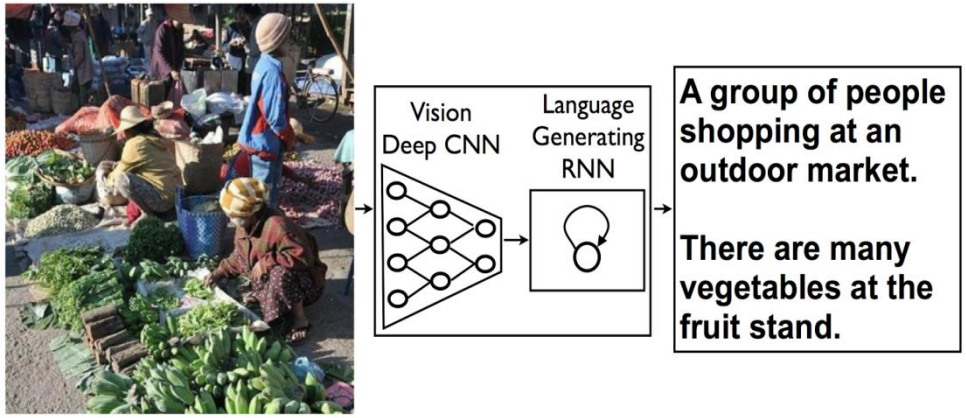
This highlighted neuron gets very excited *(green = excited, blue = not excited)* when the RNN is inside the [[ ]] markdown environment and turns off outside of it.



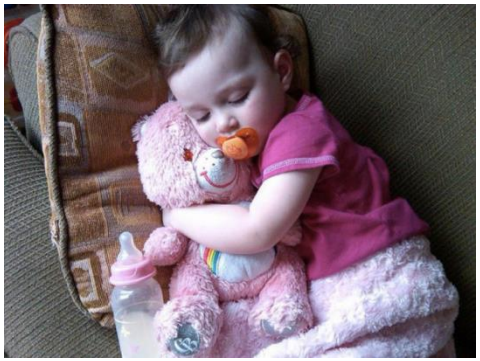
The RNN is likely using this neuron to remember if it is inside a URL or not.

Deep Learning - Basics

Image Captioning – Combining CNN and RNN



Neural Image Caption Generator generates fitting natural-language captions only based on the pixels by combining a vision CNN and a language-generating RNN.



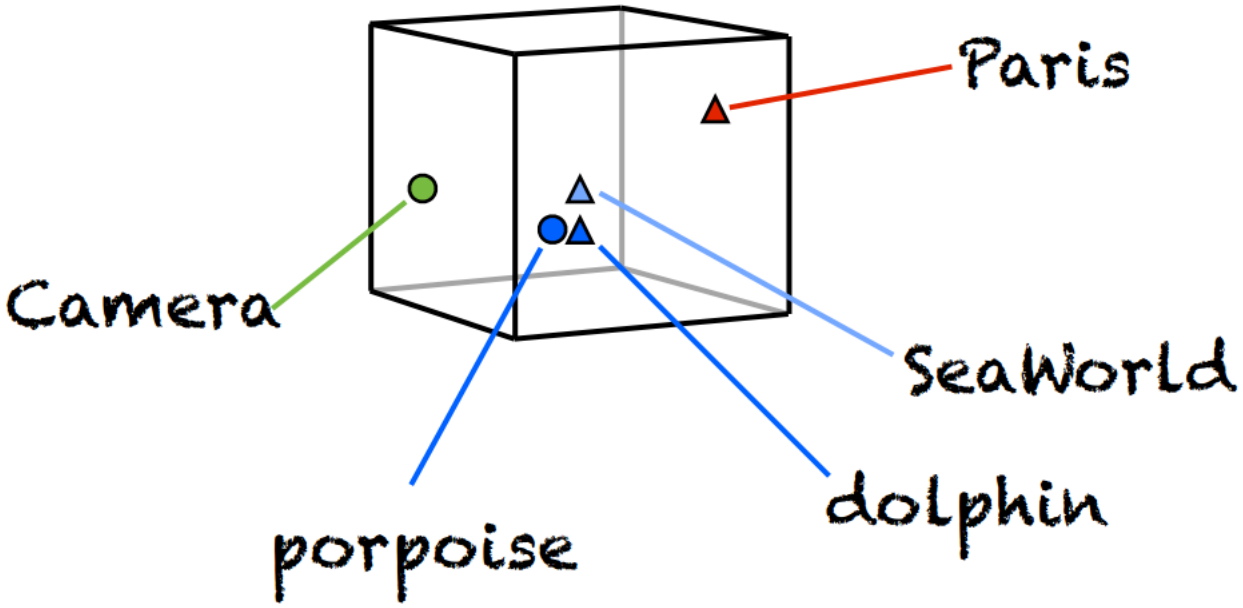
A close up of a child holding a stuffed animal

Two pizzas sitting on top of a stove top oven

A man flying through the air while riding a skateboard

Deep Learning - Basics

Natural Language Processing – Embeddings

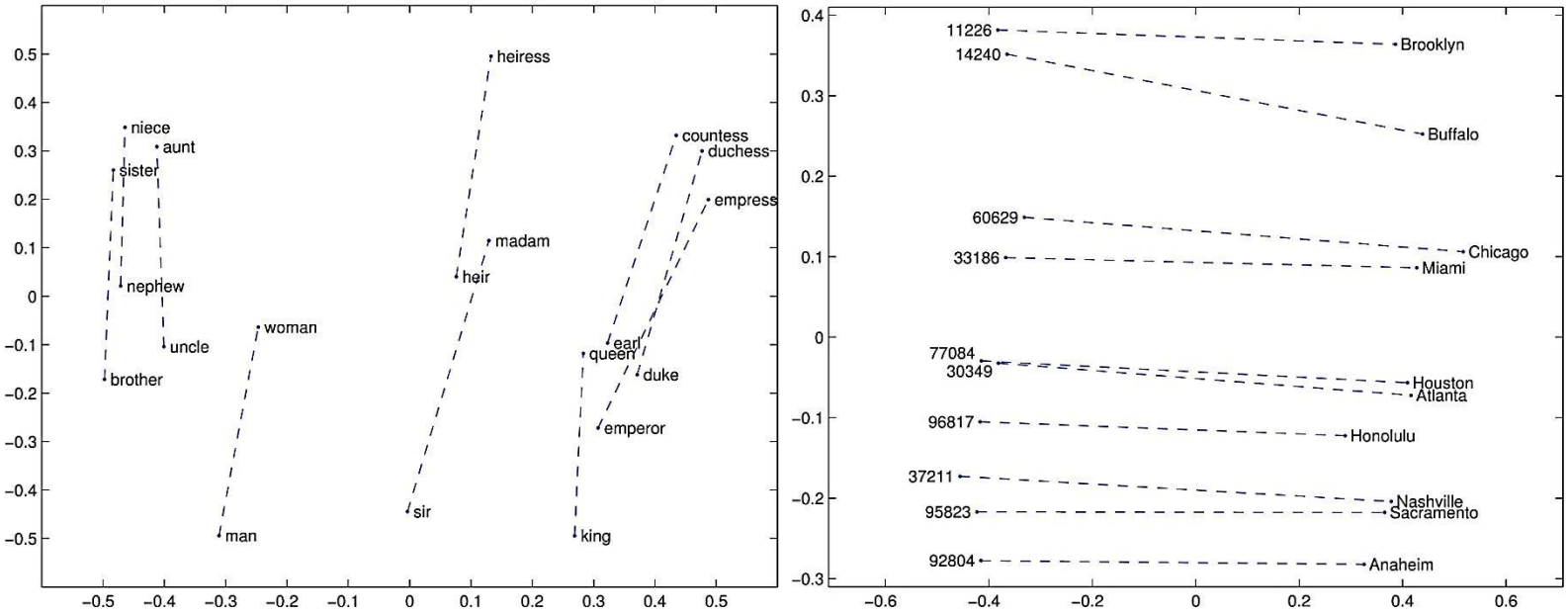


Embeddings are used to turn textual data (words, sentences, paragraphs) into high-dimensional vector representations and group them together with semantically similar data in a vectorspace. Thereby, computer can detect similarities mathematically.

Deep Learning - Basics

Natural Language Processing – Word2Vec

Word2Vec is an unsupervised learning algorithm for obtaining vector representations for words. These vectors were trained for a specific domain on a very large textual data set. GloVe is a better performing alternative.

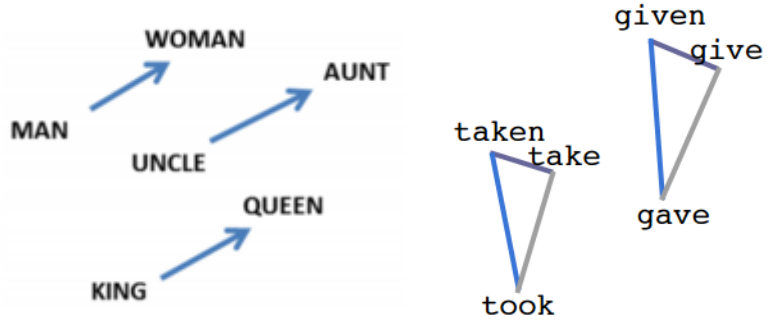


It detects similarities mathematically by grouping the vectors of similar words together. All it needs is words co-occurance in the given corpus.

Deep Learning - Basics

Natural Language Processing – Word2Vec

FRANCE	JESUS	XBOX	REDDISH	SCRATCHED	MEGABITS
AUSTRIA	GOD	AMIGA	GREENISH	NAILED	OCTETS
BELGIUM	SATI	PLAYSTATION	BLUISH	SMASHED	MB/S
GERMANY	CHRIST	MSX	PINKISH	PUNCHED	BIT/S
ITALY	SATAN	IPOD	PURPLISH	POPPED	BAUD
GREECE	KALI	SEGA	BROWNISH	CRIMPED	CARATS
SWEDEN	INDRA	PSNUMBER	GREYISH	SCRAPED	KBIT/S
NORWAY	VISHNU	HD	GRAYISH	SCREWED	MEGAHERTZ
EUROPE	ANANDA	DREAMCAST	WHITISH	SECTIONED	MEGAPIXELS
HUNGARY	PARVATI	GEFORCE	SILVERY	SLASHED	GBIT/S
SWITZERLAND	GRACE	CAPCOM	YELLOWISH	RIPPED	AMPERES



Woman – Man ≈ Aunt - *Uncle*
King - Male + Female ≈ *Queen*
Human - Animal ≈ *Ethics*

Deep Learning - Basics

Natural Language Processing – Thought Vectors

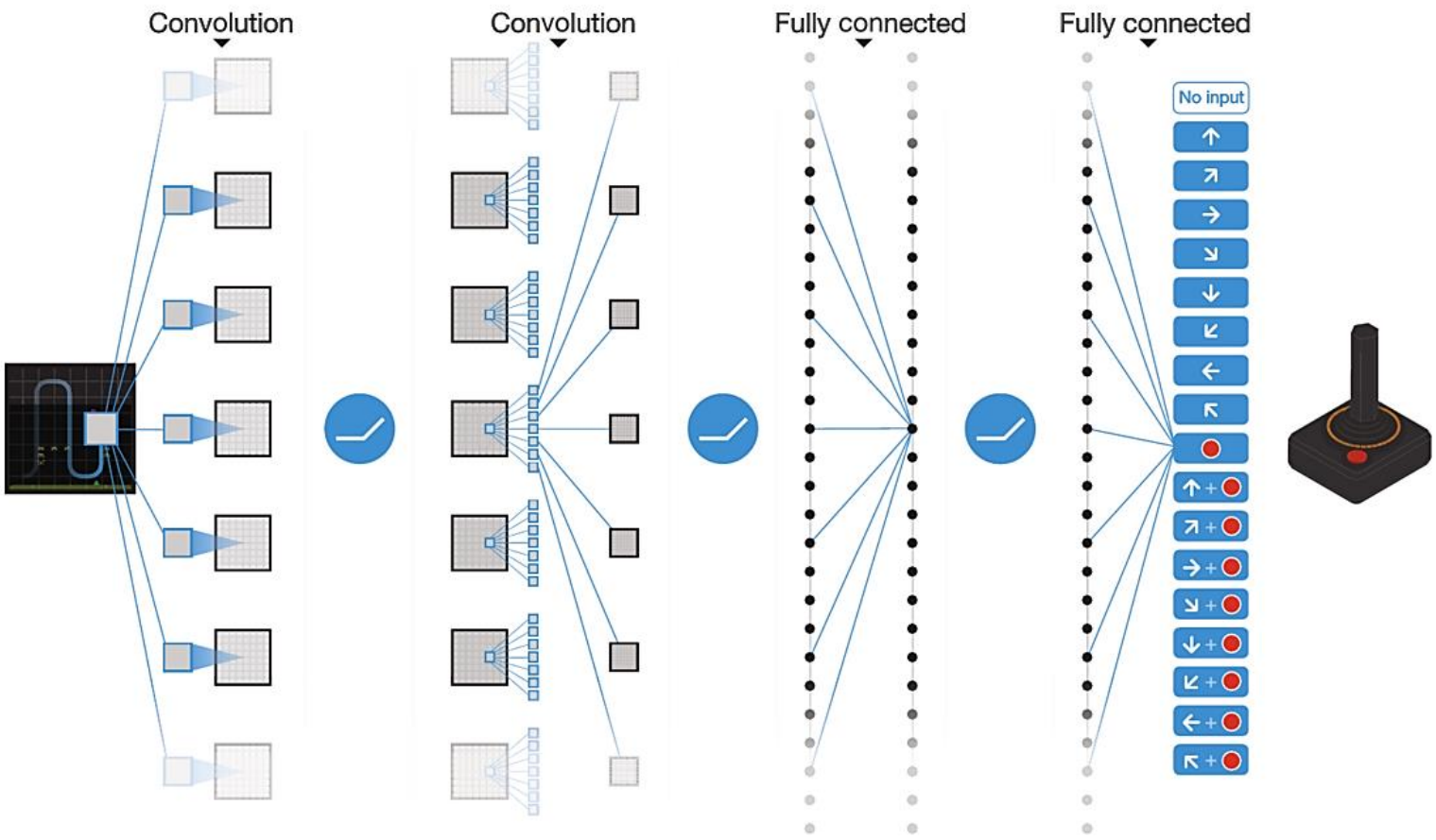
Thought vectors is a way of embedding thoughts in vector space. Their features will represent how each thought relates to other thoughts.

By reading every document on the web, computers might be able to reason like humans do by mimicking the thoughts expressed in content.

A neural machine translation is trained on bilingual text using a encoder and decoder RNN. For translation, the input sentence is transformed into a thought vector. This vector is used to reconstruct the given thought in another language.

Deep Learning - Basics

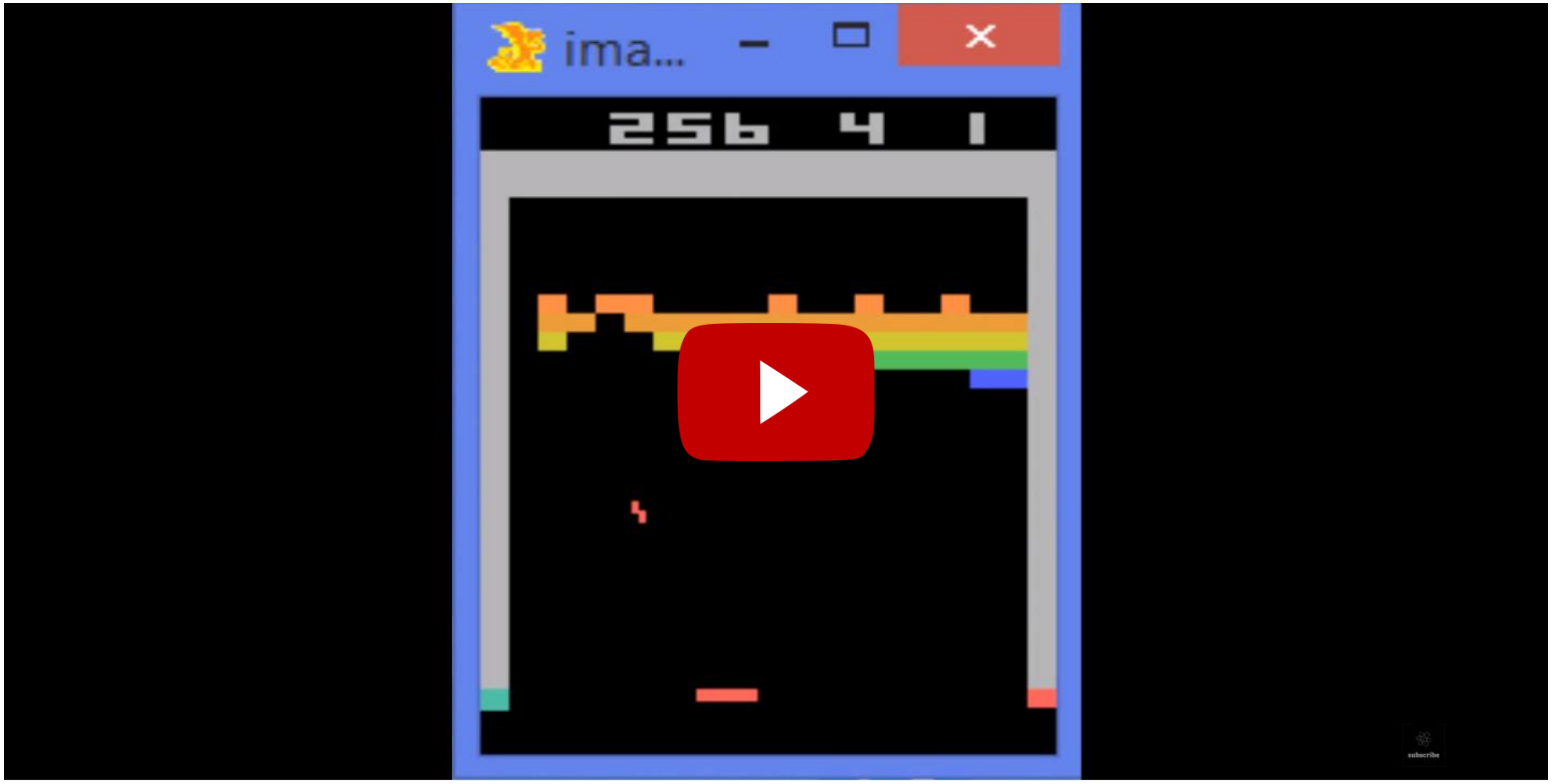
DeepMind Deep Q-Learning



Deep Q-Learning (DQN) is a model-free approach to reinforcement learning using deep networks in environments with discrete action choices

Deep Learning - Basics

DeepMind Deep Q-Learning

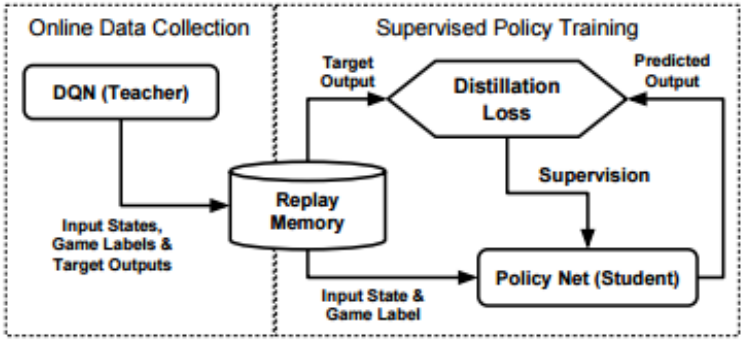


Outperforms humans in over 30 Atari games just by receiving the pixels on the screen with the goal to maximize the score (Reinforcement Learning)

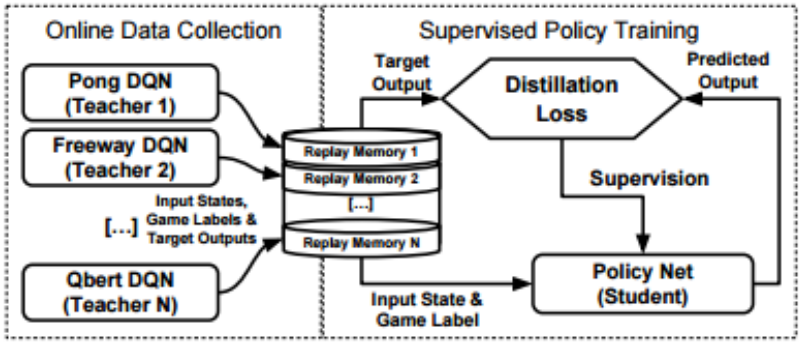
Deep Learning - Basics

DeepMind Deep Q-Learning

Policy distillation: Extracts the learned state *(policy)* of a reinforcement learning agent *(teacher)* and trains a new network *(student)* that performs at the expert level while being dramatically smaller and more efficient.



Single-task policy distillation



Multi-task policy distillation

Deep Learning - Basics

Usage Requirements

Large data set with good quality *(input-output mappings)*

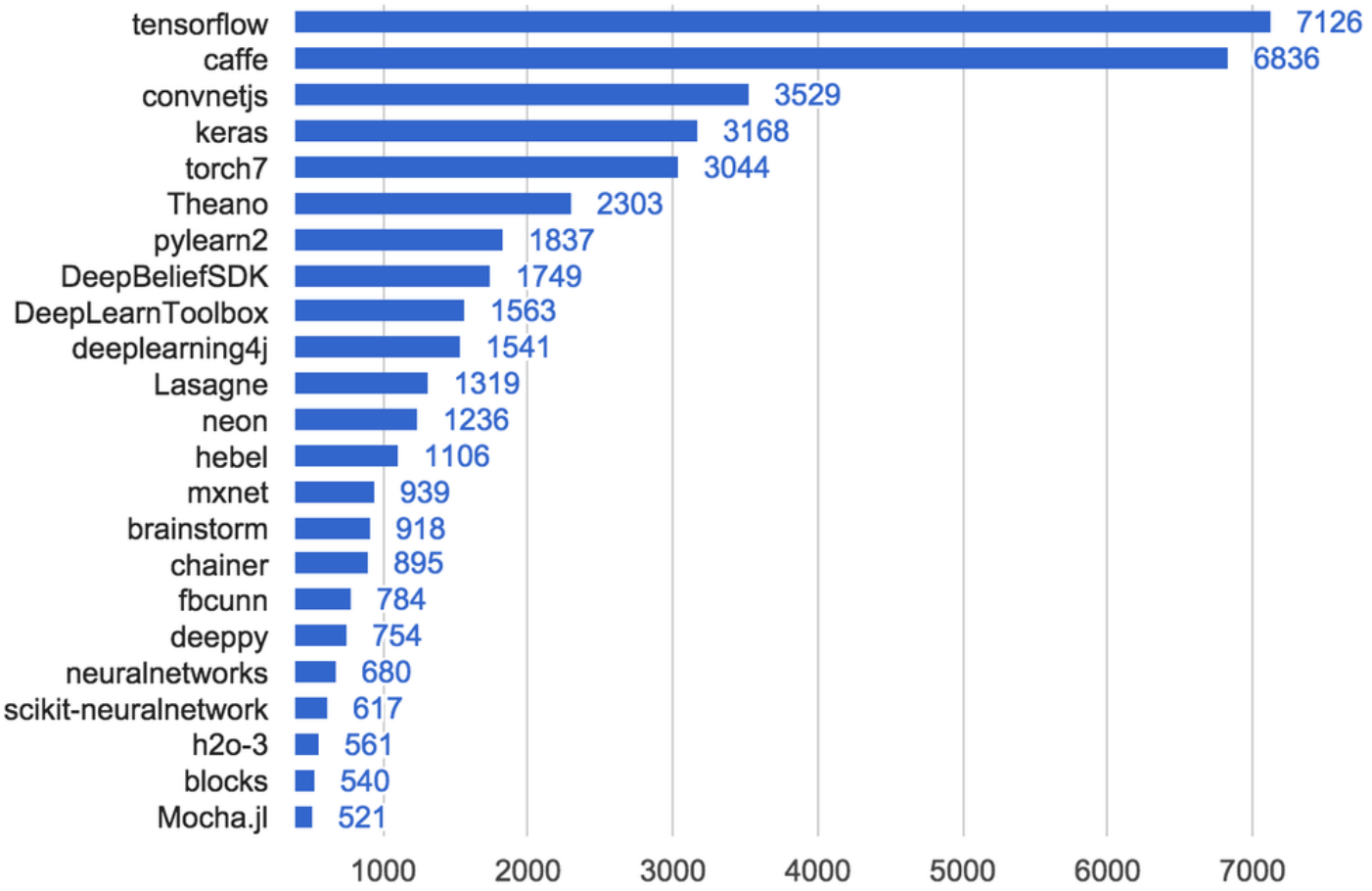
Measurable and describable goals *(define the cost)*

Enough computing power *(AWS GPU Instance)*

Excels in tasks where the basic unit *(pixel, word)* has very little meaning in itself, but the combination of such units has a useful meaning

Deep Learning - Tools

Its all Open Source



Deep Learning - Tools

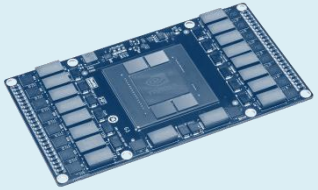
Computing is affordable

AWS EC2 GPU Spot Instance: *g2.2xlarge - $0.0782 per Hour*

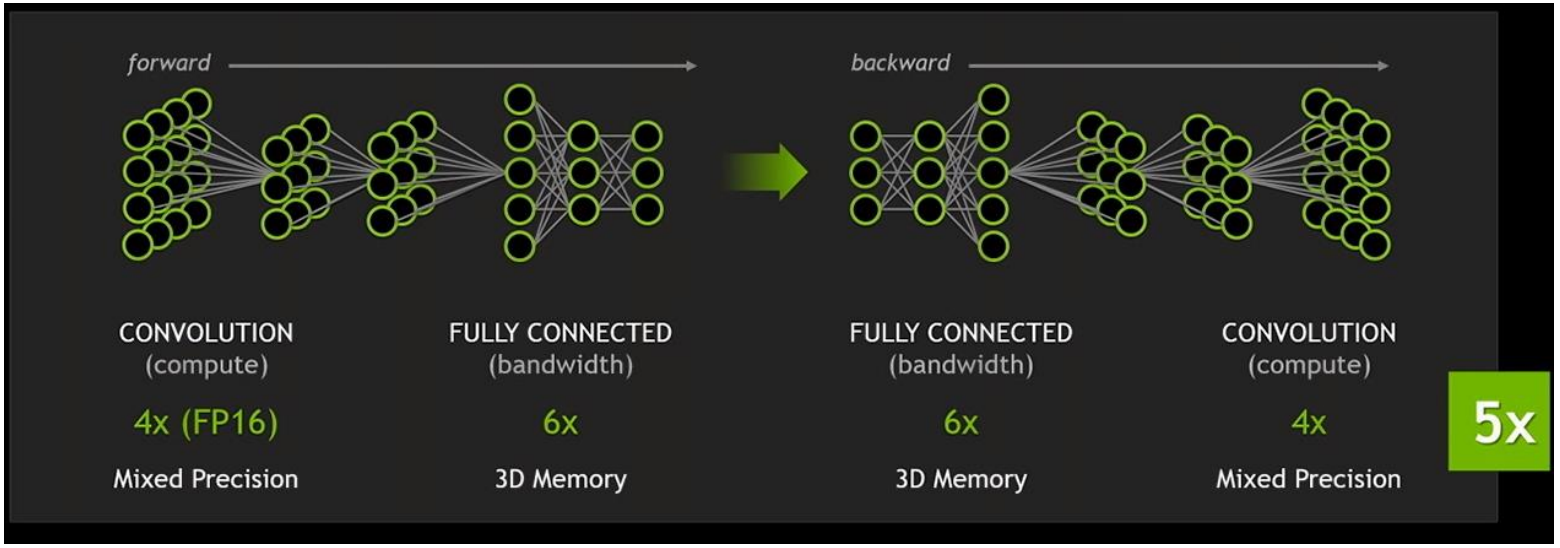
The **DIGITS DevBox** combines the world's best hardware (4 GPUs), software, and systems engineering for deep learning in a powerful solution that can fit under your desk. *Cost: $15k*

Outlook

NVIDIA Pascal



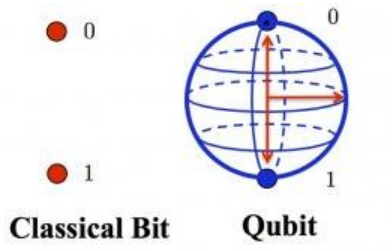
NVIDIA's Pascal GPU architecture will accelerate deep learning applications up to 10X beyond the speed of its current-generation Maxwell processors.



Outlook

Artificial Quantum Intelligence

Quantum Artificial Intelligence Lab is a joint initiative of NASA and Google to study how quantum computing might advance machine learning. This type of computing may provide the most creative and parallelized problem-solving process under the known laws of physics.

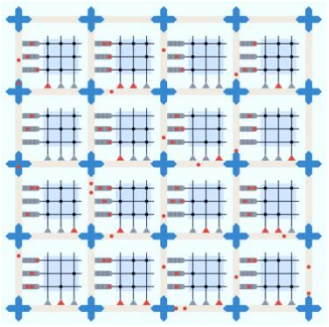


Quantum computers handle what are called **quantum bits** or qubits that can readily have a value of one or zero or anything in between.

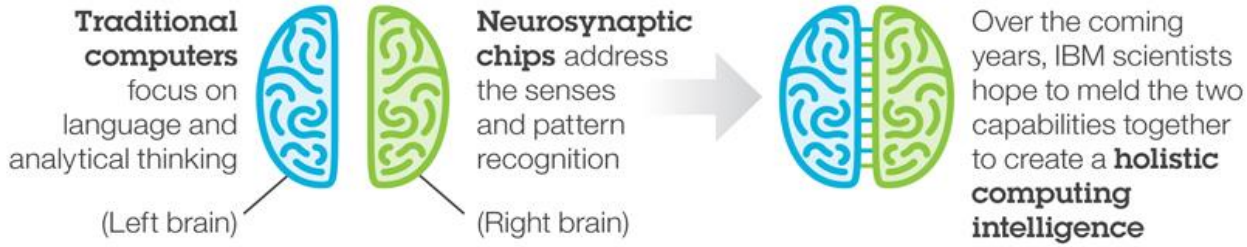
Quantum computing represents a paradigm shift, a radical change in the way we do computing and at a scale that has unimaginable power – *Eric Ladizinsky (Co-founder D-Wave)*

Outlook

Neuromorphic Chips



IBM TrueNorth is a brain-inspired computer chip that implements networks of integrate-and-fire spiking artificial neurons and uses only a tiny 70 mw of power –orders of magnitude less energy than traditional chips. The system is designed to be able to run deep-learning algorithms.



1 million
Programmable Neurons

256 million
Programmable Synapses

4096
Neurosynaptic Cores

Outlook

Deep Learning

Significant advances in deep reinforcement and unsupervised learning

Bigger and more complex architectures based on various interchangeable modules/techniques

Deeper models that can learn from much fewer training cases

Harder problems such as video understanding and natural language processing will be successfully tackled by deep learning algorithms

Takeaways

Machines that learn to represent the world from experience.

Deep Learning is no magic! Just statistics in a black box, but exceptional effective at learning patterns.

We haven't figured out creativity and human-empathy.

Transitioning from research to consumer products. Will make the tools you use every day work better, faster and smarter.

Lukas Masuch

@lukasmasuch

+lukasmasuch