Deep Learning

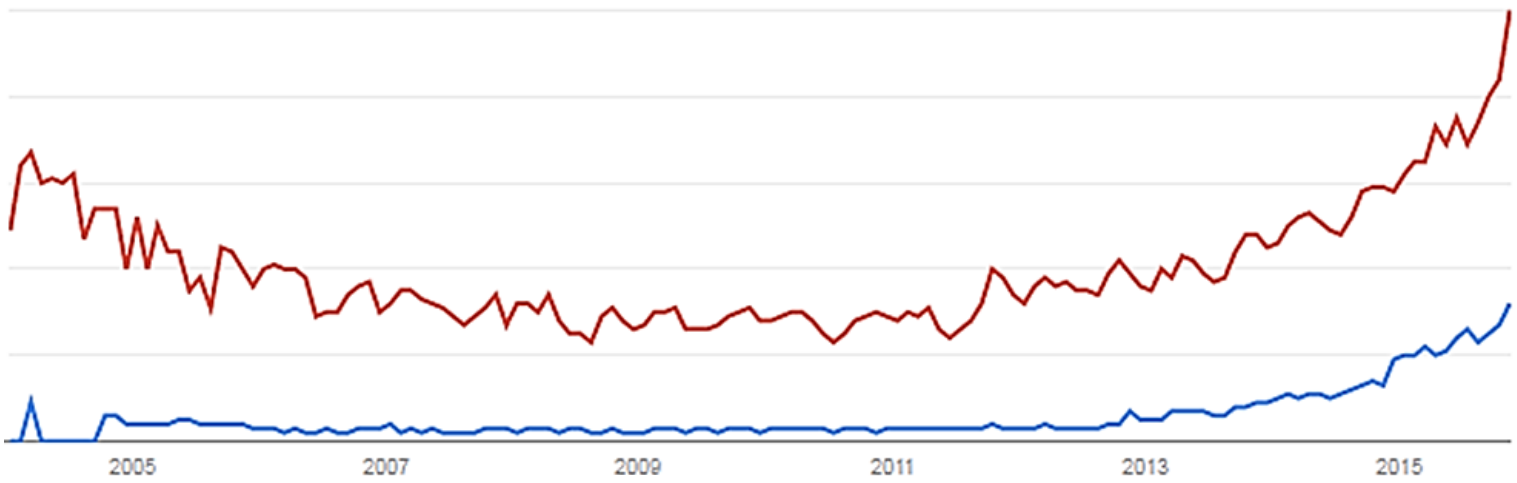
The Past, Present and Future of
Artificial Intelligence

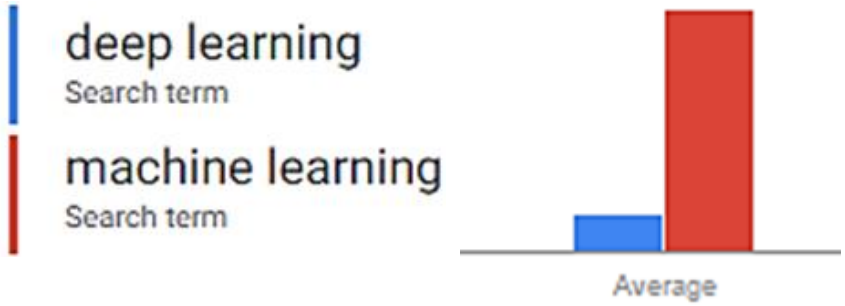
The Deep Learning Revolution

The Big Bang of Artificial Intelligence

Interest

Google Trends

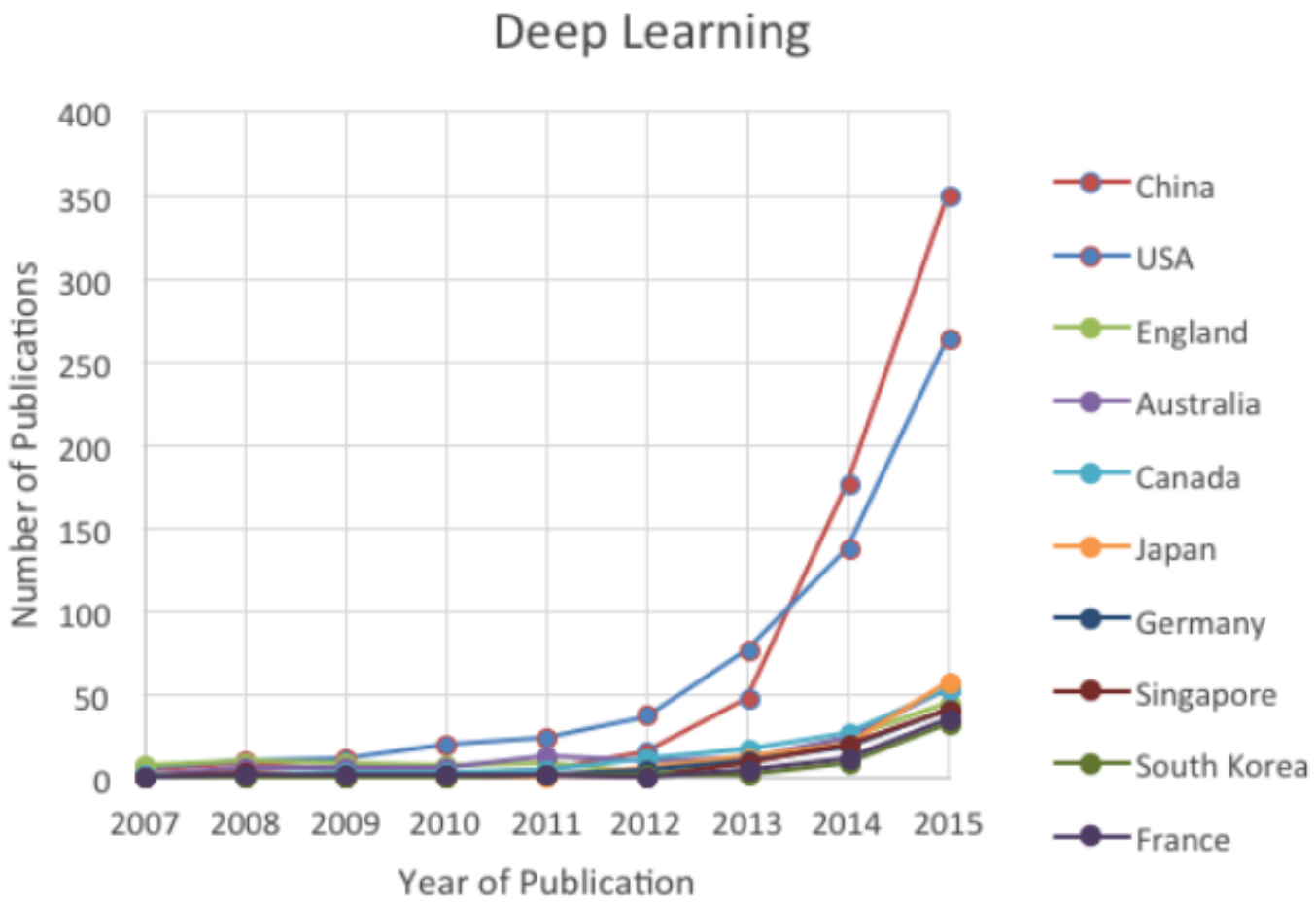




Source

Hype or Reality?

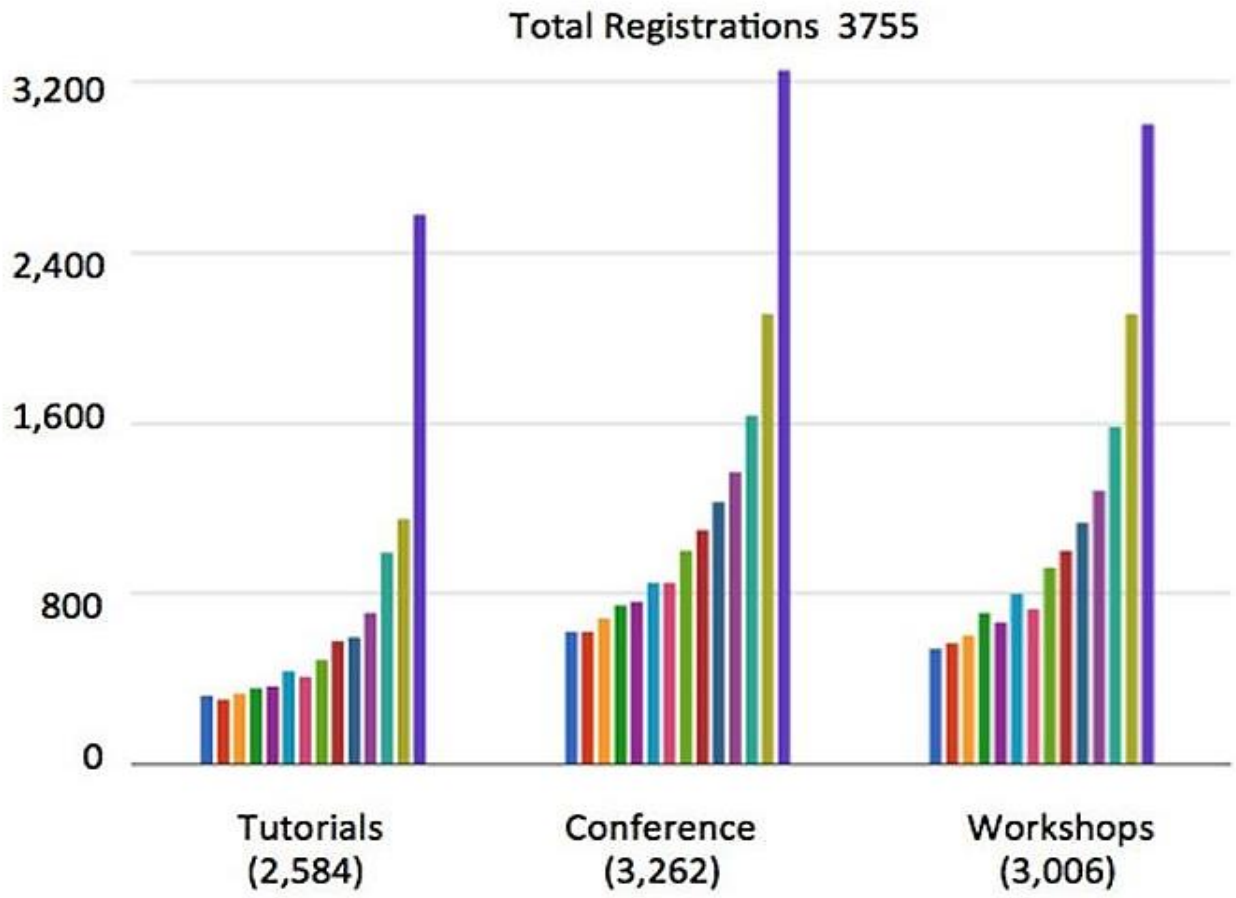
Academic Publications about Deep Learning



Source

Hype or Reality?

NIPS (Computational Neuroscience Conference) Growth



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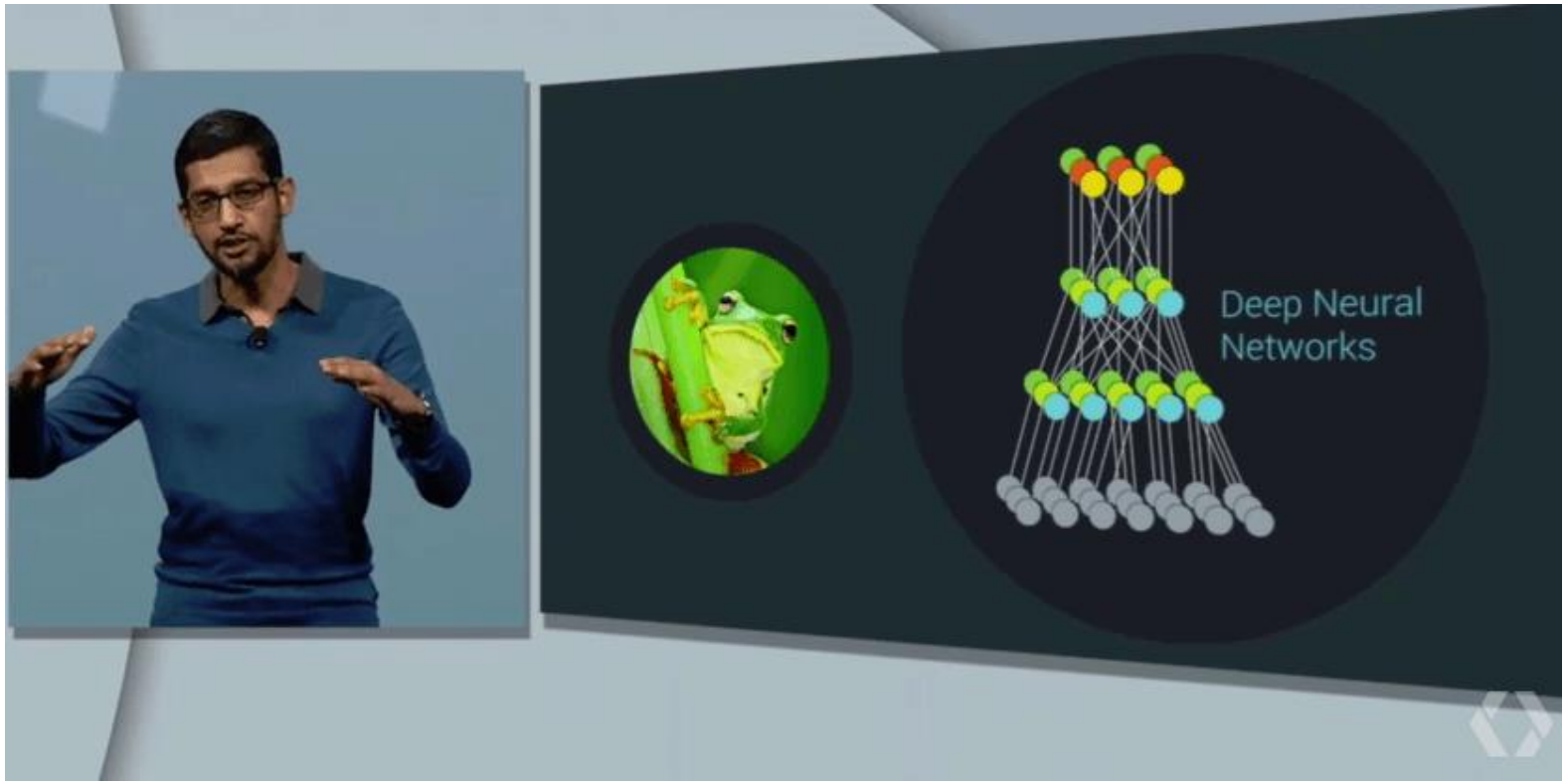
Hype or Reality?

Google

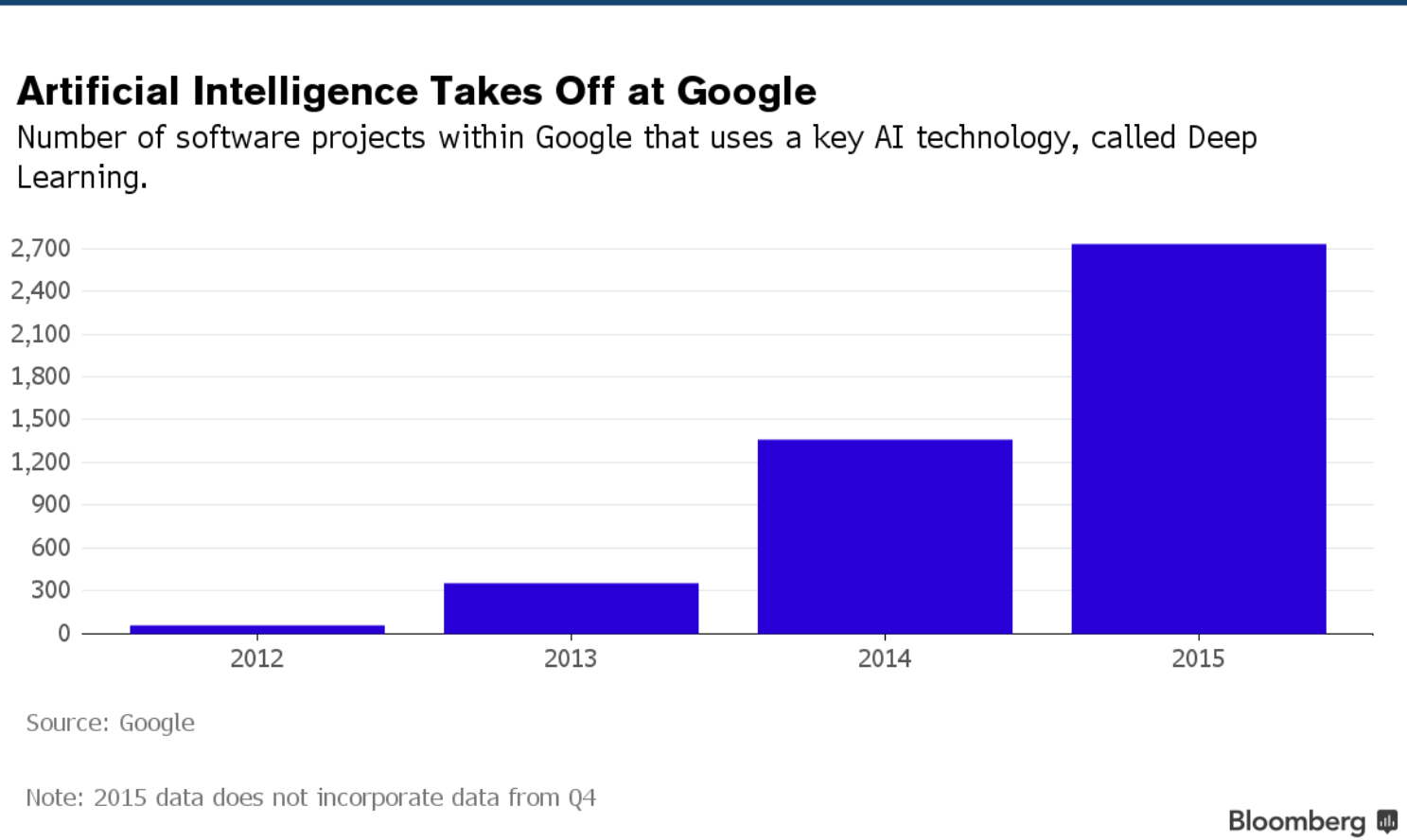


Machine learning is a core transformative way by which we are rethinking everything we are doing – *Sundar Pichai (CEO Google)*

Source

Hype or Reality?

Google



Hype or Reality?

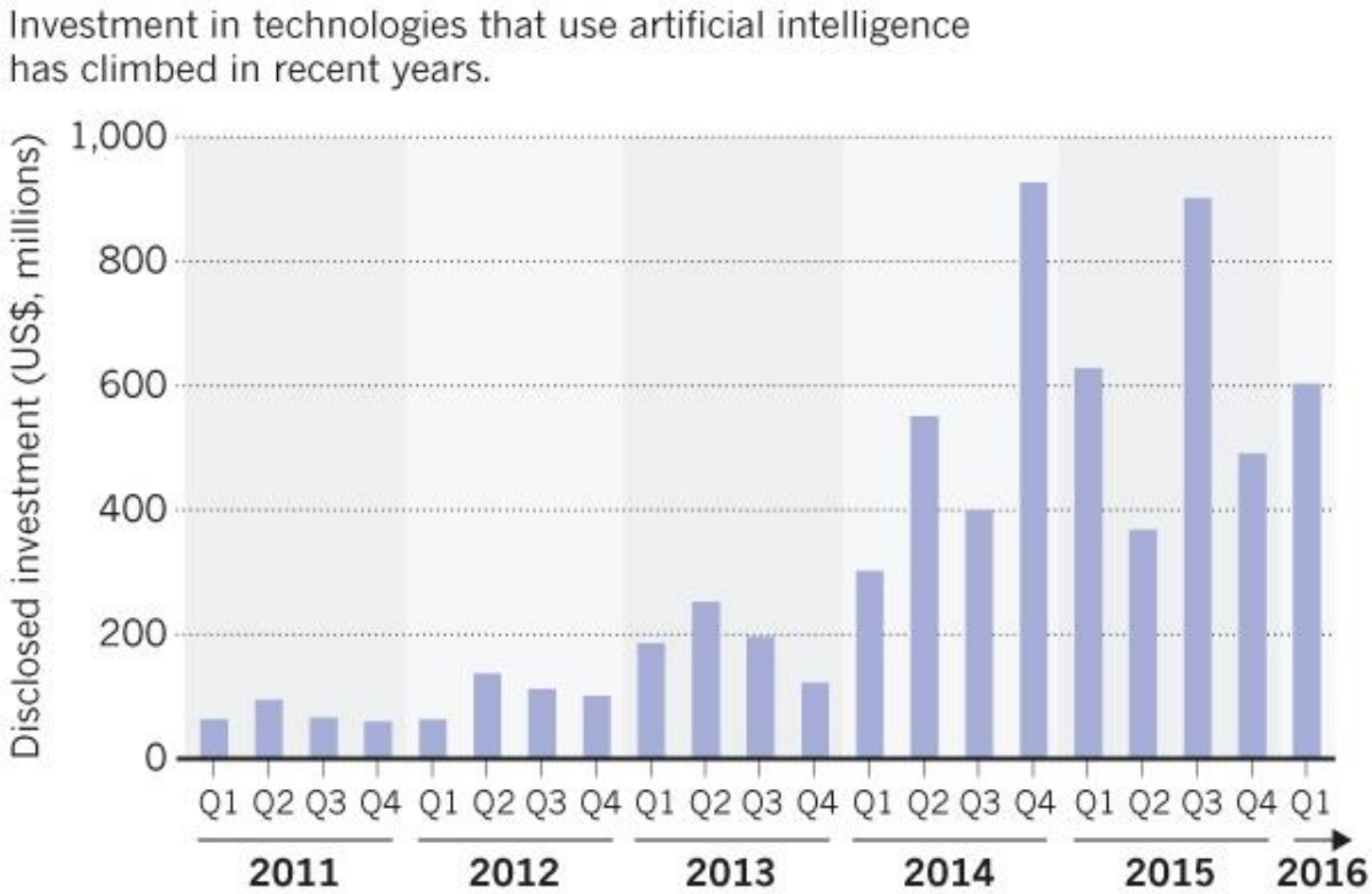
Microsoft

We are on the cusp of a paradigm shift in computing that is unlike anything we have seen in decades. This will lead to artificial intelligence (AI) being infused broadly into our computing platforms and experiences. – *Satya Nadella (CEO Microsoft)*

Source

Hype or Reality?

Investments in AI technologies



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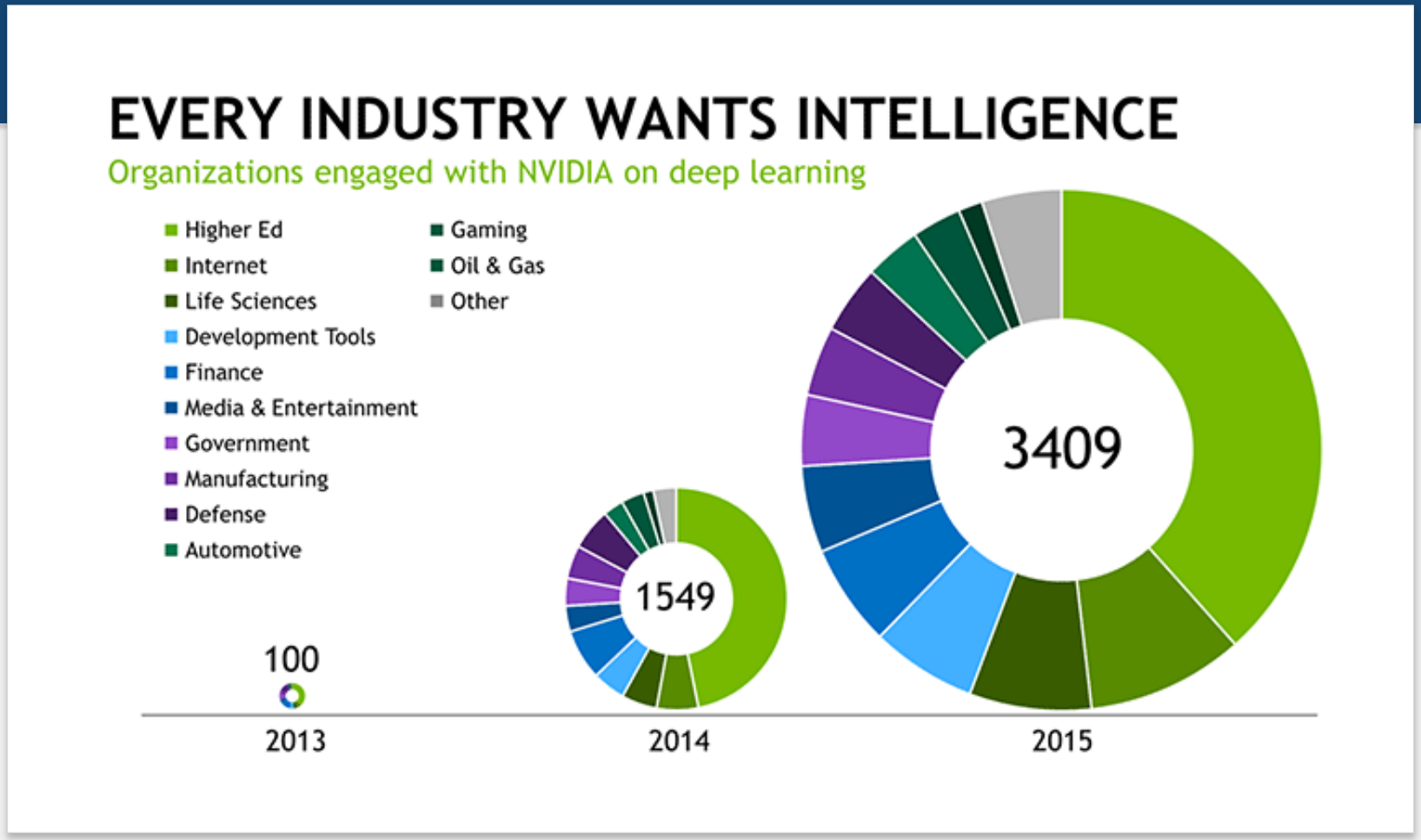
Hype or Reality?

Growing Interest from Organizations



Source

Hype or Reality?

Hawking, Musk and Gates

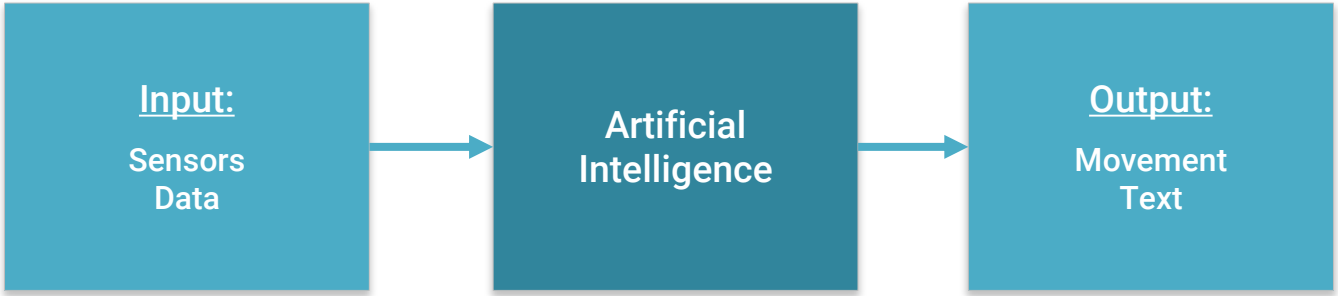
Superintelligence may be the last invention humans ever need to make, provided that the machine is docile enough to tell us how to keep it under control *– Nick Bostrom (University of Oxford – AI Philosopher)*

The pace of progress in artificial general intelligence is incredible fast. With artificial intelligence we're summoning the demon
– Elon Musk (CEO Tesla & SpaceX)

First the machines will do a lot of jobs for us and a few decades after that though the intelligence is strong enough to be a concern *– Bill Gates*

The advent of super intelligent AI would be either the best or the worst thing ever to happen to humanity *– Stephen Hawking (Physicist)*

What is Artificial Intelligence?



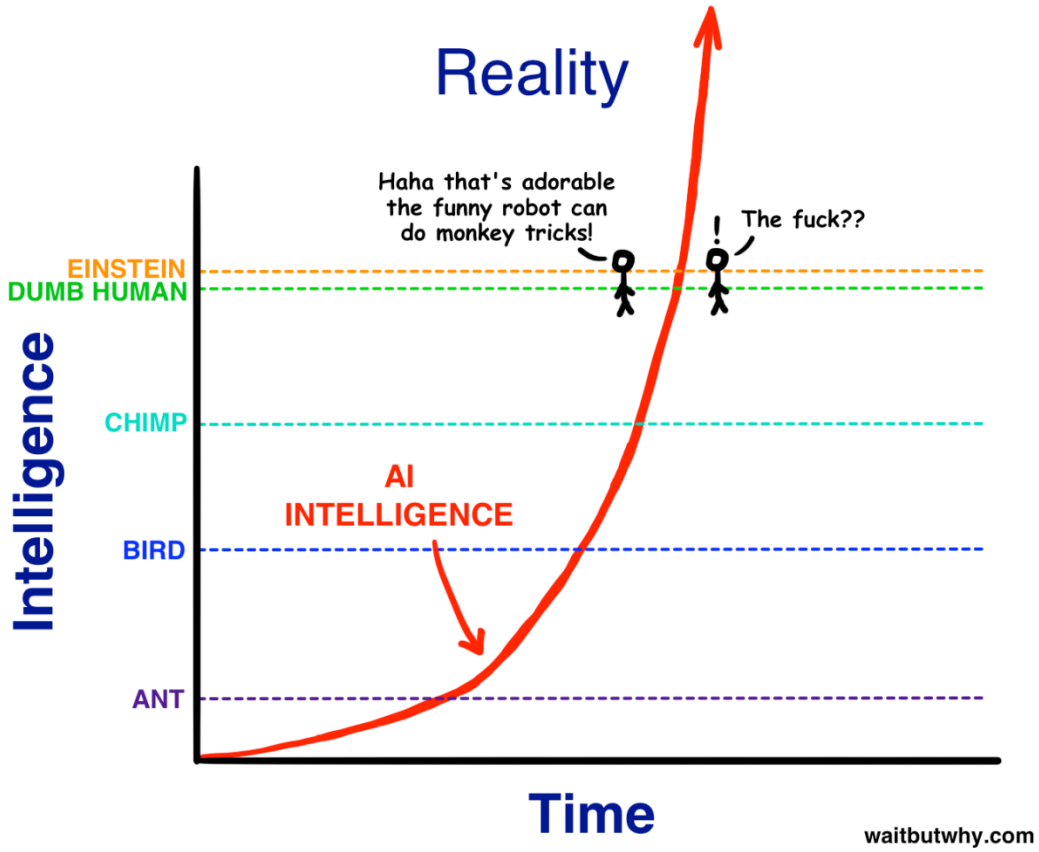
What is Artificial Intelligence?

Artificial Narrow Intelligence (ANI): Machine intelligence that equals or exceeds human intelligence or efficiency at a specific task.

Artificial General Intelligence (AGI): A machine with the ability to apply intelligence to any problem, rather than just one specific problem *(human-level intelligence).*

Artificial Superintelligence (ASI): An intellect that is much smarter than the best human brains in practically every field, including scientific creativity, general wisdom and social skills.

Superintelligence



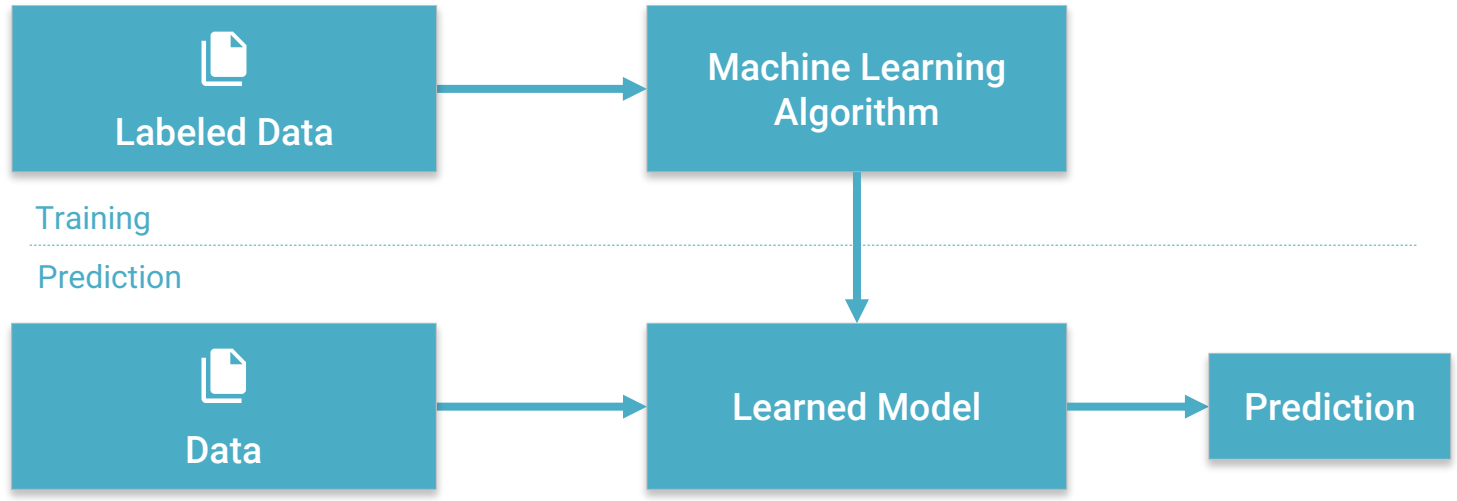
A superintelligence is any intellect that vastly outperforms the best human brains in practically every field, including scientific creativity, general wisdom, and social skills

Source

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

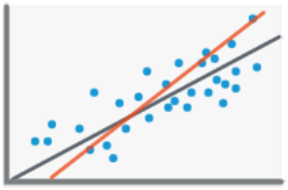
Unsupervised Learning: Discovering patterns in unlabeled data
Example: cluster similar documents based on the text content

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

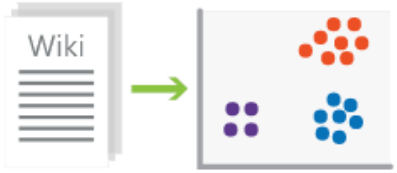
Machine Learning - Basics

Problem Types

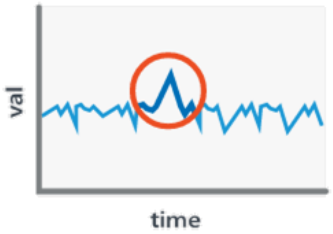
Classification
(supervised – predictive)



Regression
(supervised – predictive)



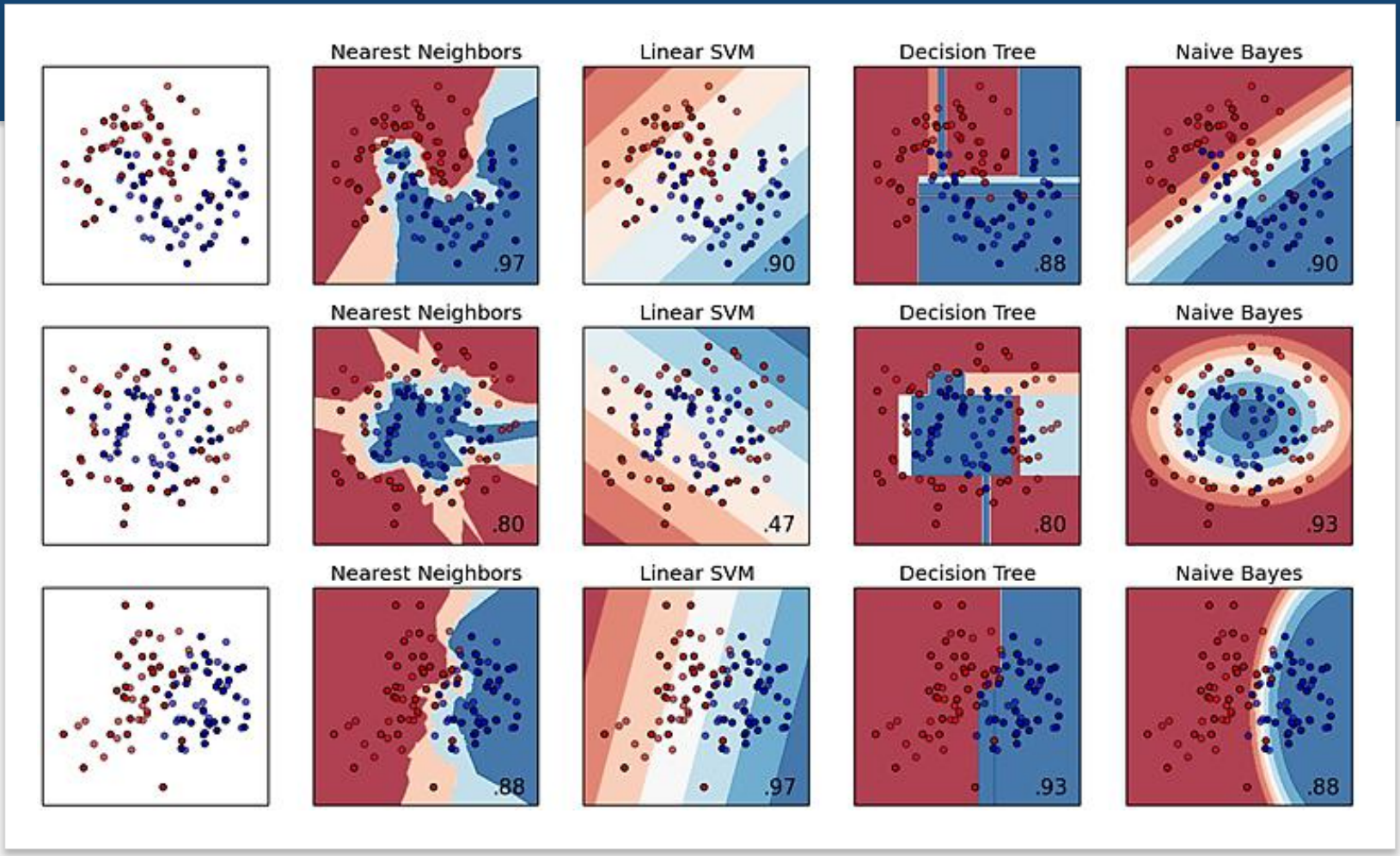
Clustering
(unsupervised – descriptive)



Anomaly Detection
(unsupervised– descriptive)

Machine Learning - Basics

Algorithms Comparison - Classification



Source

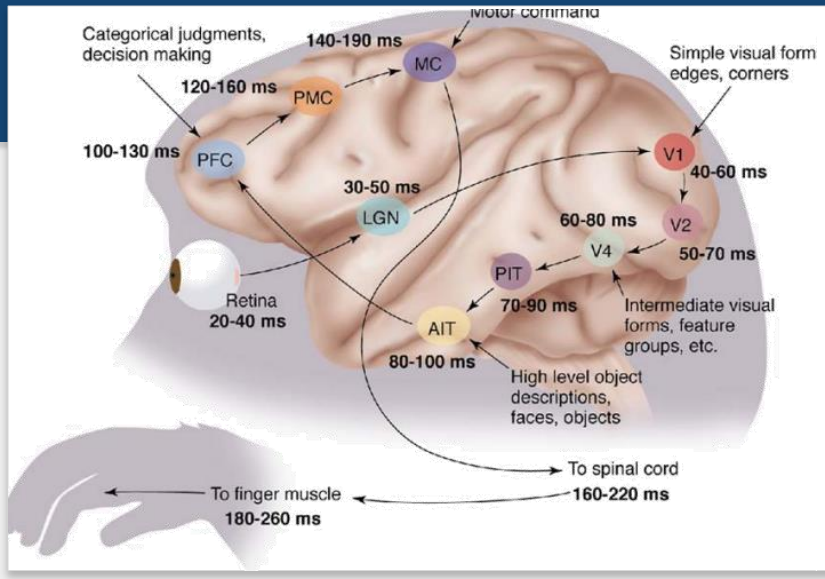
What is Deep Learning?

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/Audio Processing

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

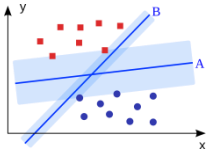
awkward silence (AI Winter)

1969

Perceptron criticized

1995

SVM reigns



2006

Restricted Boltzmann Machine

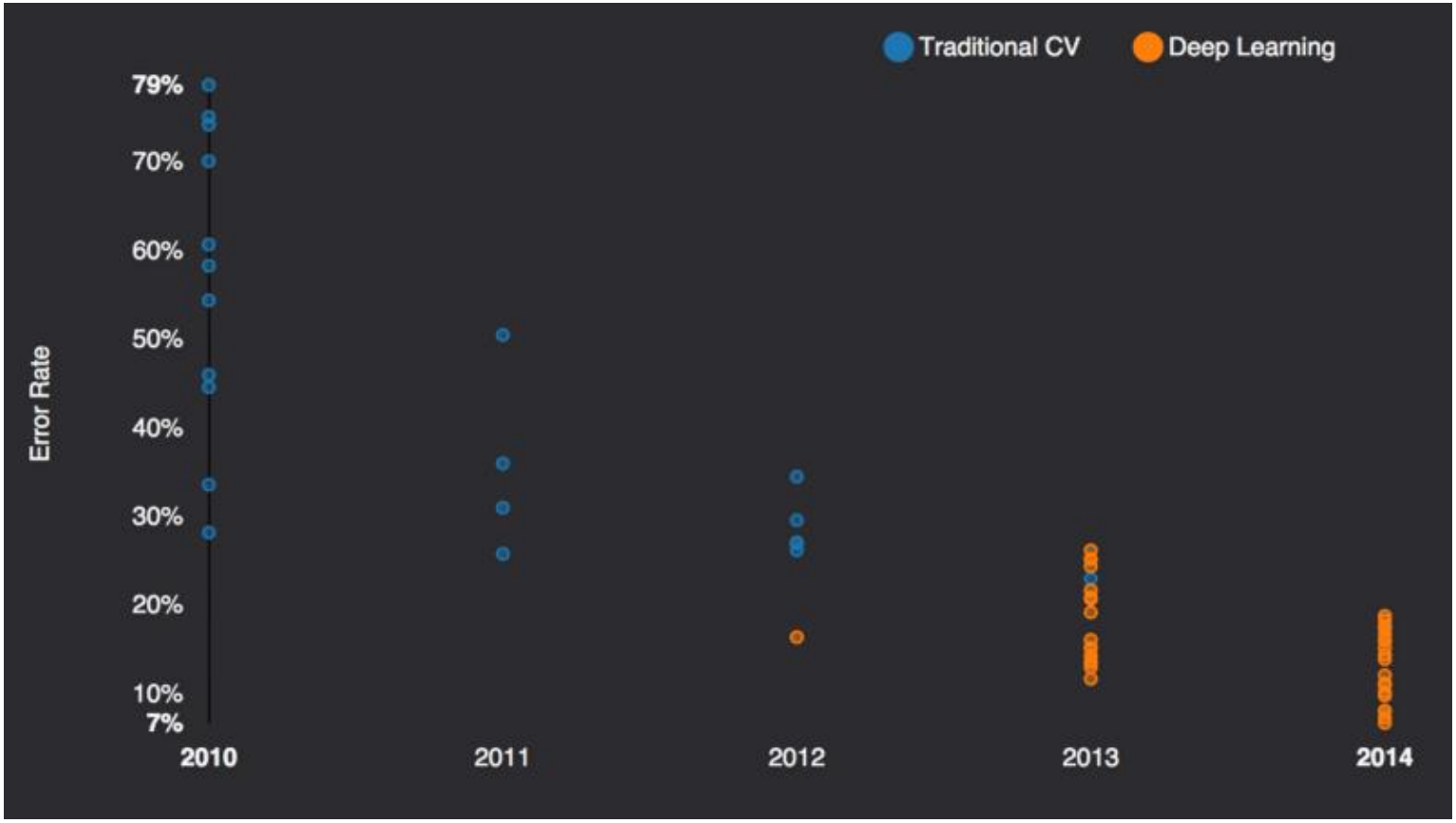
2012

AlexNet wins ImageNet

IMAGENET

A brief History

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

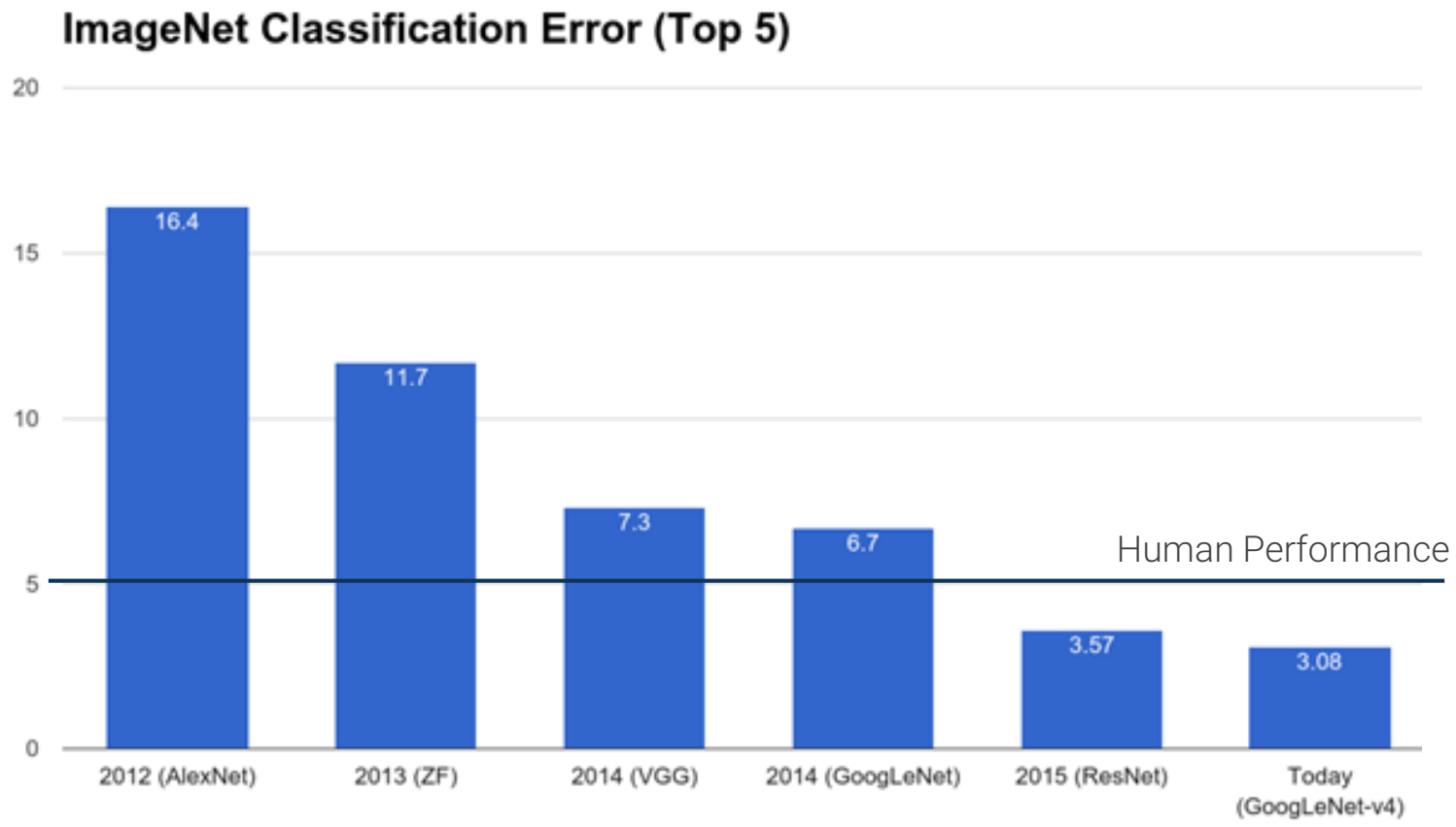


ImageNet: The “computer vision World Cup”

Source

A brief History

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

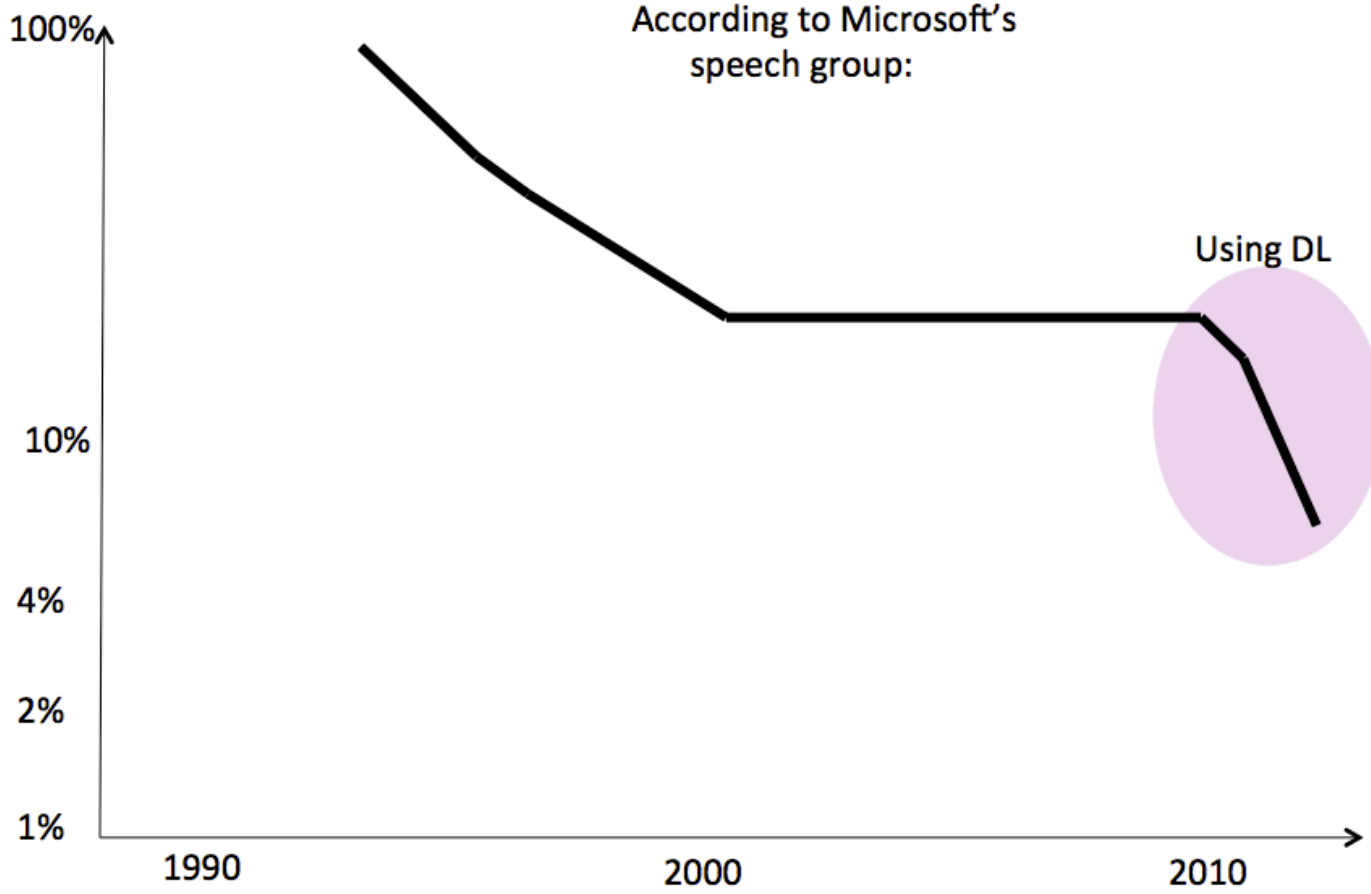


ImageNet: The “computer vision World Cup”

Source

A brief History

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

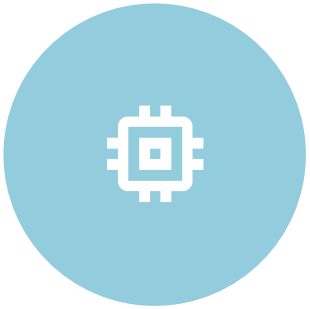


Deep Learning in Speech Recognition

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

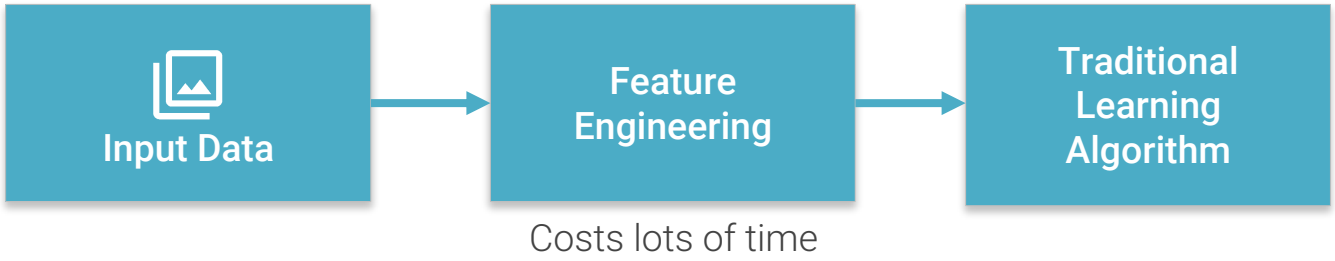
Companies

The Big Players

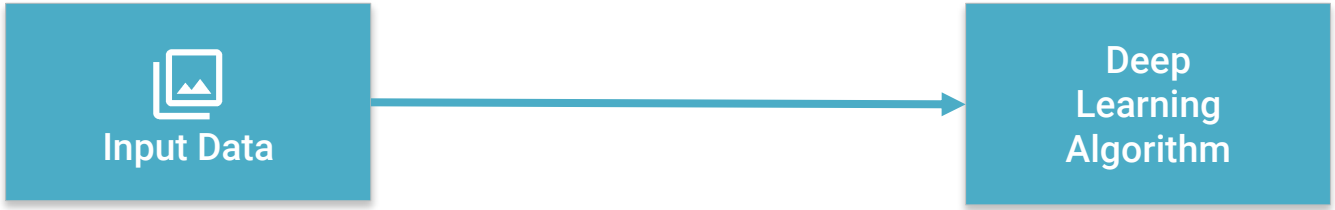
Startups

Deep Learning - Basics

No more feature engineering

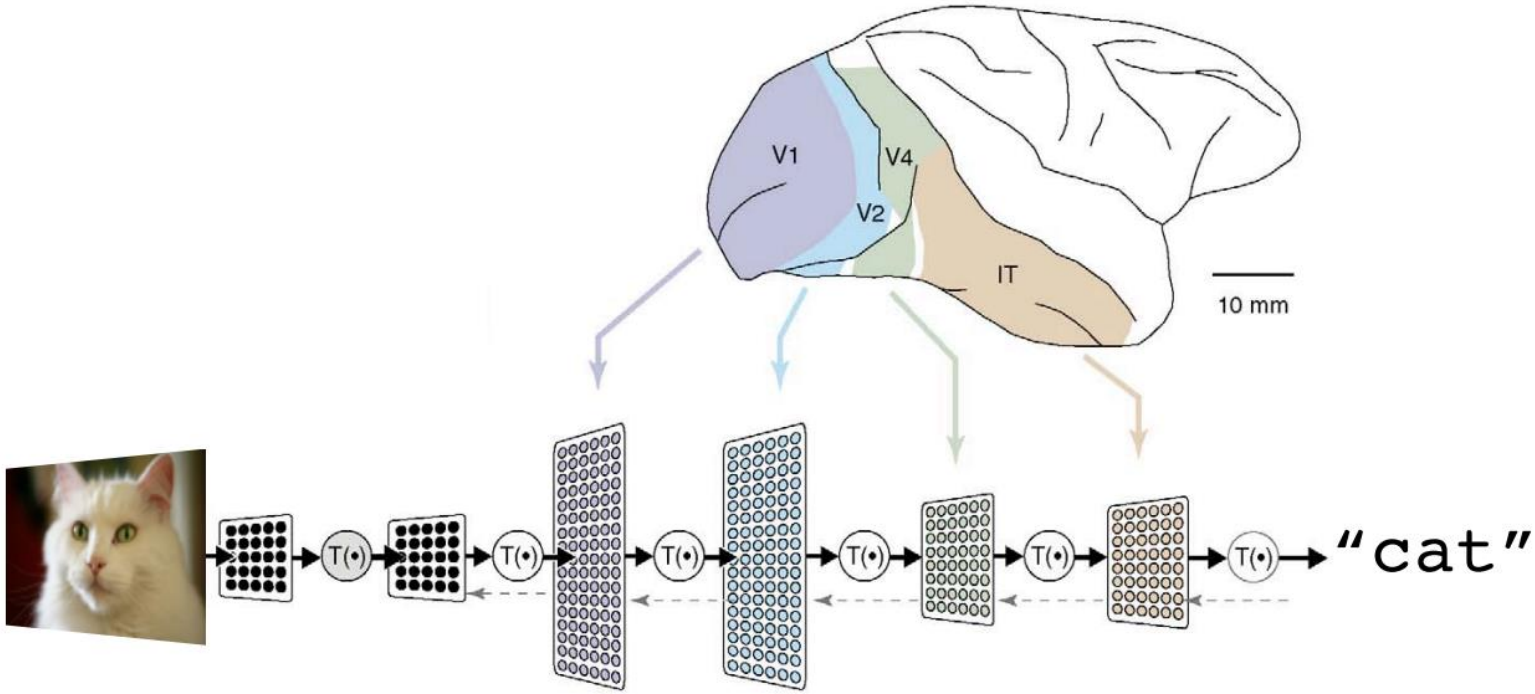


Costs lots of time



Deep Learning - Basics

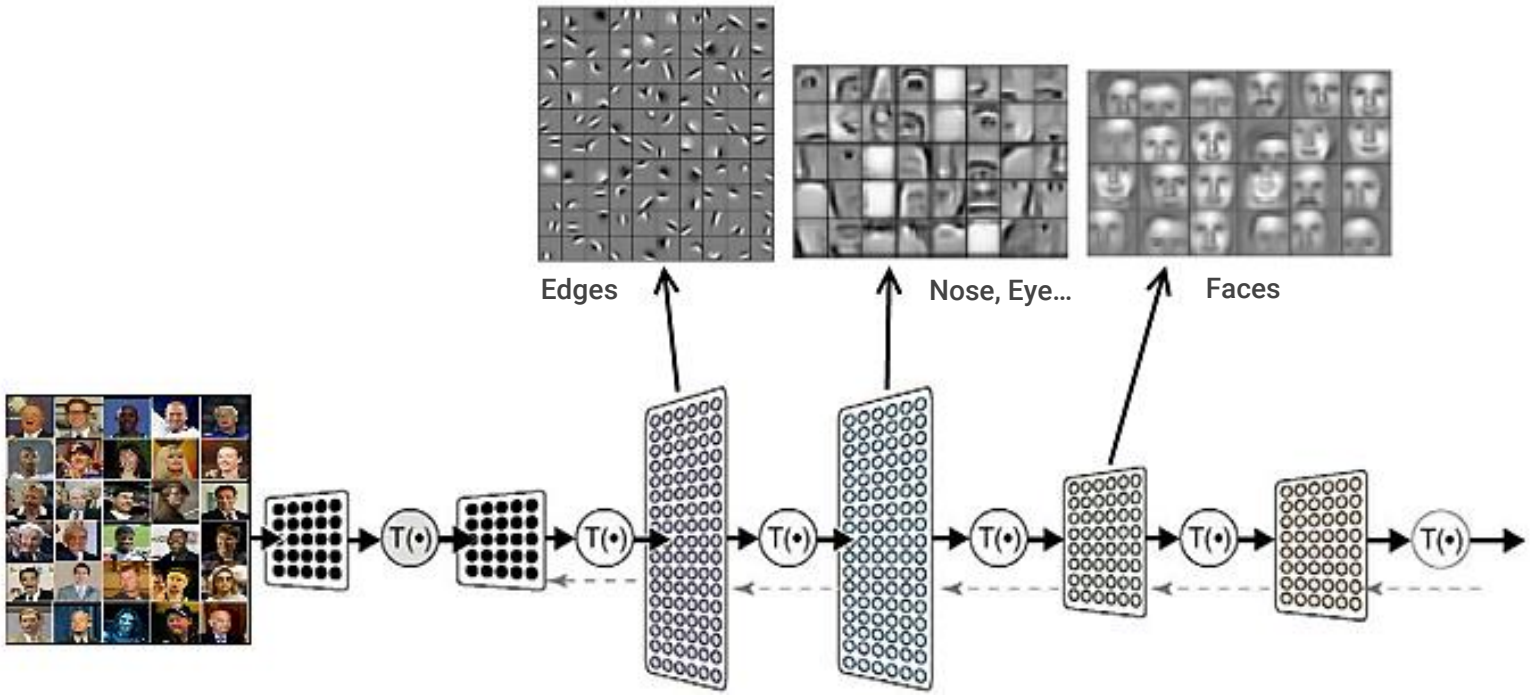
Architecture



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.

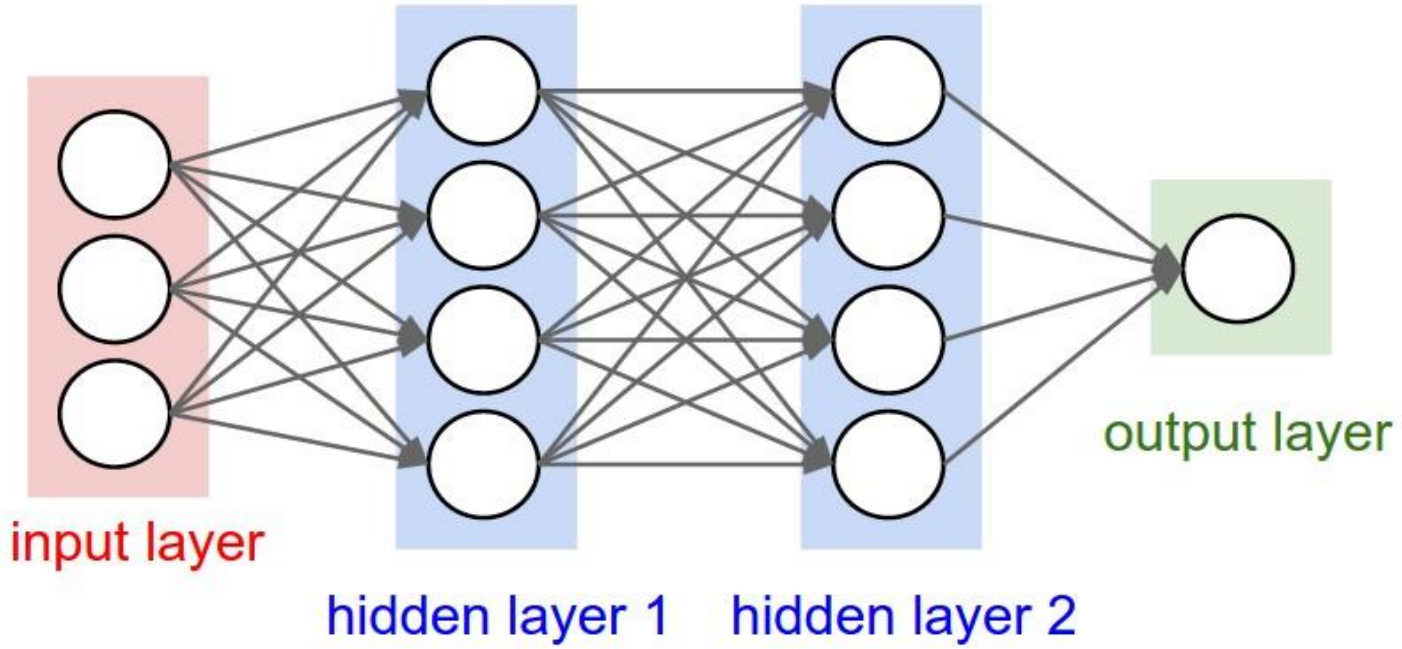
Deep Learning - Basics

What did it learn?



Deep Learning - Basics

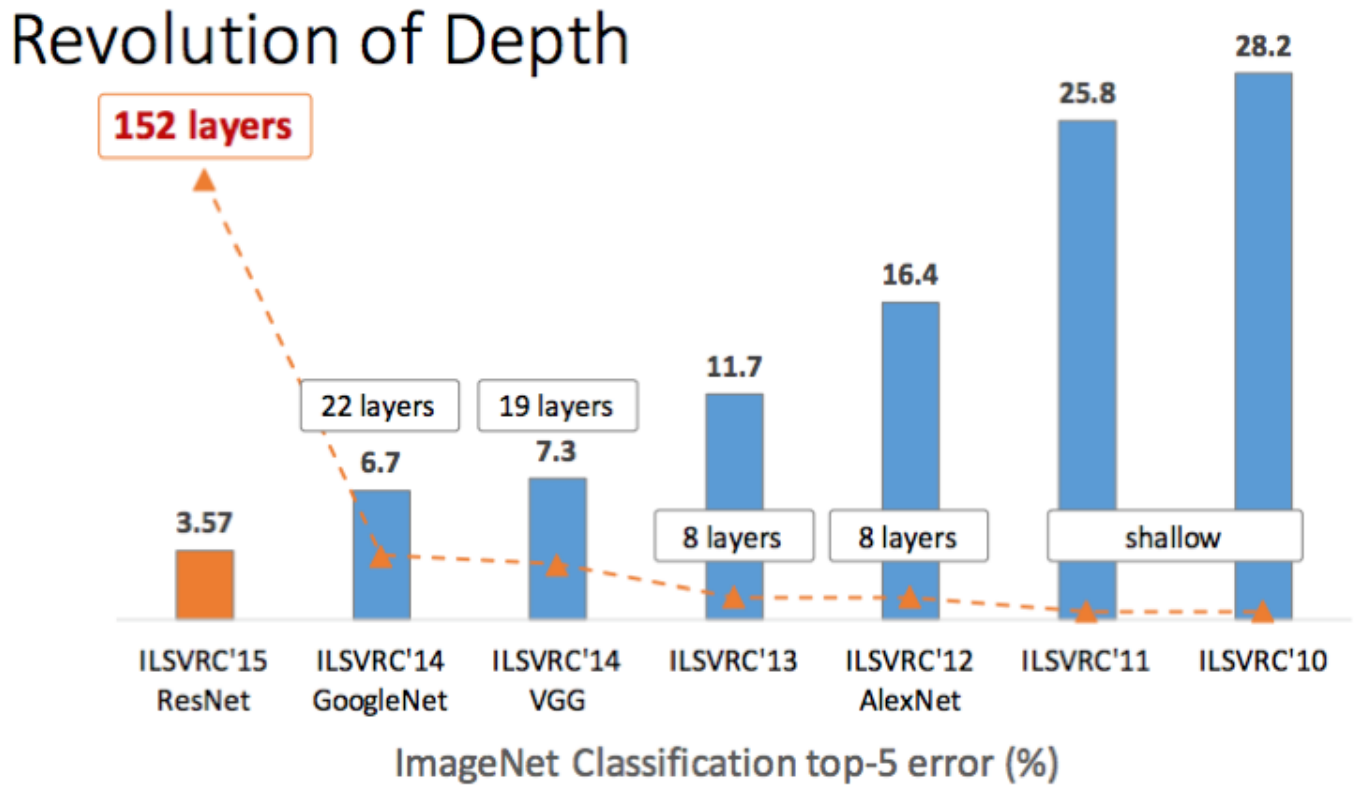
Artificial Neural Networks



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.

Deep Learning - Basics

More Layers -> Better Performance

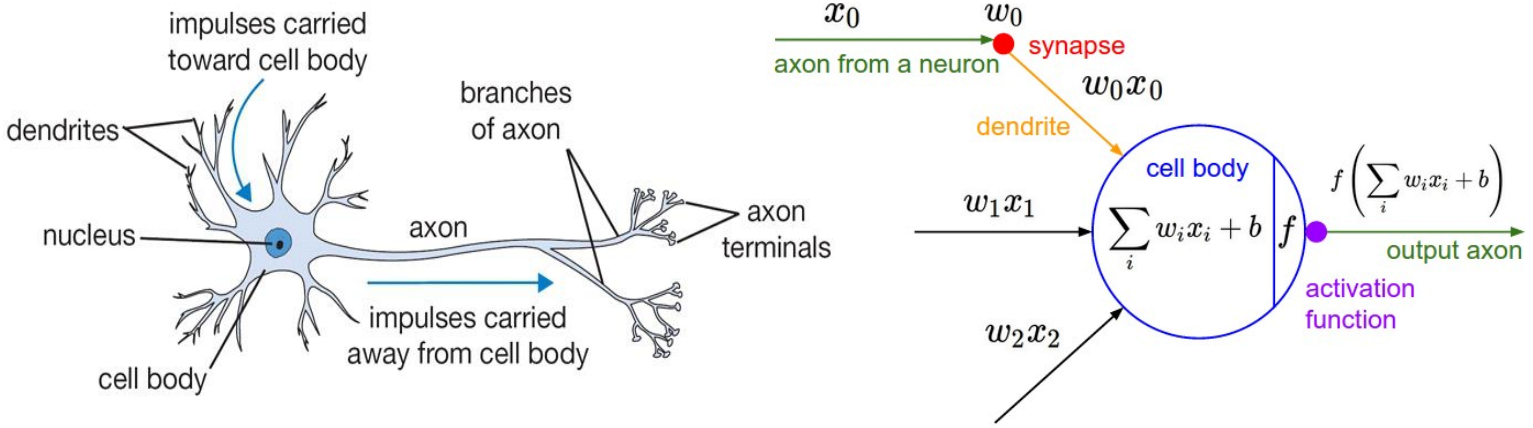


The more layers the network has, the higher-level features it will learn.

Source

Deep Learning - Basics

The Neuron

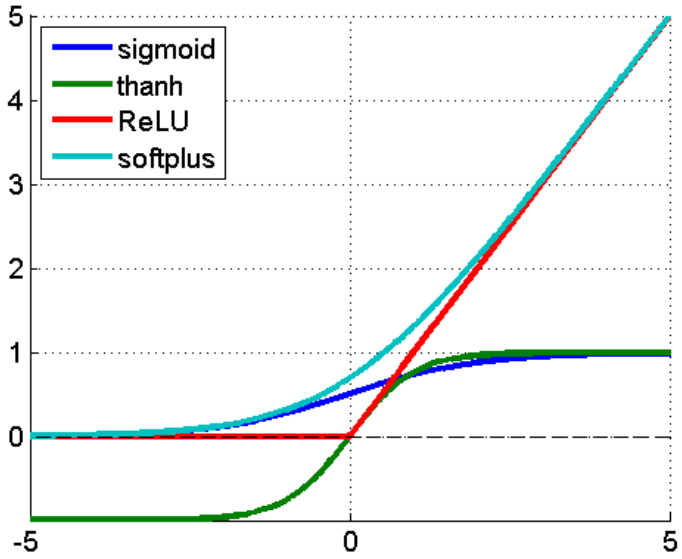


An artificial neuron contains a nonlinear activation function and has several incoming and outgoing weighted connections.

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

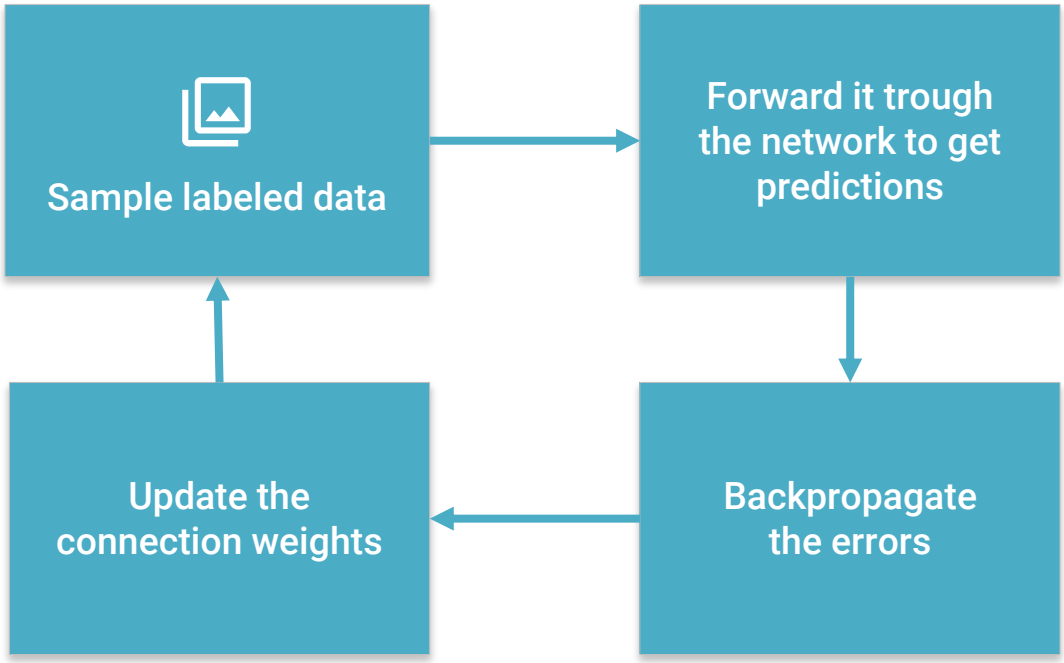


Most deep networks use ReLU - max(0,x) - nowadays for hidden layers, since it trains much faster, is more expressive than logistic function and prevents the gradient vanishing problem.

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

Deep Learning - Basics

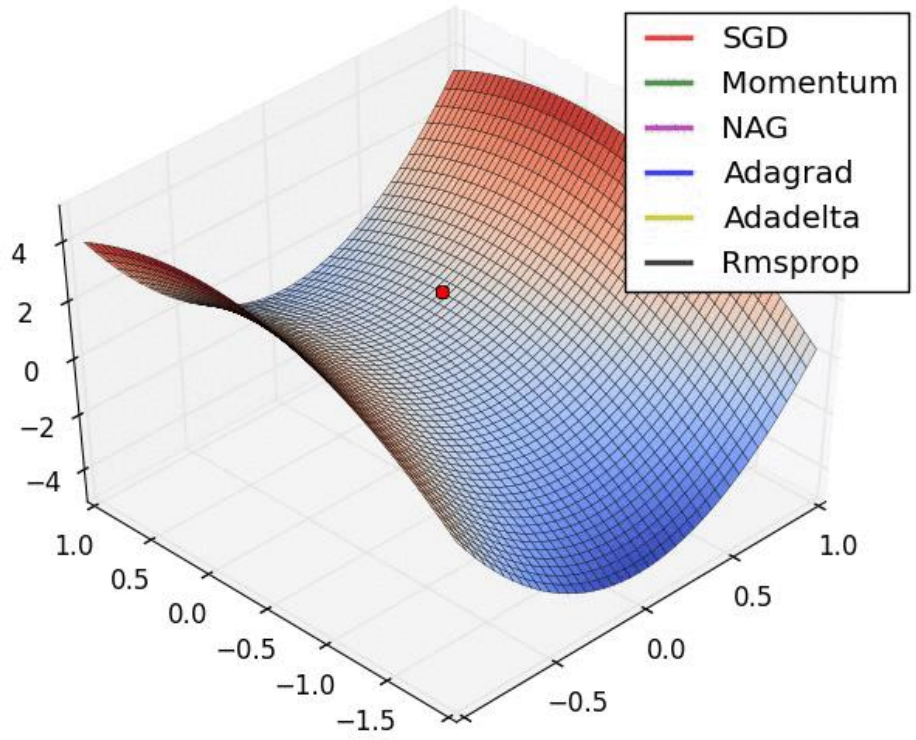
The Training Process



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

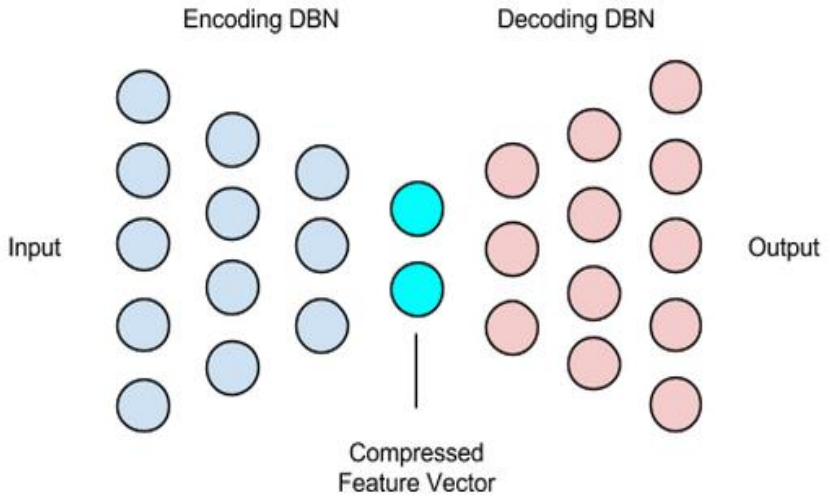
Gradient Descent



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

Deep Autoencoders



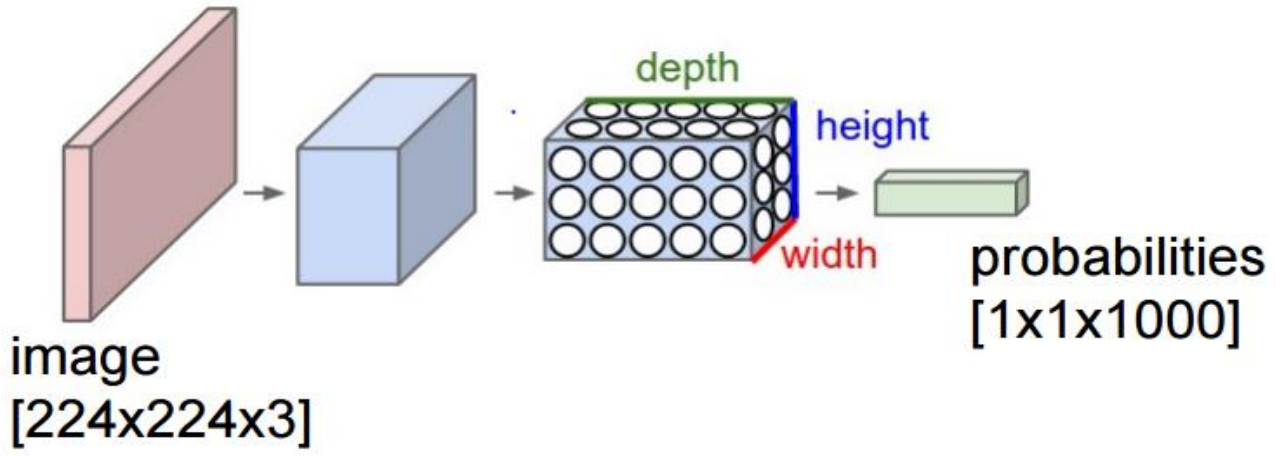
Composed of two symmetrical deep-belief networks. The encoding network learns to compresses the input to a condensed vector (dimensionality reduction). The decoding network can be used to reconstruct the data.

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)

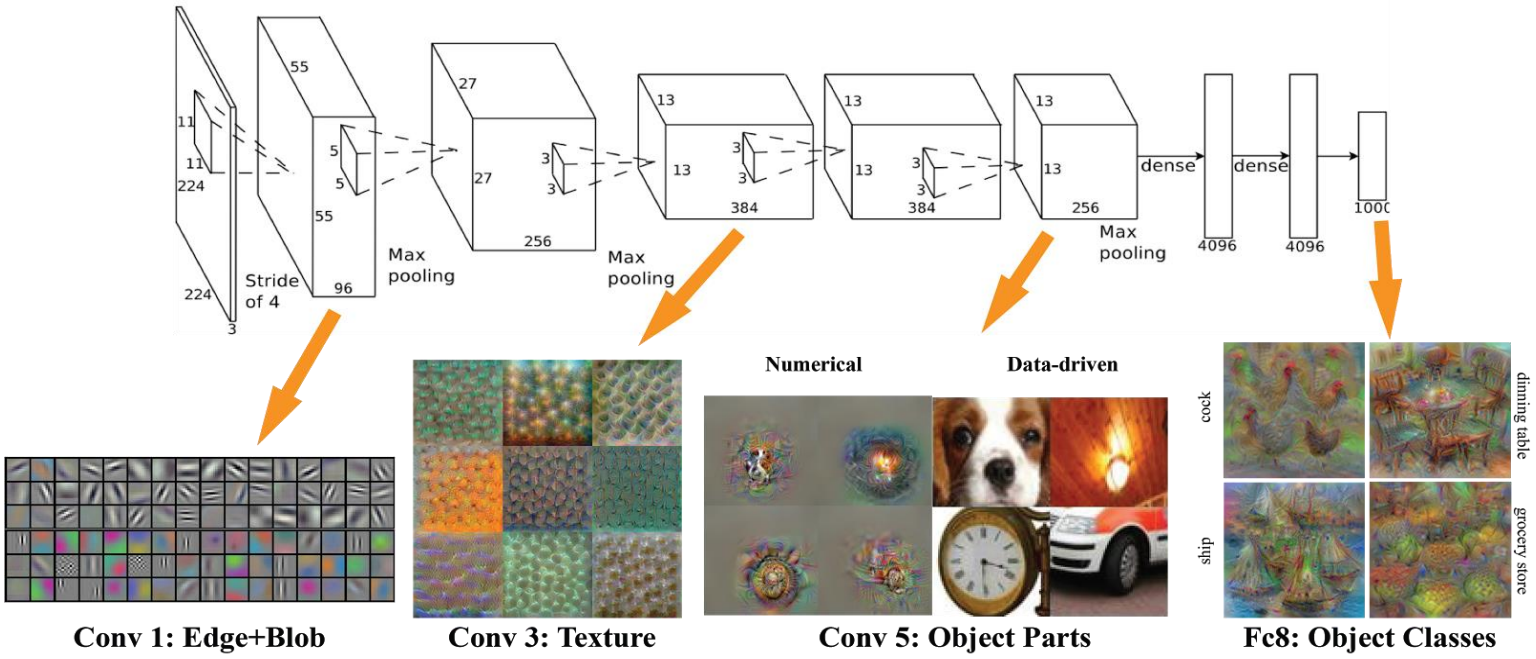
Convolutional Neural Networks learn a complex representation of visual data using vast amounts of data. They are inspired by the human visual system and learn multiple layers of transformations, which are applied on top of each other to extract a progressively more sophisticated representation of the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

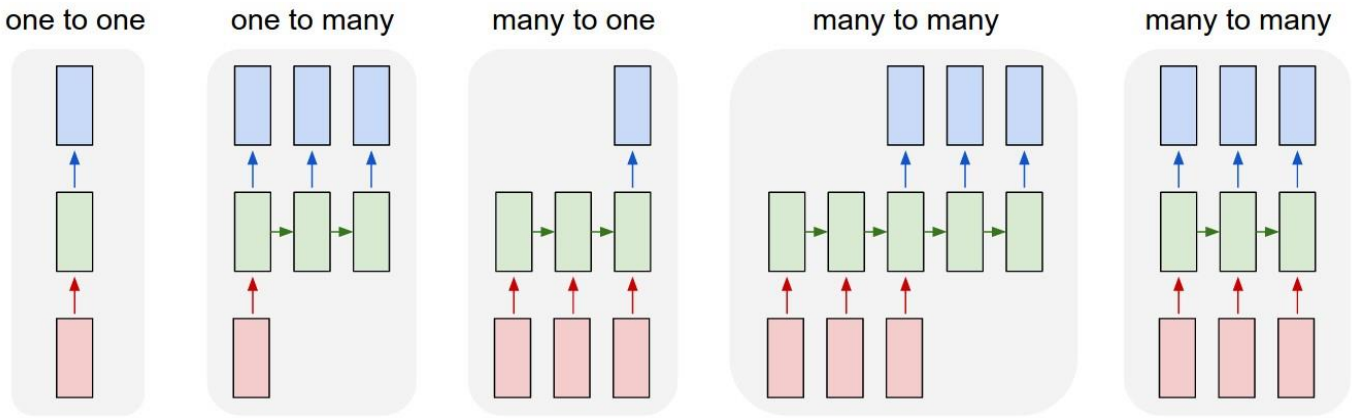


Convolution layer is a feature detector that automagically learns to filter out not needed information from an input by using convolution kernel.

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)

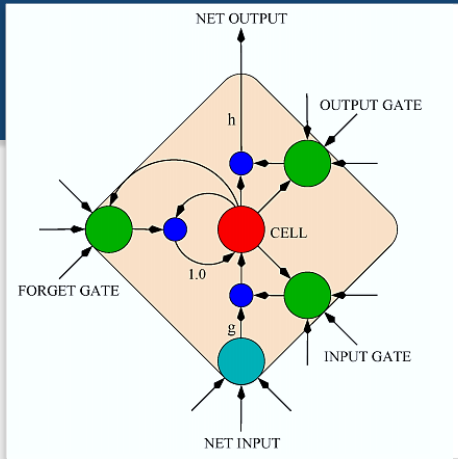


RNNs are general computers which can learn algorithms to map input sequences to output sequences (flexible-sized vectors). The output vector's contents are influenced by the entire history of inputs.

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.

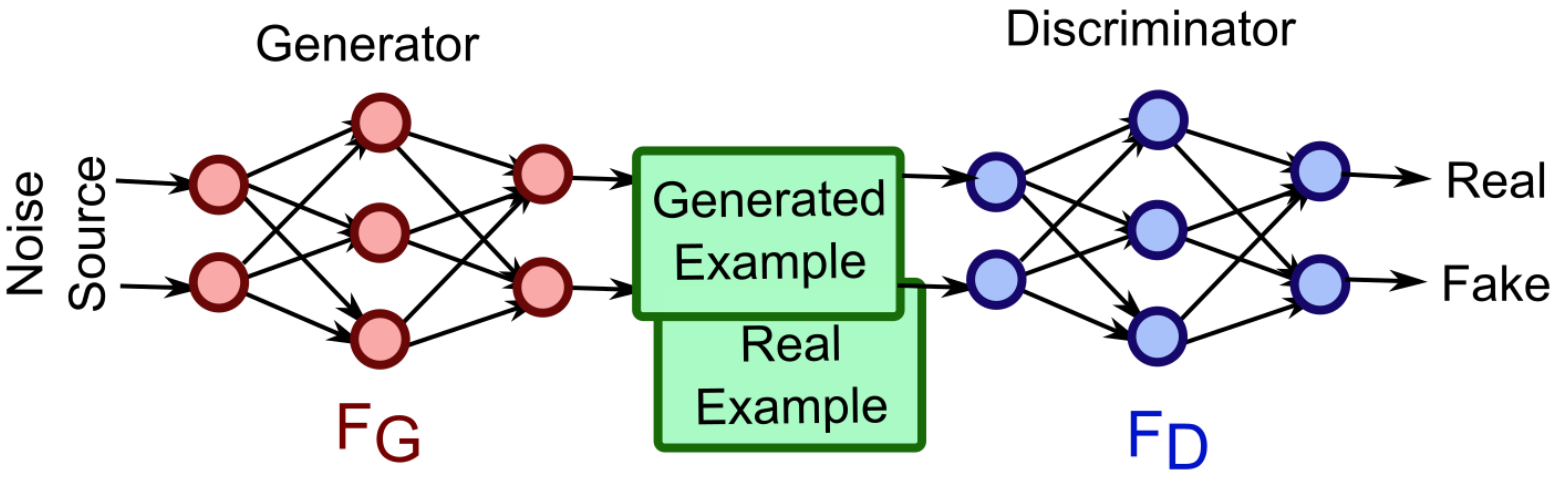
The **LSTM units** give the network memory cells with read, write and reset operations. During training, the network can learn when it should remember data and when it should throw it away.

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.

Source

Deep Learning - Basics

Generative Adversarial Networks

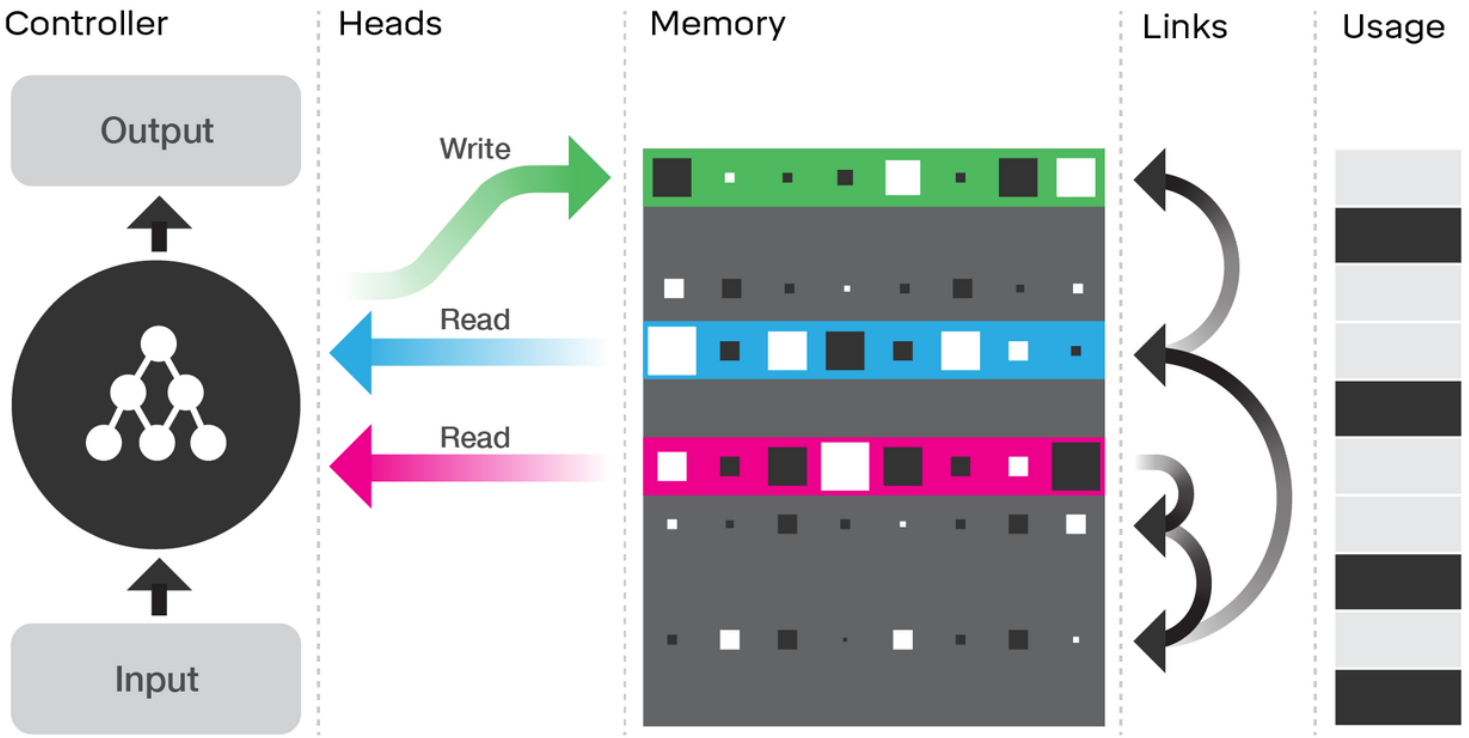


Generative Adversarial Networks (GANs) consist of any two networks with one tasked to generate content and the other has to judge content. The discriminating network receives either training data or generated content from the generative network and tries to predict the data source (real or fake). This creates a form of competition where the discriminator is getting better at distinguishing real data from generated data and the generator is learning to become less predictable to the discriminator.

Source

Deep Learning - Basics

Differentiable Neural Computer

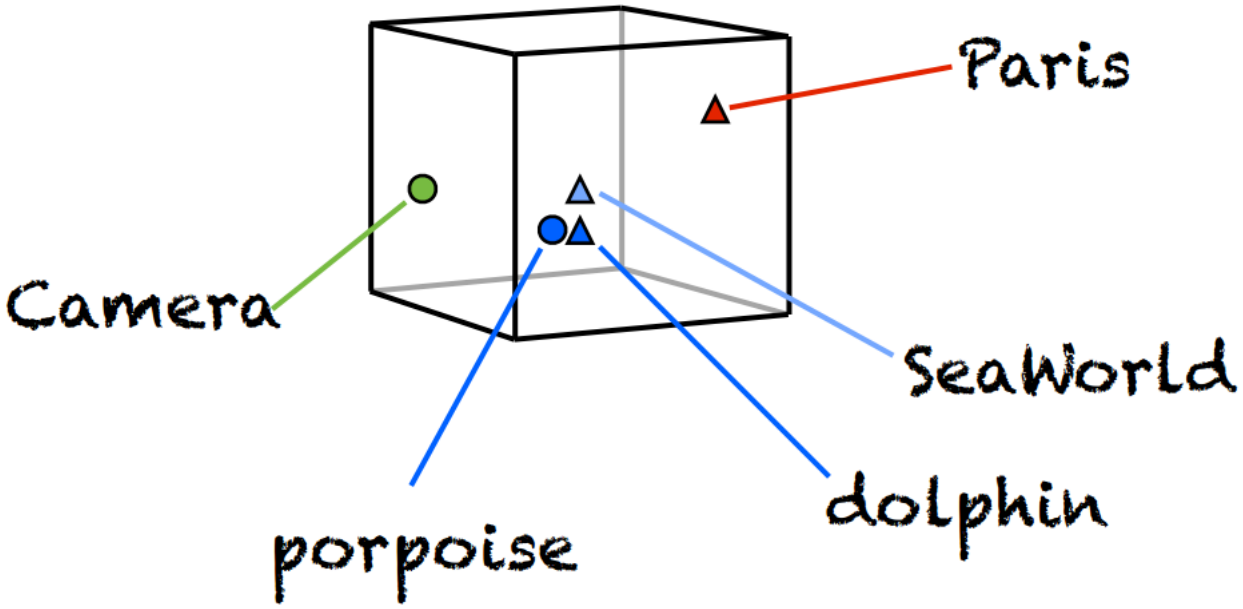


Differentiable Neural Computer is a hybrid learning machine combining neural networks with read-write memory. They learn how to use memory and how to produce answers completely from scratch. This learning machine is able, without prior programming, to organize information into connected facts and use those facts to solve problems.

Source

Deep Learning - Basics

Natural Language Processing – Embeddings



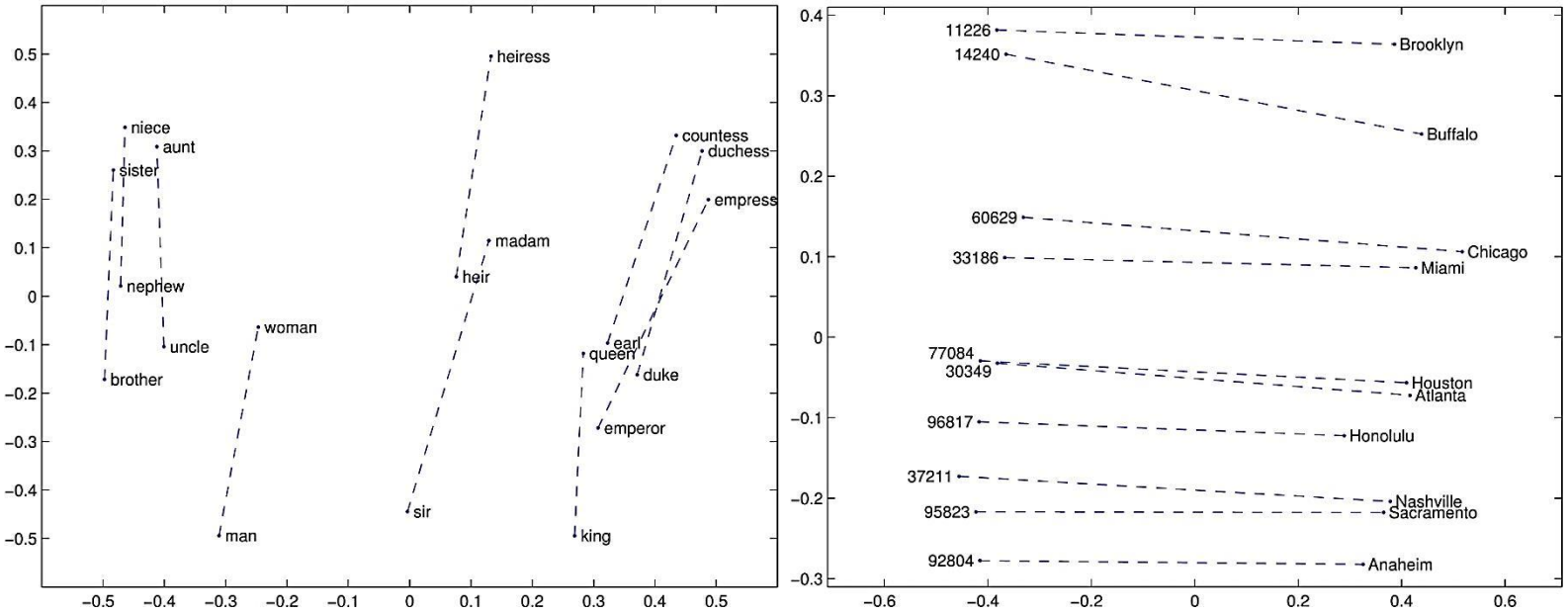
Embeddings are used to turn textual data (words, sentences, paragraphs) into high-dimensional vector representations and group them together with semantically similar data in a vectorspace. Thereby, computer can detect similarities mathematically.

Source

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.



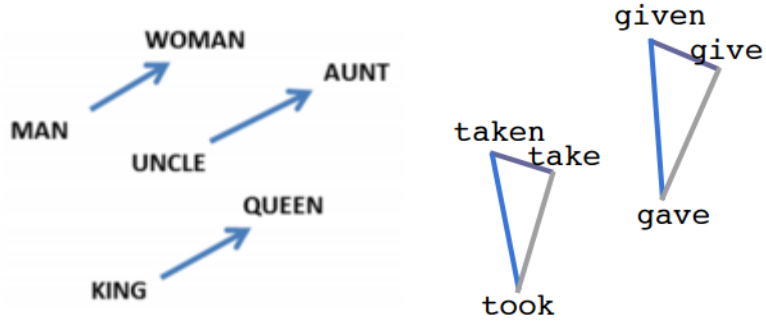
It detects similarities mathematically by grouping the vectors of similar words together. All it needs is words co-occurance in the given corpus.

Source

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*

Source

Deep Learning - Basics

Usage Requirements

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

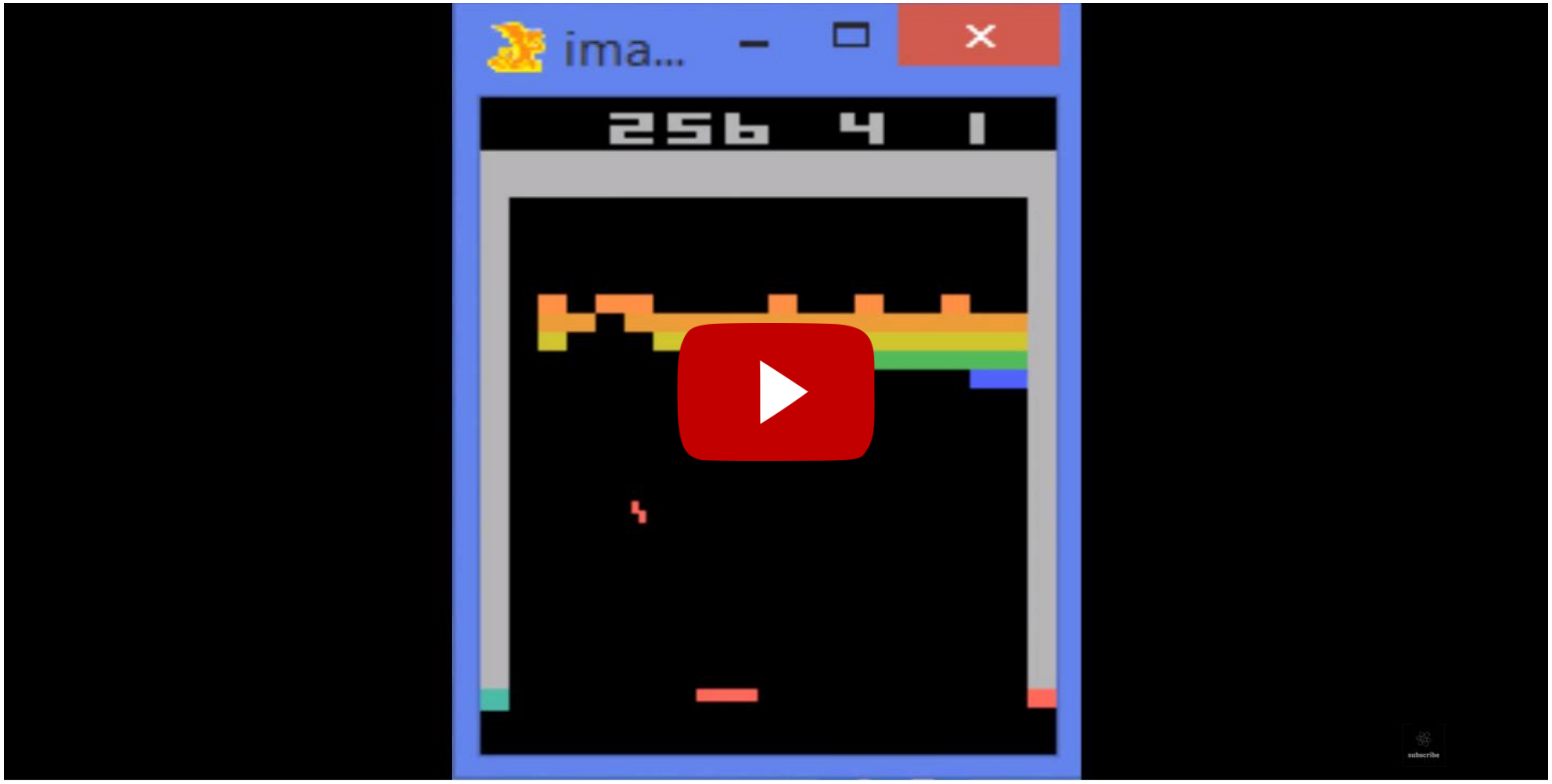
Measurable and describable goals *(define the cost)*

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 in Research

DeepMind Deep Q-Learning

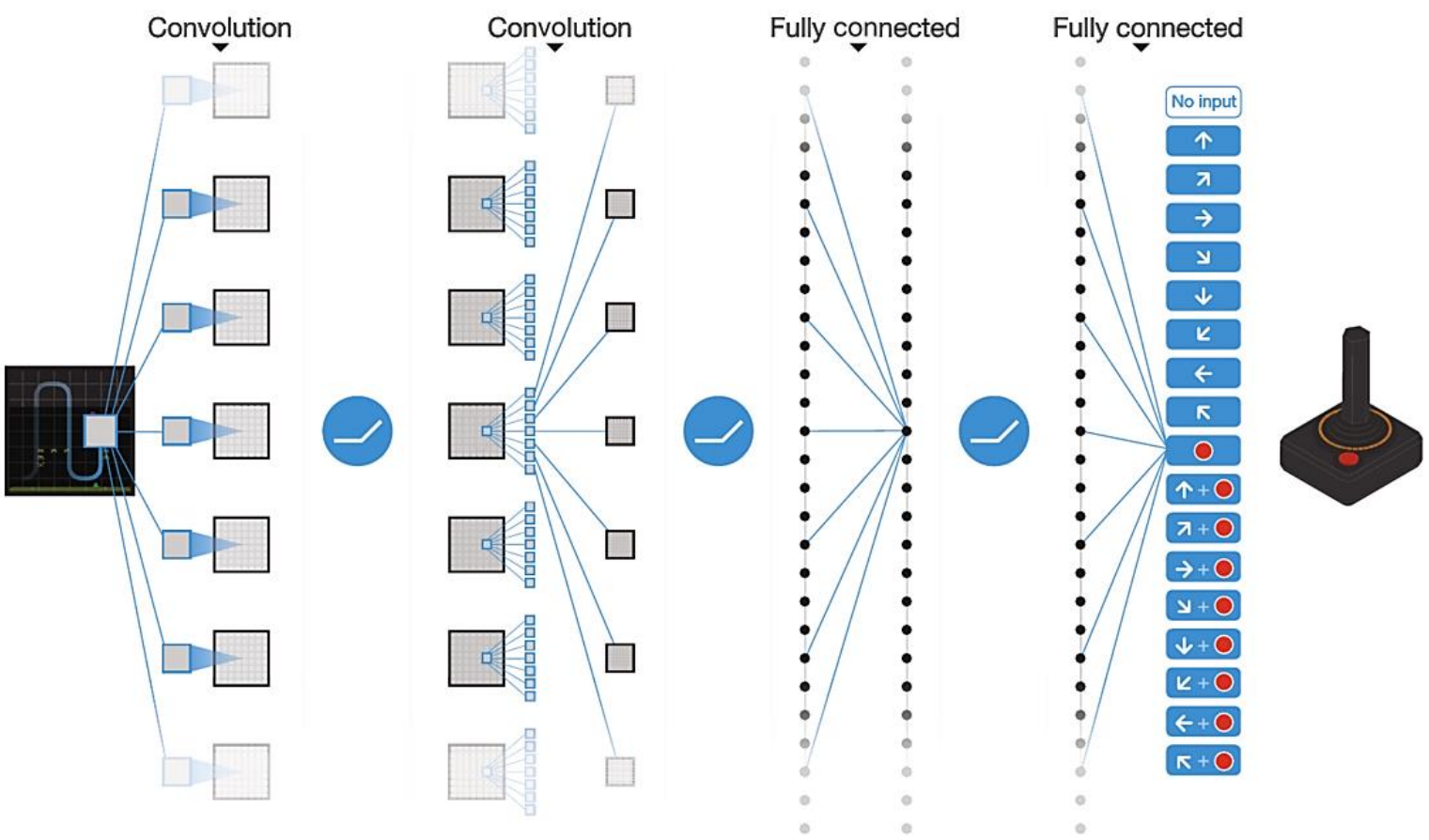


Outperforms humans in over 30 Atari games just by receiving the pixels on the screen with the goal to maximize the score (Reinforcement Learning)

Source

Deep Learning in Research

DeepMind Deep Q-Learning

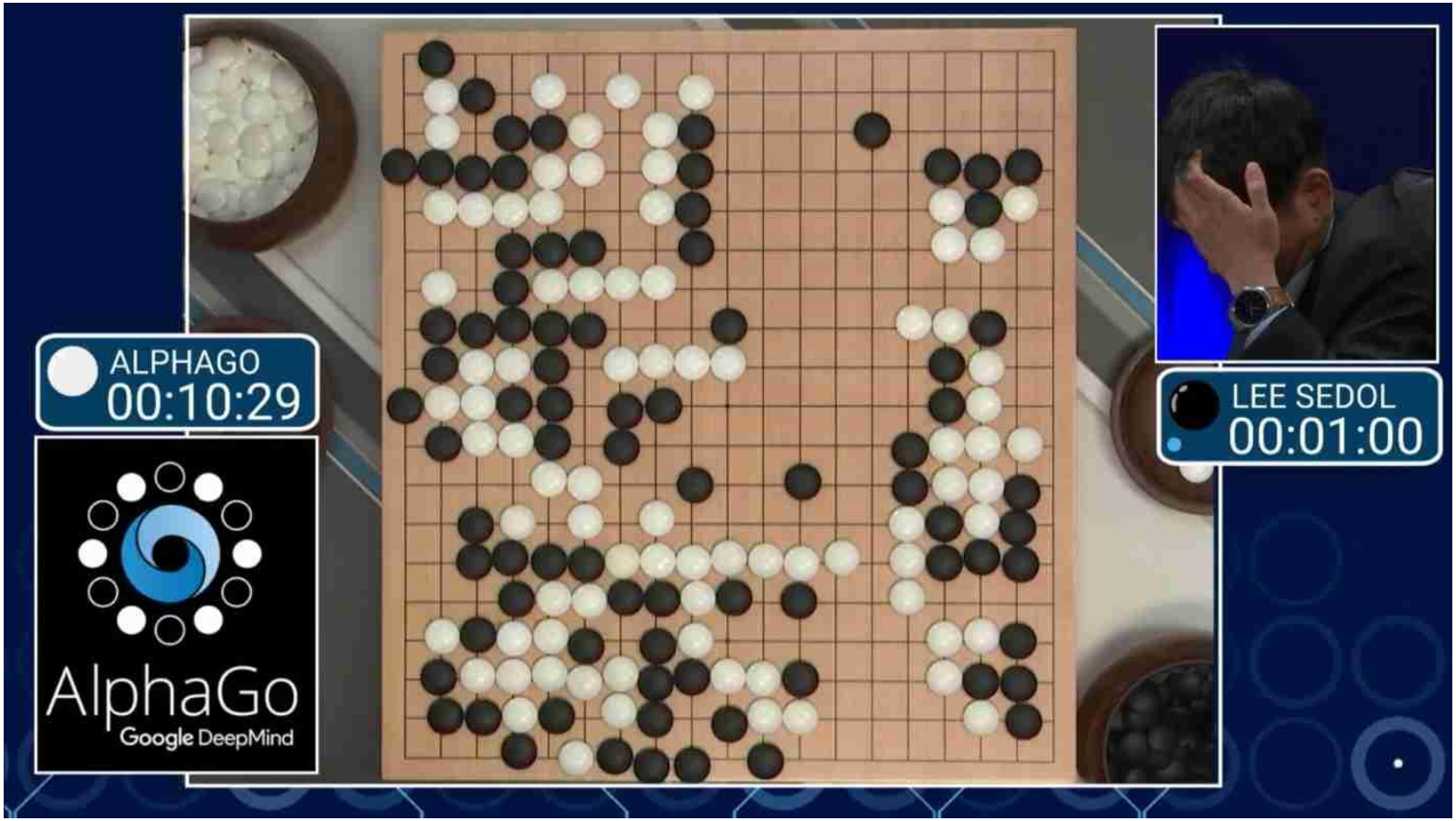


Deep Q-Learning (DQN) is a model-free approach to reinforcement learning using deep networks in environments with discrete action choices

Source

Deep Learning in Research

DeepMind AlphaGo



History is made: Google's AlphaGo wins the match against Go champion Lee Sedol

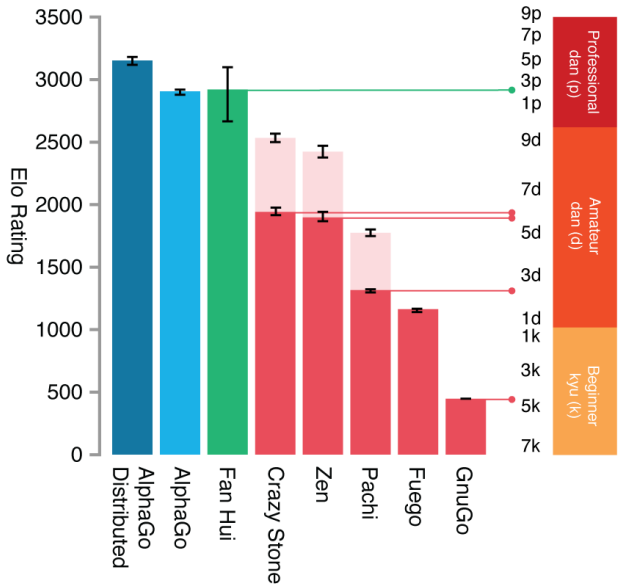
Source

Deep Learning in Research

DeepMind AlphaGo

Demis Hassabis
@demishassabis

Just been told 60m viewers watched the first match online just in China! 100m+ worldwide inc. TV, 3300 news articles just in Korea. Amazing!



AlphaGo could learn the game by examining thousands of human Go moves, and then it could master the game by playing itself over and over and over again. The result is a system of unprecedented beauty.

Source

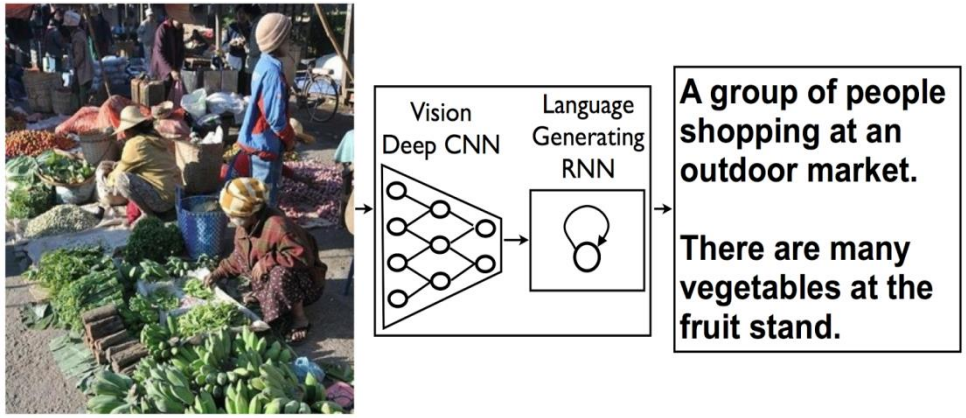
Deep Learning in Computer Vision

Image Segmentation

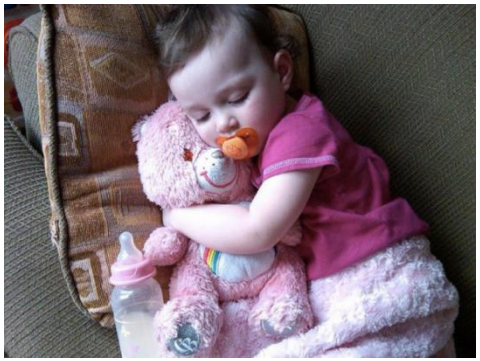
Source

Deep Learning in Computer Vision

Image Captioning



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

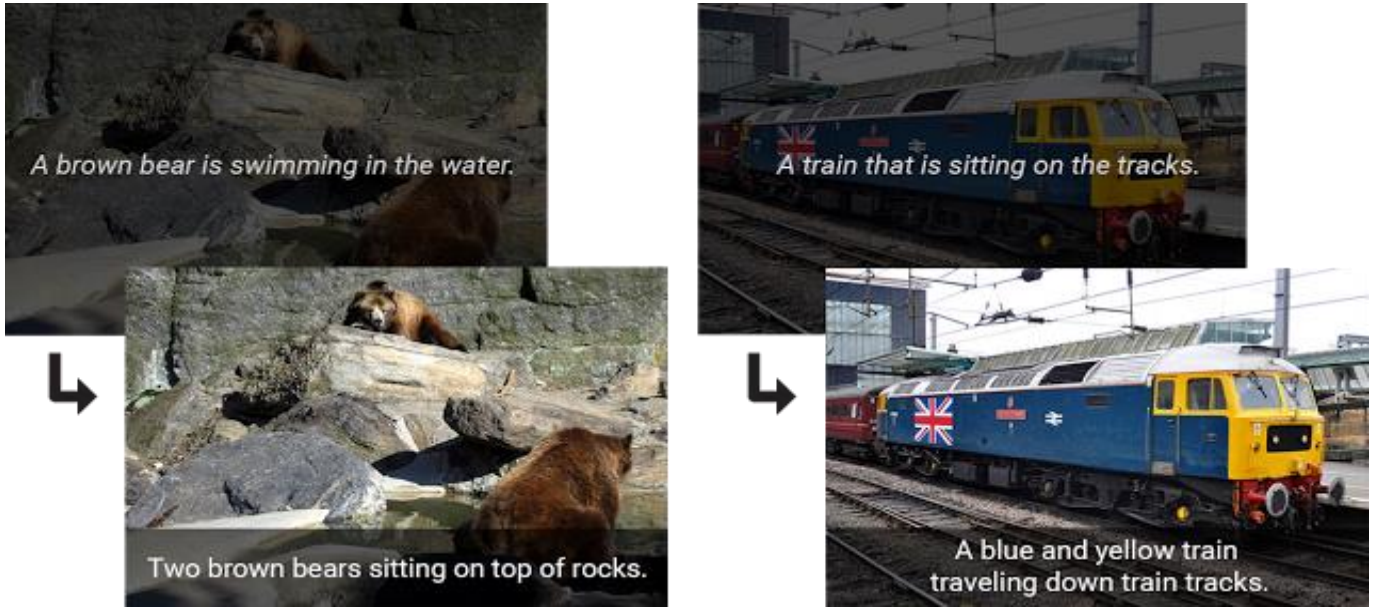
Two pizzas sitting on top of a stove top oven

A man flying through the air while riding a skateboard

Source

Deep Learning in Computer Vision

Image Captioning v2



Source

Deep Learning in Computer Vision

Image Compression

Image compression with Residual Gated Recurrent Unit (Residual GRU).
Left: Original (1419KB PNG), **Center**: JPEG (33KB), **Right**: Residual GRU (24KB).
=> 25% smaller for comparable image quality.

Source

Deep Learning in Computer Vision

Image Localization

Photo CC-BY-NC by edwin.11

Photo CC-BY-NC by stevekc

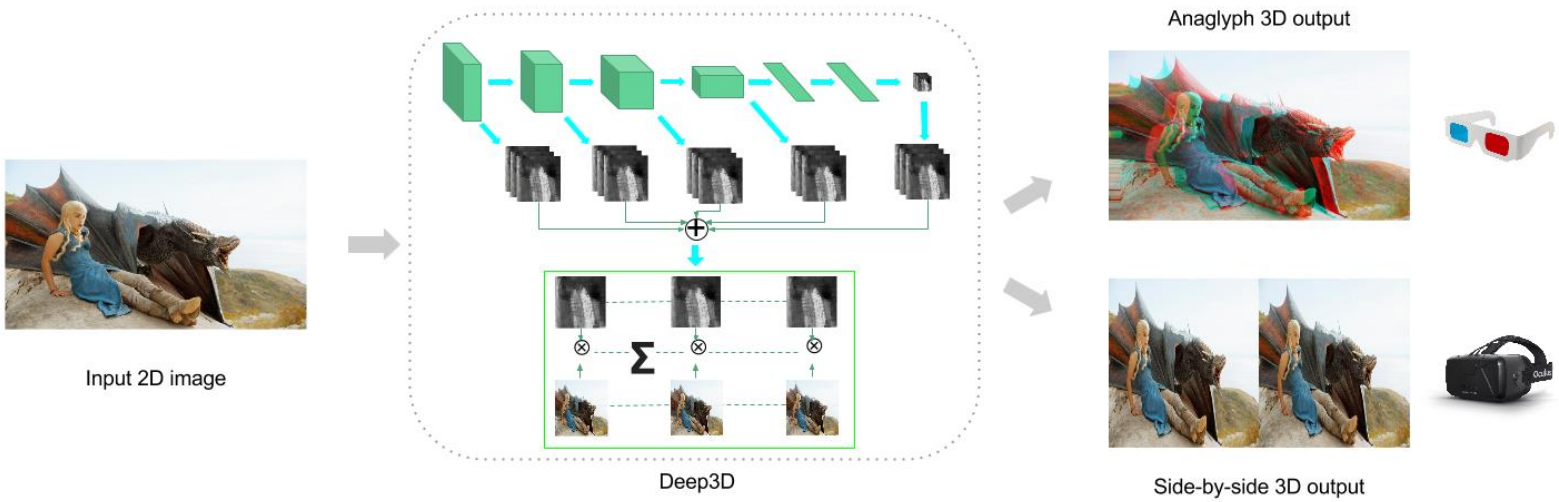
PlaNet is able to determine the location of almost any image with superhuman ability.

Source

Deep Learning in Computer Vision

Image Transformation – 2D-to-3D

Deep3D can automatically convert image/video from 2D-to-3D with Convolutional Neural Networks. It learns to infer 3D representations of the world based on training set of 3D movies.



Source

Deep Learning in Computer Vision

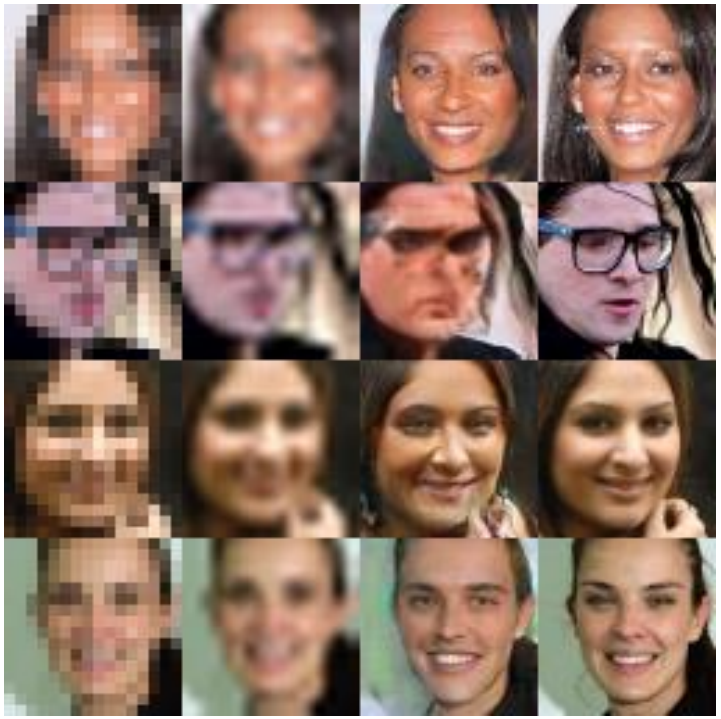
Image Colorization

Given a grayscale photograph as input, this Convolutional Neural Network tackles the problem of hallucinating a plausible color version of the photograph.

Source

Deep Learning in Computer Vision

Image Sharpening



DCGAN architecture to upscale and sharpen an image with features that are plausible based on the dataset that was used to train the neural net.

Source

Deep Learning in Computer Vision

Image Completion

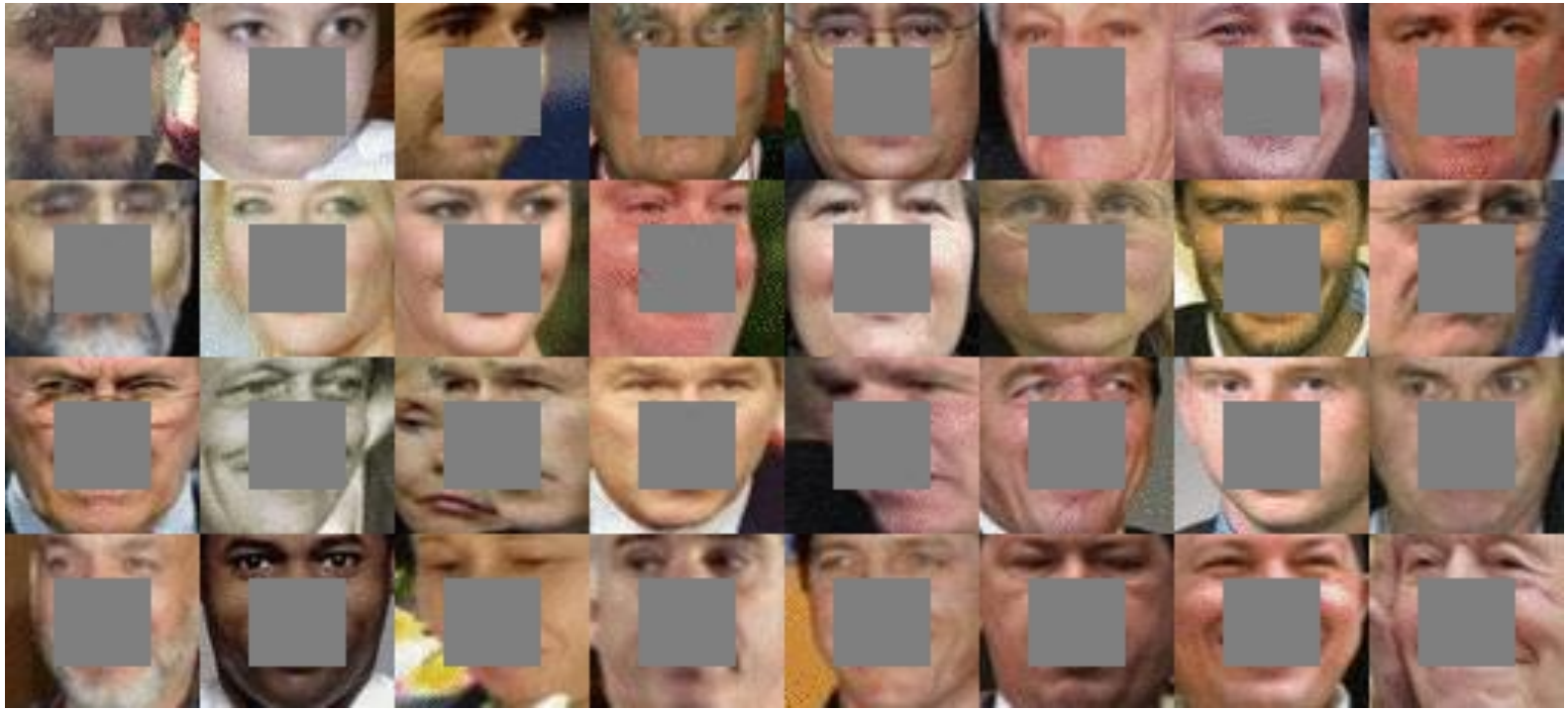
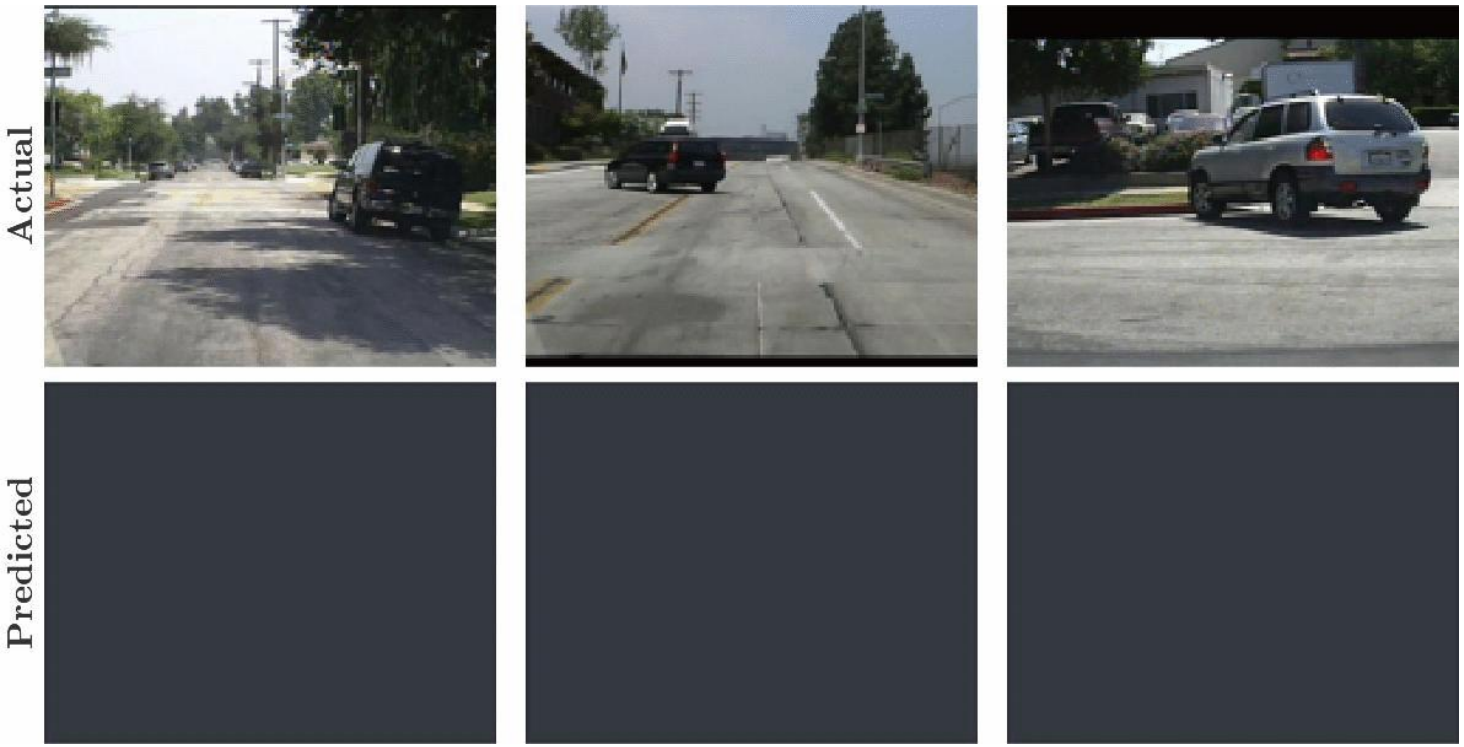


Image completion with deep convolutional generative adversarial networks (DCGAN). The centers of these images are being automatically generated.

Source

Deep Learning in Computer Vision

Video Sequence Prediction

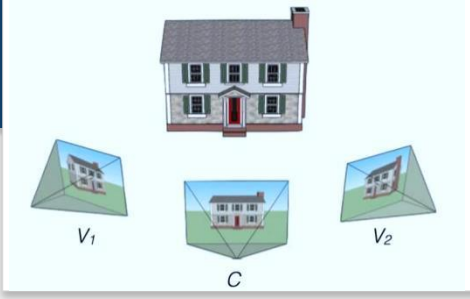


PredNet - a deep convolutional recurrent neural network that predicts the future frames in a video sequence. These networks are able to robustly learn to predict the movement of synthetic (rendered) objects.

Source

Deep Learning in Computer Vision

DeepStereo – 2D to 3D image conversion



DeepStereo: Turns images from Street View into a 3D space that shows unseen views from different angels by figuring out the depth and color of each pixel.

Source

Deep Learning in Computer Vision

Image Generation – Bedrooms

These neural networks are learning what the visual world looks like!

Source

Deep Learning in Computer Vision

Image Generation – Album Covers

Source

Deep Learning in Computer Vision

Image Generation – Faces

Generating realistic faces based on a selected person's identity, emotion, and orientation with deconvolution network. You give the network the parameters of the thing you want to draw and it does it.

Source

Deep Learning in Computer Vision

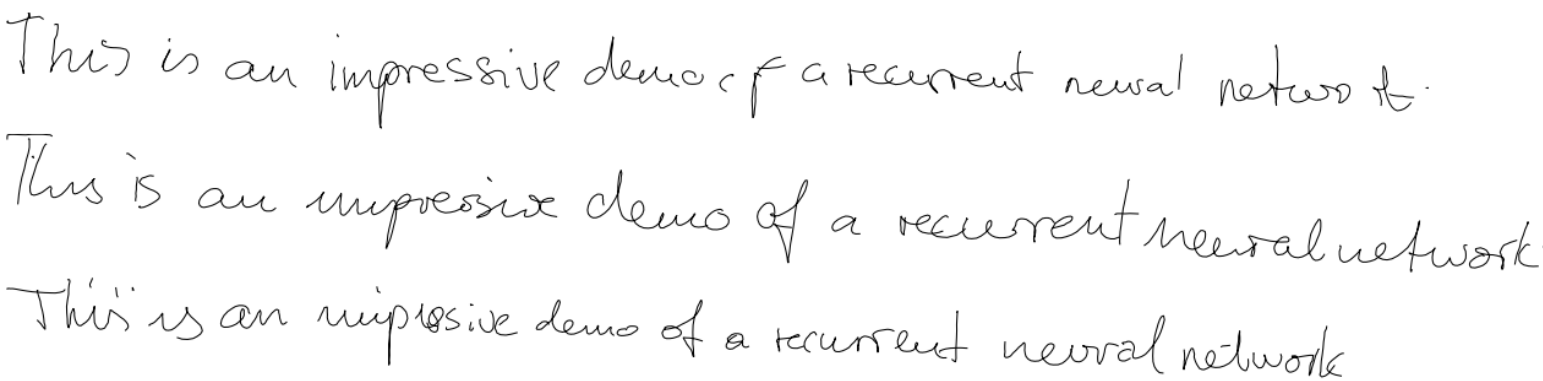
Image Generation – From Descriptions

Deep architecture and GAN formulation to translate visual concepts from characters to pixels. We demonstrate the capability of our model to generate plausible images of birds and flowers from detailed text descriptions.

Source

Deep Learning in Computer Vision

Image Generation - Handwriting



This LSTM recurrent neural network is able to generate highly realistic cursive handwriting in a wide variety of styles, simply by predicting one data point at a time.

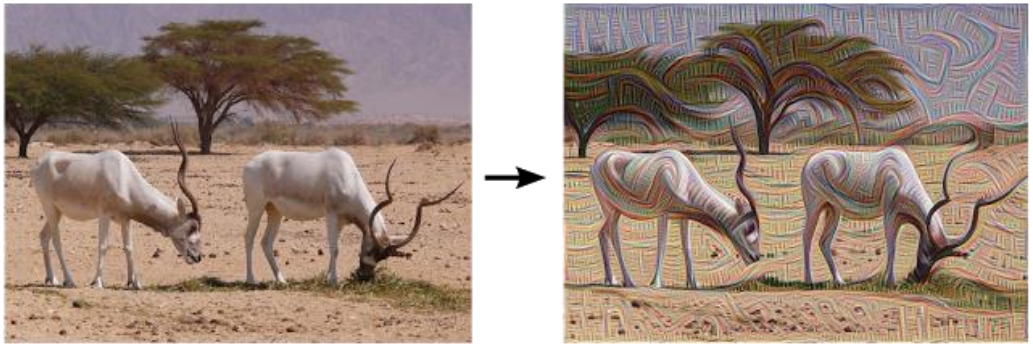
Source

Deep Learning in Computer Vision

DeepDream – Inceptionism

Inceptionism helps to understand and visualize what a neural network has learned during training

"No picture of a dumbbell is complete without a muscular weightlifter"



Let the network over-interpret whatever it detects in a selected layer *(e.g. edges)*

Source

Deep Learning in Computer Vision

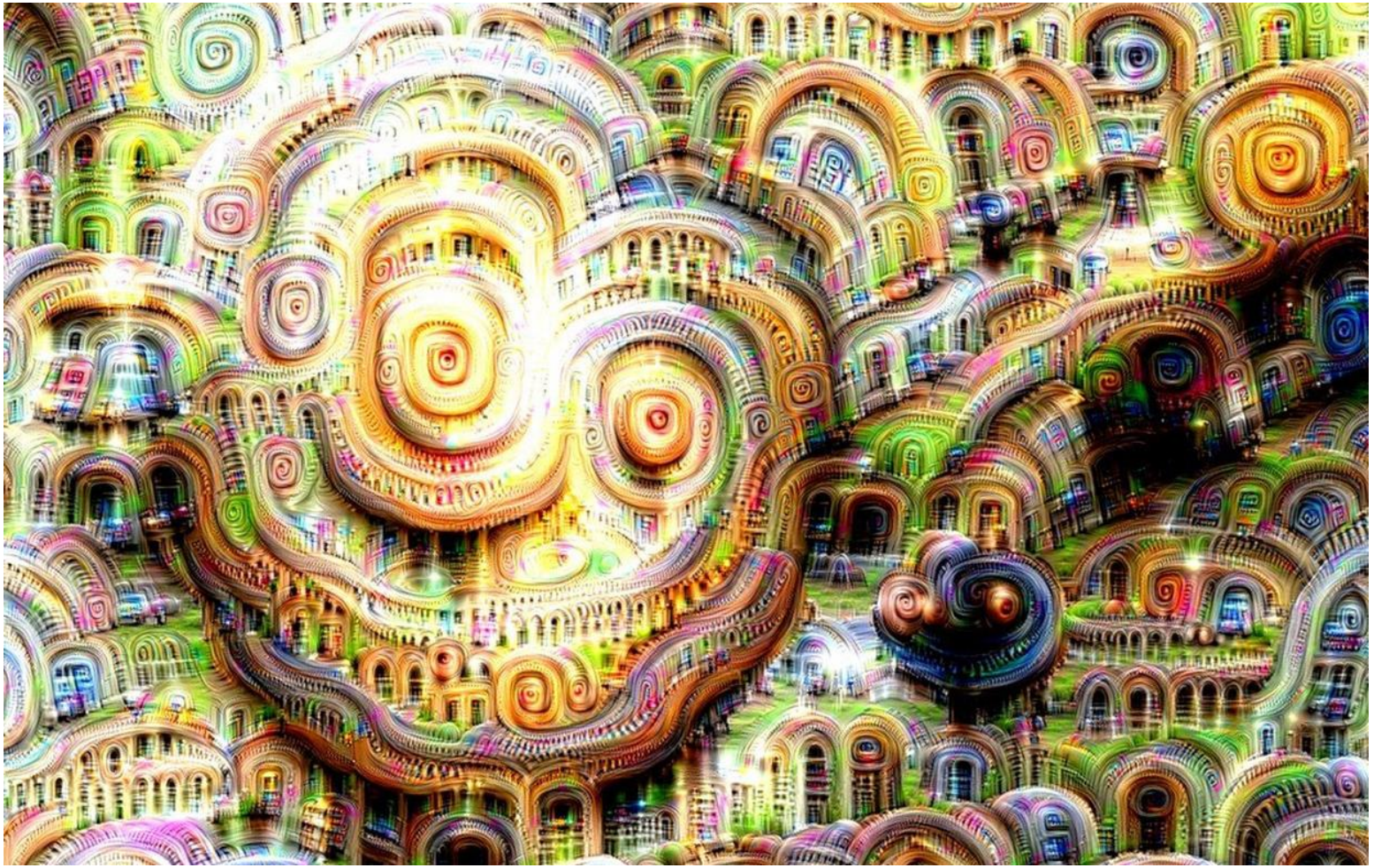
DeepDream – Inceptionism

By choosing higher level layers, more sophisticated features or even whole objects tend to emerge.

Source

Deep Learning in Computer Vision

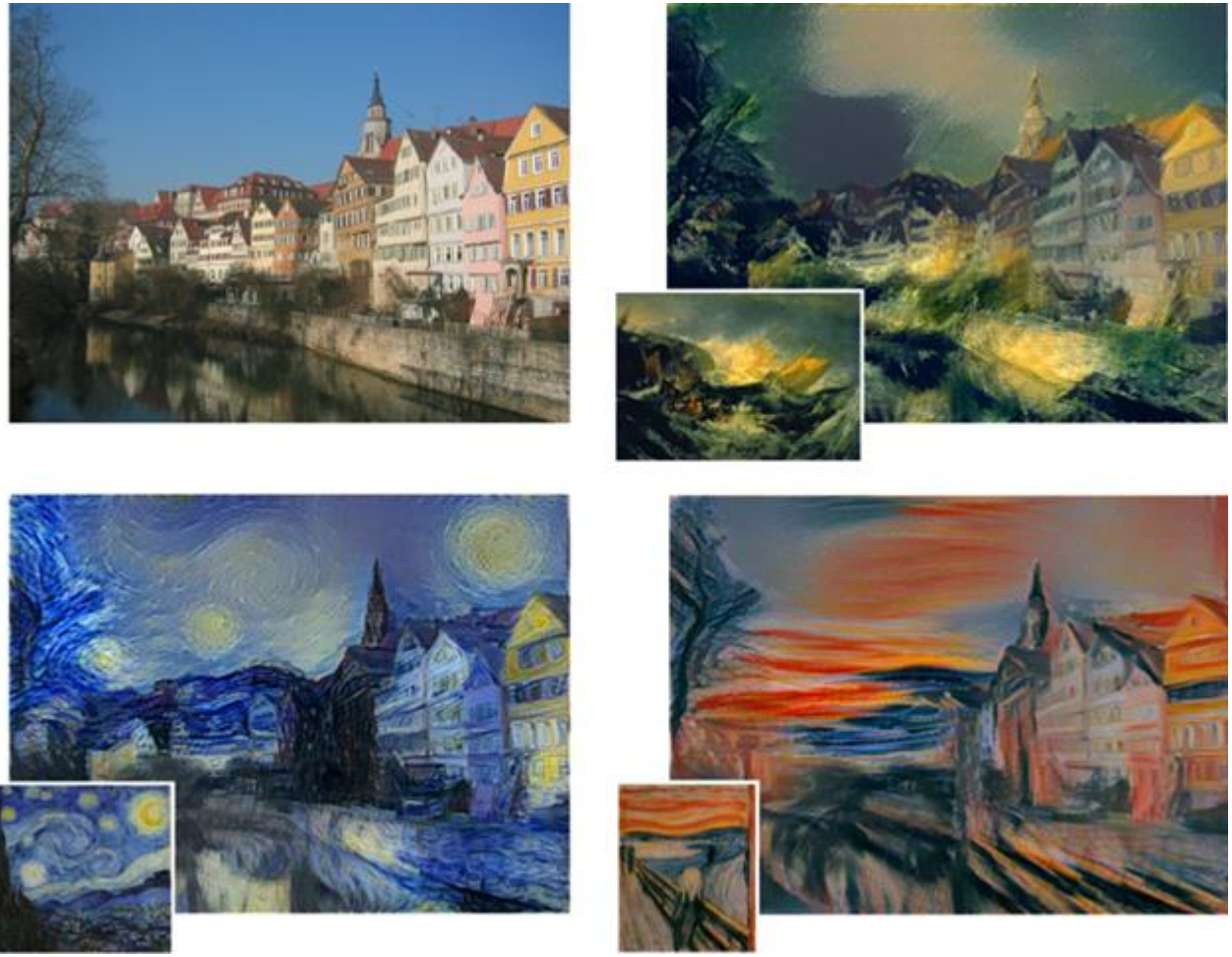
DeepDream – A Tool for Artists?



Source

Deep Learning in Computer Vision

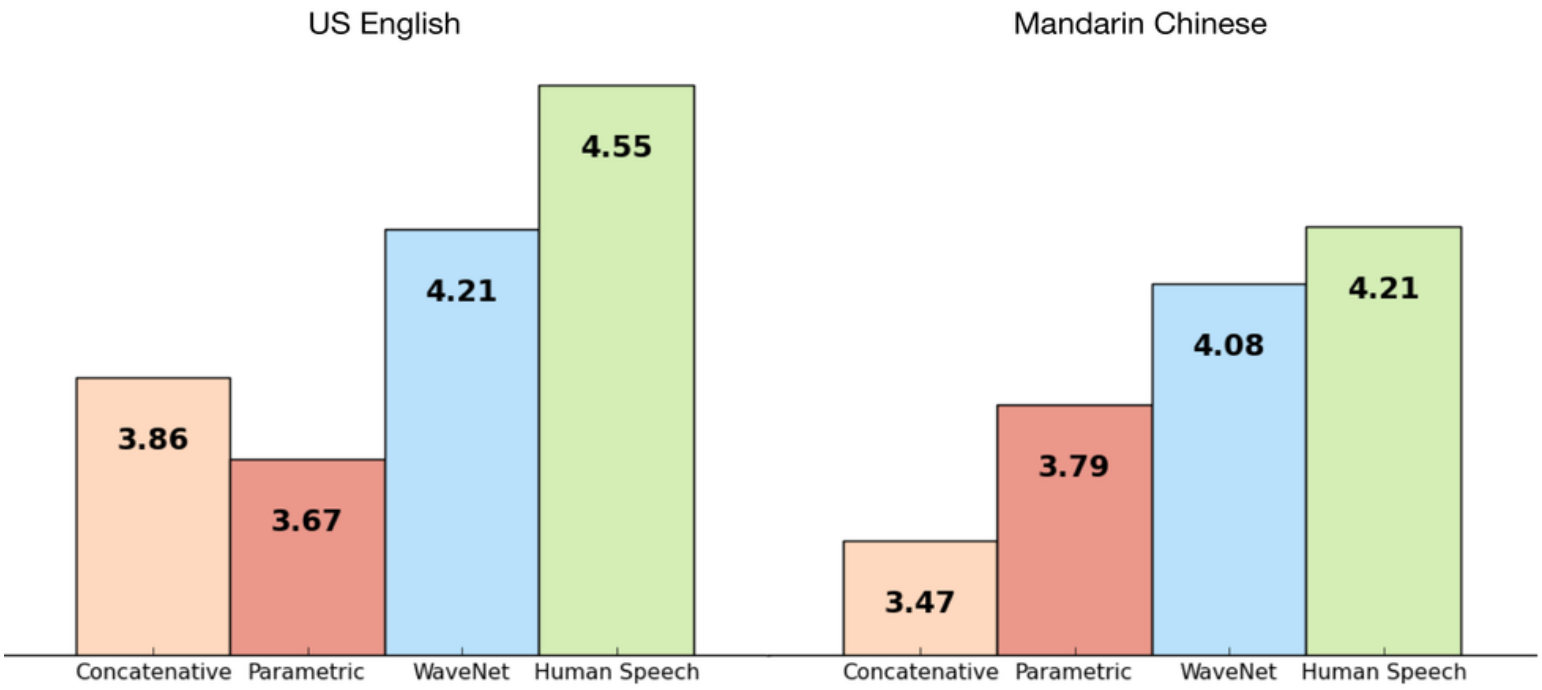
Style Transfer – morph images into paintings



Source

Deep Learning in Audio Processing

Sound Generation

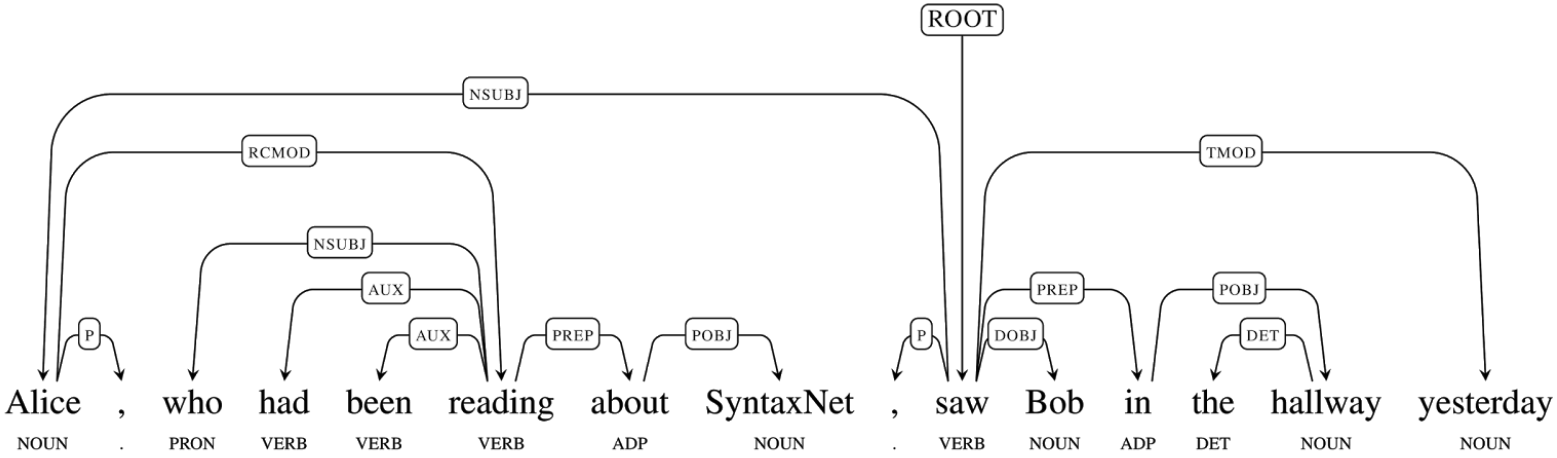


DeepMind's WaveNet is able to generate speech which mimics any human voice and which sounds more natural than the best existing Text-to-Speech systems, reducing the gap with human performance by over 50%.

Source

Deep Learning in NLP

Syntax Parsing

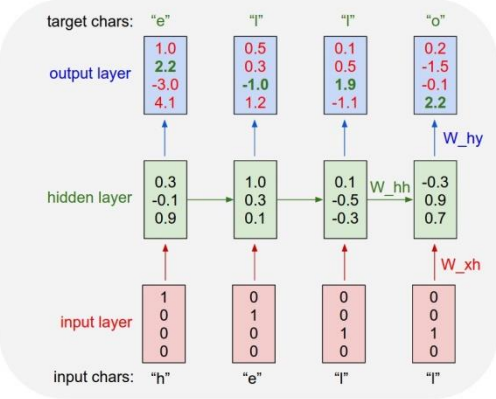


SyntaxNet (Parsey McParseface) tags each word with a part-of-speech tag, and it determines the syntactic relationships between words in the sentence with an 94% accuracy compared to a human performance at 96%.

Source

Deep Learning in NLP

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]
```

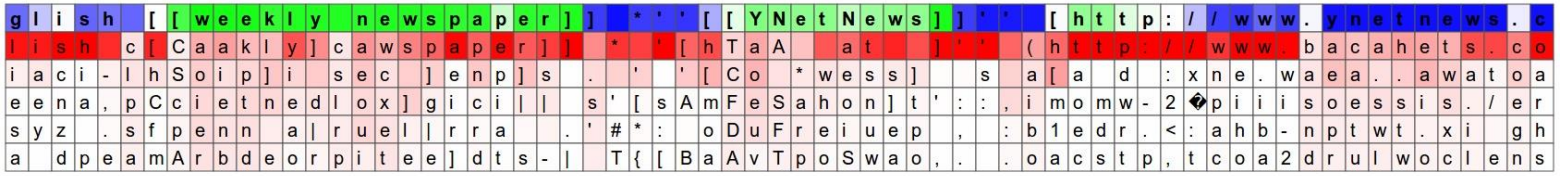
Trained on structured Wikipedia markdown. Network learns to spell English words completely from scratch and copy general syntactic structures.

Source

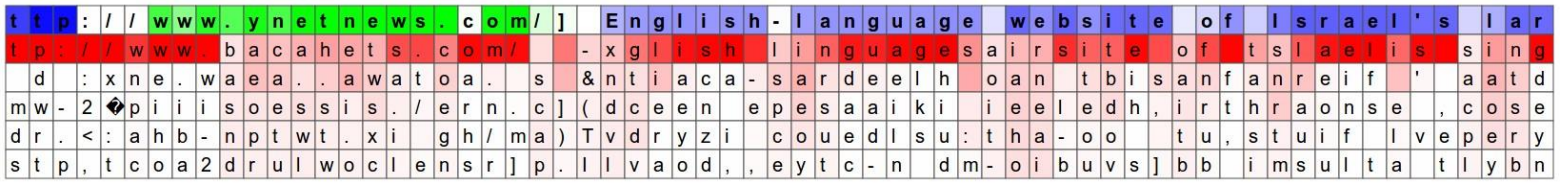
Deep Learning in NLP

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.

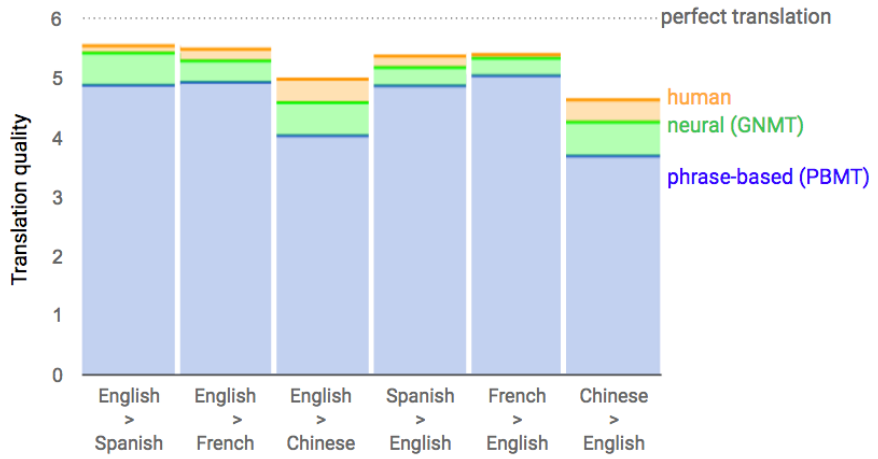


The RNN is likely using this neuron to remember if it is inside a URL or not.

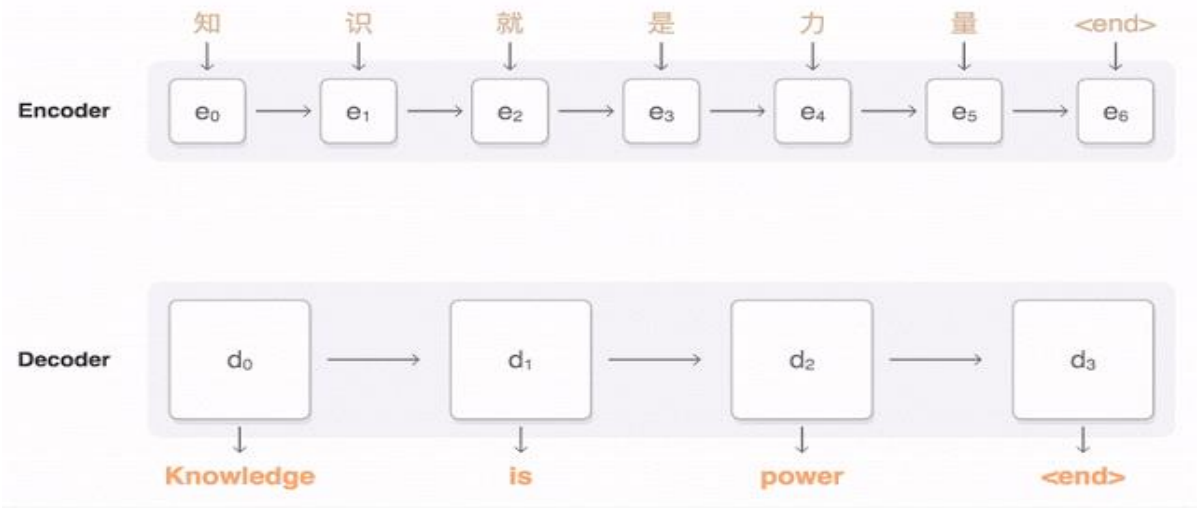
Source

Deep Learning in NLP

Neural Machine Translation



Googles Neural Machine Translation system based on a deep LSTM seq2seq architecture reduces translation errors by more than 55%-85% compared to traditional approaches.



Source

Deep Learning in NLP

Neural Conversational Model

Neural Chatbot: Predicts the next sentence given the previous sentences in a conversation.

The LSTM remembers facts, understands contexts and performs common sense reasoning in the trained domain.

Human: what is the purpose of life ?

Machine: to serve the greater good .

Human: what is the purpose of living ?

Machine: to live forever

Human: what is the purpose of existence?

Machine: to find out what happens when we get to the planet earth

Human: where are you now ?

Machine: i 'm in the middle of nowhere .

Human: what is the purpose of dying ?

Machine: to have a life

Human: what is the purpose of being intelligent ?

Machine: to find out what it is.

Human: what is the purpose of emotions ?

Machine: I don 't know .

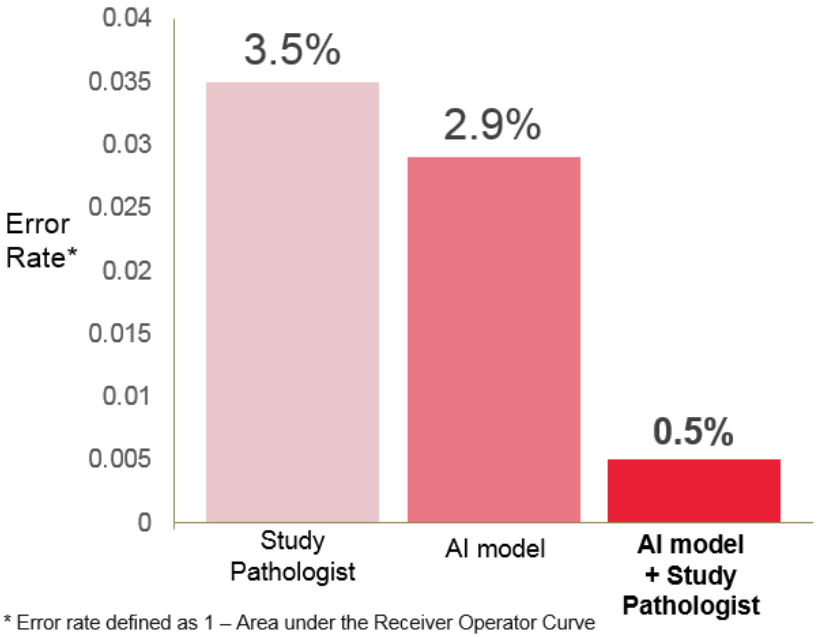
Philosophical Q&A – Network trained with OpenSubtitles (movie subtitles)

Source

Deep Learning in Science

Breast Cancer Diagnoses

(AI + Pathologist) > Pathologist



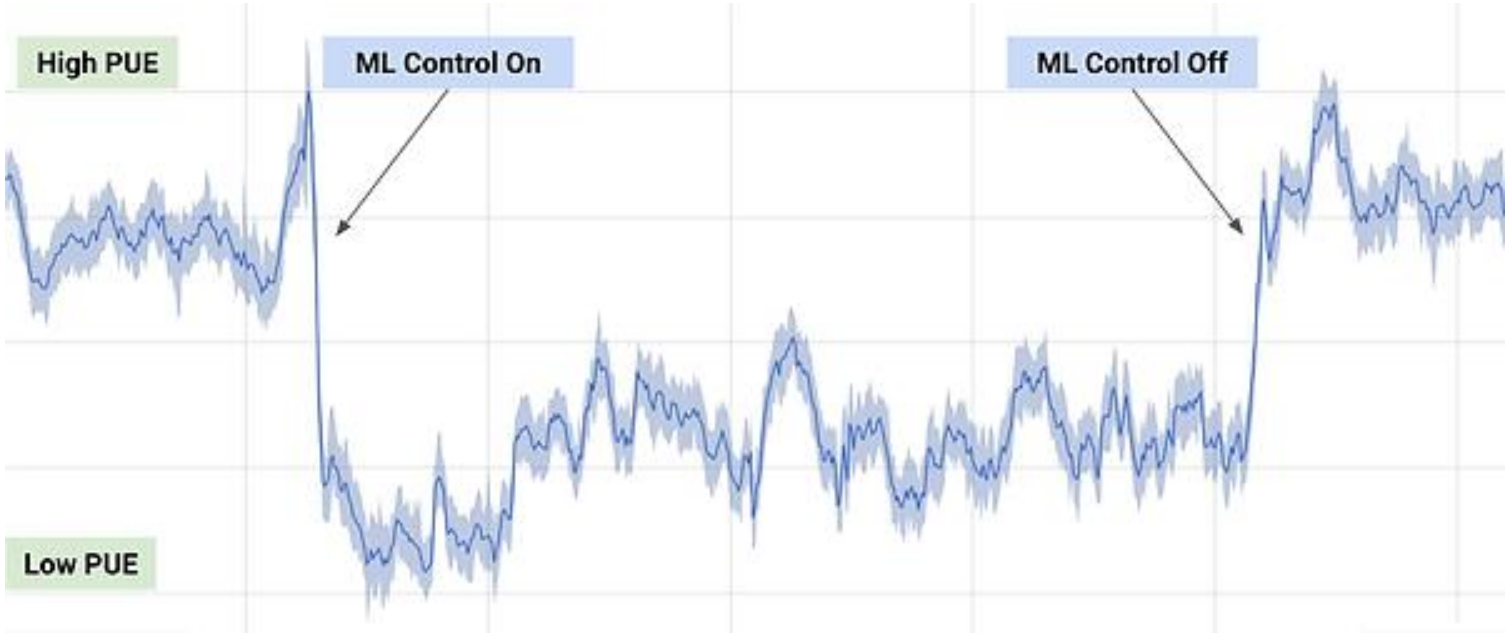
* Error rate defined as 1 – Area under the Receiver Operator Curve
** A study pathologist, blinded to the ground truth diagnoses, independently scored all evaluation slides.

Deep Learning drops error rate for breast cancer Diagnoses by 85%. Researchers trained their models with millions of labeled images to find the probability that a patch contains cancer, eventually creating tumor probability heatmaps.

Source

Deep Learning in Science

Saving Energy

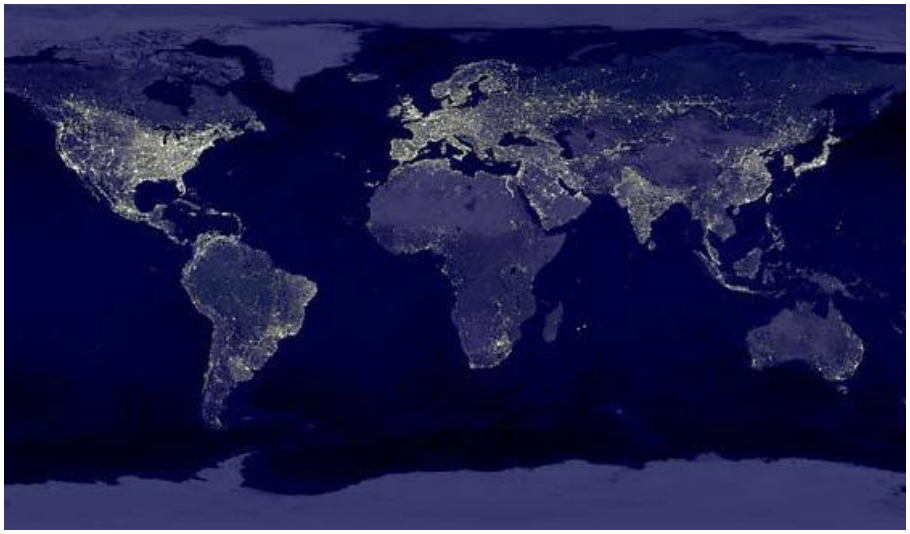


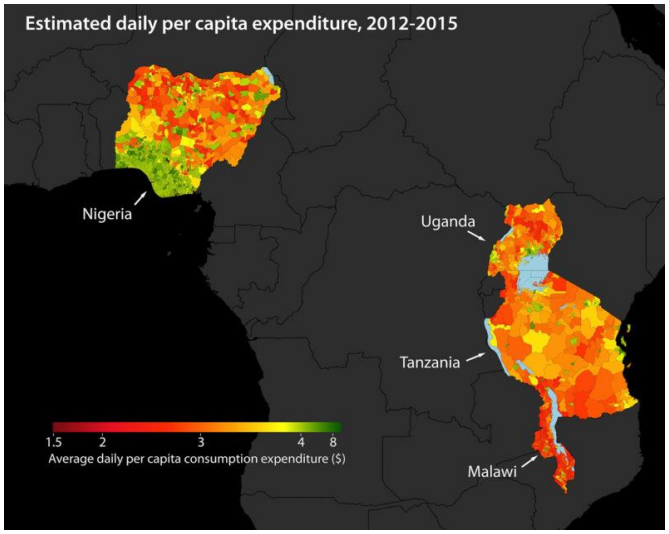
DeepMind AI reduces data center cooling bill by 40% using a system of neural networks trained on different operating scenarios and parameters within Google's data centers.

Source

Deep Learning in Science

Mapping Poverty





Combining satellite imagery and machine learning to predict poverty. A deep-learning algorithm that can recognize signs of poverty in satellite images – such as condition of roads – by sorting through a million images to accurately identify economic conditions in five African countries.

Source

Deep Learning in Robotics

Learning skills from shared experiences

Google researchers tasked robots with trying to move their arms to goal locations, or reaching to and opening a door. Each robot has a copy of a neural network that allows it to estimate the value of taking a given action in a given state. Through a trial-and-error process these robots are able to acquire new skills.

Source

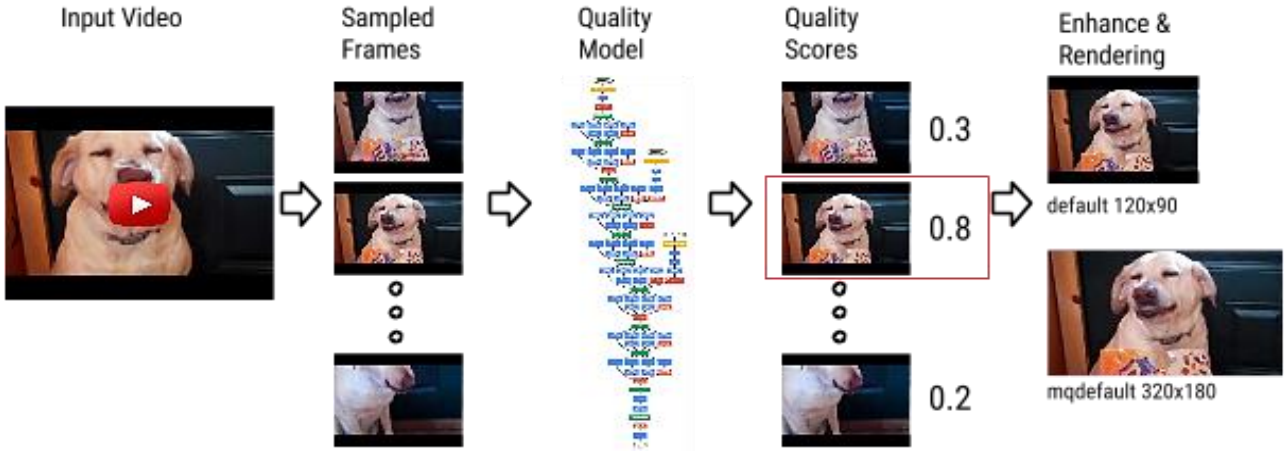
Deep Learning in Google Products

RankBrain (Search): In few months, RankBrain has become the third-most important signal contributing to the search result.

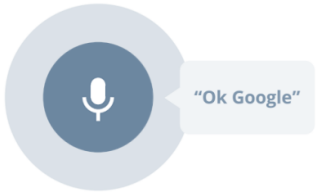
Speech Recognition (Google Now): 30% reduction in Word Error Rate for English. Biggest single improvement in 20 years of speech research.

Visual Translation (Google Translate): Real-time visual translation of 20 more languages all on the phone and without an Internet connection using a deep neural net.

Deep Learning in Google Products



Video Thumbnails (YouTube): Compared to the previous thumbnails, the DNN-powered model selects frames with much better quality



Hotword Detection (Google Now): 25% better than old system in noisy conditions.

Deep Learning in Google Products

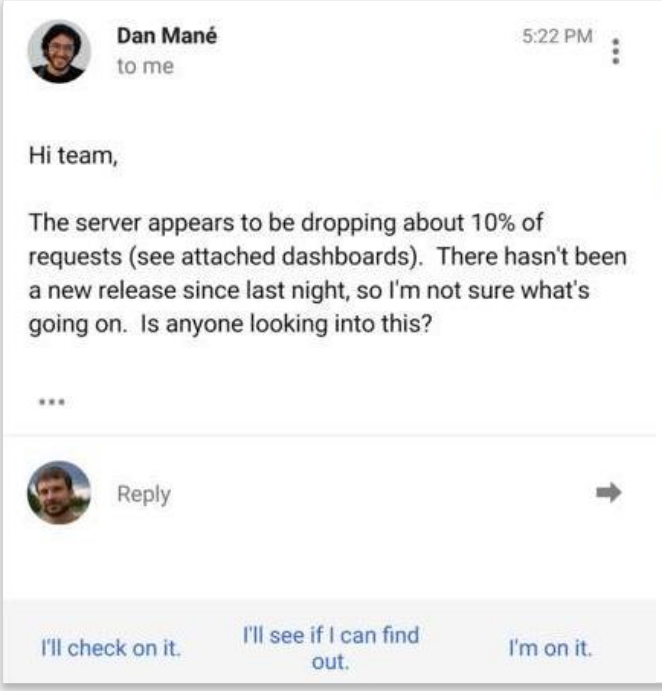
Voicemail transcriptions *(Google Voice / Project Fi)*: Using a long short-term memory deep recurrent neural network the transcription errors was cut by 49%.

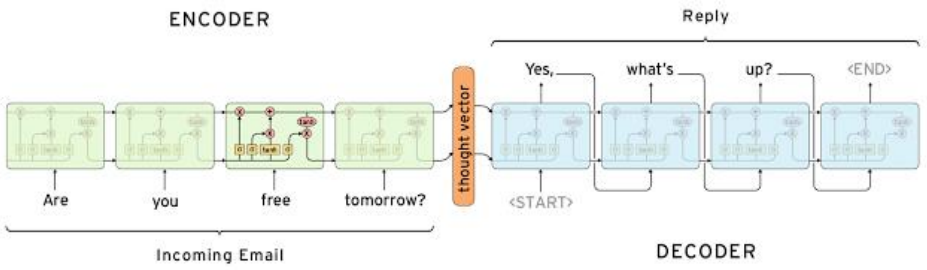
Photo Search (Google Photos): Error rate of just 5% which is as good as humans performing the same task. Also, superhuman performance in face recognition.

House number Recognition (Street View): Performance is comparable to, and in some cases exceeds, that of human operators.

Deep Learning in Google Products

Spam Filter (Gmail): Rejects 99.9% of spam, while mistaking legitimate messages for spam only 0.05% of the time.





Smart Reply (Inbox): A neural net to suggest automatic replies to emails that you can send with a single click. About 10% of all responses in inbox are done by this feature

Deep Learning - Tools

Its all Open Source

Deep Learning - Tools

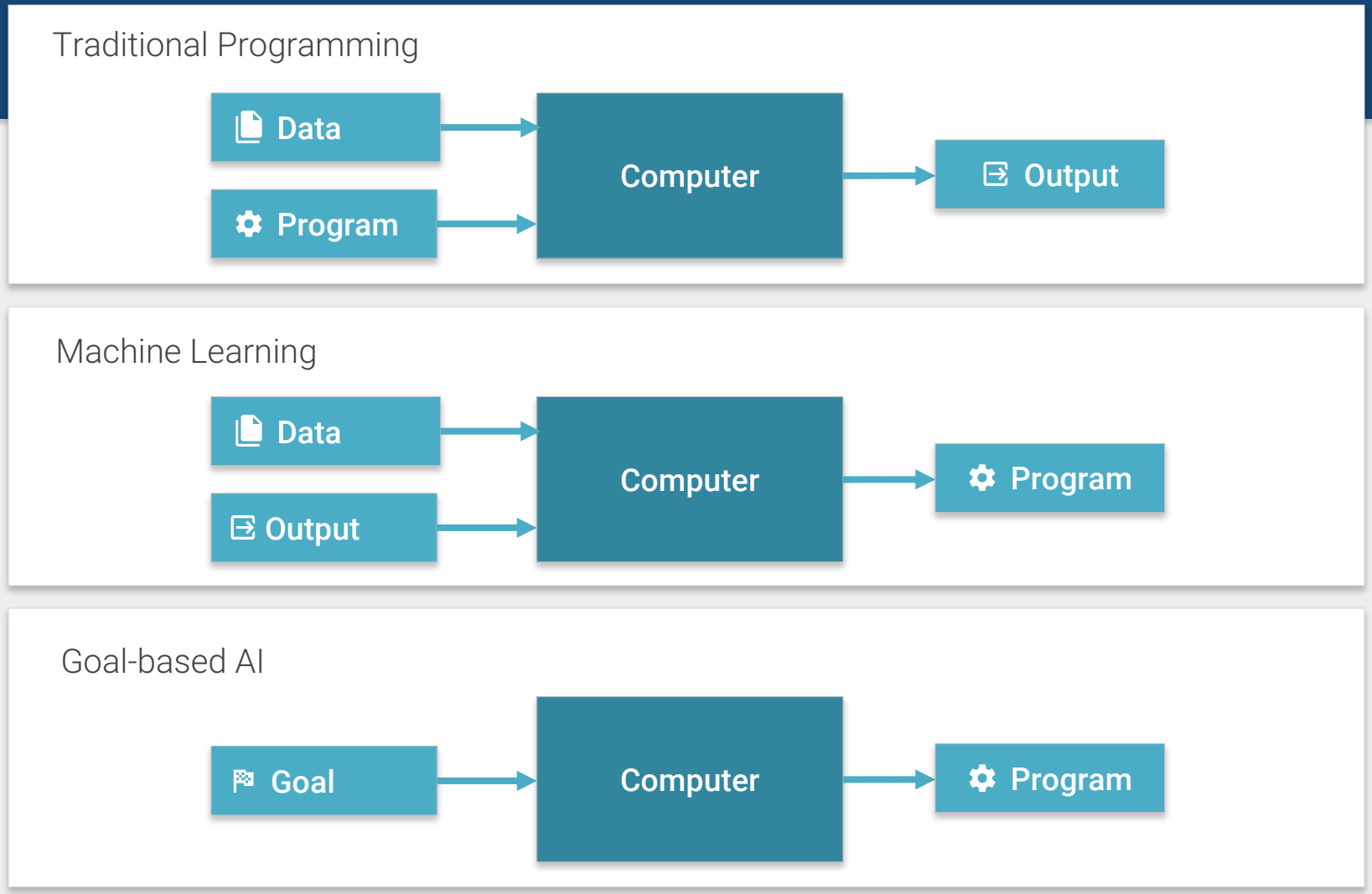
Computing is affordable

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*

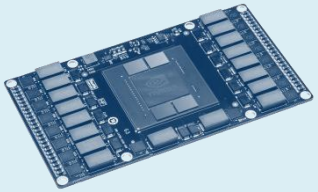
Outlook

Goal-based AI

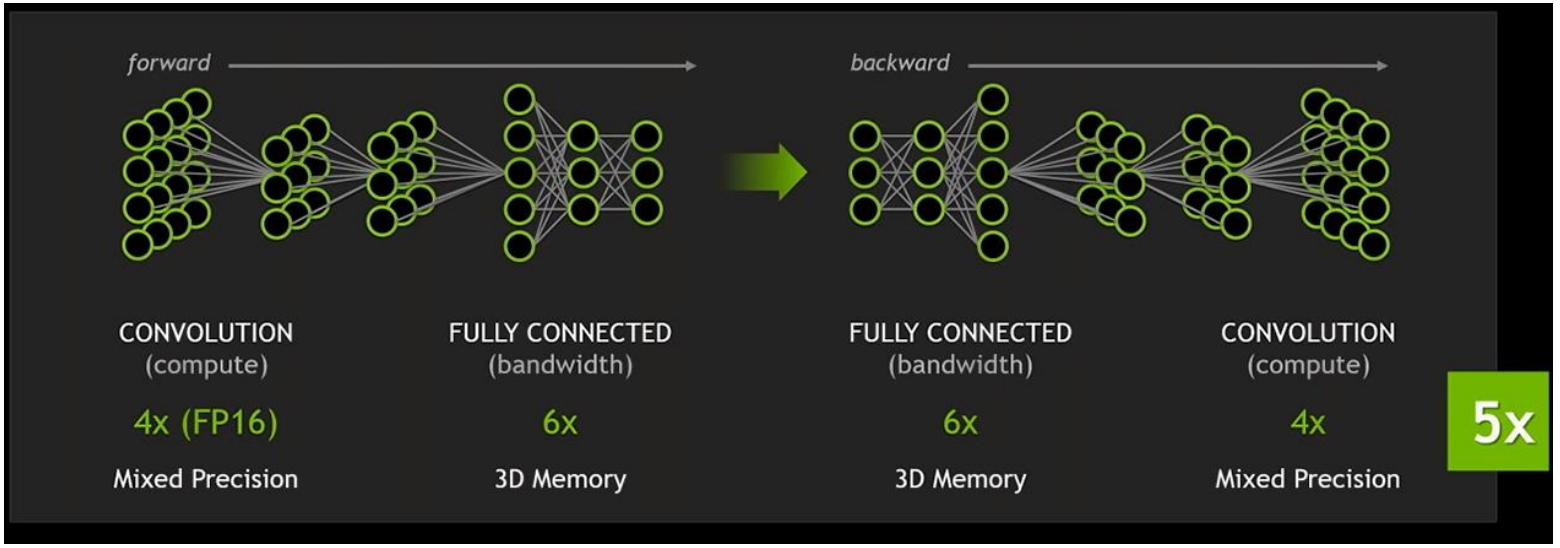


Outlook

NVIDIA Pascal



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

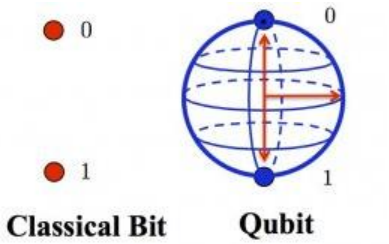


Source

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.



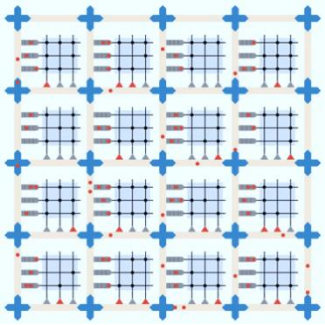
Quantum computers handle what are called **quantum bits** or qubits that can readily have a value of one or zero or anything in between.

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)*

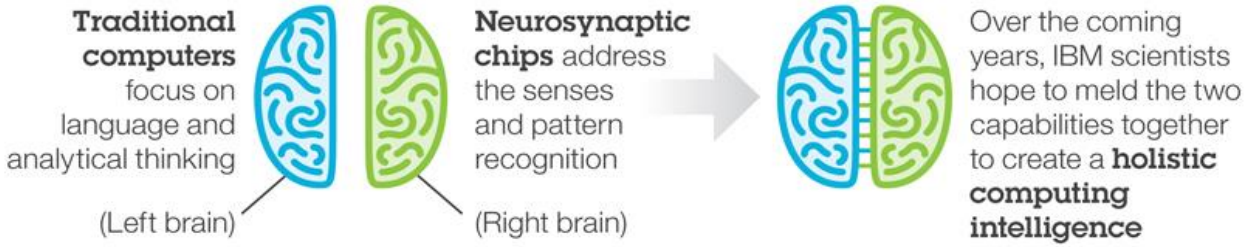
Source

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

Source

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

Outlook

The Enabler

Many of the biggest problems facing humanity today, like curing diseases or addressing climate change, would be vastly easier with the help of AI.

The Big Bang for Self-Driving Cars *(10-15 years).* Fully autonomous taxi systems will change the paradigm of the need to own a car.

AI will fuel a medical revolution *(5-10 years)* by enabling far more efficient drug discovery, diagnoses and research.

Takeaways

Machines that learn to represent the world from experience.

Deep Learning is no magic! Just statistics (matrix multiplications) 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.

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