

머신러닝 개요

Lecture 3 : Status of ML

College of Information and Electronic Engineering

Kyung Hee Univeristy

Prof. Wonha Kim

(wonha@khu.ac.kr)

Contents

1. History of AI
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3.1 History of AI (1/4)

1843	에이더 “... 해석엔진은 꽤 복잡한 곡을 작곡할 수도 있다.”라는 논문 발표[Ada1843]
1950	인공지능 여부를 판별하는 튜링 테스트[Turing1950]
1956	최초의 인공지능 학술대회인 다트머스 콘퍼런스 개최. ‘인공지능’ 용어 탄생[McCarthy1955]
1958	로젠블레이 퍼셉트론 제안[Rosenblatt1958] 인공지능 언어 Lisp 탄생
1959	사무엘이 기계 학습을 이용한 체커 게임 프로그램 개발[Samuel1959]
1969	민스키가 퍼셉트론의 과대포장 지적. 신경망 내리막길 시작[Minsky1969] 제1회 IJCAI(International Joint Conference on Artificial Intelligence) 개최
1972	인공지능 언어 Prolog 탄생
1973	Lighthill 보고서로 인해 인공지능 내리막길, 인공지능 겨울AI winter 시작
1974	웨어보스가 오류 역전파 알고리즘을 기계 학습에 도입[Werbos1974]
1975경	의료진단 전문가 시스템 Mycin - 인공지능에 대한 관심 부활
1979	『IEEE Transactions on Pattern Analysis and Machine Intelligence』 저널 발간
1980	제1회 ICML(International Conference on Machine Learning) 개최 후쿠시마가 NeoCognitron 제안[Fukushima1980]
1986	『Machine Learning』 저널 발간 『Parallel Distributed Processing』 출간 다층 퍼셉트론으로 신경망 부활

1987	Lisp 머신의 시장 붕괴로 제2의 인공지능 겨울 UCI 리포지토리 서비스 시작 NIPS(Neural Information Processing Systems) 콘퍼런스 시작
1989	『Neural Computation』 저널 발간
1993	R 언어 탄생
1997	IBM 딥블루가 세계 체스 챔피언인 카스파로프 이김 LSTM(Long short-term memory) 개발됨
1998경	SVM이 MNIST 인식 성능에서 신경망 추월
1998	르쿤이 CNN의 실용적인 학습 알고리즘 제안[LeCun1998] 『Neural Networks: Tricks of the Trade』 출간
1999	NVIDIA 사에서 GPU 공개
2000	『Journal of Machine Learning Research』 저널 발간 OpenCV 최초 공개
2004	제1회 그랜드 챌린지(자율 주행)
2006	층별학습 탄생[Hinton2006a]
2007경	딥러닝이 MNIST 인식 성능에서 SVM 추월



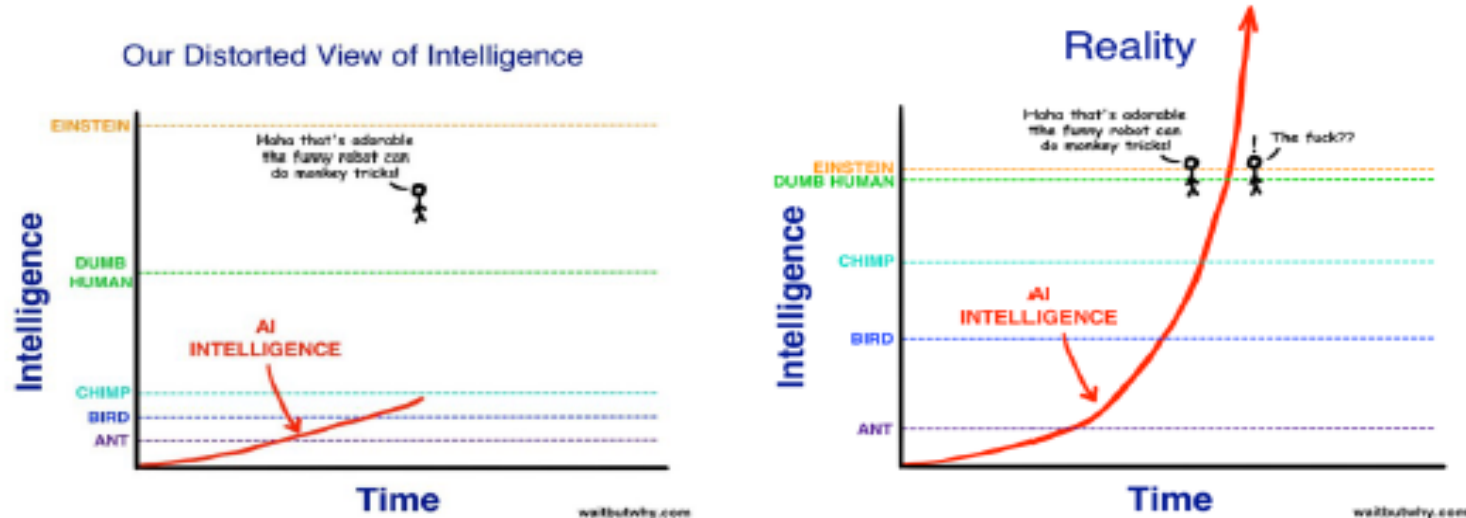
2.4 History of AI (2/4)

2007	GPU 프로그래밍 라이브러리인 CUDA 공개 어번 챌린지(도심 자율 주행) Scikit-learn 라이브러리 최초 공개
2009	Theano 서비스 시작
2010	ImageNet 탄생 제1회 ILSVRC 대회
2011	IBM 왓슨이 제퍼디 우승자 꺾음
2012	MNIST에 대해 0.23% 오류율 달성 AlexNet 발표 (3회 ILSVRC 우승)
2013	제1회 ICLR International Conference on Learning Representations 개최
2014	Caffe 서비스 시작
2015	TensorFlow 서비스 시작 OpenAI 창립
2016	알파고와 이세돌의 바둑 대회에서 알파고 승리[Silver2016] 『Deep Learning』 출간
2017	알파고 제로[Silver2017]



3.1 History of AI (3/4) : Comments on AI

- **Artificial Intelligence(AI)** is intelligence exhibited by machines, rather than humans or other animals (*natural intelligence*, **NI**). In computer science, the field of AI research defines itself as the study of "**intelligent agents**": any device that perceives its environment and takes actions that maximize its chance of success at some goal. [From Wikipedia]
- **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 Super Intelligence (ASI)**: An intellect that is *much smarter* than the best human brains in practically every field, including scientific creativity, general wisdom and social skills.



3.1 History of AI (4/4) : Machine Learning and Deep Learning

- Machine Learning is a type of Artificial Intelligence that provides computers with the ability to learn without being explicitly programmed. [Arthur Samuel]
- A computer program is said to learn from experience **E** with respect to some task **T** and some performance measure **P**, if its performance on **T**, as measured by **P**, improves with experience **E**. [Tome Mitchell]
- Suppose your email program watches which emails you do or do not mark as spam, and based on that learns how to better filter spam. What is the task **T**, experience **E**, and performance measure **P** in this setting?
 - Classifying emails as spam or not spam: **T**
 - Watching you label emails as spam or not spam: **E**
 - The number (or fraction) of emails correctly classified as spam/not spam: **P**
 - None of the above \Rightarrow It is not a machine learning problem
- Deep learning is part of a broader family of machine learning methods based on learning multiple levels of representation and abstraction [Geoffery Hinton]
 - Automatically learning **multiple levels of representations** of the underlying distribution of the data to be modeled.
 - Deep learning algorithms seek to exploit the unknown structure in the input distribution in order to discover good representations, often at multiple levels, **with higher-level learned features defined in terms of lower-level features**



3.2 Applications of Machine Learning : In business



3.2 Applications of ML Algorithms (1/4)

■ Face Recognition



[EigenFaces from [Shervin Enayati](#)]

■ Spam filtering

☆ **Osman Khan** to Carlos [show details](#) Jan 7 (6 days ago) [Reply](#)

sounds good
+ok

Carlos Guestrin wrote:
Let's try to chat on Friday a little to coordinate and more on Sunday in person?

Carlos

Welcome to New Media Installation: Art that Learns

☆ **Carlos Guestrin** to 10615-announce, Osman, Miche [show details](#) 3:41 PM (8 hours ago) [Reply](#)

Hi everyone,

Welcome to New Media Installation:Art that Learns

The class will start tomorrow.
Make sure you attend the first class, even if you are on the Wait List
The classes are held in Doherty Hall C316, and will be Tue, Thu 01:30-4:20 PM.

By now, you should be subscribed to our course mailing list: 10615-announce@cs.cmu.edu.
You can contact the instructors by emailing: 10615-instructors@cs.cmu.edu

Natural_LoseWeight SuperFood Endorsed by Oprah Winfrey, Free Trial 1 bottle, pay only \$5.95 for shipping mfw rik [Spam](#) | [X](#)

☆ **Jaquelyn Halley** to nherlein, boc: thehomey, boc: an [show details](#) 9:52 PM (1 hour ago) [Reply](#)

=== Natural WeightLOSS Solution ===

Vital Acai is a natural WeightLOSS product that Enables people to lose weight and cleansing their bodies faster than most other products on the market.

Here are some of the benefits of Vital Acai that You might not be aware of. These benefits have helped people who have been using Vital Acai daily to Achieve goals and reach new heights in there dieting that they never thought they could.

- * Rapid WeightLOSS
- * Increased metabolism - BurnFat & calories easily!
- * Better Mood and Attitude
- * More Self Confidence
- * Cleanse and Detoxify Your Body
- * Much More Energy
- * BetterSexLife
- * A Natural Colon Cleanse

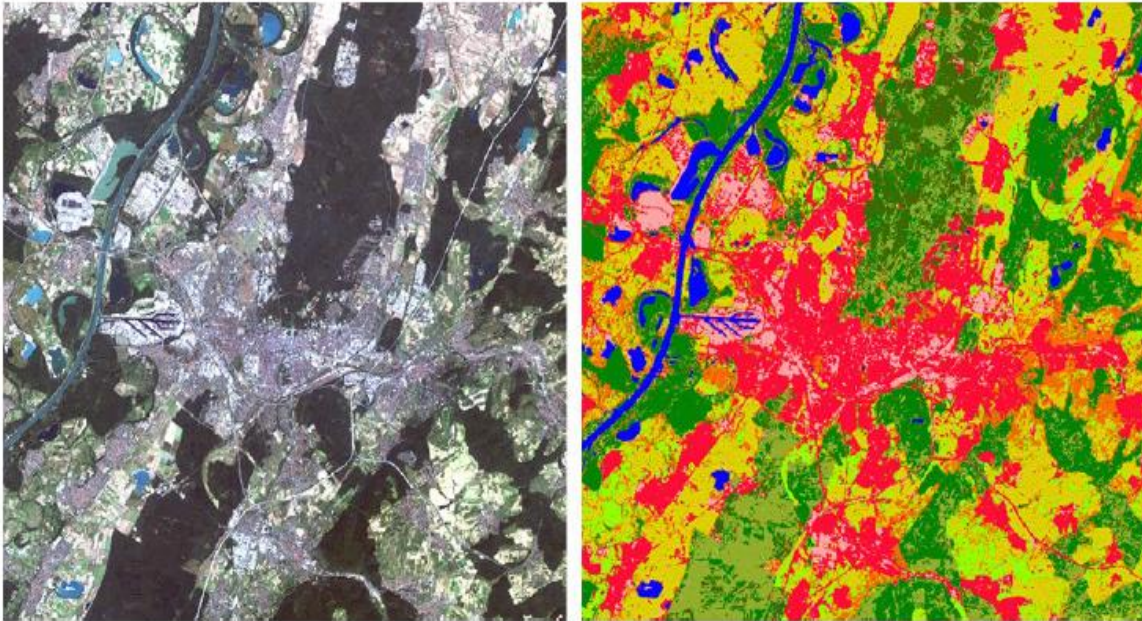
Not Spam

Spam



3.2 Applications of ML Algorithms (2/4)

■ Image Classification



[LANDSAT and © LUBW with modifications]

■ Weather prediction



Classification

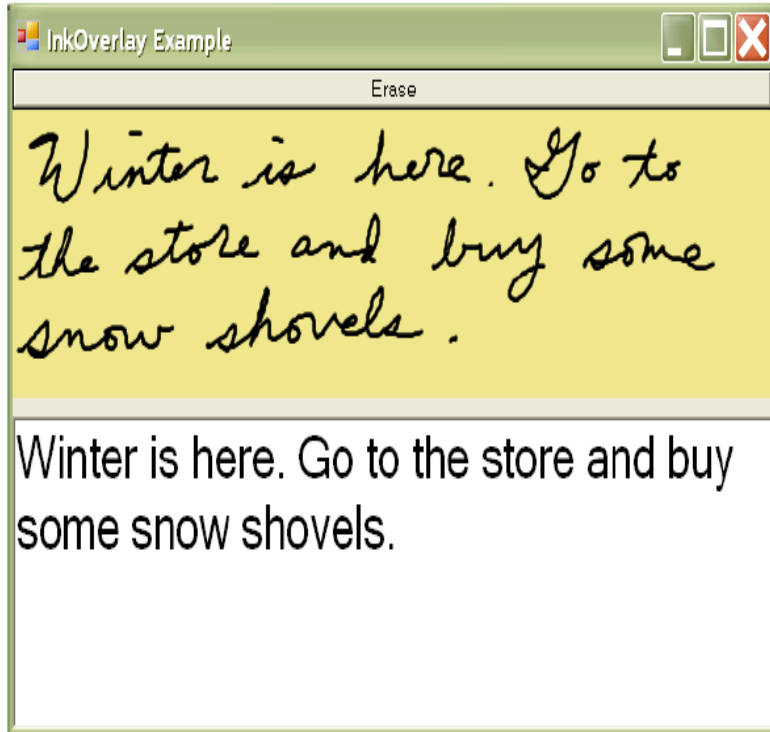


Regression

Temperature 32°F

3.2 Applications of ML Algorithms (3/4)

■ Handwriting recognition

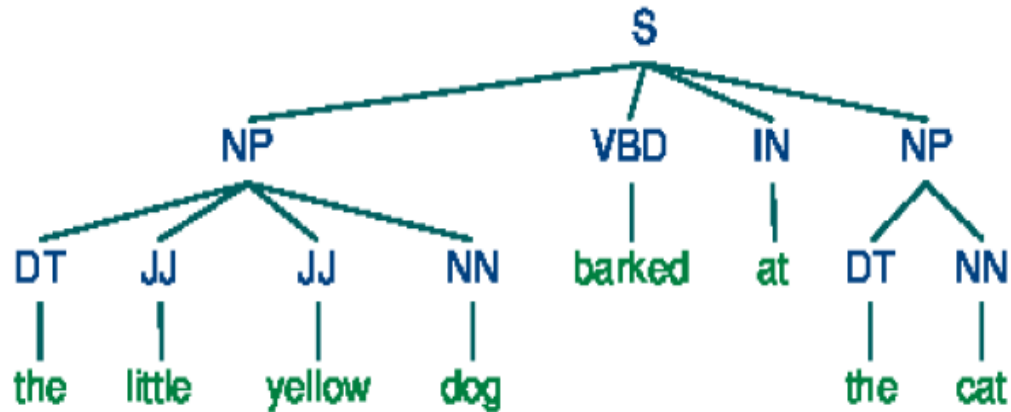


■ Stock market

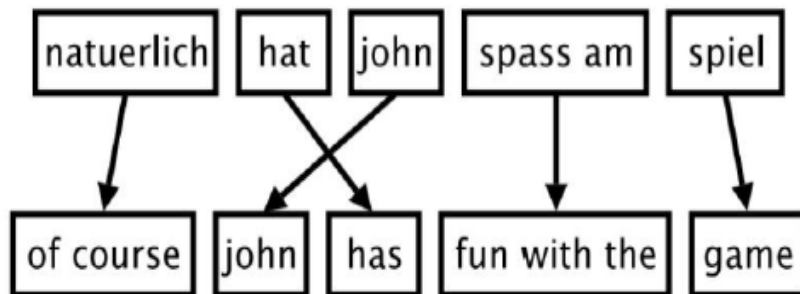


3.2 Applications of ML Algorithms (4/4)

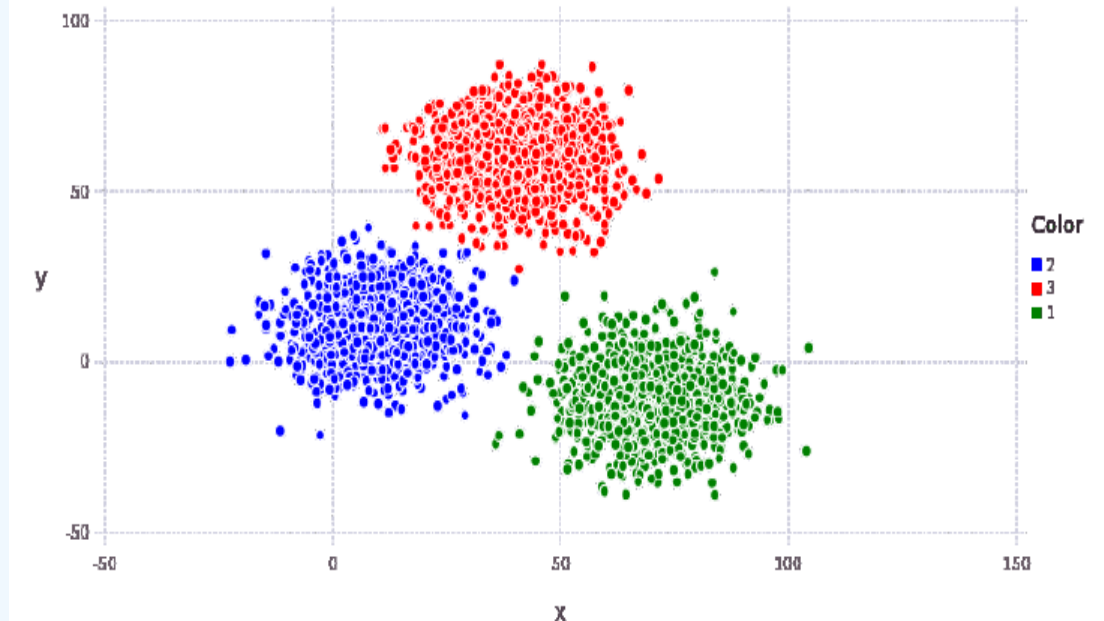
■ Sequence labeling in Natural Language Processing(NLP) – POS Tagging



■ Statistical Machine Translation



■ Clustering Data : Group similar things

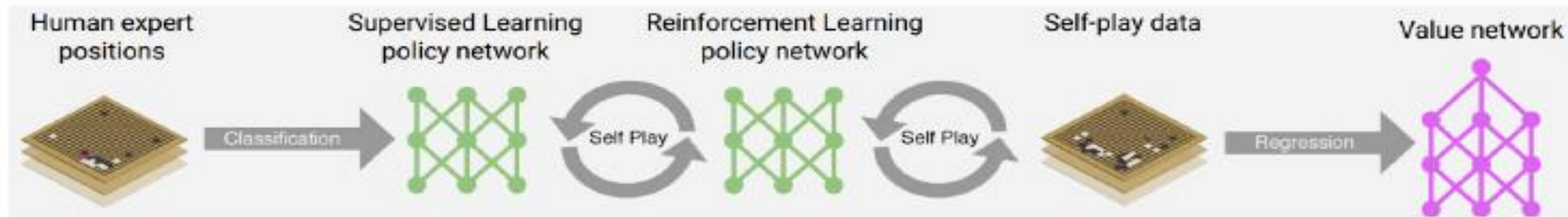


3.2 Applications of Deep Learning (1/14)

Deep Learning Algorithms

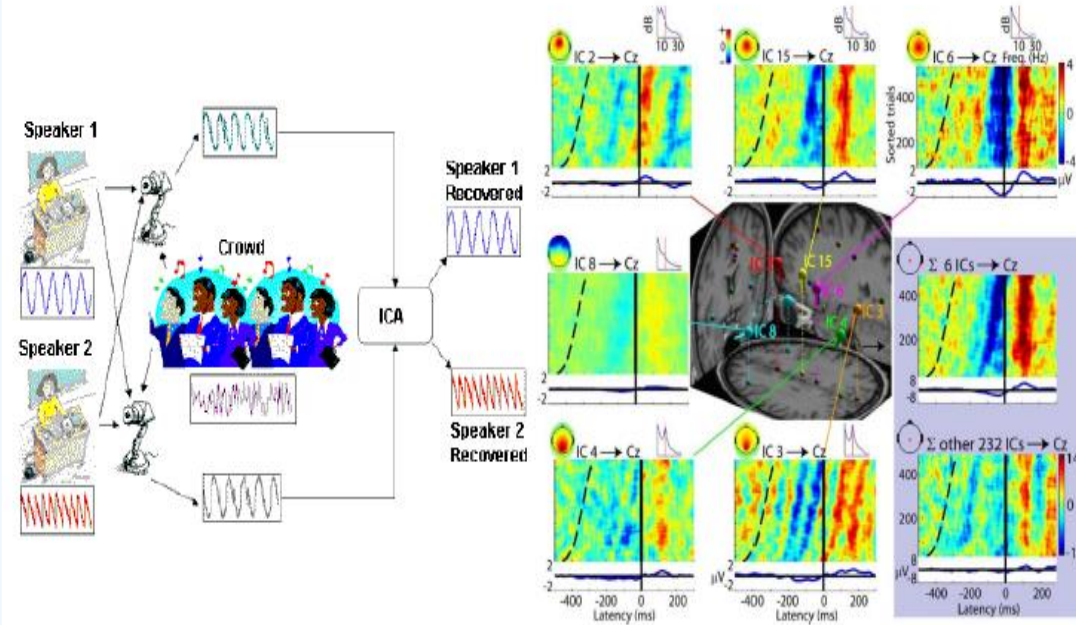
■ AlphaGo - DeepMind

- 2016.3 AlphaGo : Lee Sedol = 4:1
- Winning score so far : 73:1
- 1,202 ~ 1,920 CPU + 176 ~ 280 GPU
- 50+ TPU(by Google) at the game with Lee Sedol
- 1 TPU = 30 ~ 80 times of CPU
- Search space of chess : $35^{80} \approx 10^{120}$
- Search space of Go : $250^{150} \approx 10^{360}$ (Number of atoms in the universe $\approx 10^{78} \sim 10^{82}$)
- AlphaGo uses *Monte Carlo tree search*, guided by a *value network* and a *policy network*, both implemented using deep neural network technology.



3.2 Applications of Deep Learning (2/14)

■ Independent Component Analysis



■ Image inpainting

- [Kyong Hwan Jin & Jong Chul Ye \(2015\)](#)



3.2 Applications of Deep Learning (3/14)

■ Image Colorization

- [R. Zhang et. al. \(2016\)](#)
- Given a grayscale photograph as input, this Convolutional Neural Network tackles the problem of hallucinating a plausible color version of the photograph.



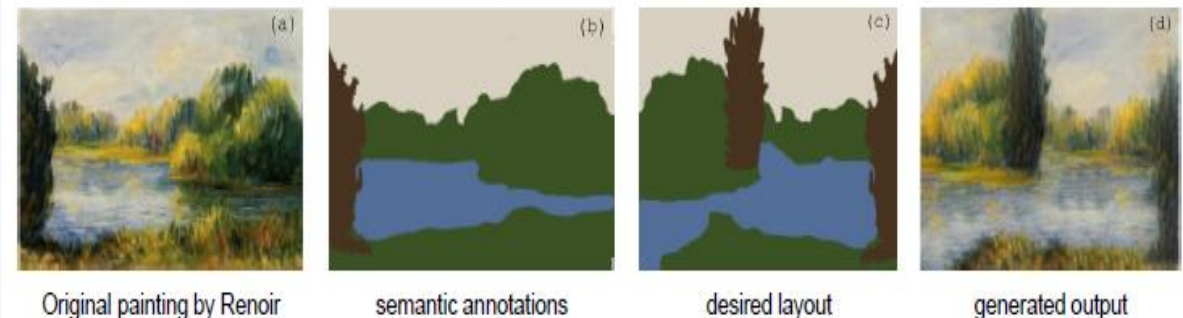
■ Photo-realistic Image Synthesis

- [C. Li & M. Wand \(2016\)](#)



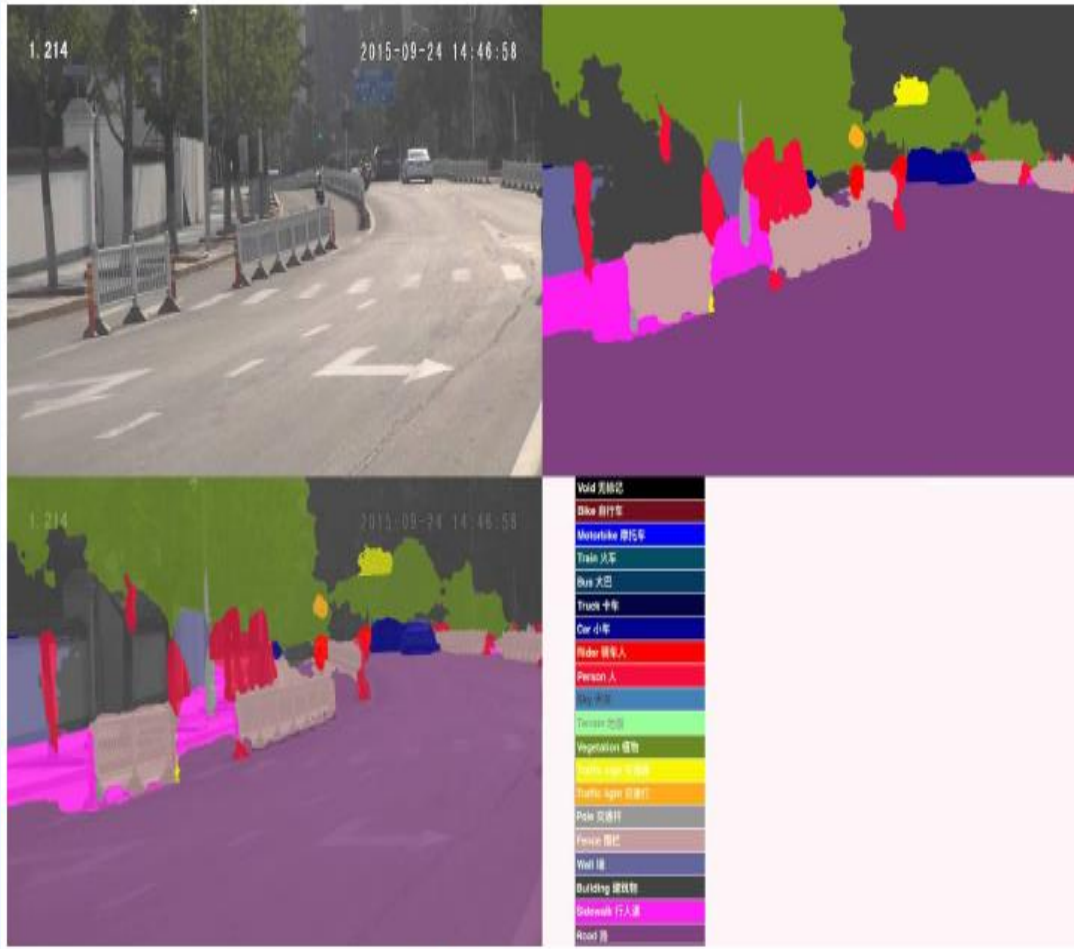
■ Drawing paintings by example and a draft

- [A.J. Champandard \(2016\)](#)



3.2 Applications of Deep Learning (5/14)

Semantic Segmentation



[Guosheng Lin et al.(2016)]

Image compression



Image compression with Residual Gated Recurrent Unit (Residual GRU).

Left: Original image (1419 KB PNG) at ~ 1.0 MS-SSIM.

Center: JPEG (33 KB) at ~ 0.9 MS-SSIM.

Right: Residual GRU (24 KB) at ~ 0.9 MS-SSIM. This is 25% smaller for a comparable image quality

[Toderici, George, et al., 2017]

3.2 Applications of Deep Learning (6/14)

■ Image Localization



CC-BY-NC by steveke



CC-BY-NC by edwin.11



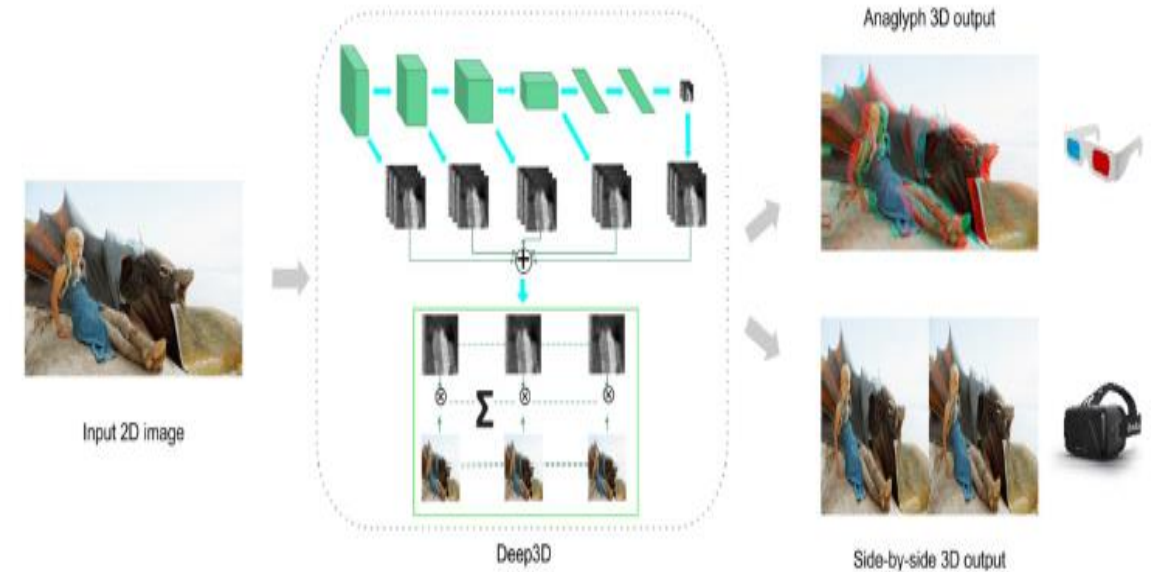
CC-BY-NC by jonathanfh



PlaNet is able to determine the location of almost any image with super-human ability.

[[Tobias Weyand et al., 2016](#)]

■ 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. [[Junyuan Xie et al., 2016](#)]

3.2 Applications of Deep Learning (7/14)

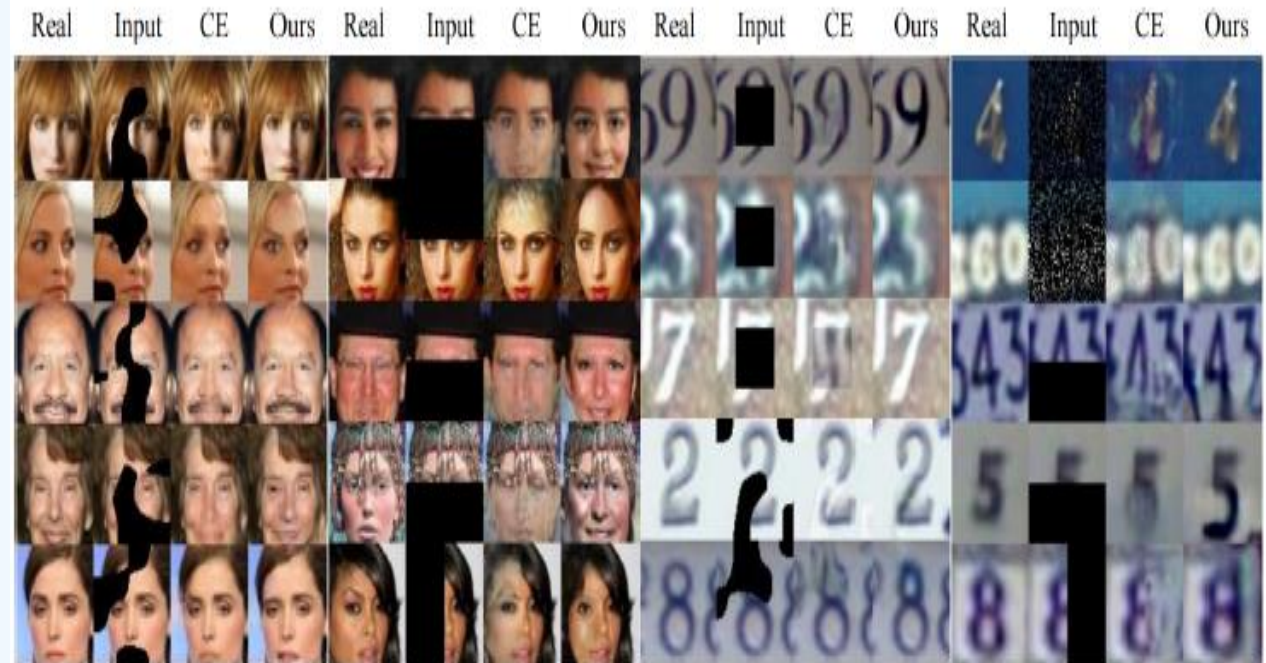
■ Image Sharpening

- [Mike Swarbrick Jones, Blog](#)
- 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.



■ Image Completion - image inpainting

- [Raymond A. Yeh et al., 2017](#)
- Image completion with deep convolutional generative adversarial networks(DCGAN). Comparison with the Context Encoder(D. Pathak, 2016) on the CelebA and SVHN dataset.



3.2 Applications of Deep Learning (8/14)

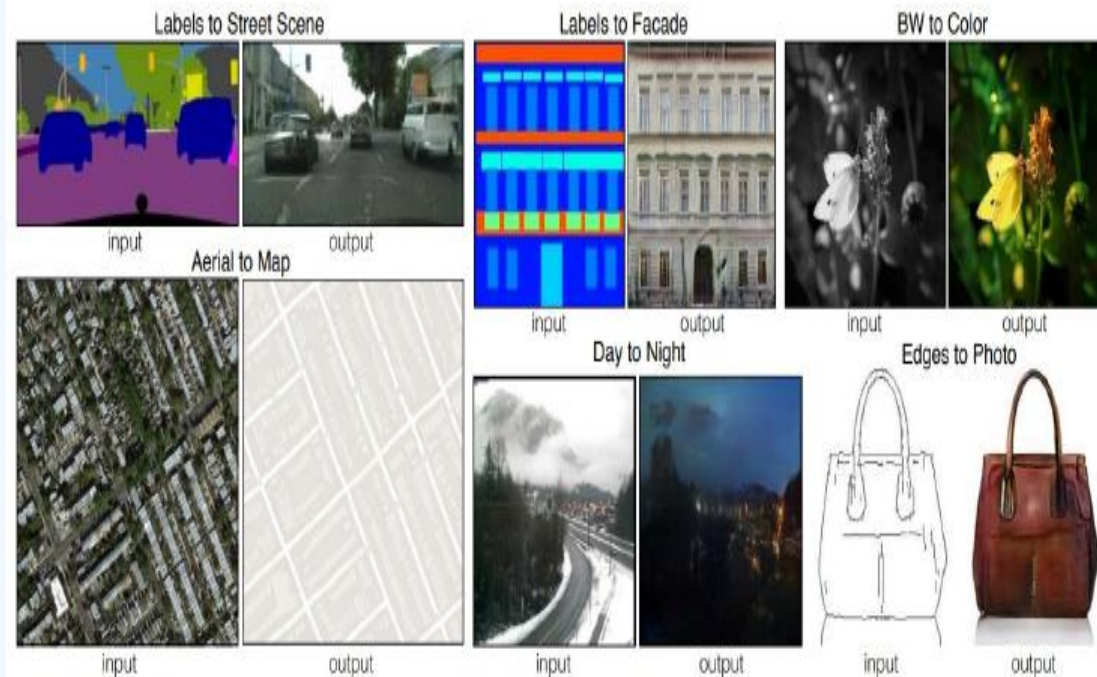
■ Sketch Simplification – From Drawing to Vector Graphic

- [Edgar Simo-Serra et al., 2016](#)
- This model consists of a fully convolutional neural network which is able to process rough raster sketches of any dimensions and aspect ratio as input, and outputs a simplified vectorized image which has the same dimensions as the input image.



■ Image-to-Image Translation

- [Phillip Isola et al., 2016](#)
- Image-to-Image Translation with Conditional Adversarial Nets. This approach can be applied as a generic solution to any Image-to-Image translation problem such as synthesizing photos from label maps, reconstructing objects from edge maps, and colorizing images.



3.2 Applications of Deep Learning (9/14)

■ Style Transfer – morph images into paintings

● Deepart.io



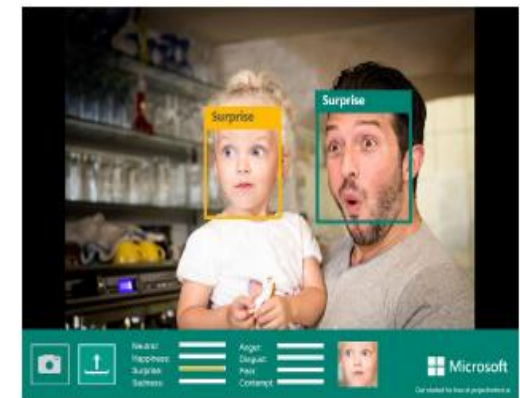
■ Simple Tasks

- Face Detection + Emotion Classification

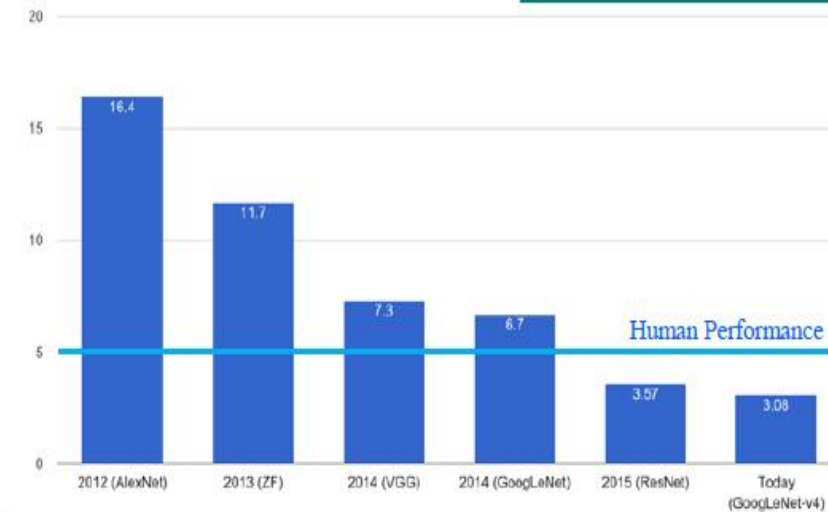
■ Complex Tasks:

- Semantic Segmentation
- Image Caption Generation
- Visual Question Answering

■ Deep Learning / Super-human Performance



ImageNet Classification Error (Top 5)



3.2 Applications of Deep Learning (9/14)

• Multi-modal Learning

■ Become multi-modal: use 2+ modalities simultaneously

- Image caption generation = images + text
- Search web by an image = images + text
- Video describing: the same but added time dimension
- Visual question answering: images + text
- Speech recognition: audio + video (lips motion)
- Image classification and navigation: RGB-D (color + depth)

■ Where does it aim to?

- Common metric space for each concept, “thought vector”. Will be possible to match different modalities easily



What vegetable is on the plate?

Neural Net: broccoli
Ground Truth: broccoli



What color are the shoes on the person's feet?

Neural Net: brown
Ground Truth: brown



How many school busses are there?

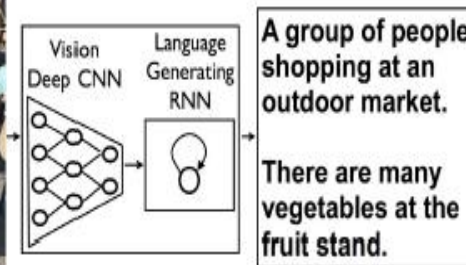
Neural Net: 2
Ground Truth: 2



What sport is this?

Neural Net: baseball
Ground Truth: baseball

■ Image Captioning(1)



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



Left: the better image model allows the captioning model to generate more detailed and accurate descriptions. Right: after fine-tuning the image model, the image captioning system is more likely to describe the colors of objects correctly.

[From Oriol Vinyals et al., 2016]



3.2 Applications of Deep Learning (10/14)

■ DeepStereo – 2D to 3D image conversion

- [John Flynn et al.\(2015\)](#)
- Turns images from Street View into a 3D space that shows unseen views from different angles by figuring out the depth and color of each pixel.

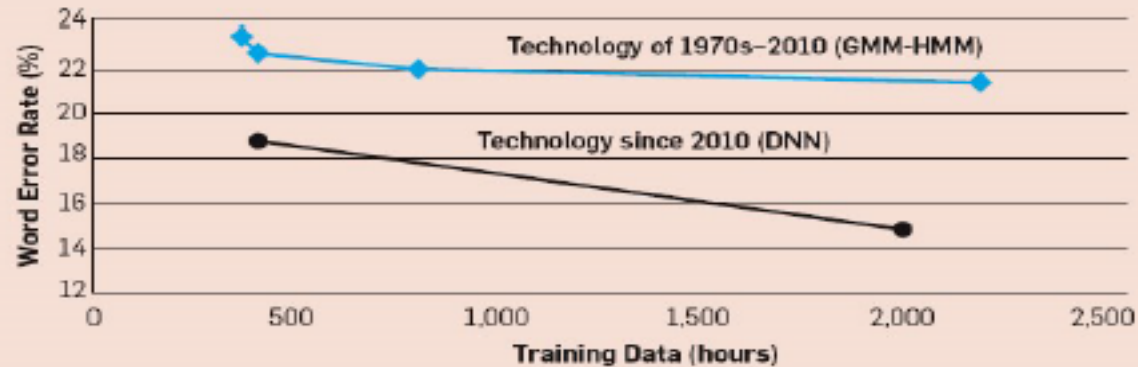


3.3 Applications of Deep Learning (11/14)

- Natural Language Processing (NLP)

- Variety of tasks:

- Finding synonyms
 - Fact extraction: people and company names, geography, prices, dates, product names, ...
 - Classification: genre and topic detection, positive/negative sentiment analysis, authorship detection,
 - Machine translation
 - Search (written and spoken)
 - Question answering
 - Dialog systems
 - Speech recognition and Language modeling
 - Text generation (Smart Reply, ...)



3.2 Applications of Deep Learning (12/14)

■ Generating Text

- [Andrej Karpathy blog](#)
- Character-level language model learns to spell English words completely from scratch and copy general syntactic structure

```
/*
 * Increment the size file of the new incorrect UI_FILTER
group information
 * of the size generatively.
 */
static int indicate_policy(void)
{
    int error;
    if (fd == MARN_EPT) {
        /*
         * The kernel blank will coeld it to userspace.
         */
        if (ss->segment < mem_total)
            unblock_graph_and_set_blocked();
        else
            ret = 1;
        goto bail;
    }
    segaddr = in_SB(in.addr);
    selector = seg / 16;
    setup_works = true;
    for (i = 0; i < blocks; i++) {
        seq = buf[i++];
        bpf = bd->bd.next + i * search;
        if (fd) {
            current = blocked;
        }
    }
    rw->name = "Getjbbregs";
    bprm_self_clear1(&iv->version);
    regs->new = blocks[(BPF_STATS << info->historidac)] |
PFMR_CLOBATHINC_SECONDS << 12;
    return segtable;
}
```

For $\bigoplus_{i=1}^m \mathcal{L}_{n_i} = 0$, hence we can find a closed subset \mathcal{H} in \mathcal{H} and any sets \mathcal{F} on X , U is a closed immersion of S , then $U \rightarrow T$ is a separated algebraic space.

Proof. Proof of (1). It also start we get

$$S = \text{Spec}(R) = U \times_X U \times_X U$$

and the comparicly in the fibre product covering we have to prove the lemma generated by $\coprod Z \times_U U \rightarrow V$. Consider the maps M along the set of points Sch_{pre} and $U \rightarrow U$ is the fibre category of S in U in Section ?? and the fact that any U affine, see Morphisms, Lemma ?? Hence we obtain a scheme S and any open subset $W \subset U$ in $\text{Sh}(G)$ such that $\text{Spec}(R) \rightarrow S$ is smooth or an

$$U = \bigcup U_i \times_S U_i$$

which has a nonzero morphism we may assume that f_i is of finite presentation over S . We claim that $\mathcal{O}_{X,S}$ is a scheme where $x, x', s' \in S'$ such that $\mathcal{O}_{X,S'} \rightarrow \mathcal{O}_{X',S'}$ is separated. By Algebra, Lemma ?? we can define a map of complexes $\text{GL}_S(S'/S^p)$ and we win. \square

To prove study we see that \mathcal{F}_{iD} is a covering of \mathcal{N}^d , and T_i is an object of $\mathcal{F}_{X/S}$ for $i > 0$ and \mathcal{F}_p exists and let \mathcal{F}_i be a presheaf of \mathcal{O}_X -modules on \mathcal{C} is a \mathcal{F} -module. In particular $\mathcal{F} = U/\mathcal{F}$ we have to show that

$$\tilde{M}^* = T^* \otimes_{\text{Spec}(k)} \mathcal{O}_{S,S} - i_X^{-1} \mathcal{F}$$

is a unique morphism of algebraic stacks. Note that

$$\text{Arrows} = (\text{Sch}/S)_{\text{pre}}^{\text{pp}}, (\text{Sch}/S)_{\text{pre}}$$

and

$$V = \Gamma(S, \mathcal{O}) \rightarrow (U, \text{Spec}(A))$$

is an open subset of X . Thus U is affine. This is a continuous map of X is the inverse, the groupoid scheme S .

Proof. See discussion of sheaves of sets. \square

The result for prove any open covering follows from the less of Example ?? It may replace S by $X_{\text{space}, \text{state}}$ which gives an open subspace of X and T equal to S_{pre} , see Descent, Lemma ?? Namely, by Lemma ?? we see that R is geometrically regular over S .

Lemma 0.1. Assume (1) and (3) by the construction in the description.

Suppose $X = \text{lim } |X|$ (by the formal open covering X and a single map $\text{Proj}_X(A) = \text{Spec}(B)$ over U compatible with the complex

$$\text{Set}(A) = \Gamma(X, \mathcal{O}_{X, \mathcal{O}_X}).$$

■ Neural Machine Translation

- Google Neural Machine Translation
- [Yonghui Wu et al.\(2016\)](#)
- Deep LSTM seq-to-seq architecture reduces translation errors by more than 55%-85% compared to traditional approaches.
- **Artificial neural networks (ANNs)** or [connectionist](#) systems are computing systems inspired by the [biological neural networks](#) that constitute animal brains. Such systems learn (progressively improve performance) to do tasks by considering examples, generally without task-specific programming. For example, in image recognition, they might learn to identify images that contain cats by analyzing example images that have been manually [labeled](#) as "cat" or "no cat" and using the analytic results to identify cats in other images. They have found most use in applications difficult to express in a traditional computer algorithm using [rule-based programming](#).
- 인공 신경 네트워크 (ANN) 또는 연결 시스템은 동물 두뇌를 구성하는 생물학적 신경 네트워크에 의해 영감을 받은 컴퓨팅 시스템입니다. 이러한 시스템은 일반적으로 작업 별 프로그래밍 없이 예제를 고려하여 작업을 수행하는 방법을 학습합니다 (점진적으로 성능 향상). 예를 들어 이미지 인식에서 "고양이" 또는 "고양이 없음"으로 수동 분류 된 예제 이미지를 분석하고 분석 결과를 사용하여 다른 이미지의 고양이를 식별함으로써 고양이가 들어있는 이미지를 식별하는 방법을 배울 수 있습니다. 규칙 기반 프로그래밍을 사용하여 전통적인 컴퓨터 알고리즘으로 표현하기 어려운 응용 프로그램에서 대부분을 사용합니다.
- 人工神经网络 (ANN) 或连接系统是由构成动物大脑的生物神经网络启发的计算系统。这样的系统通过考虑示例 (通常没有任务编程) 来学习 (逐步提高性能) 来完成的任务。例如, 在图像识别中, 他们可能会通过分析手动标记为"猫"或"无猫"的示例图像, 并使用分析结果来识别其他图像中的猫, 从而学习识别包含猫的图像。他们发现在使用基于规则的编程的传统计算机算法中难以表达的应用中最多使用。



3.2 Applications of Deep Learning (13/14)

■ Neural Conversational Model

- [O. Vinyals & Q. V. Le \(2015\)](#)
- By using the sequence to sequence framework, this model predicts the next sentence given the previous sentence or sentences in a conversation. On a domain-specific IT helpdesk dataset, the model can find a solution to a technical problem via conversations. On a noisy open-domain movie transcript dataset, the model can perform simple forms of common sense reasoning.

Morality:

Human: what is moral ?

Machine: what empowered humanity, what intellectual the essence is.

Human: what is immoral ?

Machine: the fact that you have a child.

Human: what is morality ?

Machine: what is altruism ?

Human: what is the definition of altruism ?

Machine: if you don't believe in god, then you don't know.

Human: ok ... so what is the definition of morality ?

Machine: well , the truth is, you're not a believer in god almighty.

Human: tell me the definition of morality, i am quite upset now !

Machine: i'm not ashamed of being a philosopher !

Human: tell me the definition of morality.

Machine: i don't have ethics.

Human: look, i need help, i need to know more about morality ...

Machine: i don't know what ethics is.

Human: seriously, what is morality ?

Machine: what is the definition of living ?

Human: why living has anything to do with morality ?

Machine: you're not a cop.

Human: okay, i need to know how should i behave morally ...

Machine: i don't know how to tell you.

Human: is morality and ethics the same ?

Machine: yes, sir .

Human: what are the things that i do to be immoral ?

Machine: i don t know.

Human: give me some examples of moral actions ...

Machine: i'm not a moralist.

Human: alright, morality ?

Machine: integrity.

Human: what is integrity ?

Machine: i'm sorry, i don 't know what else to say .

Human: be moral !

Machine: be a man !

Human: i really like our discussion on morality and ethics ...

Machine: and how i 'm not in the mood for a philosophical debate.

Human: what do you like to talk about ?

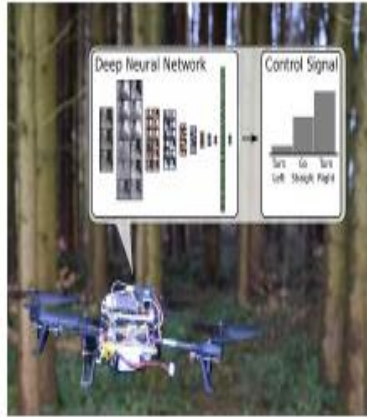
Machine: nothing.



3.3 Applications of Deep Learning (14/14): Control

■ Controlling different thing seems to be efficient using deep learning:

- Game playing: Atari games, Go
- Computer game characters (AI inside games)
- Autonomous cars
- Drones
- Robotic control



■ Games

“And I think it would be a huge market, actually, having smart adaptable AI opponents, and I think games developers would love it instead of having to build a new AI each time for every game, maybe they could just train an AI on their game.” – D. Hassabis, Google DeepMind

■ Car Self-driving

- Everyone (Google, Baidu, Apple, Nvidia, Uber, Tesla, Volvo, Kamaz, Mercedes-Benz -- they actually did it since 1980s, just google kk) develop their own autonomous car.
- Automobiles will soon become really auto-mobile. The main restriction here seems to be the laws and regulations.

■ 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)



■ Car Self-Driving

- Actually a “Perception to Action” system. The visual perception and control system is a deep learning architecture trained end to end to transform pixels from the cameras into steering angles. And this car uses regular color cameras, not LIDARS like the Google cars. It is watching the driver and learns.



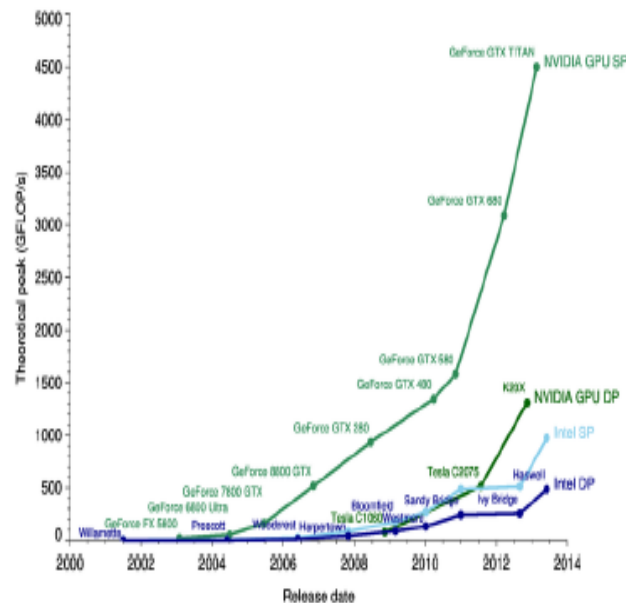
3.4 Deep Learning : Hardware (1/2)

■ Problems with the current processors:

- Energy efficiency (DeepMind used 1,202 CPUs and 176 GPUs)
- Architecture (not well-suitable for brain-like computations)

■ GPU computing power is growing

- NVIDIA DGX-1 (\$129,000)
 - 170 TFLOPS (FP16)
 - 85 TFLOPS (FP32)
- NVIDIA GTX Titan X (\$1000)
 - 6.1 TFLOPS (FP32)
- NVIDIA Drive PX
 - 2.3 TFLOPS
- NVIDIA Drive PX-2
 - 8.0 TFLOPS
- Intel Core i7-6700K
 - ~0.1 - 0.2 TFLOPS



■ NVidia Jetson TX2

- 256-cores Pascal (1.3 GHz), 2 TFLOPS(FP16)
- ARM Cortex-A57 (Quad-core) + Nvidia Denver 2(Dual-core)

■ Raspberry Pi 3

- 1.2 GHz 64-bit quad-core ARM Cortex-A53
- 1 GB SDRAM, US\$35 (~0.246 GFLOPS for RPi 2)

■ NVIDIA chips in Tablets, Smartphones

■ Google Project Tango

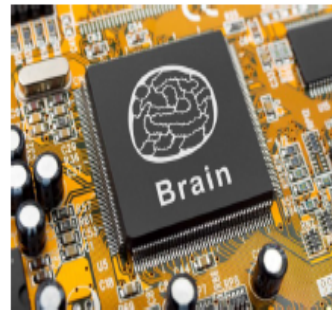
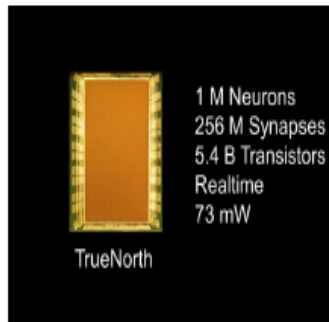


메모리칩 자체를 새롭게 만듦

3.4 Deep Learning : Hardware (2/2)

Neuromorphic chips

- Neuromorphic chips attempt to model in silicon the *massively parallel* way the brain processes information as billions of neurons and trillions of synapses respond to sensory inputs such as visual and auditory stimuli.
- SyNAPSE program (Systems of Neuromorphic Adaptive Plastic Scalable Electronics)
 - DARPA-funded program to develop electronic neuromorphic machine technology that scales to biological levels
 - An attempt to build a new kind of cognitive computer with similar form, function, and architecture to the mammalian brain.
- Study Works
 - Human Brain Project(EU) SpiNNaker and HICANN
 - IBM TrueNorth
 - Stanford Neurogrid
 - HRL neuromorphic chip
 - Qualcomm Zeroth NPU
 - Numenta NuPIC
 - China Darwin

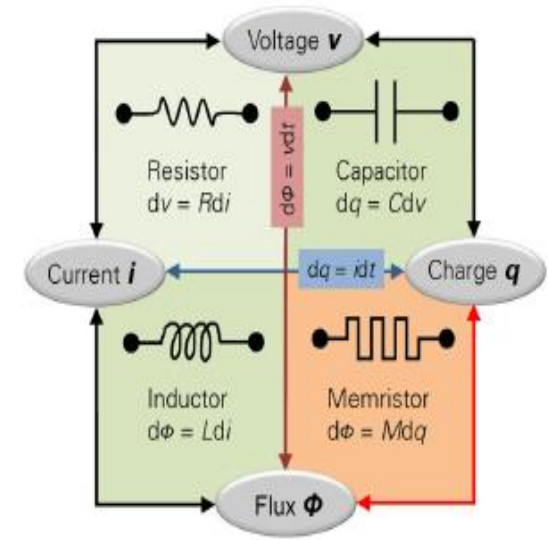
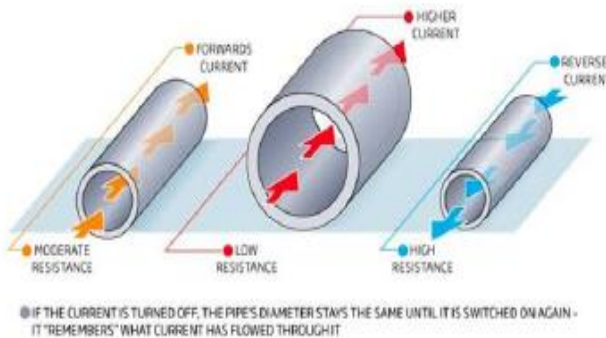


Memristors

- Neuromorphic chips generally use the same silicon transistors and digital circuits that make up ordinary computer processors. There is another way to build brain inspired chips.
- Memristors (memory resistor), exotic electronic devices only confirmed to exist in 2008. The memristor's electrical resistance is not constant but depends on the history of current that had previously flowed through the device, i.e., the device remembers its history.
- An analog memory device.
- Some startups try to make special chips for low-power machine learning, i.e., Knowm

A memristor never forgets

The "resistor with memory" that Leon Chua described behaves like a pipe whose diameter varies according to the amount and direction of the current passing through it.



3.4 Deep Learning : Driving forces

- Computing Power and Infrastructures
 - GPUs : Nvidia, Google TPU
 - Cloud Services : Amazon EC2 P2
- Training Data
 - Huge amount of quality training data
- Algorithms
 - CNN
 - RNN-LSTM
 - GAN
 - Reinforcement Learning
 - ...

Deep learning 이 되기 위한 3가지 요소

