Artificial Intelligence
and
Deep Learning

2019 - 2020
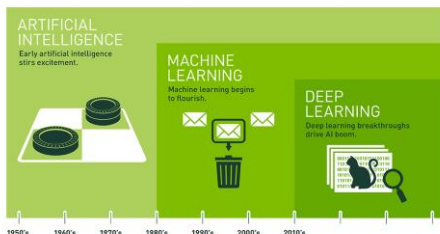
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AI, ML, and DL

Deep Learning is a domain of Machine Learning and they are state-of-the-art approaches of AI (source: NVIDIA Blog)

딥러닝은 머신러닝의 한 방법이며, 이들은 인공지능의 최신기술이다.

- Artificial Intelligence — Human intelligence exhibited by machines
  - ▶ "**General AI**": complex machines that possessed the same characteristics of human intelligence.
    - ➲ C-3PO, the Terminator
  - ▶ "**Narrow AI**": technologies that are able to perform specific tasks as well as, or better than, we humans can.
    - ➲ image classification
- Machine Learning — An approach to achieve artificial intelligence
  - ▶ algorithmic approaches: decision tree learning, inductive logic programming, clustering, reinforcement learning, and Bayesian networks, Artificial Neural Networks
- Deep Learning — A technique for implementing machine learning based on artificial deep neural network

https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

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AI

- Artificial intelligence (AI: 인공지능)
  - ▶ the capability of a machine to imitate intelligent human behavior.
  - ▶ Machine learning (ML) is a subset of AI.
  - ▶ Deep learning (DL) is a subset of ML.
  - ▶ The AI itself is a rather generic term for solving tasks that are easy for humans, but hard for computers. It includes all kinds of tasks, such as doing creative work, planning, moving around, speaking, recognizing objects and sounds, performing social or business transactions, etc.
    - ➲ http://geoawesomeness.com/whats-difference-artificial-intelligence-machine-learning-deep-learning/

- 약한인공지능: 정해진 목적에 특화된 작업 수행 (자율주행차, 번역기)
- 강한인공지능: 인간 수준의 지능을 보유하여 전반적인 문제 해결
- 초인공지능: 모든 영역에서 가장 유능한 사람보다 뛰어난 능력

- Narrow AI (약한 인공지능, 협의의 인공지능)
  - ▶ AI that is skilled at one specific task.
    - ➲ IBM's Deep Blue (1996 - Chess)
    - ➲ Google DeepMind's AlphaGo (2016 - Go)

- Artificial General Intelligence (AGI) (강한 인공지능, 일반적 인공지능)
  - ▶ AGI is AI that is considered human-level, and can preform a range of tasks.

- Super-intelligent AI (초 인공지능)
  - ▶ SAI is an intellect that is much smarter than the best human brains in a practically every field, including scientific creativity, general wisdom and social skills. (the machines have outsmarted us)

http://www.techrepublic.com/article/understanding-the-differences-between-ai-machine-learning-and-deep-learning/
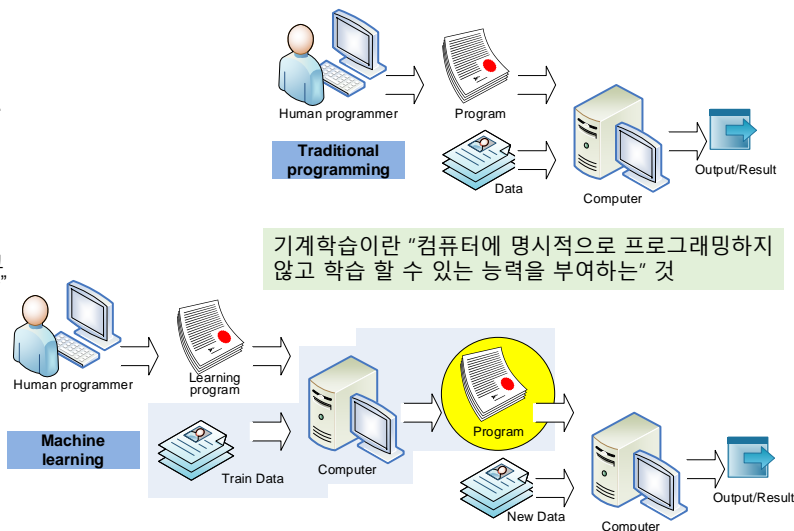
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ML

- Machine learning (기계학습)
  - ► ML gives computers the abilities to learn without being explicitly programmed to complete a task. – Arthur Samuel, 1959.
    - ⊃ (기계학습은 컴퓨터가 '특정한 일을 처리하도록' '명시적인 프로그래밍 없이' '배울 수 있게하는 능력')
    - ⊃ 기계학습이란 "컴퓨터에 명시적으로 프로그래밍하지 않고 학습 할 수 있는 능력을 부여하는" 것
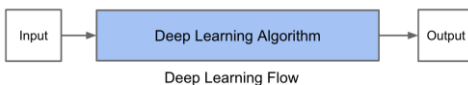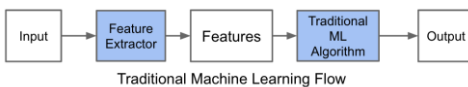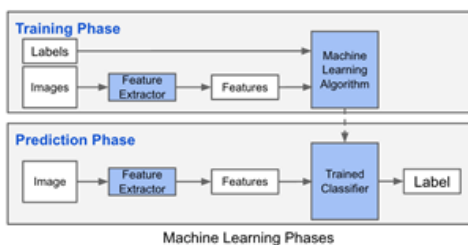 - ► ML is designed to take a large set of data, analyze it, and learn from it.
  - ► ML systems recognize patterns, understand speech, and make predictions.

Human programmer → Program → Data → Computer → Output/Result

Traditional programming

기계학습이란 "컴퓨터에 명시적으로 프로그래밍하지 않고 학습 할 수 있는 능력을 부여하는" 것

Human programmer → Learning program

Machine learning

Train Data → Computer → Program → New Data → Computer → Output/Result

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ML v.s. DL

Training Phase

Labels / Images → Feature Extractor → Features → Machine Learning Algorithm

Prediction Phase

Image → Feature Extractor → Features → Trained Classifier → Label

Machine Learning Phases

Input → Feature Extractor → Features → Traditional ML Algorithm → Output

Traditional Machine Learning Flow

Input → Deep Learning Algorithm → Output

Deep Learning Flow

- Training phase: train a machine learning algorithm using a dataset comprised of the images and their corresponding labels.
  - ► Feature Extraction: utilize domain knowledge to extract new features that will be used by the machine learning algorithm.
  - ► Model Training: utilize a clean dataset composed of the images' features and the corresponding labels to train the machine learning model.
- Prediction phase: utilize the trained model to predict labels of unseen images.

- Differences between ML v.s. DL
  - ► ML: hand-craft feature engineering
  - ► DL: automatic feature engineering by the algorithm

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Terminologies

- ■ Regression (회기, 回歸)
  - ► A statistical technique used to measure the relation between variables (변수들 사이의 관계를 유추하는 통계적 기법)
  - ► predict new values based on the past, inference
    - ⊃ an attempt to predict a continuous attribute
  - ► compute the new values for a dependent variable based on the values of one or more measured attributes (한 개 또는 여러 개의 측정된 특성으로 종속변수의 새 값을 계산)
- ■ Clustering (군집화, 群集化)
  - ► partitioning of a data set into subsets (clusters) so that data in each subset ideally share some common characteristics (공통된 특징을 갖는 보다 작은 집합으로 나누는 것)
  - ► 입력 데이터의 분포 특성(입력값의 유사성)을 분석하여 임의의 복수 개의 그룹으로 나누는 것
- ■ Classification (분류, 分類)
  - ► divide samples in classes (샘플을 클라스로 나눈다)
  - ► use a trained set of previously labeled data (미리 꼬리표(label)가 붙은 샘플로 트레이닝한다.)
  - ► It is similar to the clustering, but requires that the analyst knows ahead of time how classes are defined. (이것은 군집화와 유사하지만, 미리 클라스가 정의되어 있다는 점에서 차이가 있다.)
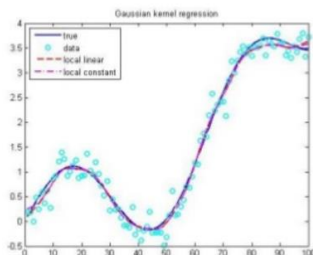 - ► 주어진 데이터 집합을 이미 정의된 몇 개의 클래스로 구분하는 것

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Terminologies
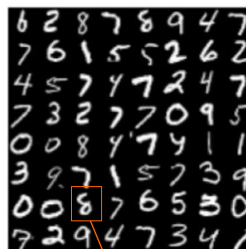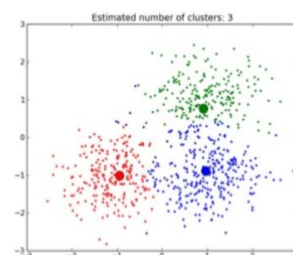
Label A ➔ means '8'
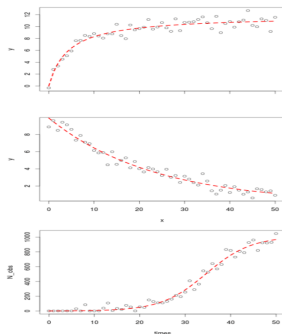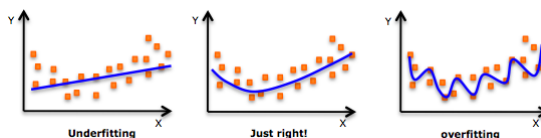
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Regression

■ Curve fitting
► find a well defined and known function underlying data (주어진 데이터에 잘 맞는 알려진 함수를 찾는 것)
  ➲ **Linear regression**

■ Data table statistical correlation
► mapping without any prior assumption on the functional form of the data distribution
  ➲ **Logistic regression**
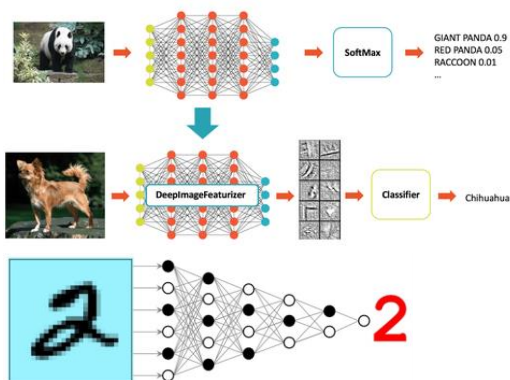► machine learning algorithms well suited for this.

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Classification

■ To predict group membership for data instances

► Probabilistic classification (통계적 분류)
  ➲ given an input, the classifier returns its probabilities to belong to each class

► Crispy classification (결정적 분류)
  ➲ given an input, the classifier returns its label

Softmax is a function to transform a number of input values to a range of value to between 0 ~ 1.
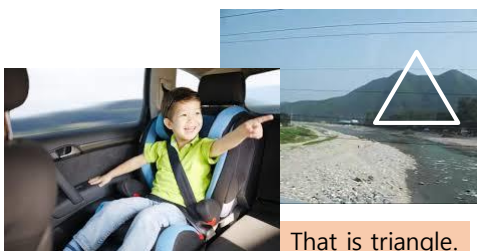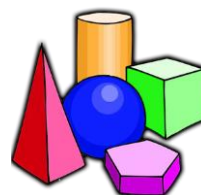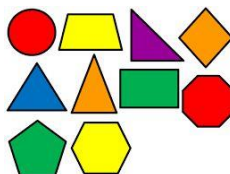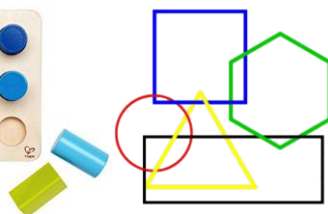➔ Multinomial logistic

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Clustering

- How many groups can you divide?
  - ► Circle and rectangle
  - ► Red, yellow, blue
  - ► Edible and not

- This process is called 'clustering'
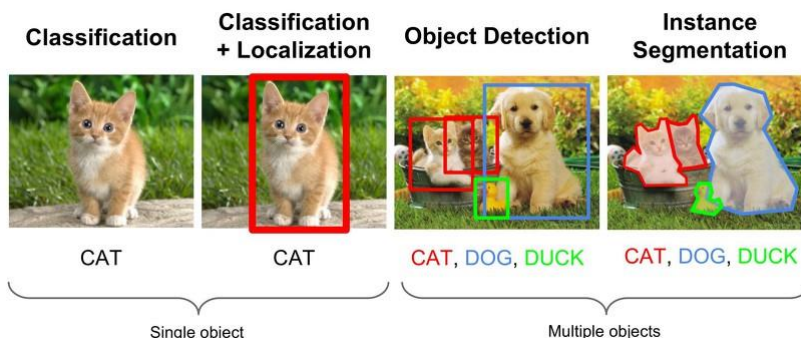
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Clustering and classification

Learning shape and geometry

That is triangle.

Beautiful v.s. ugly?
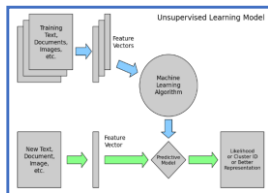Good and bad?
Mine and not mine?

(12)

Object classification and detection

Types of learning of machine learning
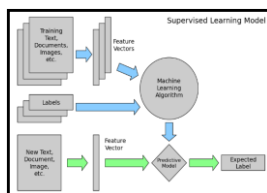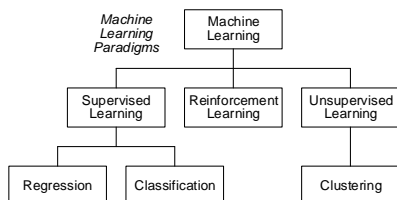
- **Supervised learning (지도학습)**
  - ► Labelled data (metrics) is already given to the computer.
  - ► Solving two types of problems
    - ⊃ Regression problem: target variable is continuous
    - ⊃ Classification problem: target variable is categorical

- **Unsupervised learning (자율학습/비지도학습)**
  - ► Finding hidden structures in datasets without any labels
  - ► Data is clustered using several clustering algorithms
  - ► Ex) Google News, Social Network Analysis, translation

- **Reinforcement learning (강화학습)**
  - ► No data given. Agent interacts with the environment calculating cost of actions.
  - ► Network is only provided with a grade, or score, which indicates network performance.
  - ► Gives reward instead of label
  - ► Action selection, policy learning, gaming
  - ► Ex) Google AlphGo

http://www.astroml.org/sklearn_tutorial/general_concepts.html

Data sets

- **Training set**
  - ► data for model building by training
  - ► a set of examples used for learning, where the target value is known.

- **Validation set**
  - ► data for estimating error while training
  - ► It should not be the same as training set and used as training.
  - ► a set of examples used to tune the architecture of a classifier and estimate the error.

- **Test set**
  - ► data for estimating error
  - ► used only to assess the performances of a classifier. It is never used during the training process so that the error on the test set provides an unbiased estimate of the generalization error.
    - • Training error: error by training data set
    - • Generalization error (test error, out-of-sample error): error by test data set in order to evaluate the training model.
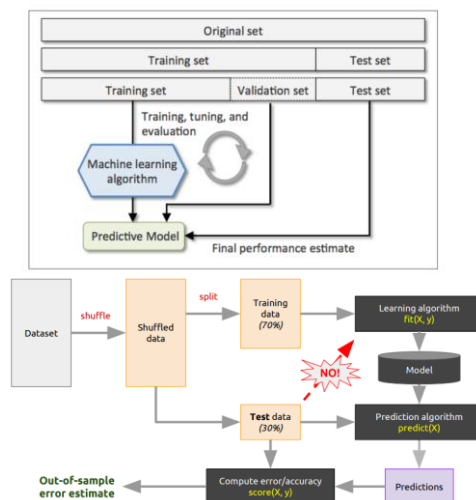
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Training strategy
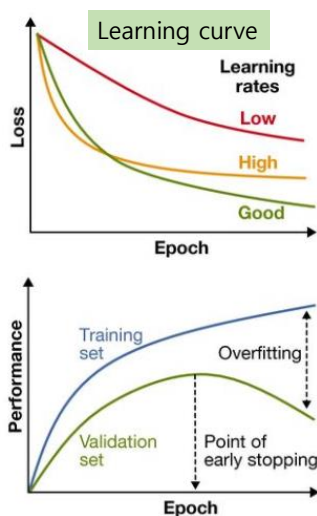
- ■ Split data into train, validation, and test sets Keep 10-30% of data for validation
  - ► Plot learning curves as training progresses
  - ► Stop when validation loss starts to increase
  - ► Use model with minimum validation loss

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Training strategy
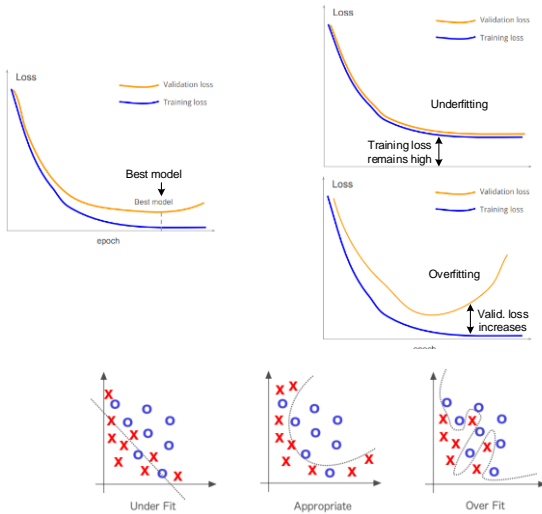
- Underfitting
  - ► Symptoms:
    - ⊃ Training loss decreases at first but then stops
    - ⊃ Training loss still high
    - ⊃ Training loss tracks validation loss
  - ► Try:
    - ⊃ Increase model capacity
    - ⊃ Add more layers, increase layer size
    - ⊃ Use more suitable network architecture
    - ⊃ Use better optimization (algorithm to reduce error)
- Overfitting
  - ► Symptoms:
    - ⊃ Training loss continues to go down
    - ⊃ Validation loss decreases at first, then starts increasing
  - ► Try:
    - ⊃ Find more training data
    - ⊃ Add stronger regularization
    - ⊃ dropout, drop-connect
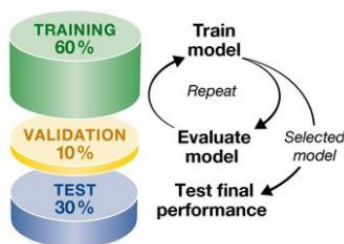   - ⊃ Data augmentation (flips, rotations, noise)
    - ⊃ Reduce complexity of the model
  - ► Learn the "data", but not the underlying function

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Overfitting (과적합)

- 학습 데이터 셋을 지나치게 정확하게 구분하도록 학습된 경우, 학습 데이터가 아닌 것에 대해 제대로 된 결과를 내지 못하는 문제
  - ► 일반화(generalization) 성능이 오히려 낮게 되는 문제가 발생
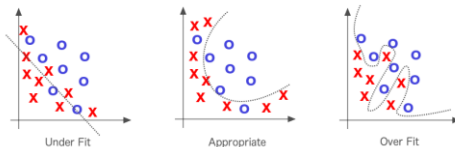
- Over-fit의 원인
  - ► 학습 데이터가 너무 작아서 쉽게 학습이 된 경우
  - ► 학습 데이터 셋이 전체 데이터 셋의 특성/분포를 반영하지 못하는 경우
  - ► 모델이 너무 복잡하여 대체로 많은 특징을 모델에서 반영하게 된 경우

- Parameter regularization (정규화, 일반화, 규제화, 정칙화)
  - ► 같은 현상을 설명하는 여러 개의 주장이 있다면 간단한 쪽을 선택한다.
  - ► 특정 가중치가 과도하게 반영되지 않도록 하여 모델의 일반화를 유도하는 방법
  - ► Regularization, Dropout, Early Stopping

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Data set, batch, epoch and iterations

- Data set
  - ► training data and validation data
  - ► it will be large amount of data.
- Batch
  - ► Training data set is divided into a number of parts.
  - ► The part of data set is 'batch'.
- Epoch
  - ► One Epoch is when an ENTIRE dataset is passed forward and backward through the neural network only ONCE.
  - ► Since, one epoch is too big to feed to the computer at once we divide it in several smaller batches.
- Iteration
  - ► The number of batches needed to complete one epoch

- We can divide the dataset of 2000 examples into batches of 500 then it will take 4 iterations to complete 1 epoch.
- If you have 1000 training examples, and your batch size is 500, then it will take 2 iterations to complete 1 epoch.
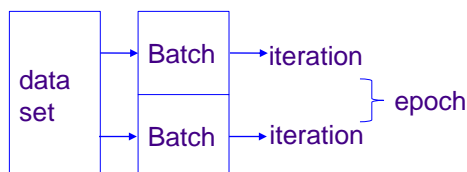

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DL

- Deep learning
  - ► Deep learning refers to artificial neural networks that are composed of many layers.

  A technique for implementing machine learning based on underlined artificial deep neural network

http://www.aliannajmaren.com/2017/01/27/deep-learning-the-fast-evolution-of-artificial-intelligence/
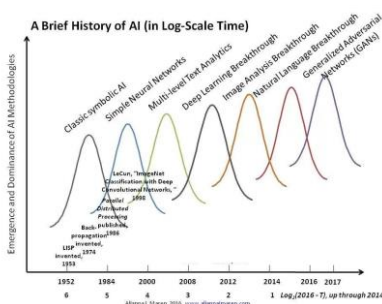
- ► feed data into 'artificial neural networks' that learn the characteristics of something, like a face.
- ► uses some ML techniques to solve real-world problems by tapping into neural networks that simulate human decision-making.

https://www.quora.com/What-is-deep-learning

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Deep Learning Design Flow

Model development	

Human programmer

Learning program
(Deep Learning Network)

기계학습이란 "컴퓨터에 명시적으로 프로그래밍하지 않고 학습 할 수 있는 능력을 부여하는" 것
→ 딥러닝은 머신러닝의 한 방법이며, 이들은 인공지능의 최신기술이다.

Training

Train Data
(Train data)

Computer

Program
(Weight-augmented network)

Inference

New Data

Computer

Output/Result

- Training (학습, learning): Process for machine to "learn" and optimize model from data
- Inference (추론, prediction, deply): Using trained models to predict/estimate outcomes from new observations in efficient deployments

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AI to DL

- **AI (인공지능)**
  - ▶ 지능적인 사람의 행동/판단을 모사하는 기계의 능력
- **ML (기계학습)**
  - ▶ 명시적인 프로그램하지 않고 컴퓨터가 배우는 능력에 대해 공부하는 영역
- **BI (두뇌모사)**
  - ▶ 두뇌가 작동하는 방식에 기초한 알고리즘
- **NN (뉴론네트웍)**
  - ▶ 생물학적 뉴론 네트웍에 기초한 퍼셉트론을 네트웍
- **DL (딥러닝)**
  - ▶ 많은 수의 숨은 레이어를 갖는 인공 뉴론 네트웍에 기초한 기계학습의 구현

Artificial Intelligence

Machine Learning

Brain-Inspired

Neural Network

Deep Learning
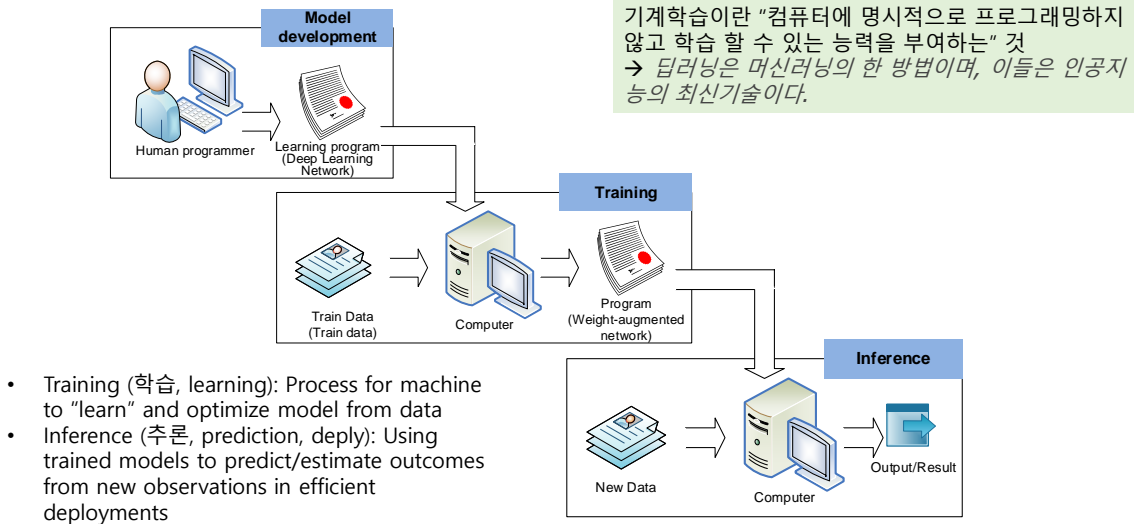
The capability of a machine to imitate intelligent human behavior.

Field of study that gives computers the ability to learn without being explicitly programmed.

An algorithm that takes its basic functionality from our understanding of how the brain operates.

A network of connected perceptions that are inspired by the biological neural networks.

A technique for implementing machine learning based on artificial neural network with deep hidden layers.

Artificial Intelligence

Machine Learning

Deep Learning

Breadth

1950s   1980s   2010s   Present

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Applications of DL

- **Mature applications**
  - ► Image
    - ➲ Classification: determine object class
    - ➲ Recognition: more narrow classification
    - ➲ Detection: assigning bounding boxes to objects
    - ➲ Segmentation: assigning object class to every pixel
  - ► Speech & language
    - ➲ Speech recognition: audio to text
    - ➲ Translation
    - ➲ Natural language processing: text to meaning
    - ➲ Audio generation; text to audio
  - ► Games
    - ➲ AlpaGo

- **Emerging applications**
  - ► Image
    - ➲ action recognition
    - ➲ image generation
  - ► Self-driving cars
  - ► Medical
    - ➲ Diagnostic: Cancer detection
  - ► Finance
    - ➲ Trading
    - ➲ Risk
  - ► Infrastructure
    - ➲ Structure safety
    - ➲ Traffic
  - ► Weather forecasting
  - ► Event detection

https://www.nextplatform.com/2016/09/14/next-wave-deep-learning-applications/

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Popular Deep Neural Networks

Image classification case

	LeNet-5	AlexNet	GoogLeNet (V1)	ResNet-50	ResNet-152
Data set	MNIST	ImageNet	ImageNet	ImageNet	ImageNet
Purpose	Handwritten digit classification	Image classification	Image classification	Image classification	Image classification
Error (%)[Human]	0.95 [0.2~0.3]	16.4 [5]	6.7	5.3	3.57
Year	1998	2012	2014	2015	2015
Image size	28x28	227x227	224x224	224x224	
Layers	4	8	22	50	152
Weights	431k	61M	7M	25.5M	??
MACs	2.3M	724M	1.43G	3.9G	??
Training time		a week			
Inference time					
etc		2 GPU			

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Data set: MNIST
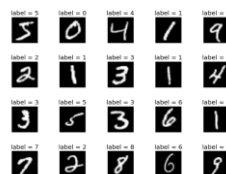
■ The MNIST database (Modified National Institute of Standards and Technology database)
  ► a large database of handwritten digits that is commonly used for training various image processing systems.

■ Digit classification
  ► 28x28 pixels (B&W)
  ► 10 classes: 0, 1, …, 9
  ► training set: 60,000 training image
  ► test set: 10,000 testing imag

Type	Classifier	Error rate (%)
Linear classifier	Pairwise linear classifier	7.6
K-NN	K-Nearest Neighbors	0.52
Neural network	2-layer	1.6, 0.7
Deep NN (LeNet-5)	5-layer	0.95
Deep NN	6-layer	0.35
Convolutional NN	6-layer	0.31~0.21

1998: LeNet, 0.95% error
2013: ICML, 0.21% error

http://rodrigob.github.io/are_we_there_yet/build/classification_datasets_results.html

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Data set: CIFAR-10/CIFAR-100

■ CIFA: Canadian Institute For Advanced Research

■ CIFA-10
  ► Object classification
  ► image dataset consists of 60,000 (32x32-pixesl/image) color images in 10 classes, with 6,000 images per class.
  ► 32x32 pixels (color)
  ► 10 classes containing 6,000 images each
  ► 50,000 training
  ► 10,000 testing

■ CIFA-100
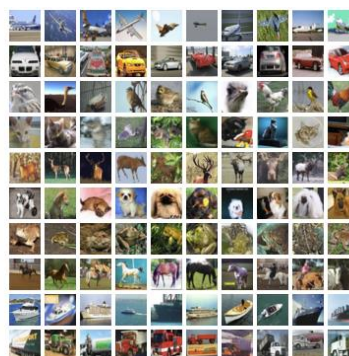 ► 100 classes containing 600 images each

airplane
automobile
bird
cat
deer
dog
frog
horse
ship
truck

https://www.cs.toronto.edu/~kriz/cifar.html

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Data set: VOC2012

■ VOC: PASCAL Visual Object Classes
  ▶ Pattern Analysis, Statistical Modeling and Computational Learning
  ▶ http://host.robots.ox.ac.uk/pascal/VOC/
  ▶ VOCO: 2005~2012
  ▶ VOC2012
    ➲ 20 classes
    ➲ 11k images
    ➲ The train/val data has 11,530 images containing 27,450 ROI (region of interest) annotated objects and 6,929 segmentations.
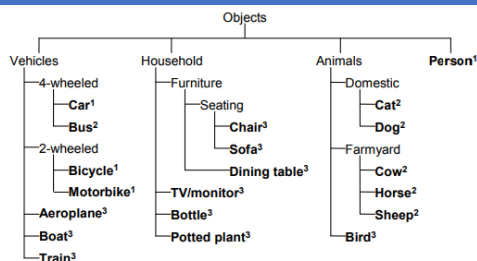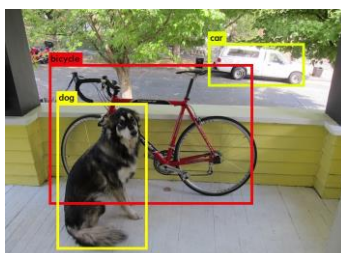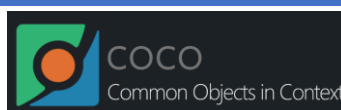

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Data set: COCO

■ COCO: Common Objects in Context
  ▶ 100k images
  ▶ 80 classes
  ▶ detection labels
  ▶ http://cocodataset.org/#home

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Data set: ImageNet and ILSVRC

- The **ImageNet** project is a large visual database designed for use in visual object recognition software research since 2009.
  - http://www.image-net.org/
  - Over 15M labeled high resolution images
    - ⮑ Annotated
  - 256x256 pixels (color)
  - Roughly 22K categories
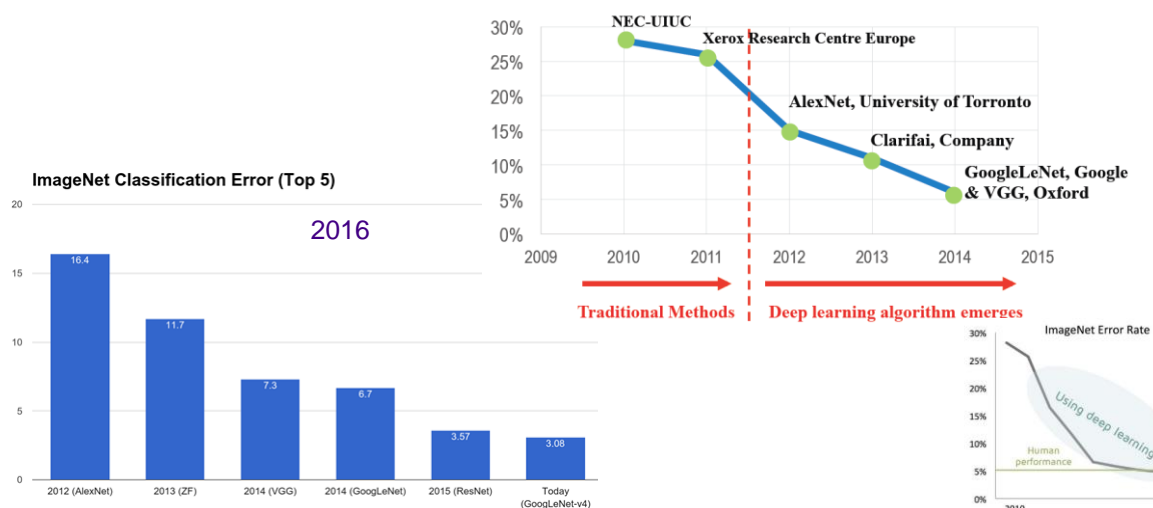 - Collected from web and labeled by Amazon Mechanical Turk (Mturk)

- ILSVRC: ImageNet Large-Scale Visual Recognition Challenge
  - An annual software contest run by ImageNet project since 2010
  - http://image-net.org/challenges/LSVRC/
  - 150K images, 1K object classes
  - Error by human: ~5% (classification)

IMAGENET

Classification: person, motorcycl
Detectio
n
Person
Motorcycle
Action: riding bicycle

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ImageNet and ILSVRC results

ImageNet Classification Error (Top 5)

2016

16.4 — 2012 (AlexNet)
11.7 — 2013 (ZF)
7.3 — 2014 (VGG)
6.7 — 2014 (GoogLeNet)
3.57 — 2015 (ResNet)
3.08 — Today (GoogLeNet-v4)

NEC-UIUC
Xerox Research Centre Europe
AlexNet, University of Torronto
Clarifai, Company
GoogLeNet, Google & VGG, Oxford

Traditional Methods → **Deep learning algorithm emerges** →

ImageNet Error Rate
Using deep learning
Human performance
2010 — Present

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Image Classification Summary

■ Image data sets

	MNIST	CIFAR-10	CIFAR-100	ImageNet
Year	1998	2009	2009	2012
Resolution	28x28	32x32	32x32	256x256
Classes	10	10	100	1000
Training	60k	50k	50k	1.3M
Testing	10k	10k	10k	100k
Accuracy (%)	0.21 (2013)	3.47 (2015)	24.28 (2015)	2.99 (2016)

http://rodrigob.github.io/are_we_there_yet/build/
https://en.wikipedia.org/wiki/List_of_datasets_for_machine_learning_research

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Training and inference

weights/parameters

training dataset

Training

Inference

test image

model

training hardware

inference hardware
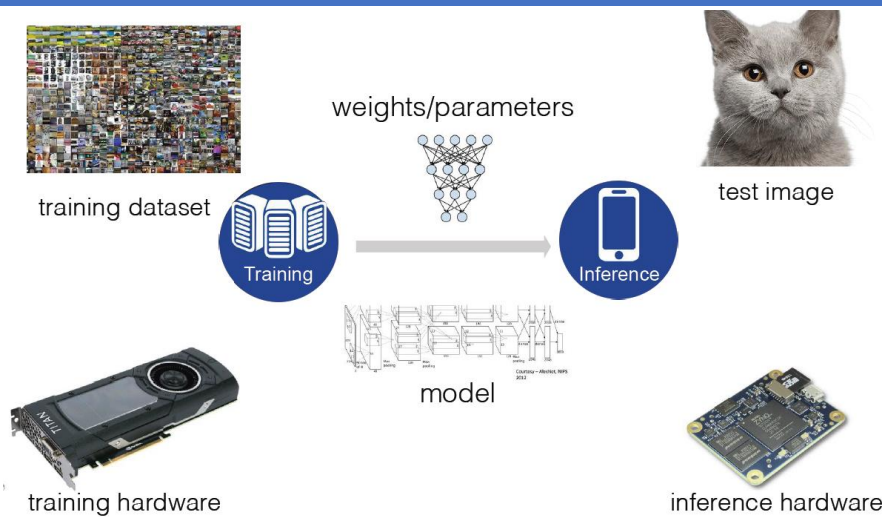
Song Han, Deep Learning Tutorial and Recent Trends, FPGA'17, 2017.

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What have been addressed

- Artificial intelligence (AI), Machine learning (ML), Deep learning (DL)
- Regression, clustering, classification
- Supervised learning, unsupervised learning
- Data set: Training set, validation set, test set, epoch, batch, iteration
- Underfitting, overfitting
- Model development, training, inference
- Data sets: MNIST, CIFAR-10, VOC, COCO, ImageNet

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