Learning Deep Learning with PyTorch

(1) Introduction

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October 15th, 2020

About the series

- A crush course for general audience
  - **Intuitive:** avoiding math to explain the fundamentals
  - **Practical**: jupyter notebook examples on basic techniques
  - **Broad and Latest**: high-level descriptive review

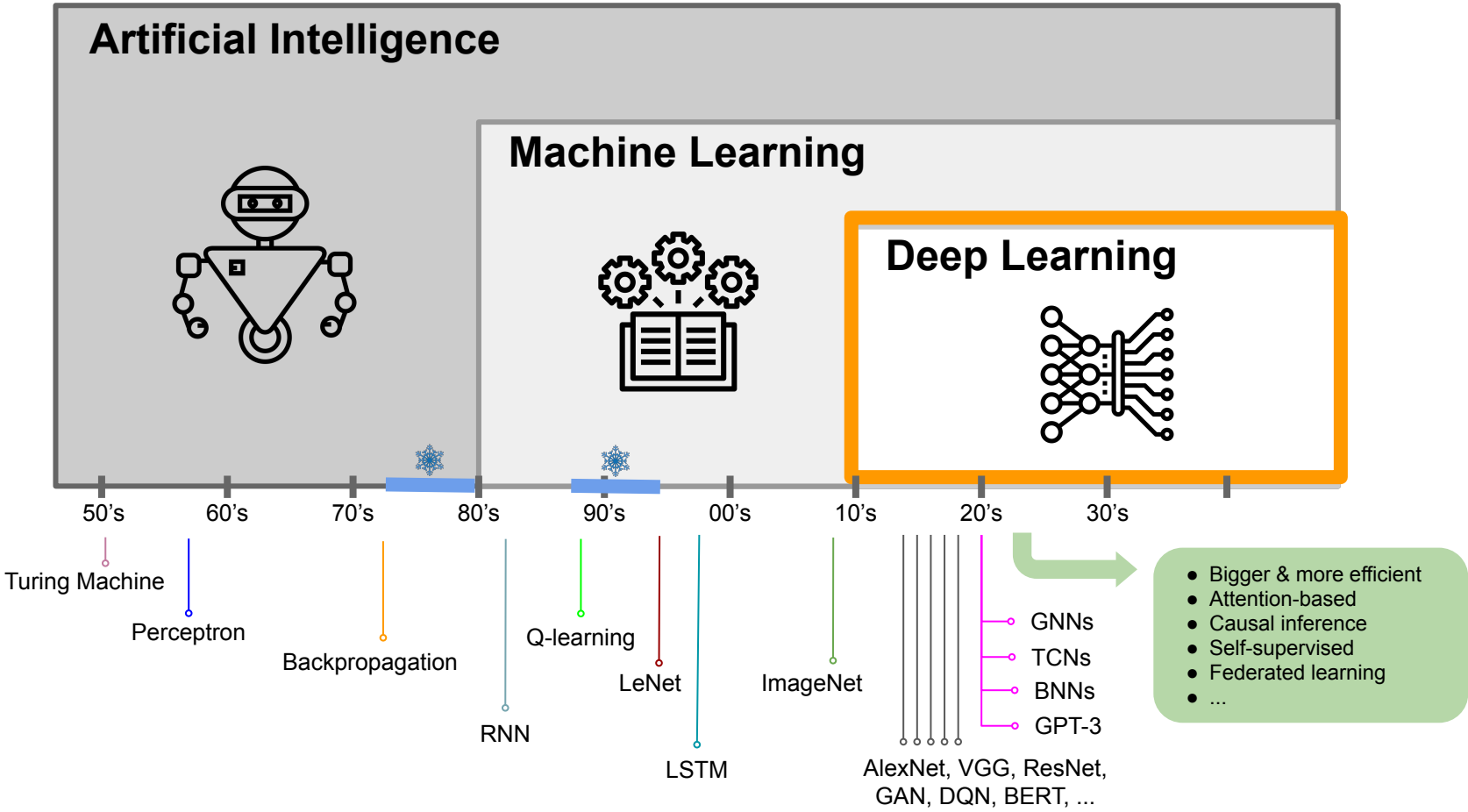
- Workshop plan in this quarter
  - Introduction (Oct 15, 2020)
  - Mechanics of Deep Learning (Oct 20, 2020)
  - Knowing PyTorch (Oct 22, 2020)
  - Convolutional Neural Networks (Oct 27, 2020)
  - Improving CNNs' Performance (Oct 29, 2020)
  - Generative Adversarial Networks (Nov 3, 2020)

Slides only

w/ PyTorch examples

Topics in future quarters

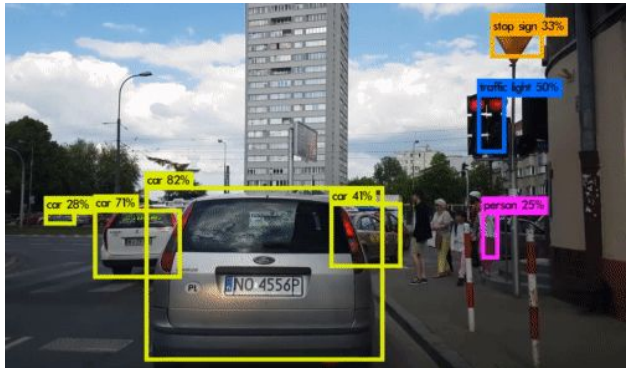
? LSTM & NLP
? Reinforcement
? Model-specific
? Domain-specific


Artificial Intelligence
Machine Learning
Deep Learning
50's
60's
70's
80's
90's
00's
10's
20's
30's
Turing Machine
Perceptron
Backpropagation
RNN
Q-learning
LeNet
LSTM
ImageNet
AlexNet, VGG, ResNet,
GAN, DQN, BERT, ...
GNNs
TCNs
BNNs
GPT-3
Bigger & more efficient
Attention-based
Causal inference
Self-supervised
Federated learning
...

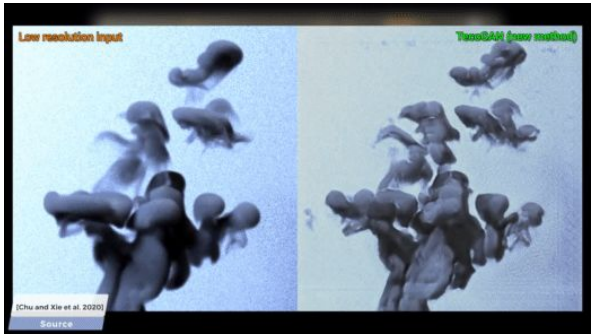
Amazing Deep Learning Achievements in 2020

GPT-3

YOLO Fastest



Wavelet Turbulence Simulation



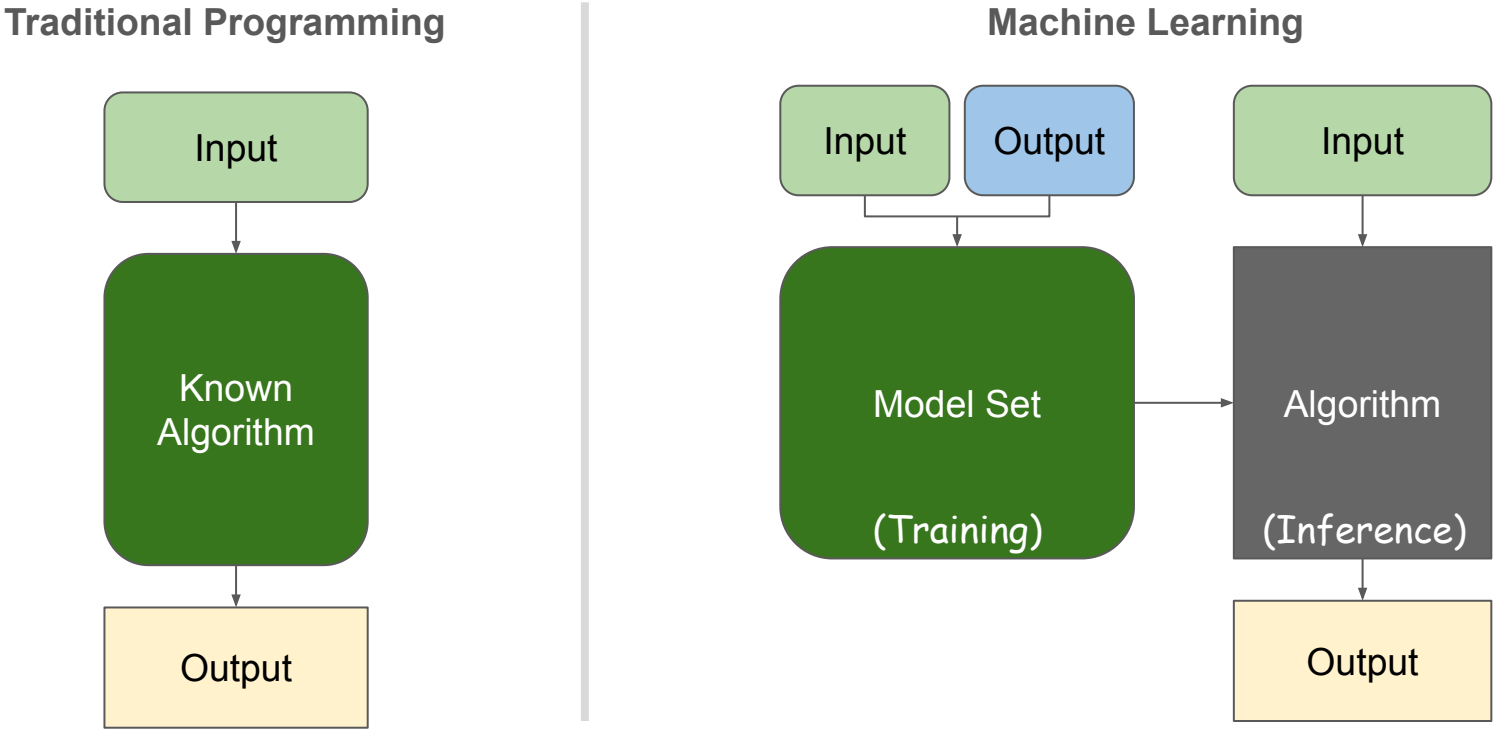
Creating Faces From Sketches

AI Beats Fighter Pilot

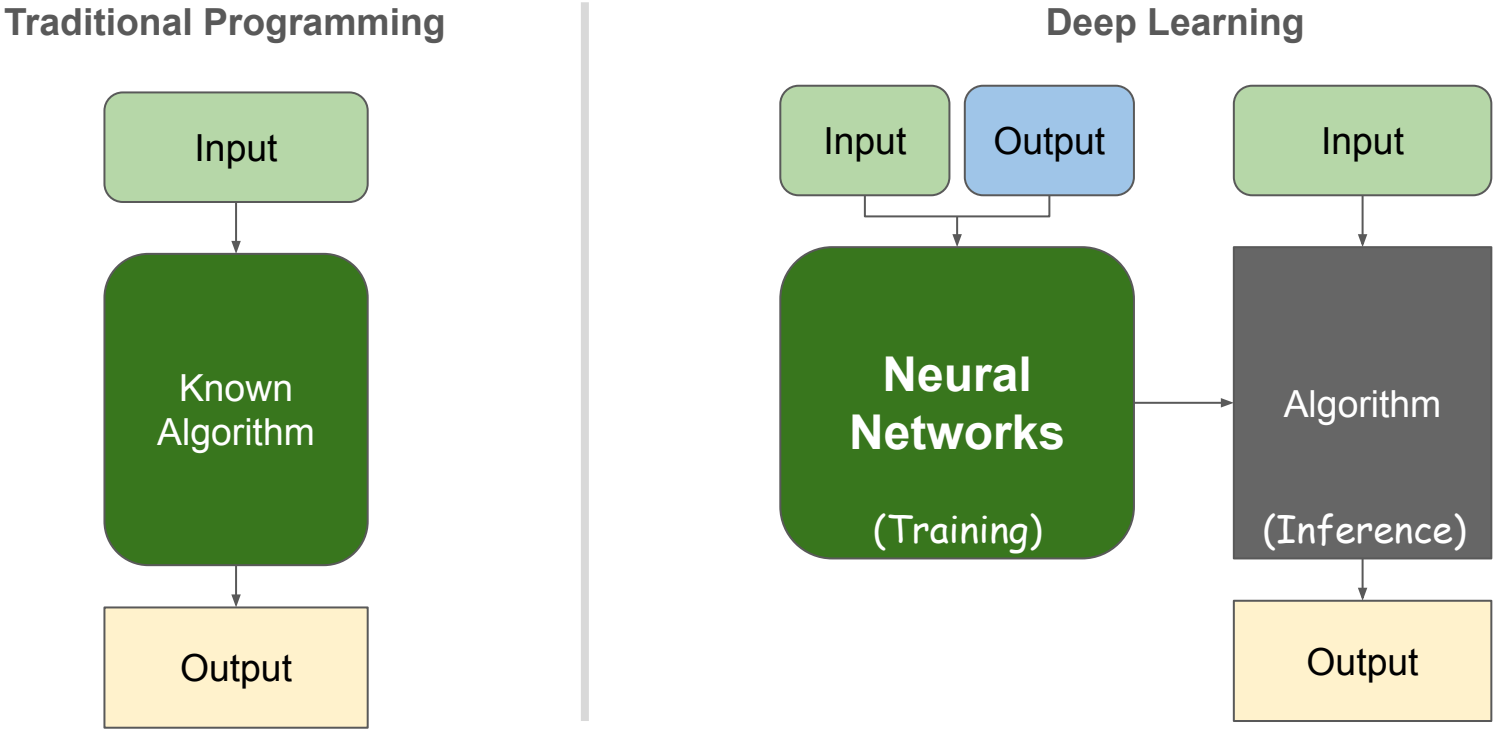
Equation-solving AI

EQUATION	SOLUTION
$y' = \frac{16x^3 - 42x^2 + 2x}{(-16x^8 + 112x^7 - 204x^6 + 28x^5 - x^4 + 1)^{1/2}}$	$y = \sin^{-1}(4x^4 - 14x^3 + x^2)$
$3xy\cos(x) - \sqrt{9x^2\sin(x)^2 + 1}y' + 3y\sin(x) = 0$	$y = c\exp(\sinh^{-1}(3x\sin(x)))$
$4x^4yy'' - 8x^4y'^2 - 8x^3yy' - 3x^3y'' - 8x^2y^2 - 6x^2y' - 3x^2y'' - 9xy' - 3y = 0$	$y = \frac{c_1 + 3x + 3\log(x)}{x(c_2 + 4x)}$

What is Machine Learning?

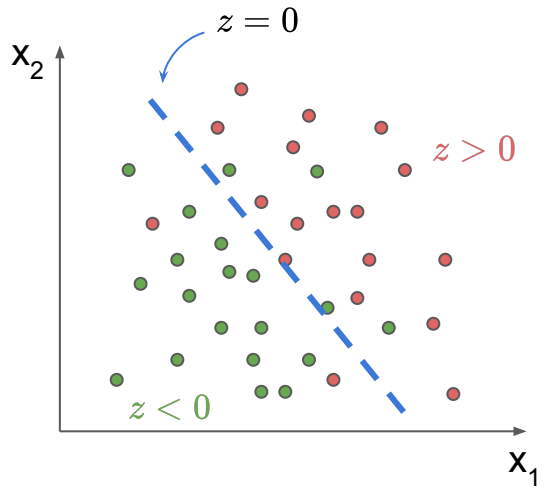


What is Deep Learning?

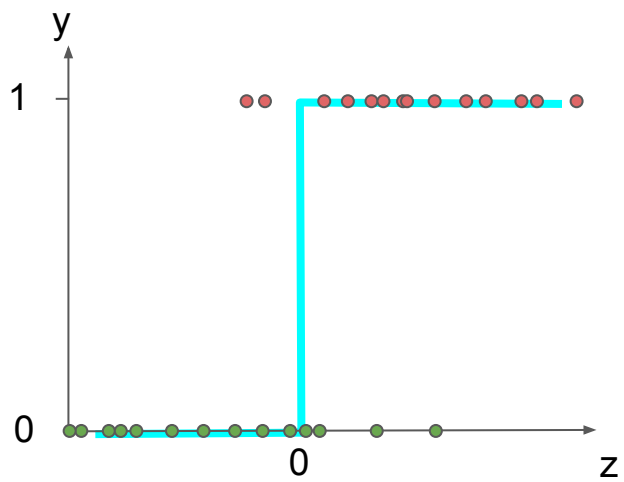


What is Neural Network?

- Recap for simple linear classification problem

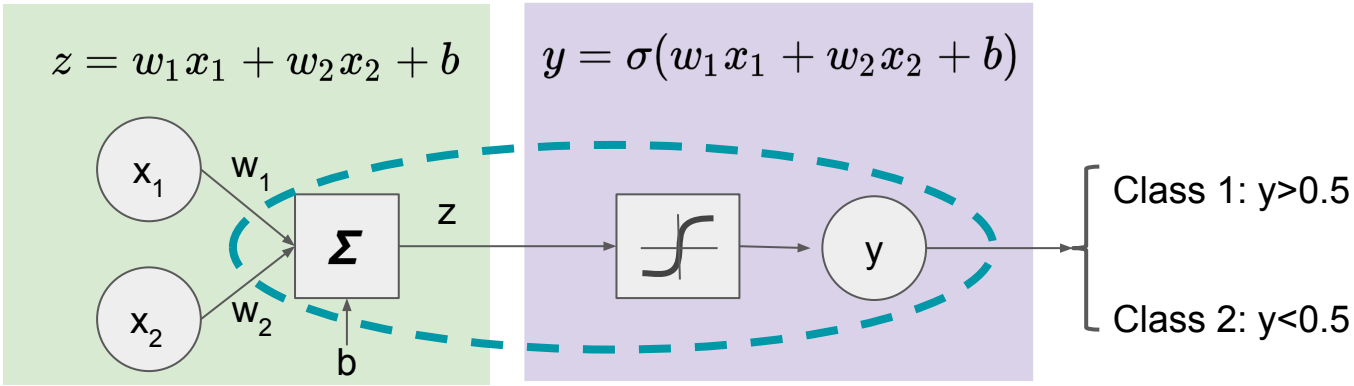


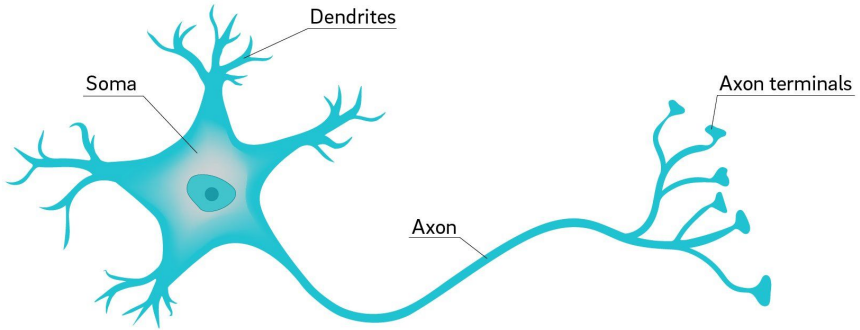
$$z = w_1 x_1 + w_2 x_2 + b$$



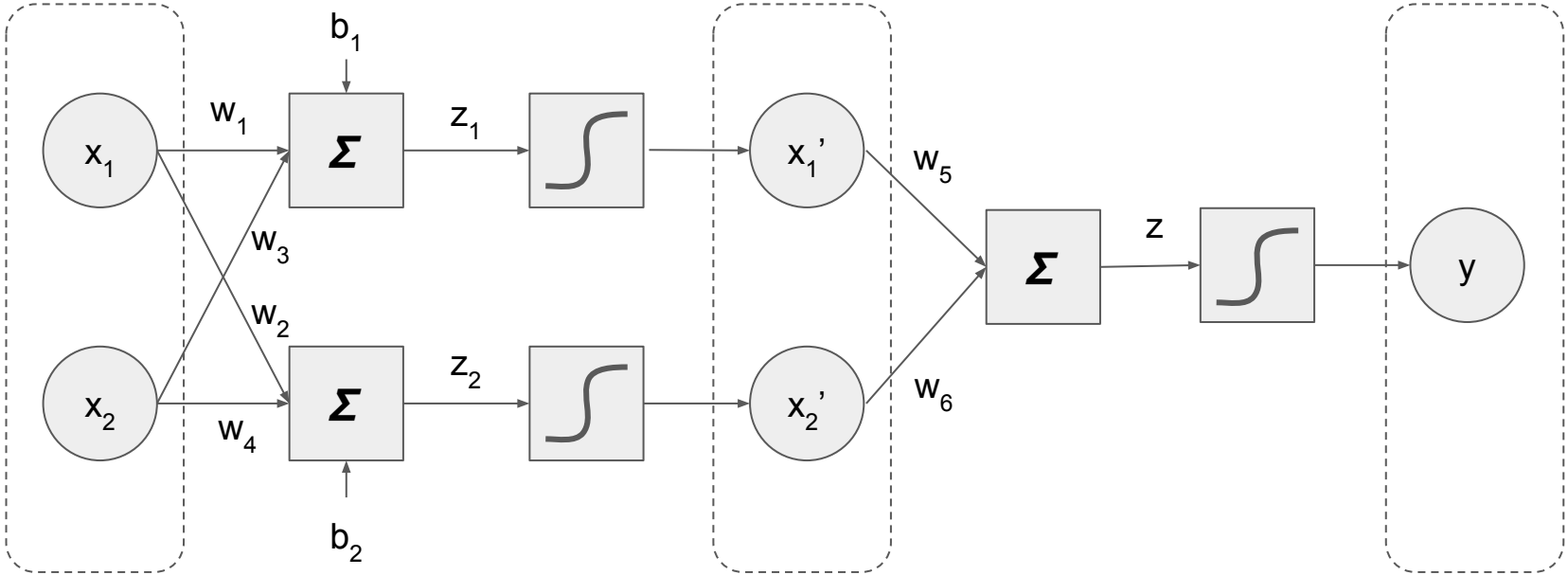
$$y = \sigma(z) = \begin{cases} 1 & \text{if } z > 0 \\ 0 & \text{if } z < 0 \end{cases}$$

A linear classifier ~ one artificial neuron





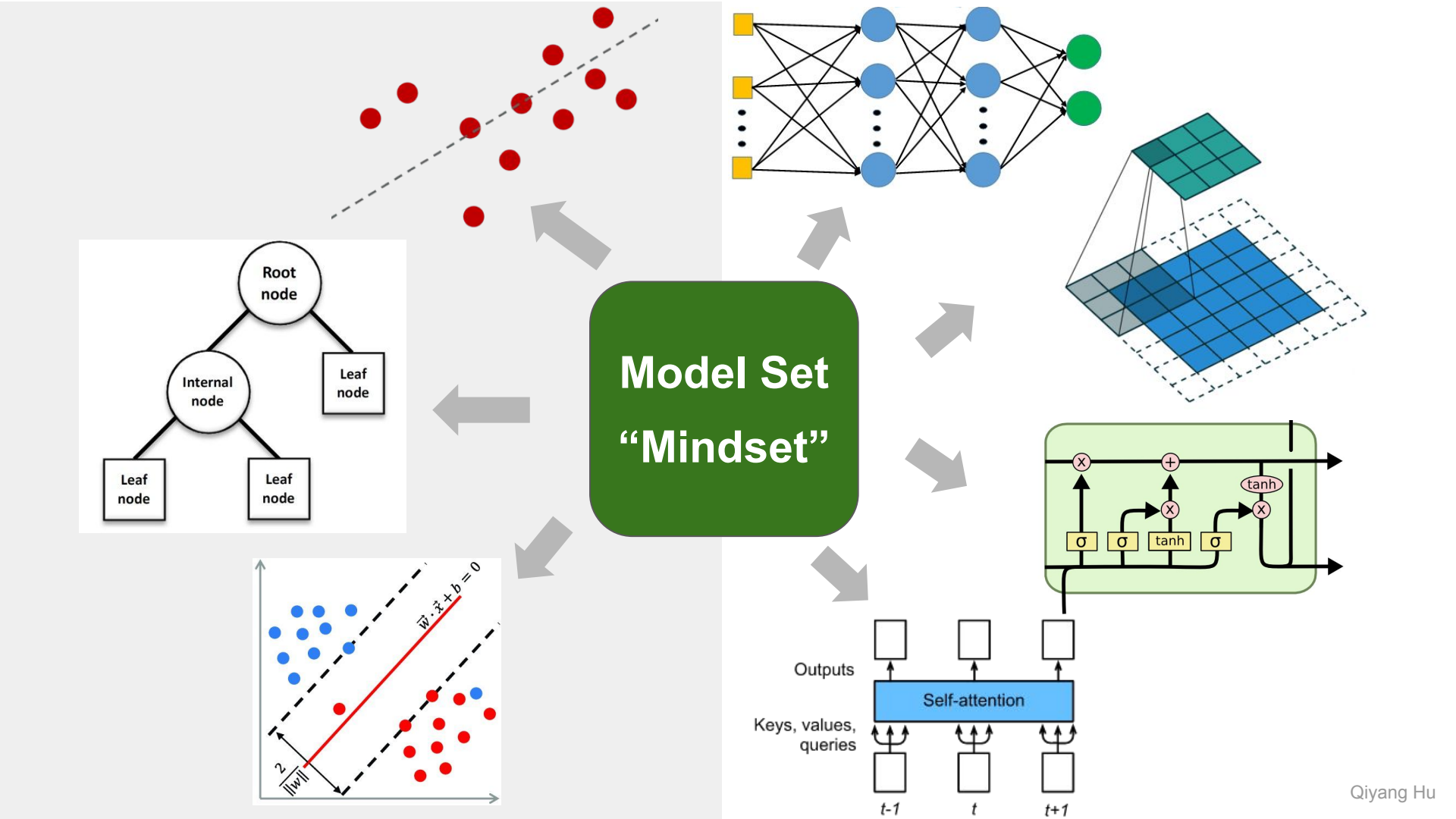
(Deep) Neural Networks ~ piling/stacking logistic-regression classifiers



How deep a deep learning network can be?

- LeNet-5 (1998) 

Year	CNN	Developed by	Place	Top-5 error rate	No. of parameters
1998	LeNet(8)	Yann LeCun et al			60 thousand
2012	AlexNet(7)	Alex Krizhevsky, Geoffrey Hinton, Ilya Sutskever	1st	15.3%	60 million
2013	ZFNet()	Matthew Zeiler and Rob Fergus	1st	14.8%	
2014	GoogLeNet(19)	Google	1st	6.67%	4 million
2014	VGG Net(16)	Simonyan, Zisserman	2nd	7.3%	138 million
2015	ResNet(152)	Kaiming He	1st	3.6%	


Model Set
“Mindset”
Root node
Internal node
Leaf node
Leaf node
Leaf node
$\vec{w} \cdot \vec{x} + b = 0$
$\frac{2}{\|w\|}$
tanh
σ
σ
tanh
σ
Outputs
Self-attention
Keys, values, queries
t-1
t
t+1

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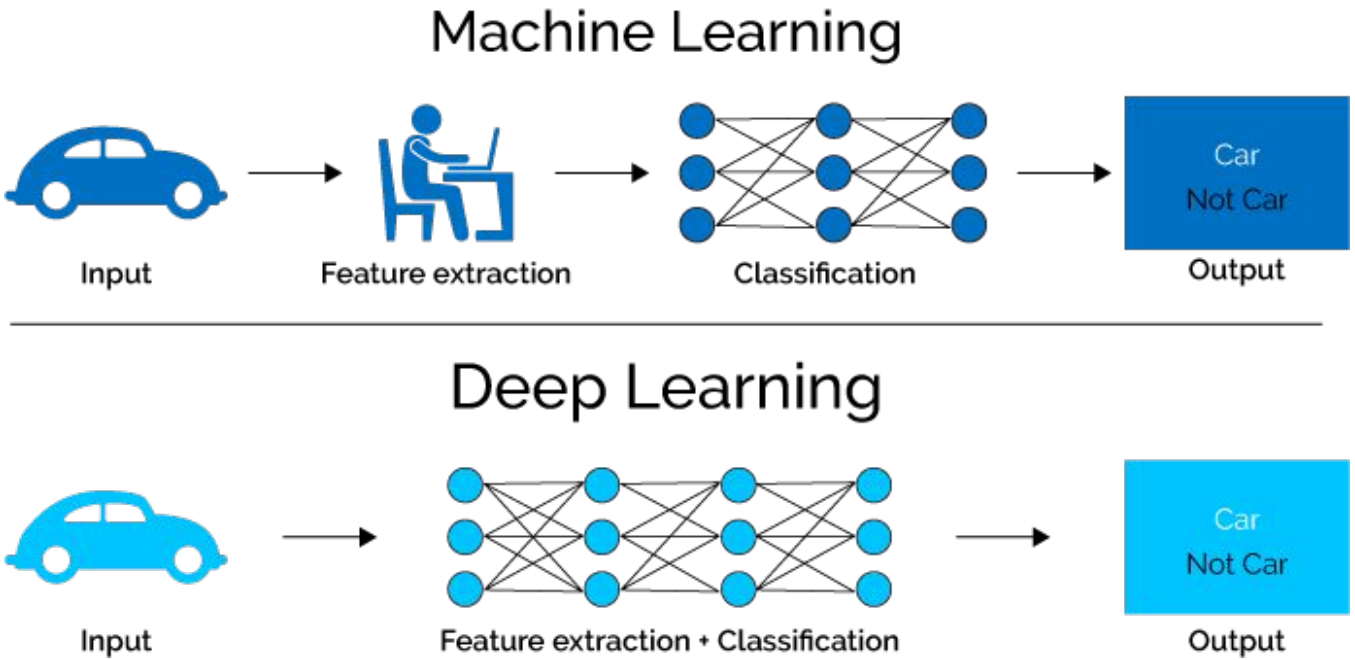
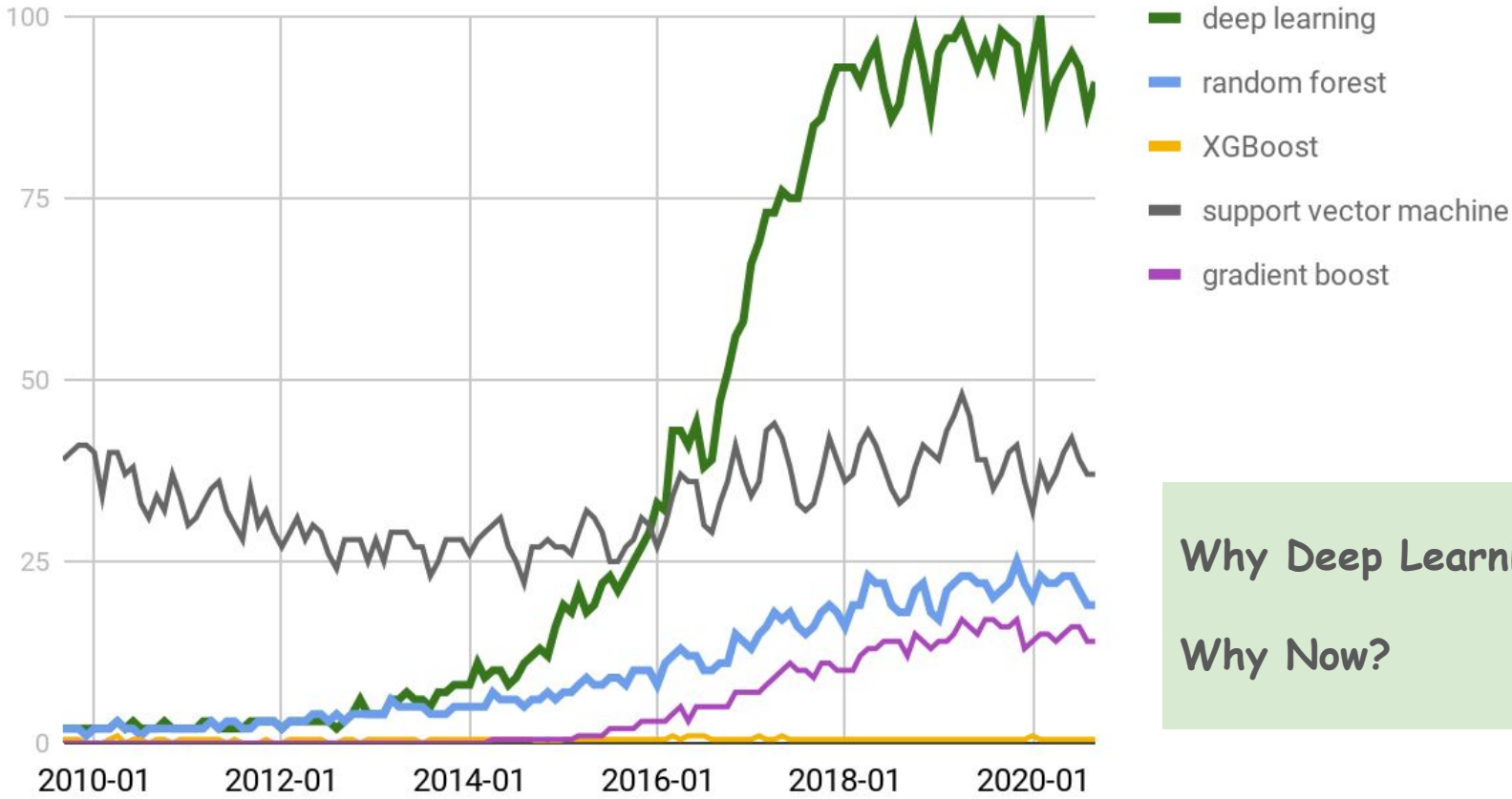
Machine Learning vs. Deep Learning



Source: https://www.xenonstack.com/blog/log-analytics-deep-machine-learning/

Interest over time from Google Trends



Why Deep Learning?

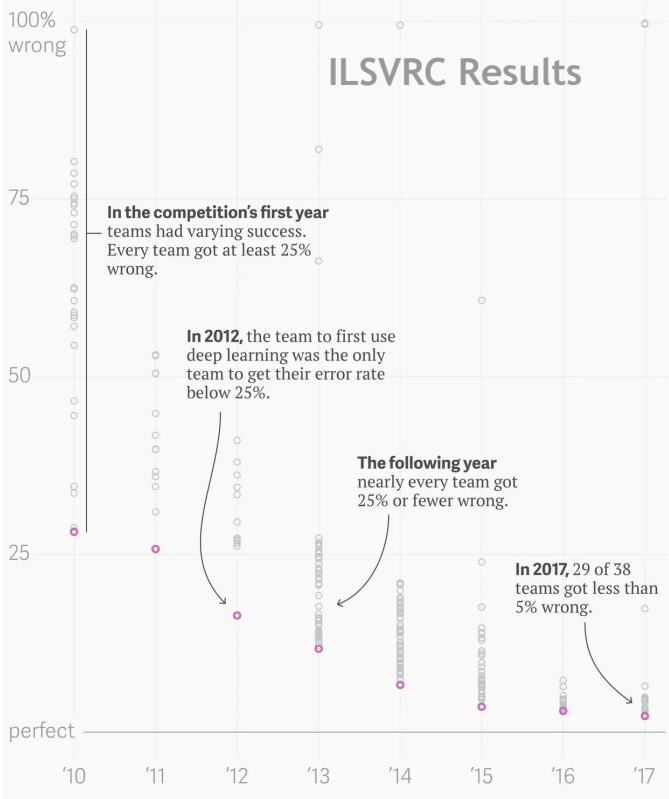
Why Now?

Driving Forces in Deep Learning (1): *Algorithms*

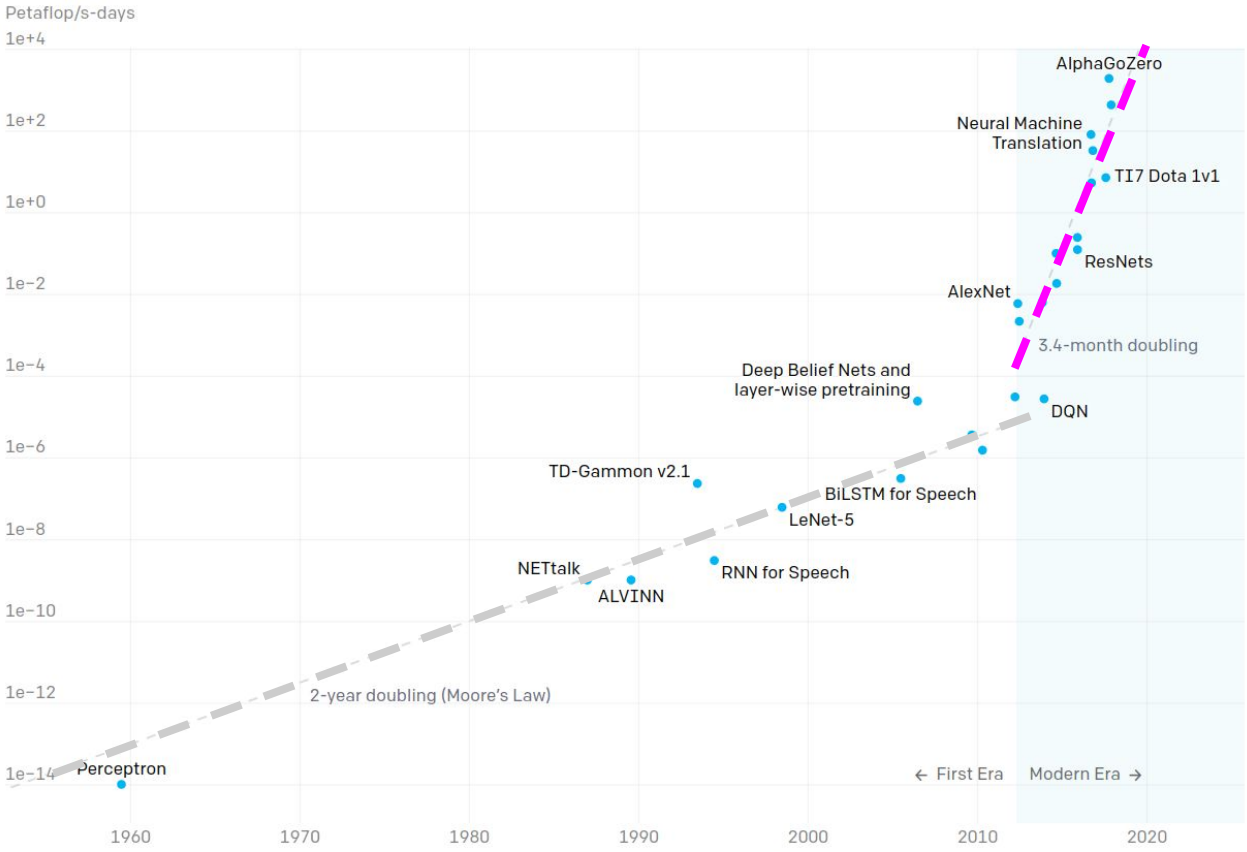
- Key Issues in Deep Learning:
  - Optimization for models with huge number of parameters
  - Gradient Propagation through stacks of layers
    - Gradient vanishing and exploding
- Algorithmic improvements in 2009-2010:
  - Better activation functions, weight-initialization schemes, optimization schemes
- Advanced techniques in 2014-2018:
  - Batch normalization/Drop-out
  - Residual/skip connections
  - Depth-wise separable convolutions
- Progress keeps accelerating! 2019-
  - Low precision neural networks, Graph neural networks, Pre-training & fine-tuning, ...

Driving Forces in Deep Learning (2): *Data*

- ImageNet (a large dataset of annotated photographs built on 2009)
  - 14 million+ images
  - 21,000 groups or classes
  - ILSVRC competition (1.2 million image, 1000 classes)
- Kaggle (Founded in 2010, acquired by Google in 2017)
  - 1,000,000+ registered users in 194 countries in 2017
  - Hosts 19K+ of datasets and 200K+ code snippets
  - Famous for the high-rewards competitions
- Datasets from the rise of internet
  - User-generated image tags on Flickr
  - Video dataset/tags on Youtube
  - Data from Wikipedia for NLP



AI compute amount increases 10 times per year!



Source: [OpenAI Report]

Driving Forces in Deep Learning (3): *Hardware*

Inference on Device

SoCs (FPGAs, ASICs, *x*PUs, Neuromophic Chips)

Inference on Cloud

FPGAs

intel
ALTERA now part of Intel
XILINX
AWS Inferentia

ASICs

TPUs

IPUs

Colossus Mk2

Neuro-Morphic Chips

IBM TrueNorth
intel Loihi

Training

GPUs

NVIDIA
RADEON GRAPHICS AMD

Quantum AI Chips

??

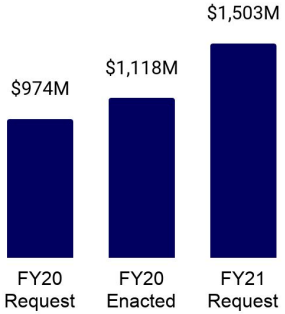
Free GPU Computation Resources

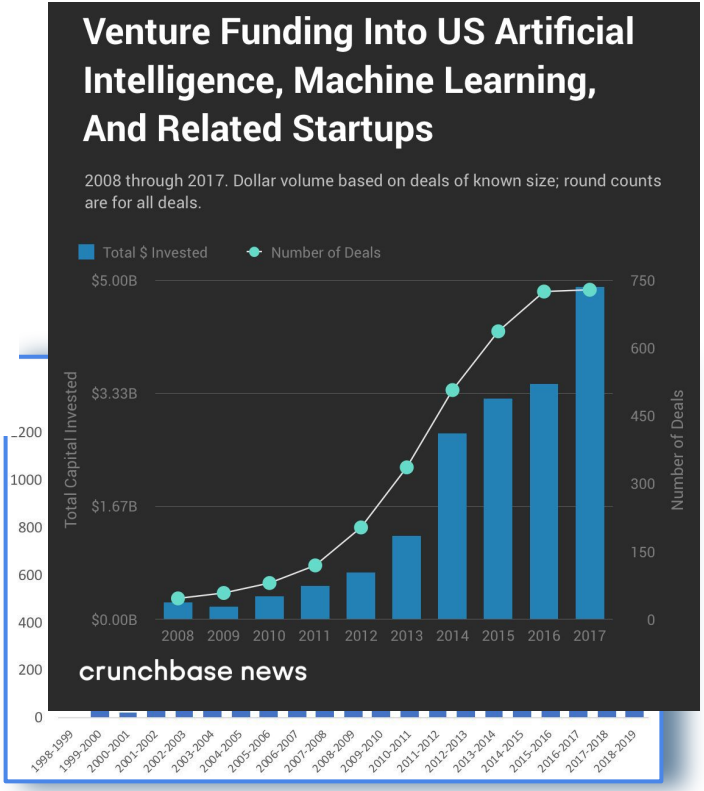
- Cloud-based resources (Google Colaboratory, Kaggle, Paperspace's Gradient)
  - A free Jupyter notebook env that requires no setup and runs entirely in the cloud.
  - Google Drive ➛ New ➛ More ➛ Google Colaboratory
  - Kaggle.com ➛ Log in ➛ Kernel ➛ New Kernel
- Hoffman2 (GPU resources)
  - Work under python shell in terminal:
    - qrsh -l gpu,P4
      module load python/anaconda3
      conda activate pytorch-1.3.1-gpu
  - Work in Jupyter notebook session:
    - For the very first time, add the virtual env to kernel in the ***above*** qrsh session:
      - python -m ipykernel install --user --name=pytorch-1.3.1-gpu
    - Using h2jupynb:
      - ./h2jupynb -v anaconda3 -g yes -c P4 -l 10.0

	Google Colab	Hoffman2
CPU Type	Intel Xeon 2.30GHz	Intel Xeon 2.80GHz
Slots/Threads available	1 core / 2 threads	8 cores / no hyper-threads
RAM available	12 GB	24 GB
Disk available	311 GB	1 TB
GPU Type	Tesla P4, T4, V100	Tesla P4
GPU SP Floating-Point Perf	8 ~ 16 TFLOPs	5.5 TFLOPs
GPU Memory	16 ~ 32 GB	8 GB
Active Time Limit	8 hours	24 hours

Driving Forces in Deep Learning (4): *Investment*

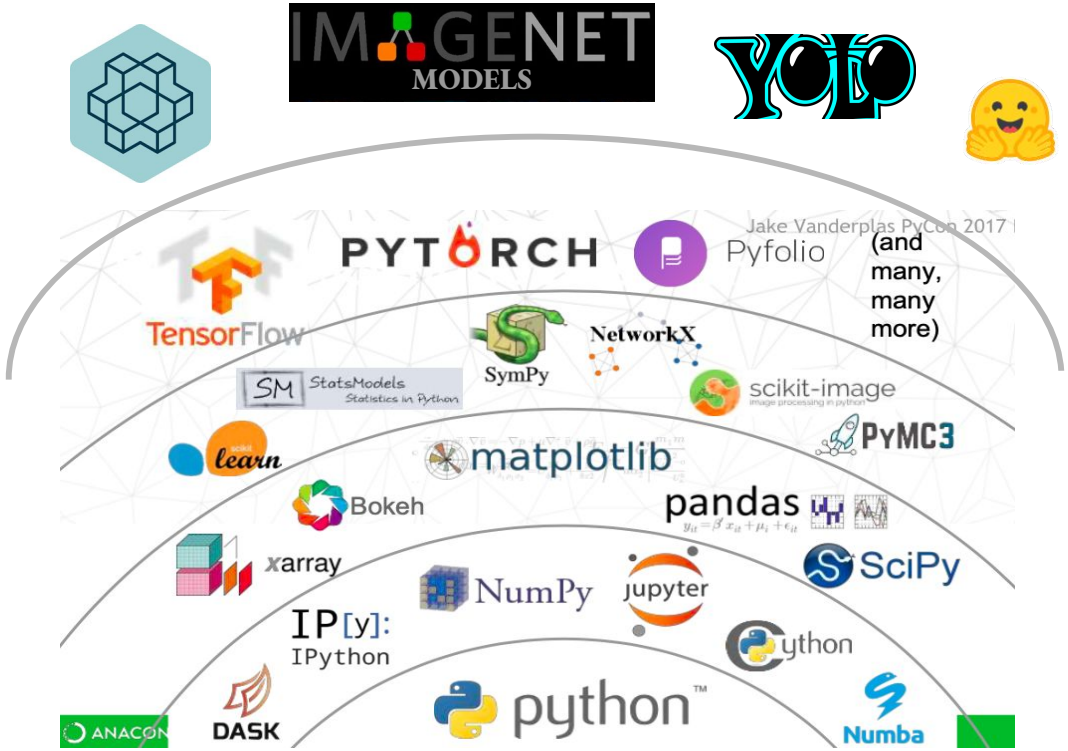
- Venture Capital Investment soars
  - Source
  - 20x increase in 8 years
  - Most for deep-learning
- Federal fundings
  - For non-defense AI R&D
- AI acquisitions
  - Google: $500M for DeepMind (2013)
  - Intel: $400M for Nervana Systems (2016)
  - Tons of M&As undisclosed
- Demand drives supply
  - 100x more people working on deep learning





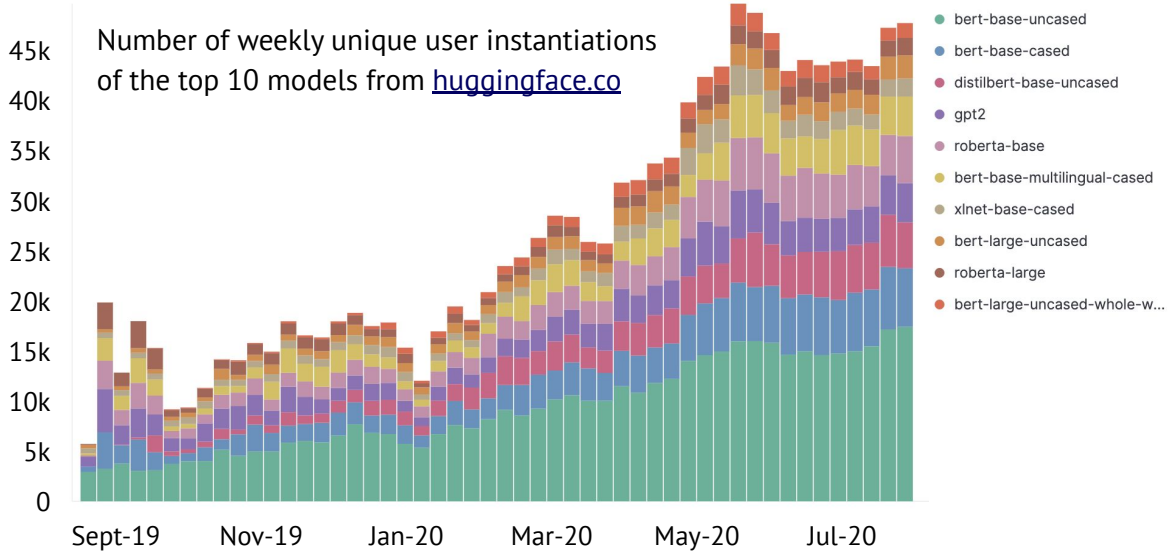
Driving Forces in Deep Learning (5): *Dev Tools*

- From C++/Cuda to scripting languages (Python, R)
- From library packages to frameworks
- From toolsets to open-source pre-trained models



Example: Hugging face 🤗 Transformer Libraries

- Used by 1000+ companies
- 5M pip installs
- 2,500+ community transformer models
- Trained in >164 languages
- 430 contributors

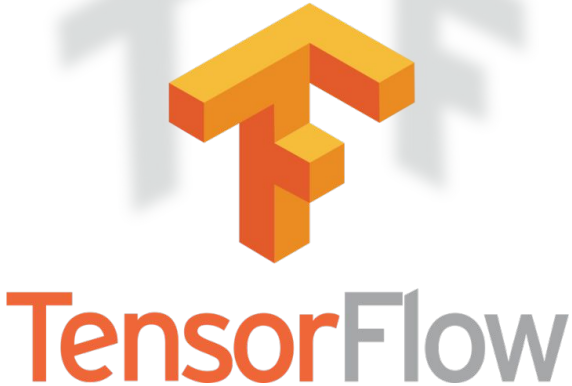


Data & Figure from stateof.ai 2020

Deep Learning Framework Battles

Finals?

vs.



Key Terminology in Deep Learning

- Datasets:
  - Label: a desired output (e.g. house price)
  - Feature: a known input (e.g. address, condition, household income, etc)

- Model: relationship between input & output
  - Parameter: to be learned from data, e.g. weight, coefficients
    - Weight: a coefficient for a feature in linear model
    - Bias: an intercept or offset from an origin
  - Hyperparameter: often set by heuristics, e.g. learning rate, depth of trees, batch, epoch.
  - Batch: a subset from the division of training datasets
  - Epoch: all data in training sets has had an opportunity to update the internal model parameters

Complete Glossary

A lot of “Learning”s to learn

- Supervised Learning (data with labels)
  - Regression
  - Classification
- Unsupervised Learning (data without labels) (Auto Encoders)
- Semi-supervised Learning (data with partial labels)
- Reinforcement Learning (reward rules to get data) (PPO, Deep Q-learning)
- Self-supervised learning (no rules & no labels) 
- Transfer Learning (data with unrelated labels)

  (zero-shot learning, one-shot learning, few-shot learning, etc.)

⇒ Continuous learning

⇒ Meta Learning (MAML)

FYI

- Github Repo:
  - https://github.com/huqy/idre-learning-deep-learning-pytorch
- Slack workspace:
  - bit.ly/Join-LDL
- Contact me
  - huqy@idre.ucla.edu
  - Direct message in Slack