Machine Learning Frontiers

Lecture 25

Review of what we've covered

Exciting applications

Challenges in the field

Where to go from here?

Supervised Learning
K-Nearest Neighbors
Linear regression
Perceptron
Logistic regression
Linear Discriminant Analysis (LDA) / Fisher's Linear Discriminant
Quadratic Discriminant Analysis
Naïve Bayes
Classification and Regression Trees
Random Forests
Neural Networks, backpropagation, CNNs
Kernel Methods / Support Vector Machines

Ensemble methods
Bagging, boosting, stacking
Regularization (ridge and lasso), feature selection, cost functions, and norms
Decision theory
Gradient descent and stochastic gradient descent

Performance Evaluation
Cross validation
Bootstrap sampling
Confusion Matrices
ROC curves
Precision/Recall/Error Types
Bias-variance tradeoff
Curse of Dimensionality

Unsupervised Learning
Clustering
K-Means
Gaussian mixture model
Agglomerative clustering
DBSCAN
Spectral clustering
Density Estimation
Kernel density estimation
Gaussian mixture models
Dimensionality Reduction
Principal Component Analysis, LDA

Markov Models
Markov chains
Hidden Markov Models
Markov reward processes
Markov Decision Processes

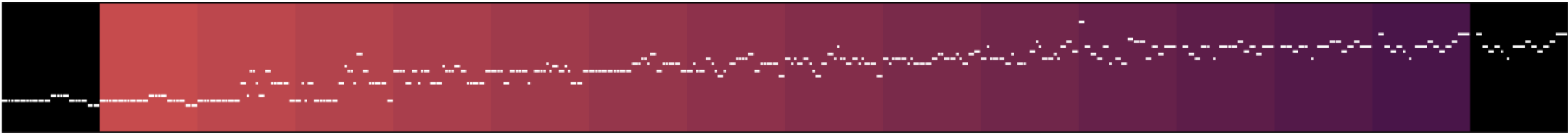
Reinforcement Learning
Dynamic Programming
Policy Evaluation
Policy Improvement
Policy Iteration
Value Iteration
Generalized policy iteration
Monte Carlo Control
Model free / model-based learning

Topics we covered

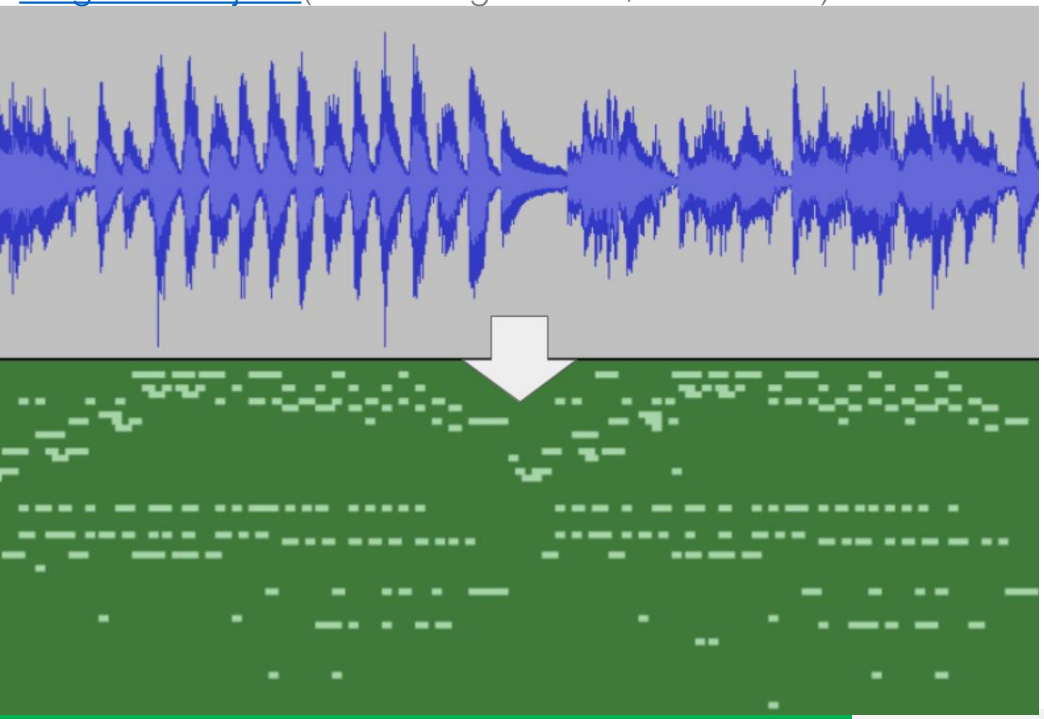
Machine Learning Applications

Music

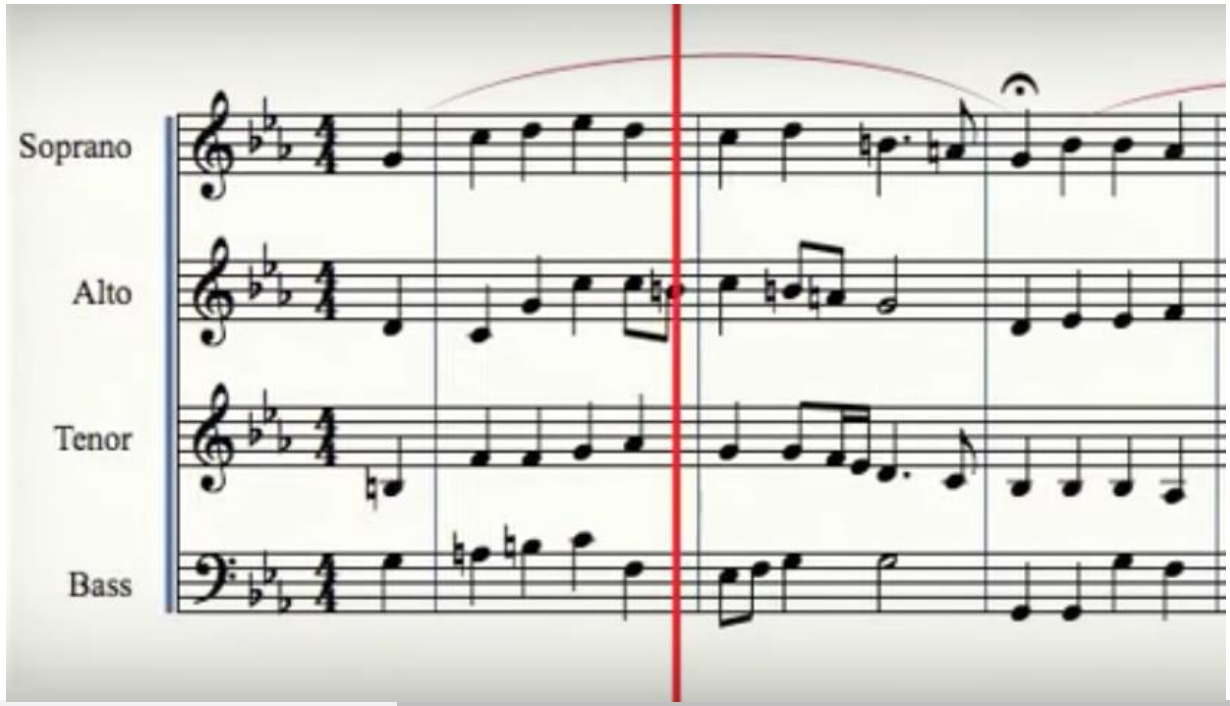
MusicVAE (Magenta):
Blending musical scores (link)
Magenta Project (from Google Brain / tensorflow)



Onsets and Frames:
Automated transcription (link)
Magenta Project (from Google Brain / tensorflow)



Deep Bach:
Automated transcription (link)
Flow Machines by Sony Computer Science Laboratories



Computer Vision

Handwriting completion:
…with Neural Networks (link)

Carter et al. 2016, our Experiments in Handwriting with a Neural Network (Google Brain)

SketchRNN:
Automated sketching (link)

Magenta Project (from Google Brain / tensorflow)

Computer Vision & Visual Arts

Deep Dream: Style Transfer and Abstract Art (link)

Originally developed by Alexander Mordvintsev from Google

Computer Vision

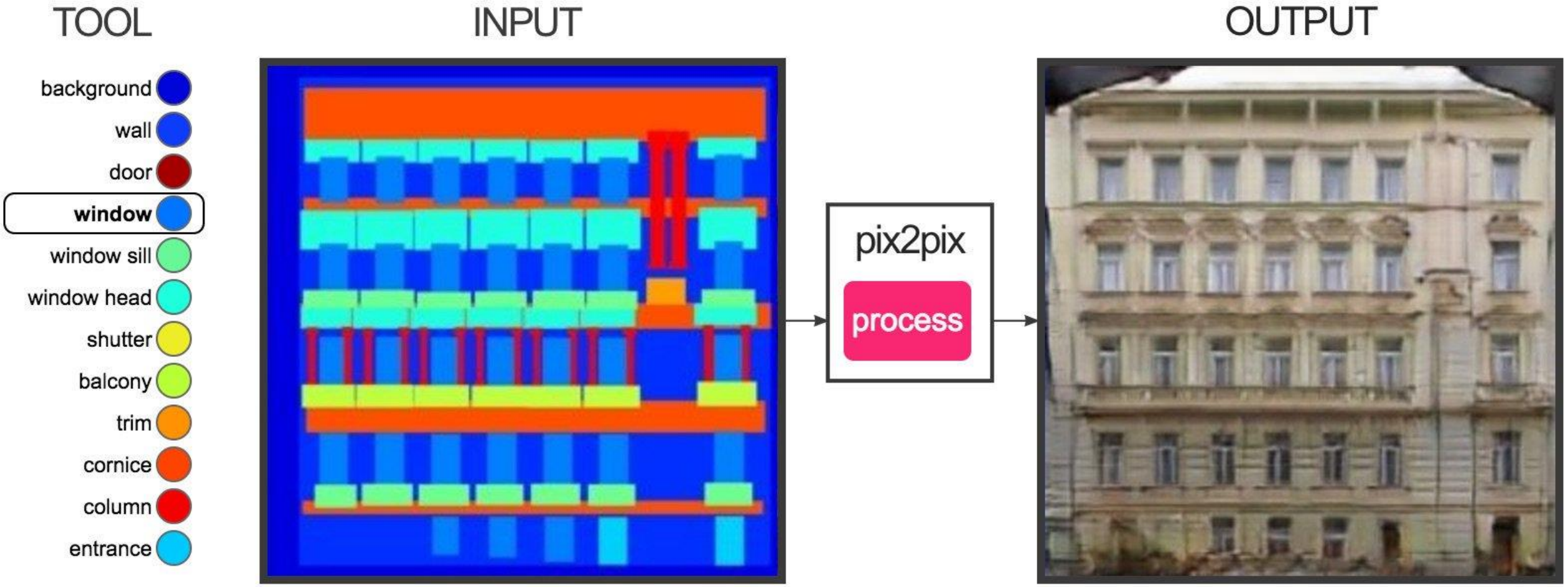
Style Transfer (link)

Dumoulin et al. 2016, A learned representation for artistic style

Computer Vision

Image-to-Image Translation (link)

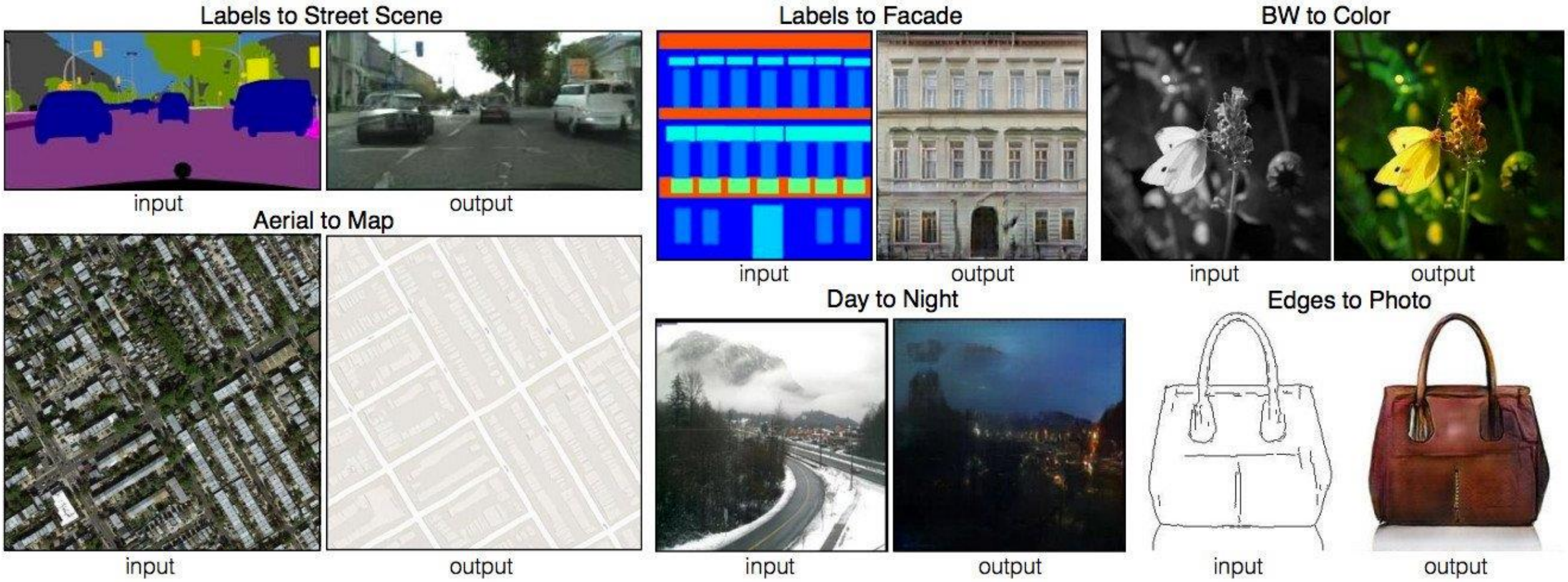
Isola et al. 2017, Image-to-image translation with conditional adversarial networks



Computer Vision

Image-to-Image Translation (link)

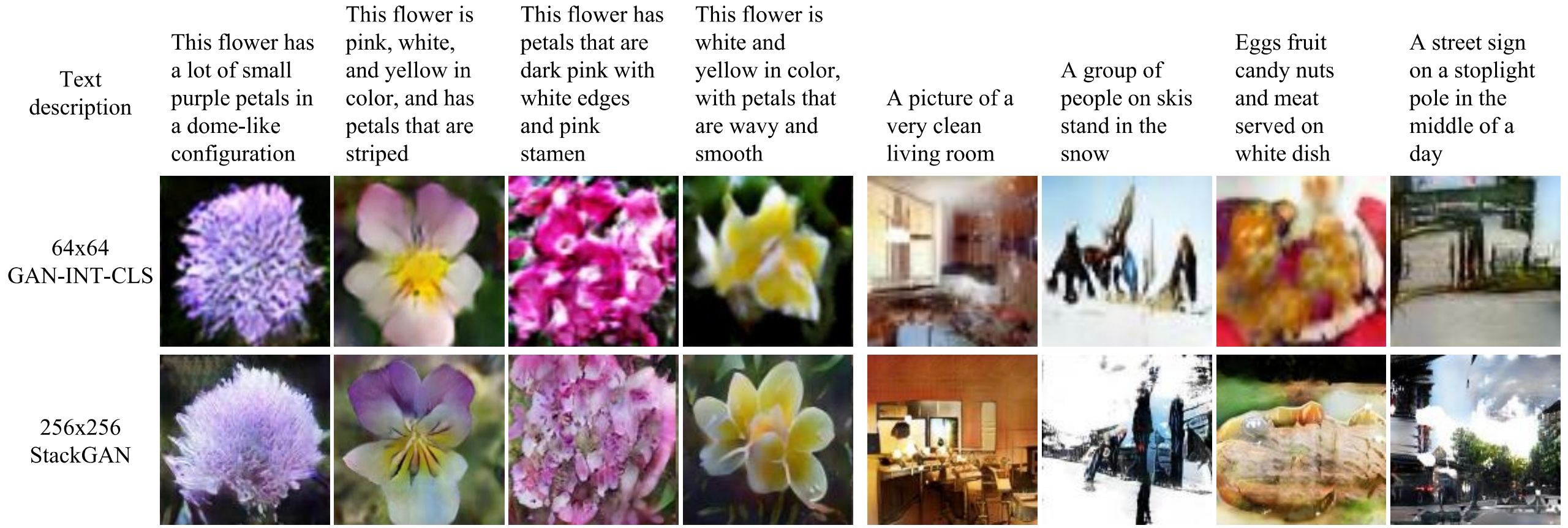
Isola et al. 2017, Image-to-image translation with conditional adversarial networks



Computer Vision

StackGAN:
Image Synthesis from Text Descriptions (link)

Zhang et al. 2017, StackGAN: Text to Photo-realistic Image Synthesis with Stacked Generative Adversarial Networks



Computer Vision

Image Synthesis (link)

Karras et al. 2018, NVIDIA: Progressive growing of GANS for improved quality, stability, and variation

These images are all synthetic

Computer Vision

Image Synthesis (link)

Karras et al. 2018, NVIDIA: Progressive growing of GANS for improved quality, stability, and variation

These images are all synthetic

Mao et al. (2016b) (128 × 128)

Gulrajani et al. (2017) (128 × 128)

Our (256 × 256)

Karras et al. 2018

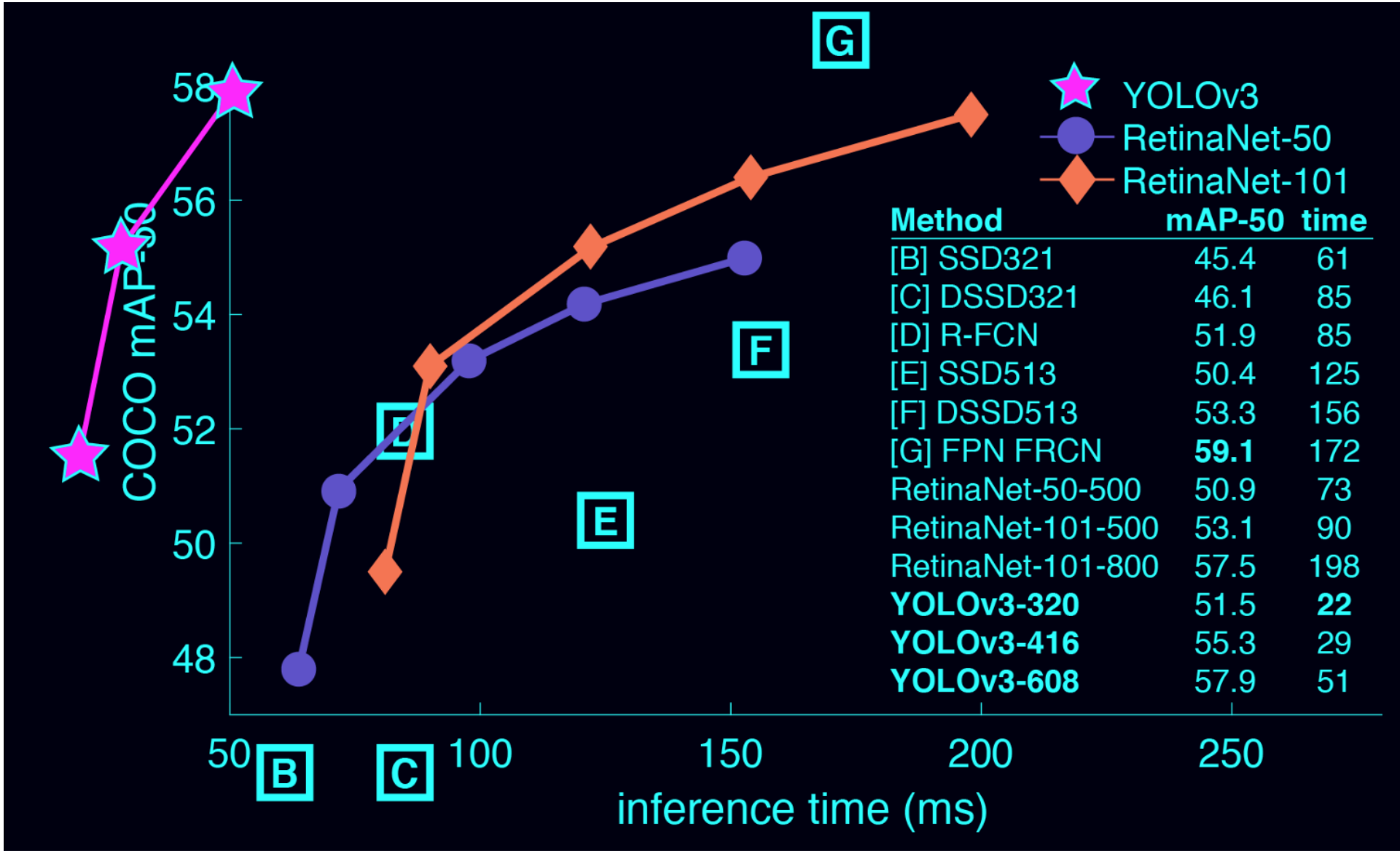
Computer Vision

YOLO: Real-time object identification (link)

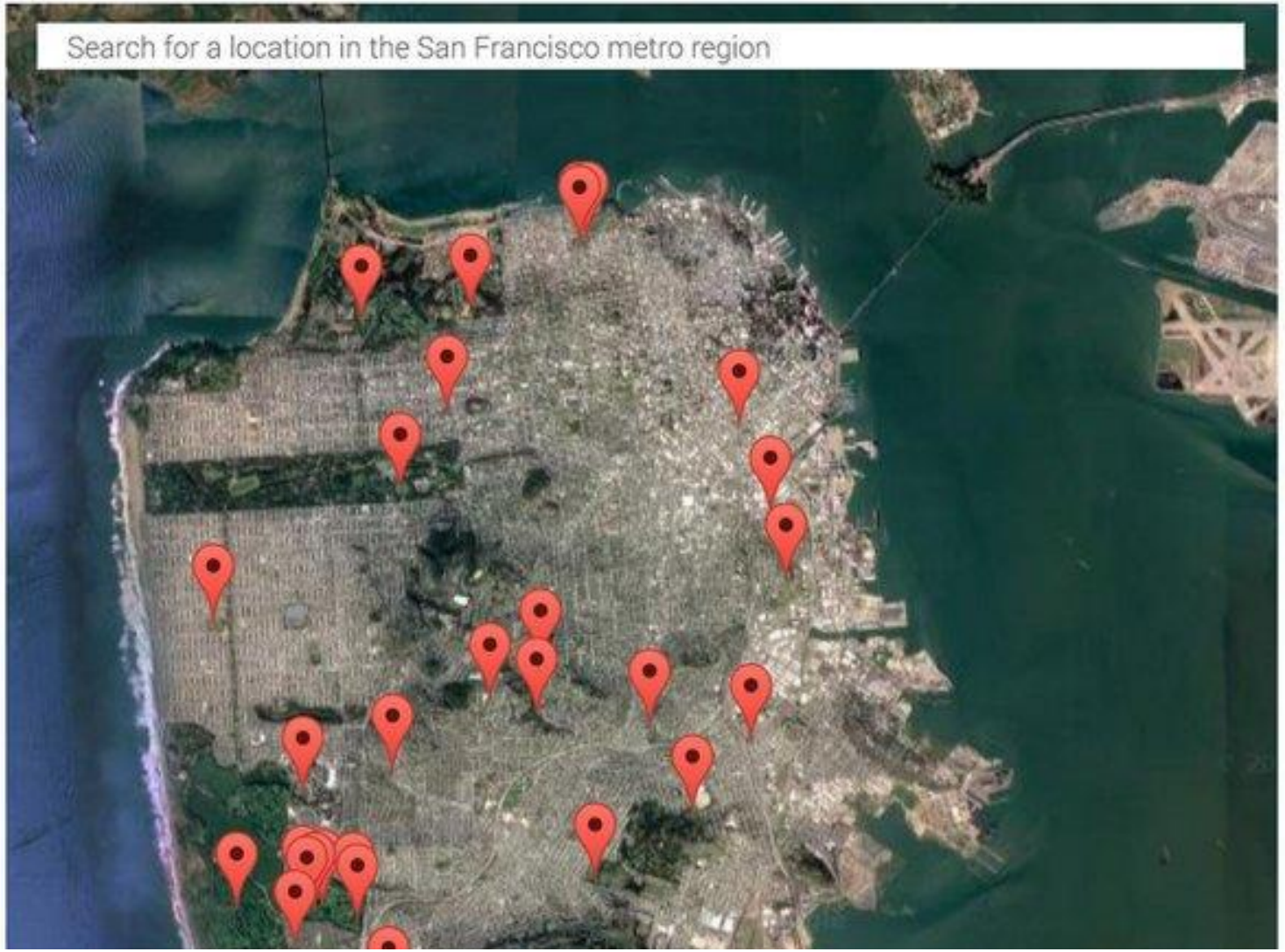
Redmon et al. 2016, You Only Look Once: Unified, Real-Time Object Detection

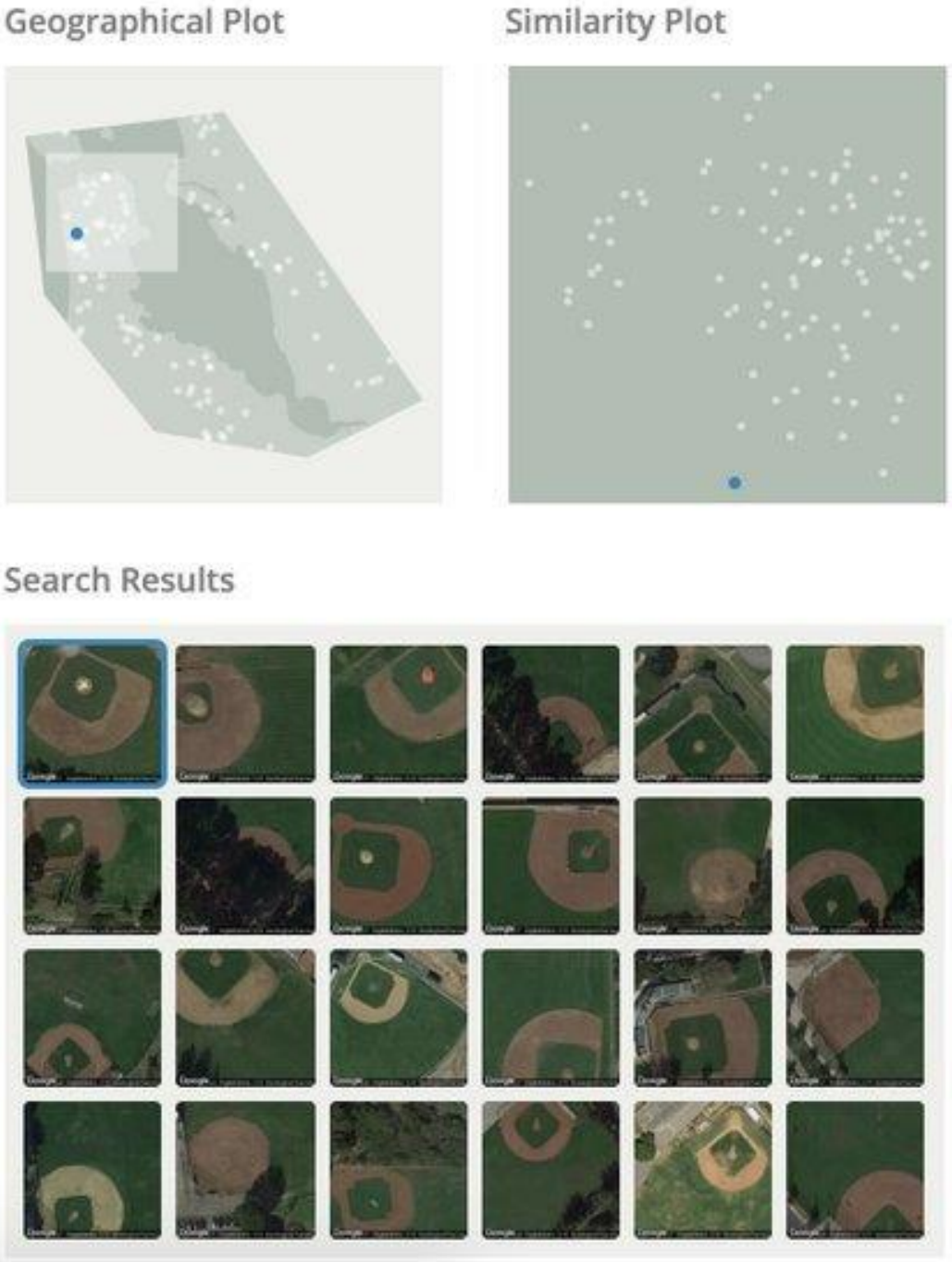
Example Video link

Y-Axis:
Mean average precision (mAP) measured at 0.5 intersection over union



Method	mAP-50	time
[B] SSD321	45.4	61
[C] DSSD321	46.1	85
[D] R-FCN	51.9	85
[E] SSD513	50.4	125
[F] DSSD513	53.3	156
[G] FPN FRCN	**59.1**	172
RetinaNet-50-500	50.9	73
RetinaNet-101-500	53.1	90
RetinaNet-101-800	57.5	198
YOLOv3-320	51.5	**22**
YOLOv3-416	55.3	29
YOLOv3-608	57.9	51





Geospatial Image Analysis

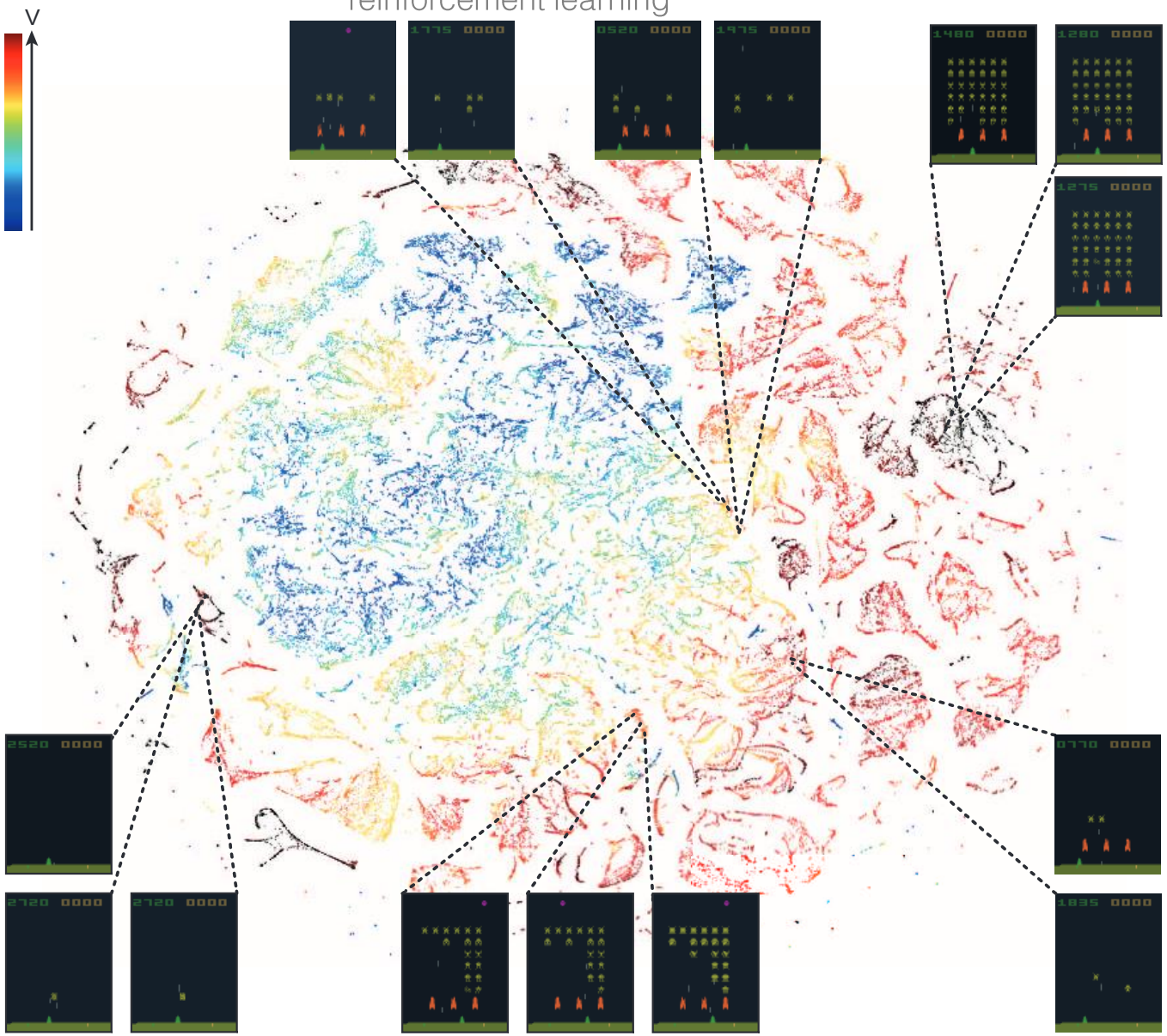
TerraPattern (link) [Levin, Newbury, McDonald et al.]

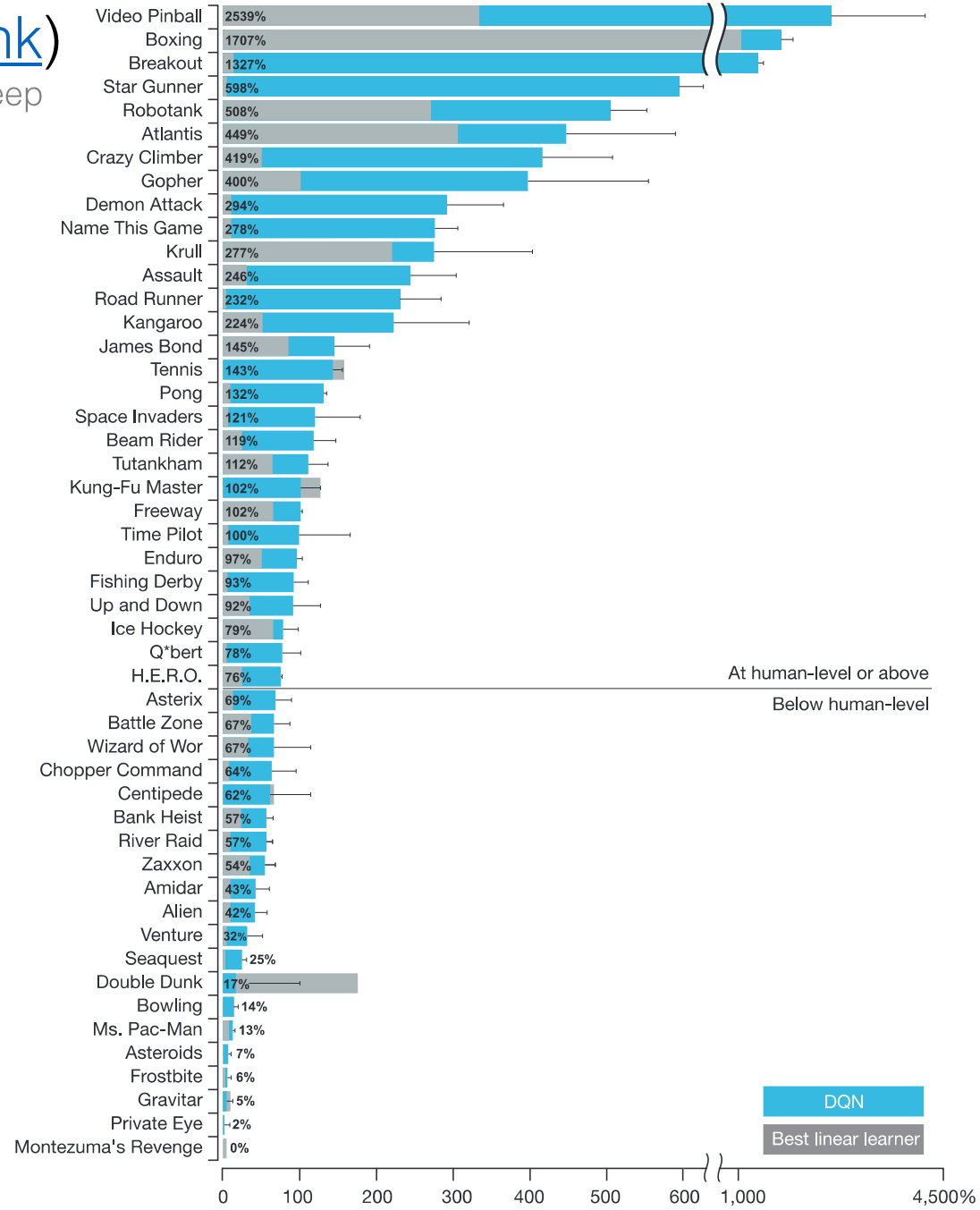
…similar tool available from Descartes Labs (link)

Games

Reinforcement Learning for Atari (link)

Mnih et al. 2015 (DeepMind), Human-level control through deep reinforcement learning





Games

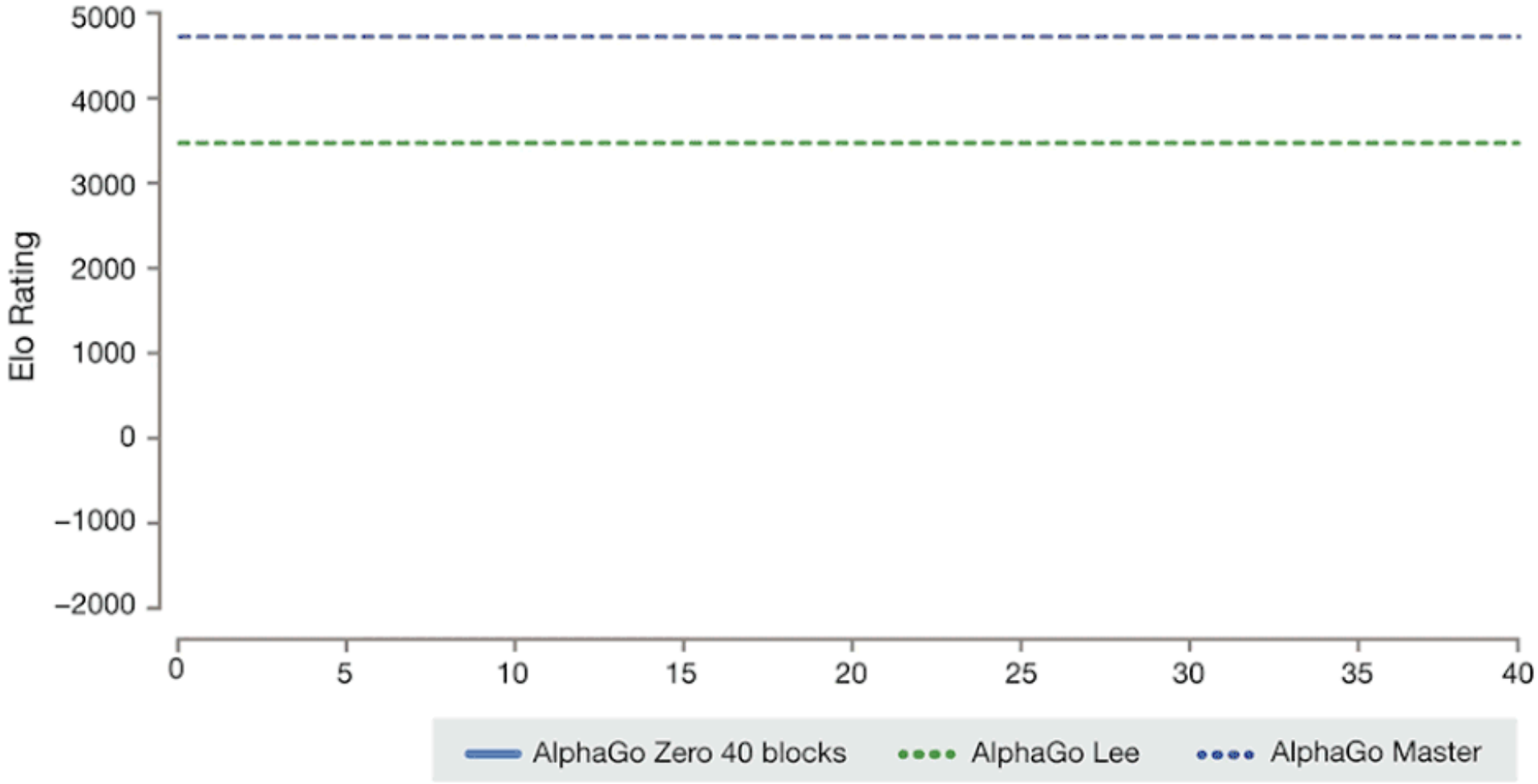
AlphaZero (link)

Silver et al. 2017 (DeepMind), Mastering Chess and Shogi by Self-Play with a General Reinforcement Learning Algorithm

Learning Go starting from random play

Mastered in 24 hours

Did the same with Chess



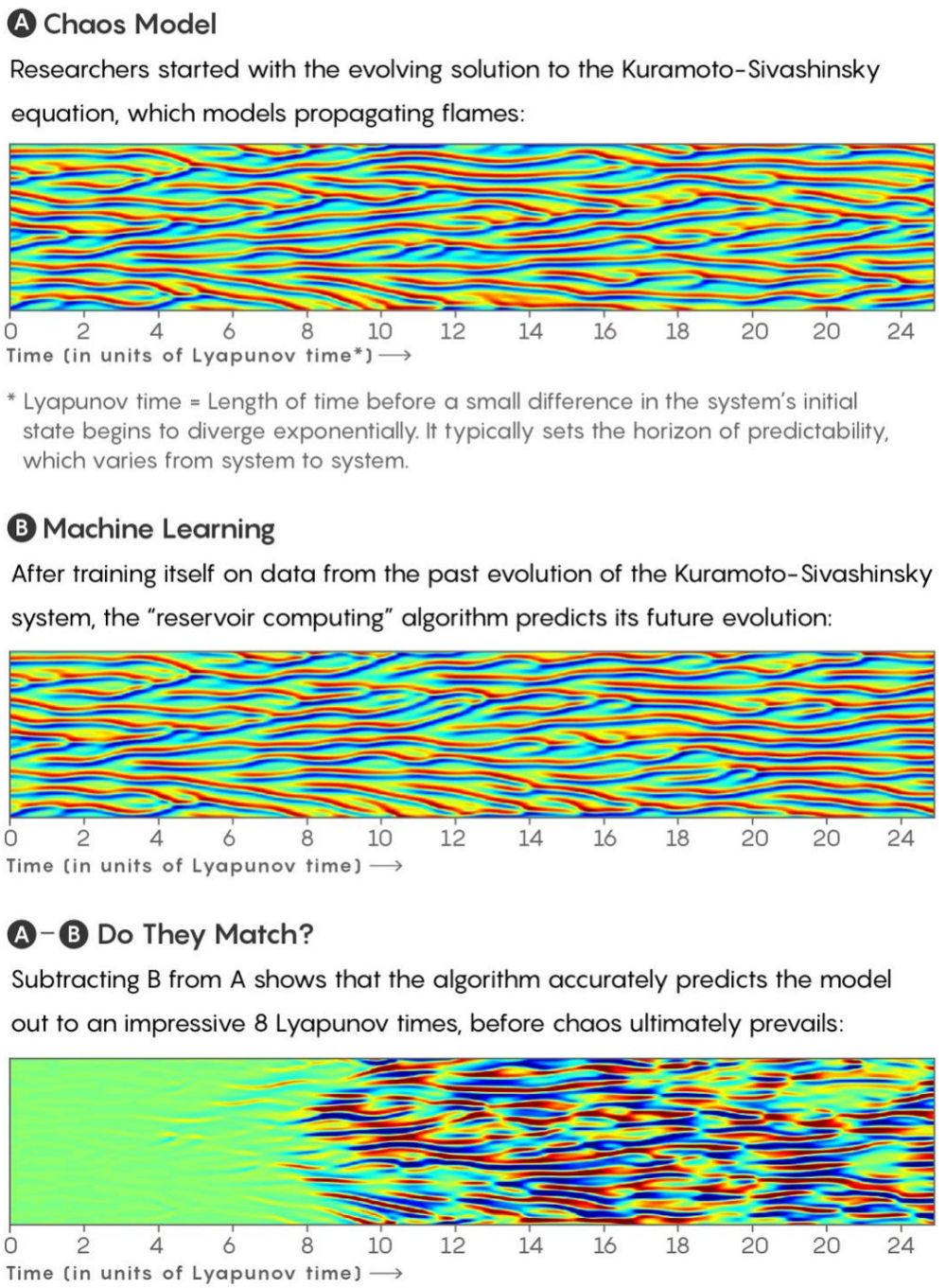
Other applications

Forecasting Chaos (link)

Pathak et al. 2017, Model-Free Prediction of Large Spatiotemporally Chaotic Systems from Data: A Reservoir Computing Approach

Figure (right) from Quanta Magazine (link)

- Weather prediction
- Heart attack prediction (monitoring cardiac arrhythmias)
- Monitoring neuronal firing patterns for signs of neuron spikes
- Predicting solar flares



Other applications

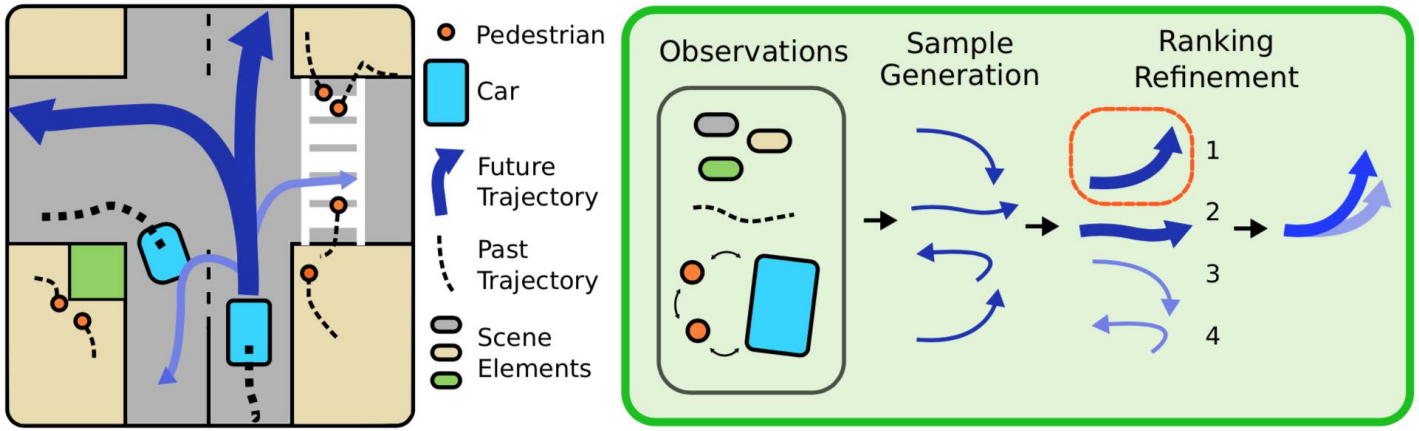
Machine translation (link)

Vaswani et al. 2017, Attention Is All You Need

(a) Future prediction example

Self-driving cars (link)

Lee et al. 2017, DESIRE: Distant Future Prediction in Dynamic Scenes with Interacting Agents



(b) Workflow of *DESIRE*

Open source frameworks

Tensorflow (link)

Framework for implementing graphical models, such as neural networks

TensorFlow

OpenAi (link)

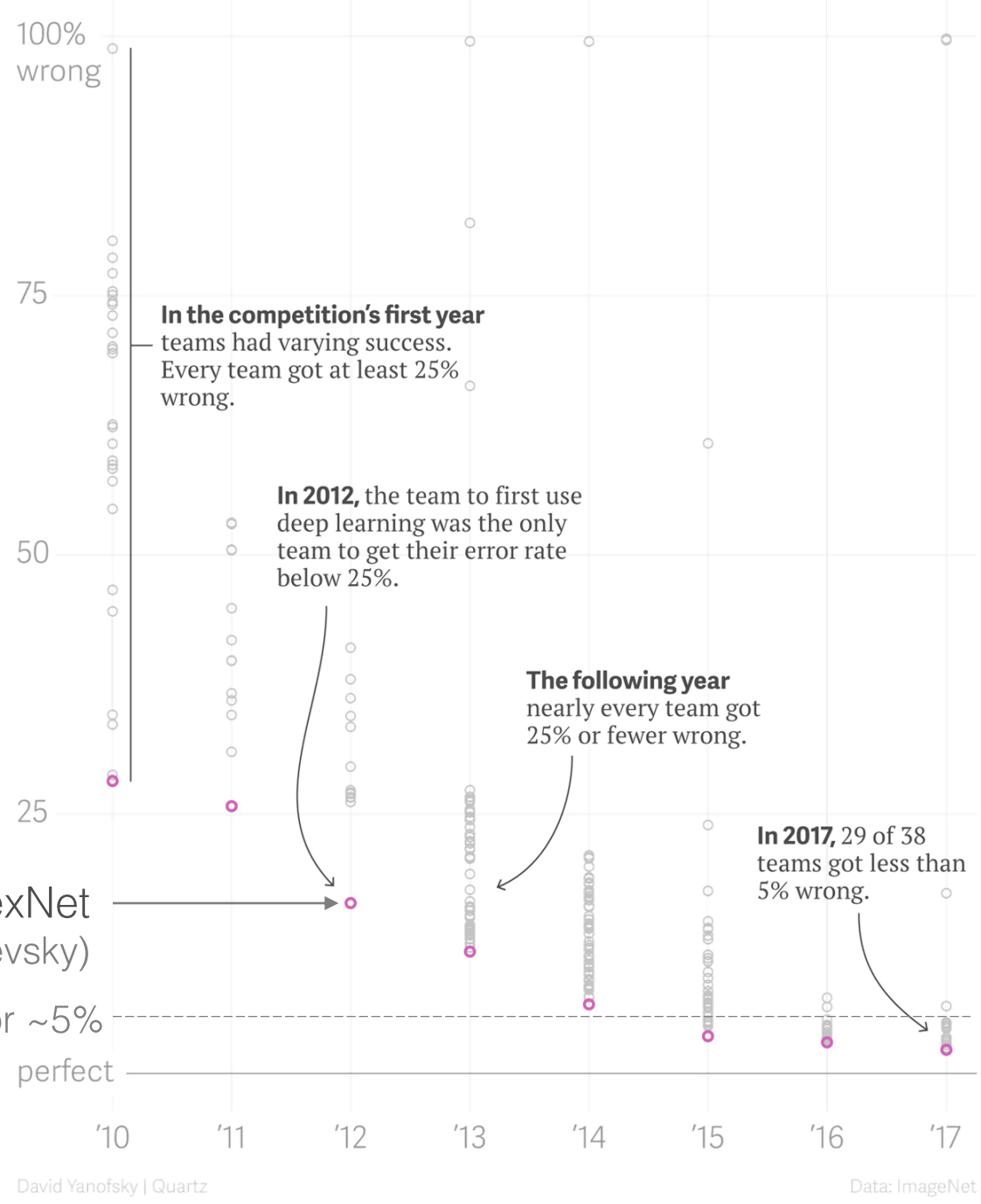
OpenAi Gym is a toolkit for developing and comparing reinforcement learning algorithms

OpenAI

ImageNet Large Scale Visual Recognition Challenge (ILSVRC)

Fei-Fei Li et al. 2010 (link)

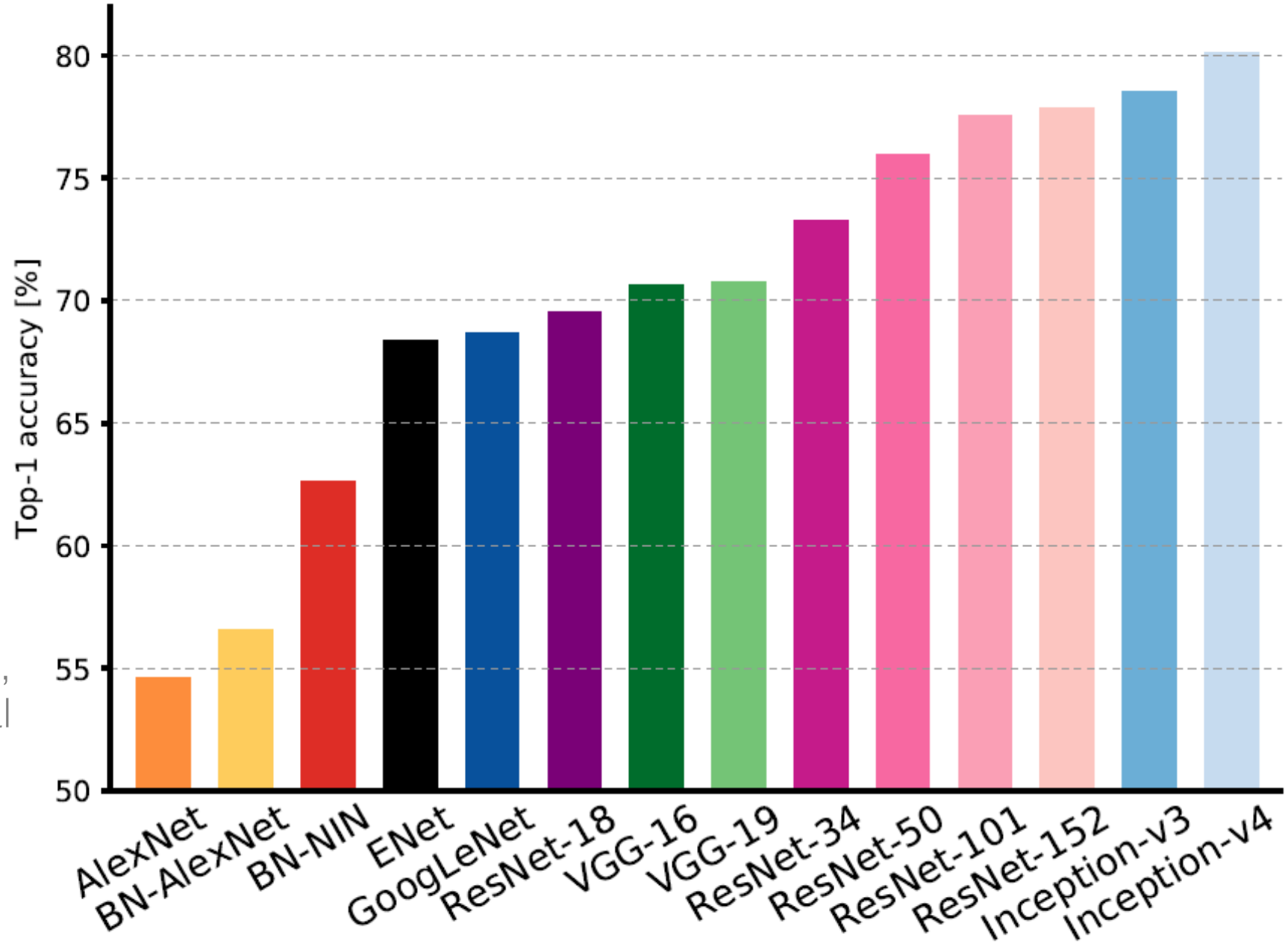
Competition at:
Conference on Computer Vision and Pattern Recognition (CVPR)



Source: Quartz, link

Comparison of deep learning techniques

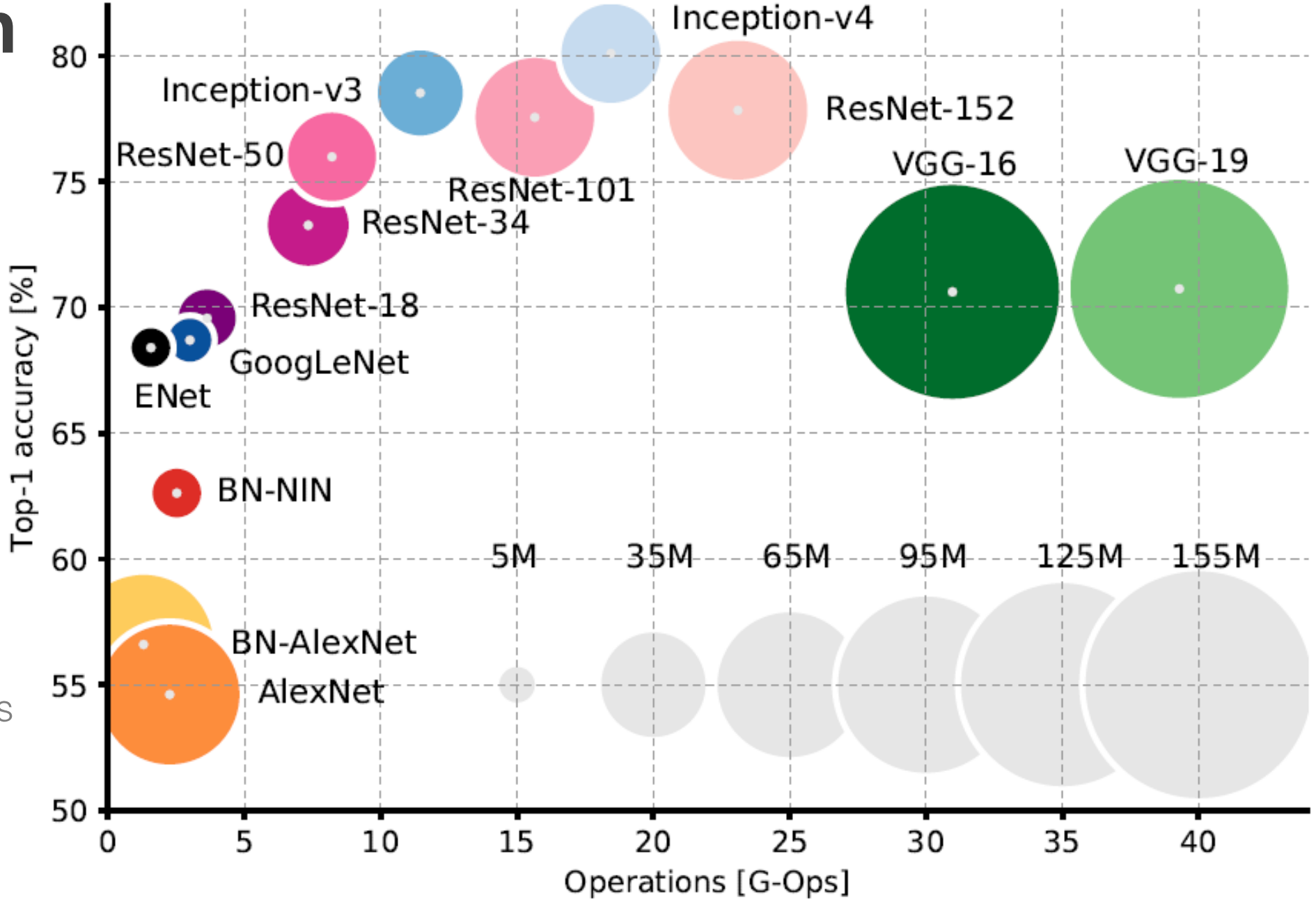
On the ImageNet data



Canziani, Culurcillo, and Paszke, 2017, An analysis of deep neural network models for practical applications (link)

Comparison of deep learning techniques

On the ImageNet data



Canziani, Culurcillo, and Paszke, 2017, An analysis of deep neural network models for practical applications (link)

Neural Networks

Backfed Input Cell

Input Cell

Hidden Cell

Probablistic Hidden Cell

Output Cell

Match Input Output Cell

Recurrent Cell

Memory Cell

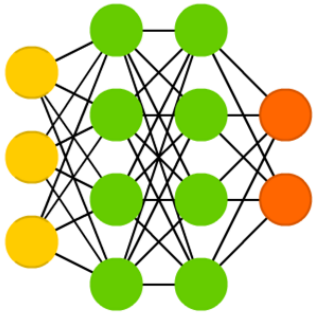
Kernel

Convolution or Pool

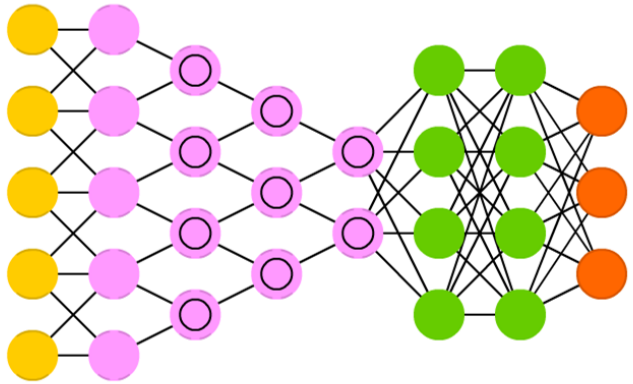
Perceptron (P)

Feed Forward (FF)

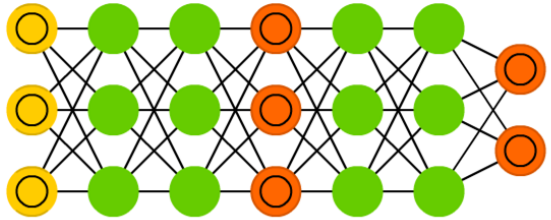
Deep Feed Forward (DFF)



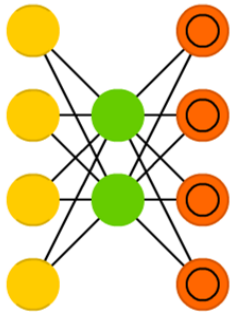
Deep Convolutional Network (DCN)



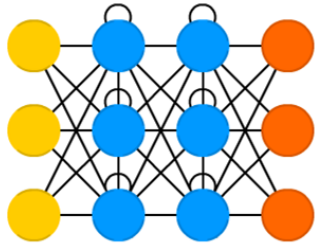
Generative Adversarial Network (GAN)



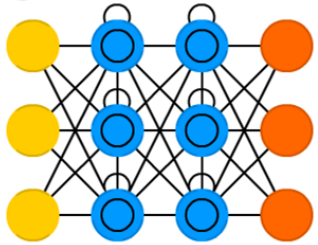
Auto Encoder (AE)



Recurrent Neural Network (RNN)



Long / Short Term Memory (LSTM)



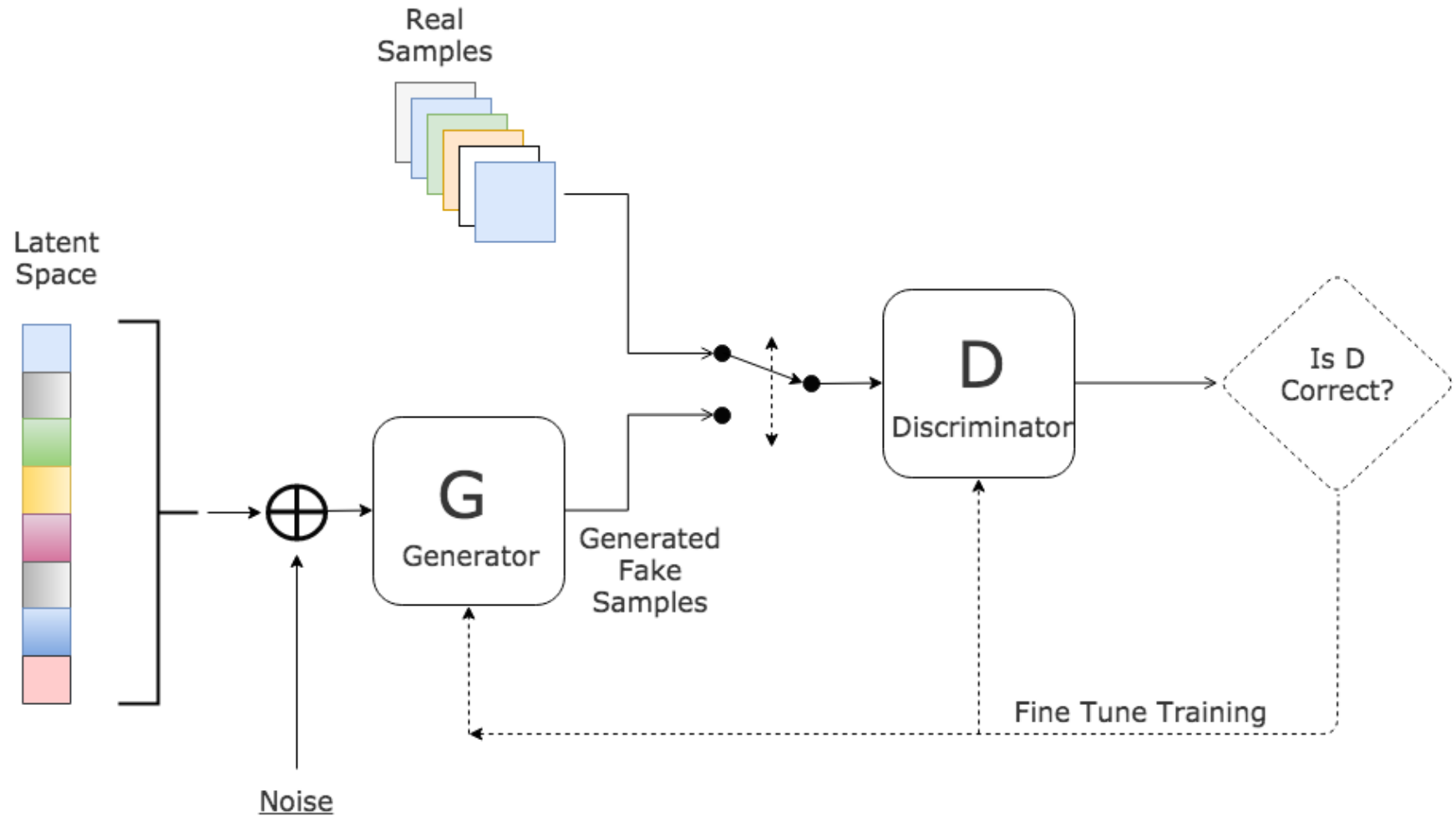
van Veen, 2016, The Azimov Institute (link)

Hinton's Capsule Networks… (link)

Generative Adversarial Networks

Generative Adversarial Nets (link)

Goodfellow et al. 2014



Hitawala 2018 Comparative Study on Generative Adversarial Networks

Hardware

NVIDIA
Graphics Processing Units (GPU)
(link)

Google
Tensor Processing Unit (TPU)
(link)

Challenges in machine learning

Generalizing from **small numbers of examples** (one-shot learning)

Adapting to **new environments** and non-stationary problems

Transferring knowledge between tasks (transfer learning)

Interpretability for confidence in algorithms

Ethics, fairness, and privacy

Greenwald and Oertel, 2017, Future Directions in Machine Learning

Where to go from here?

Courses at Duke (Link)

Computer Science Department

- Algorithmic Aspects of Machine Learning
- Computational Systems Biology
- Computer Vision (Fall 2015 materials)
- Introduction to Artificial Intelligence
- Machine Learning

Electrical and Computer Engineering

- Acoustics and Hearing
- Adaptive Filters
- Digital Image and Multidimensional Processing
- Digital Processing of Speech Signals
- Digital Signal Processing
- Fundamentals of Digital Signal Processing
- Information Theory
- Introduction to Digital Communication Systems
- Introduction to Robotics and Automation
- Introduction to Signals and Systems
- Linear Control Systems
- Random Signals and Noise
- Sensor Array Signal Processing
- Sound in the Sea: Introduction to Marine Bioacoustics

Mathematics Department

- Applied Stochastic Processes
- Scientific Computing
- Stochastic Calculus

Statistical Sciences Department

- Applied Stochastic Processes
- Computational Data Analysis
- Introduction to Statistical Methods
- Modeling and Scientific Computing
- Modern Nonparametric Theory and Methods
- Probability and Statistical Models
- Statistical Case Studies

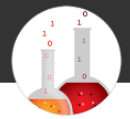
For current lists of courses offered, see departmental course websites:

- Computer Science courses
- Electrical and Computer Engineering courses
- Mathematics courses
- Statistical Science courses

Foundations of Deep Learning (link)

Staying up-to-~~data~~date

Data Elixir



ISSUE 202 *Oct 2nd 2018*

— In the News —

One Small Step for the Web...

Tim Berners-Lee announced a new platform that gives users complete control over their data. The platform works on the existing web but within its ecosystem, **you decide where you store your data.** Partly because of the people involved, this project is worth paying attention to.

inrupt.com

AI Could Provide Moment-by-Moment Nursing for a Hospital's Sickest Patients

ICUs are one of the most expensive parts of the medical system. The sickest patients often receive round-the-clock care and are typically attached to multiple machines and monitors. There's also vast amounts of data, which makes ICUs a prime target for AI disruption. In this article, the founders of Autonomous Healthcare explore the problems and opportunities.

ieee.org

— Sponsored Link —

Try Mode Studio: a complete toolkit for every analyst

Mode Studio combines a SQL editor, Python & R notebooks, and a visualization builder in one platform. And it's free forever. Connect data from anywhere and analyze with the best language for the job, without having to jump between tools. Build custom visualizations or use our out-of-the-box charts. Share your analysis with a click—every report lives at a URL.

modeanalytics.com

Reach Data Elixir readers by sponsoring an issue. Click here for details.

— Tools and Techniques —

Data Machina

Data Machina - Issue #143

Data Machina - Issue #143

By Data Machina • Issue #143 • View online

This is really cool: *The GAN Lab: Play with Generative Adversarial Networks (GANs) in Your Browser*

There's a lot! going on in Open Source *Modern Data Engineering*. Check out: *Facebook's LogDevice: A Distributed, High-availability Storage for Sequential Data* and *Uber's Marmaray: A Scalable, Data Ingestion Framework for Any Source, Any Sink*

This is a fascinating read: *The Man Who Won The Lottery 14 Times*

If you enjoy Data Machina, please consider a little donation. Thanks!

10 Link-o-Troned

1. Time-Series Prediction Using RNN-LSTM
2. Forecasting @Uber: An Introduction
3. Machine Learning, Information Theory & Tail Bounds
4. The Use of Embeddings in OpenAI Five
5. AVA Algorithms: The Art & Science of Image Discovery @Netflix

Data Science Roundup

Scaling Knowledge. 5 Tips for Better DS Writing. Infrastructure @ Stitch Fix. New Data o...

Scaling Knowledge. 5 Tips for Better DS Writing. Infrastructure @ Stitch Fix. New Data on DS Jobs. [DSR #152]

By Tristan Handy • Issue #152 • View online

Special thanks to Domino Data Lab for sponsoring this week's Roundup. I've actually jumped on the "Sponsored Content" bandwagon—you'll see a post from Domino below with a "Sponsored" callout in the title. We'll only accept sponsorships like this from organizations we think highly of and—of course—will always prioritize your reading experience.

Enjoy this week's issue :)

- Tristan

❤️ Want to support us? Forward this email to three friends!

💌 Forwarded this from a friend? Sign up to the Data Science Roundup here.

This Week's Most Useful Posts

Scaling Knowledge

Data scientists, analysts, and engineers are ultimately employed by companies for the single purpose of producing and disseminating knowledge. And yet we spend all of our time talking about the *producing* part, with very little time dedicated to the *disseminating* part. As a result, we as an industry all-too-frequently produce amazing analysis that we utterly fail to disseminate throughout our organizations. This is a big problem.

Kaggle Newsletter

kaggle

Hey there!

This month's newsletter is sure to inspire those new to Kaggle (like me 🐣) and experts alike. See a motivational **interview with our first-ever Kernels Grandmaster**, Martin Henze (AKA "Heads or Tails") as he shares his tips and tricks for getting to the next level. If you're still getting your feet wet, start with **this video discussion with our own Meg Risdal**, who breaks down the basic steps to beginning a project.

Speaking of videos... Did you tune in for the **43-minute livestream** of Siraj Raval competing in our **Taxi Duration Challenge**?

Read on for more of the month's data science notes, highlights and competitions. And, oh — we're hiring, too!

Have a great one,
Rachel

TALKING DATA SCIENCE

Profiling Top Kagglers: Martin Henze, World's First Kernels Grandmaster

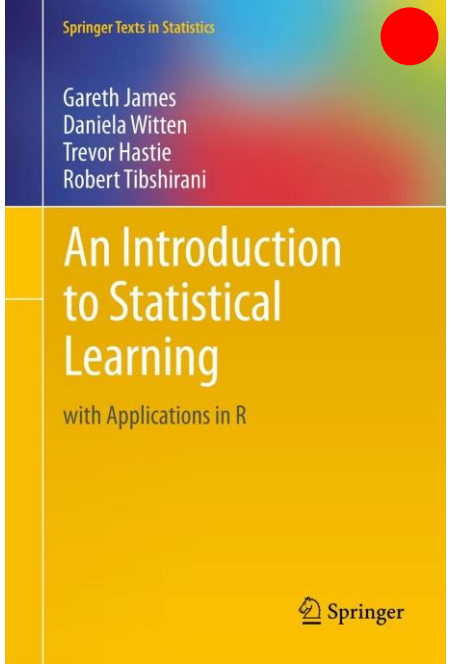
Meet Martin, our first Kernels Grandmaster. Just one year ago his goal was to improve his "very rudimentary knowledge of machine learning tools and methods." He's come a long way! **Read this in-depth interview here »**

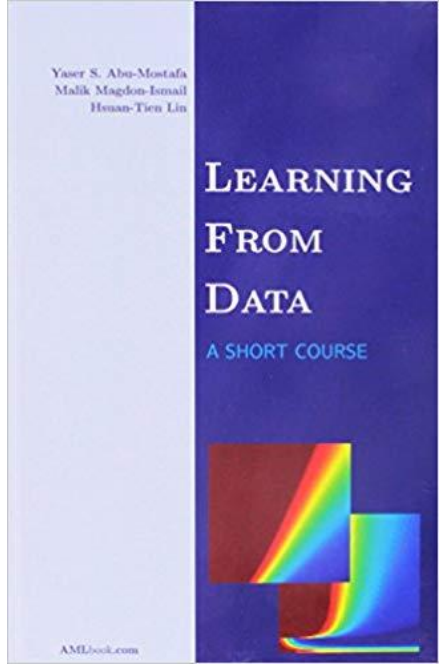
Data Science Books

Additional Resources Available at:
https://kylebradbury.org/datascience.html

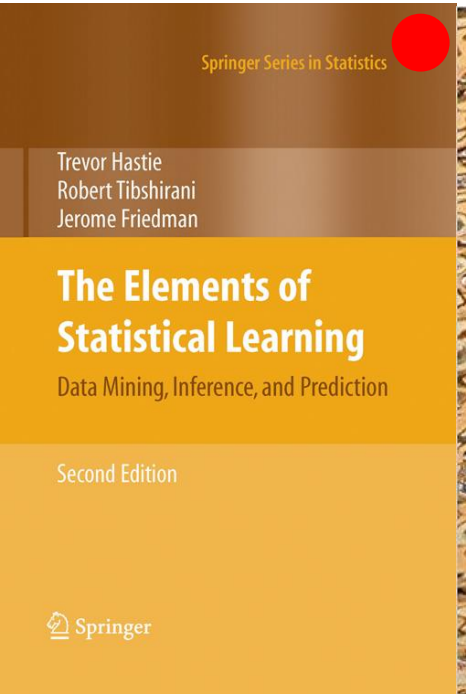
Introductory Texts

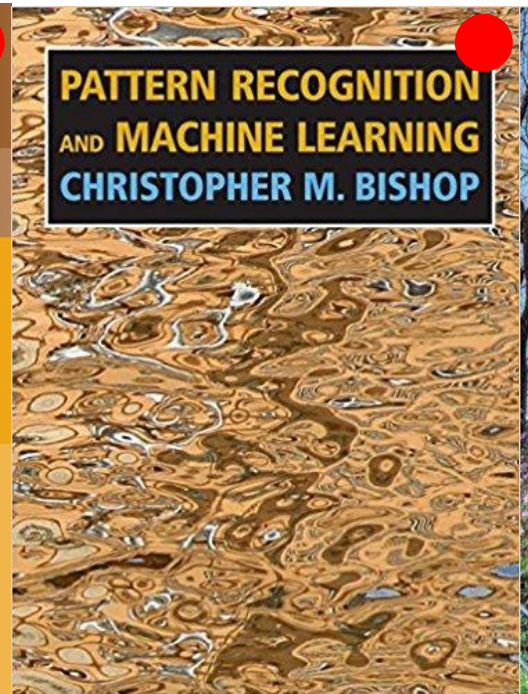
Free online

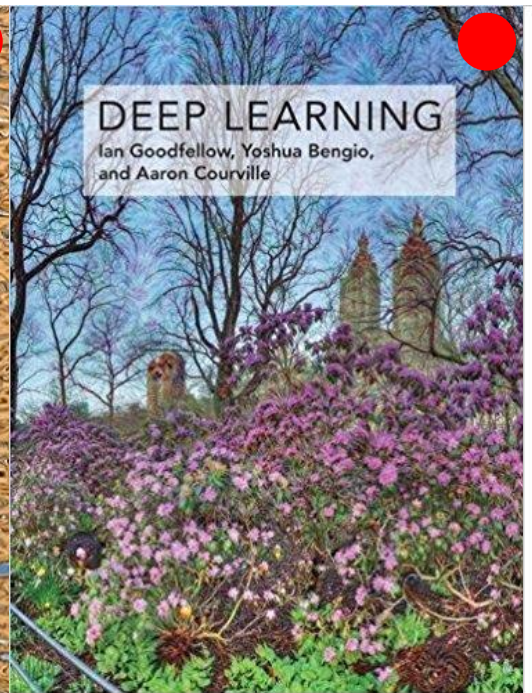




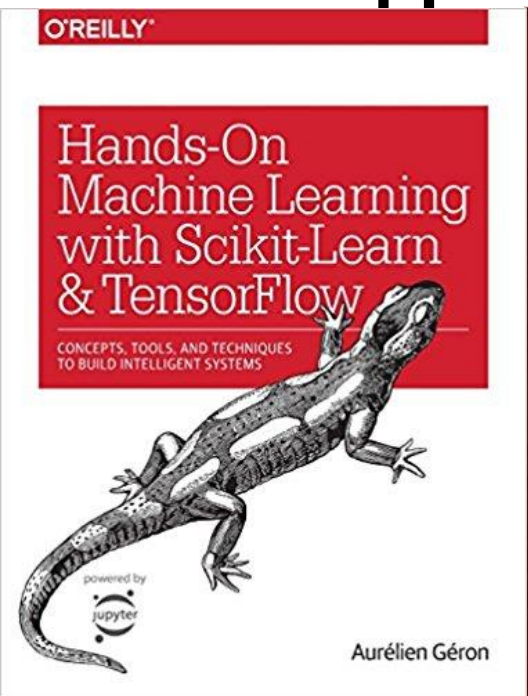
Advanced Texts

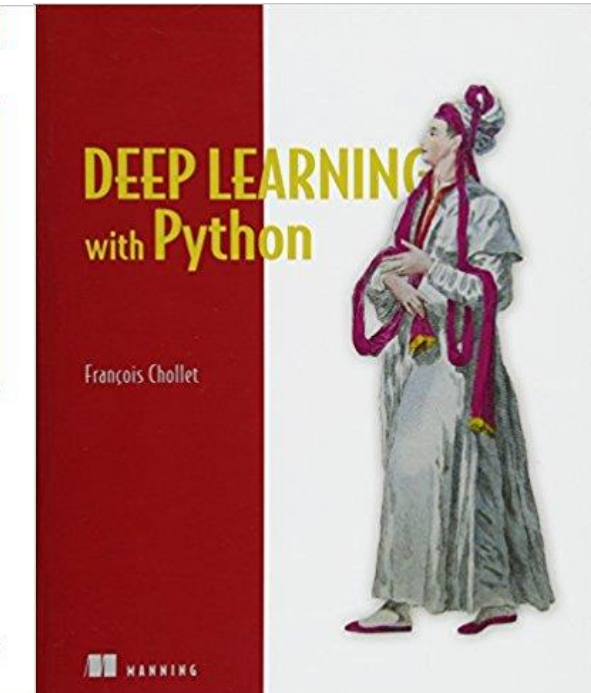






Applied Texts



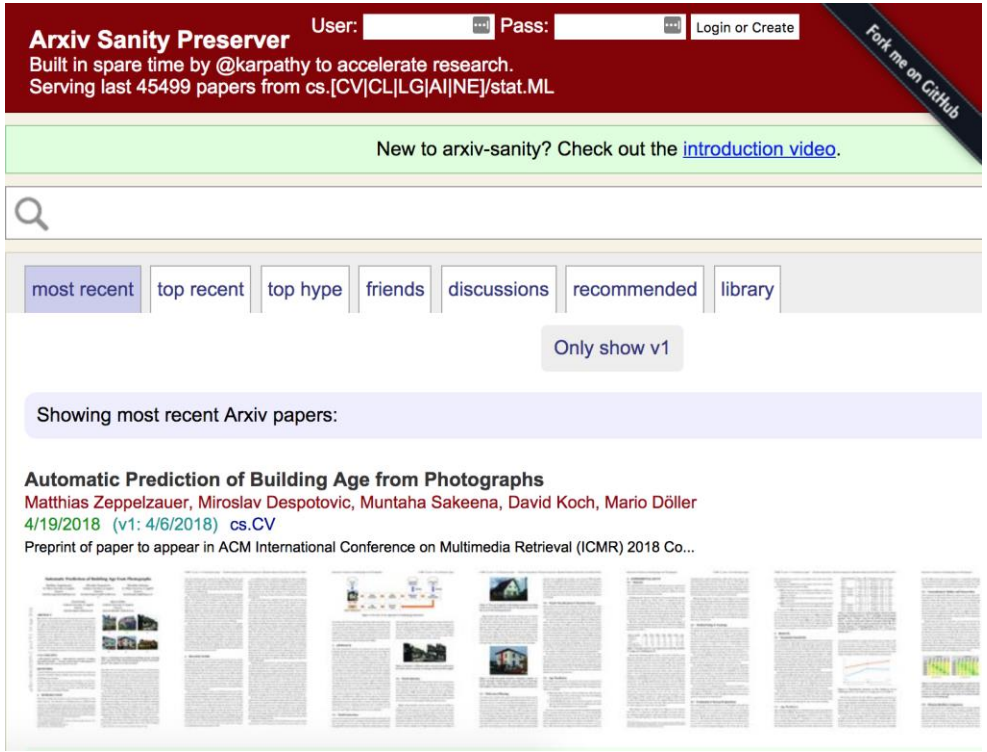


Staying up-to-date

Blogs:

Google Research (link)
Microsoft Research (link)
DeepMind Research (link)
Kaggle (link)

Arxiv (link) (Arxiv sanity-preserver)



Conferences:

ICML: International Conference on Machine Learning (link)
NeurIPS (formerly NIPS): Neural Information Processing Systems (link)
ICLR: International Conference on Learning Representations (link)
CVPR: IEEE Conference on Computer Vision and Pattern Recognition (link)
SIGKDD: ACM International Conference on Knowledge Discovery & Data Mining (link)

TWO MINUTE PAPERS

by Károly Zsolnai-Fehér

Summaries of latest ML research

([link])

What's So Hard About Cloth Simulations?

26K views • 3 days ago

CC

The Bitter Lesson - Compute Reigns Supreme

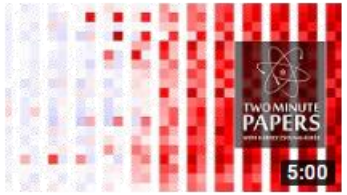
40K views • 1 week ago

CC

Beautiful Gooey Simulations, Now 10 Times Faster

44K views • 1 week ago

CC



NeuroSAT: An AI That Learned Solving Logic...

44K views • 2 weeks ago

CC

This AI Learned to "Photoshop" Human Faces

32K views • 2 weeks ago

CC

Google's PlaNet AI Learns Planning from Pixels

35K views • 3 weeks ago

CC

DeepMind: The Hanabi Card Game Is the Next Frontier fo...

46K views • 3 weeks ago

CC

Liquid Splash Modeling With Neural Networks

31K views • 4 weeks ago

CC

GANPaint: An Extraordinary Image Editor AI

32K views • 1 month ago

CC

This Experiment Questions Some Recent AI Results

34K views • 1 month ago

CC

Do Neural Networks Need To Think Like Humans?

32K views • 1 month ago

CC

Google AI's Take on How To Fix Peer Review

35K views • 1 month ago

CC

AlphaZero: DeepMind's AI Works Smarter, not Harder

33K views • 1 month ago

CC

AI-Based 3D Pose Estimation: Almost Real...

27K views • 1 month ago

CC

This AI Learned Image Decolorization..and More

27K views • 1 month ago

CC

Extracting Rotations The Right Way

28K views • 1 month ago

CC

OpenAI - Learning Dexterous In-Hand Manipulation

25K views • 2 months ago

CC

DeepMind's AlphaStar Beats Humans 10-0 (or 1)

204K views • 2 months ago

CC

AI Learns Real-Time Defocus Effects in VR

None of These Faces Are Real

What Makes a Good Image Generator AI?

This AI Produces Binaural (2.5D) Audio

6 Life Lessons I Learned From AI Research

This AI Learns From Humans...and Exceeds Them

Jeffrey Hinton
Google &
U. of Toronto

Backpropagation for neural nets. Won ImageNet Competition in 2012.

Image: Toronto Star

Andrew Ng
Baidu & Stanford

Founder of Google Brain, co-founder of Coursera

Image: Twitter

Andrej Karpathy
Tesla (formerly OpenAI)

CNNs for computer vision and natural language processing

Image: Stanford

Yann LeCunn
Facebook & NYU

Creator of the LeNet, Optical Character Recognition, and CNNs

Image: Facebook Research

Yoshua Bengio
Université de Montréal

Deep learning expert

Image: Université de Montréal

Ian Goodfellow
Google Brain

Creator of generative adversarial networks

Image: Michael Dukakis Institute

Fei-Fei Li
Stanford Artificial Intelligence Lab

Creator of ImageNet, works in computer vision

Image: Twitter

David Silver
DeepMind

Deep reinforcement learning

Image: Business Insider UK

People to know & read about in Machine Learning

The Bitter Lesson (link,video)

Richard Sutton

"The biggest lesson that can be read from 70 years of AI research is that general methods that leverage computation are ultimately the most effective, and by a large margin."

Hinton's Hints

Hinton is now "**deeply suspicious**" of backpropagation

"…'Science progresses **one funeral at a time**.' The future depends on some graduate student who is deeply suspicious of everything I have said."

"…I suspect that means getting rid of back-propagation. I don't think it's how the brain works," he said. "We clearly **don't need all the labeled data**."

Interview with Axios (link)

Educating the **mind** without educating the **heart** is no education at all.

Aristotle