Machine Learning Frontiers

Lecture 26

Review of what we’ve covered

Exciting applications

Challenges in the field

Where to go from here?

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

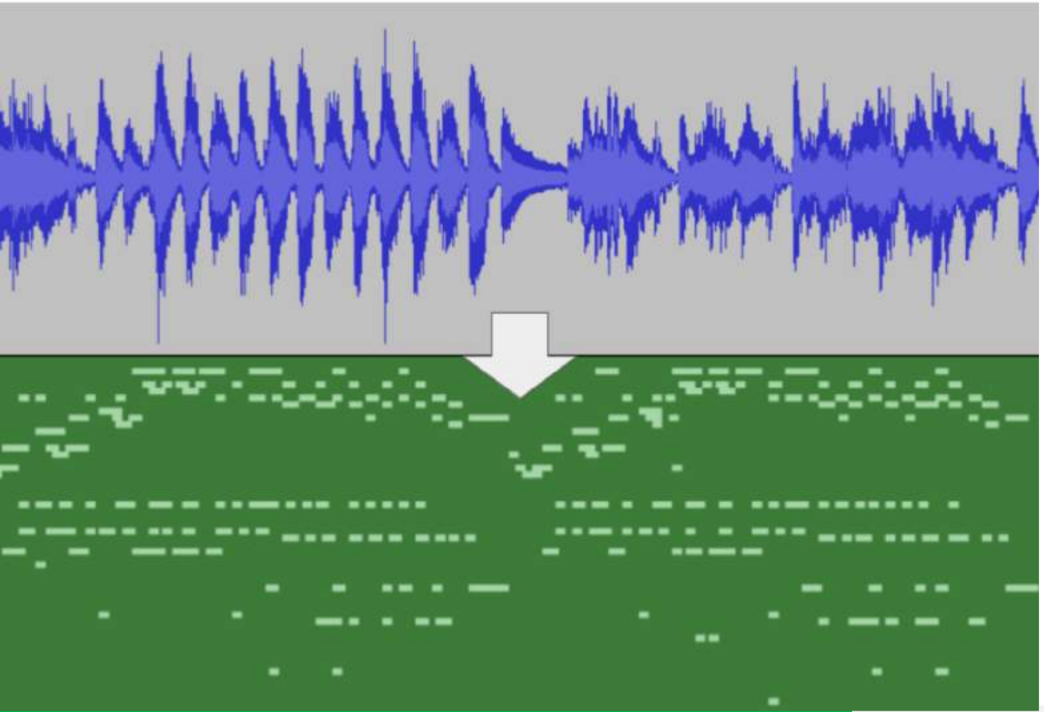
Topics we covered

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

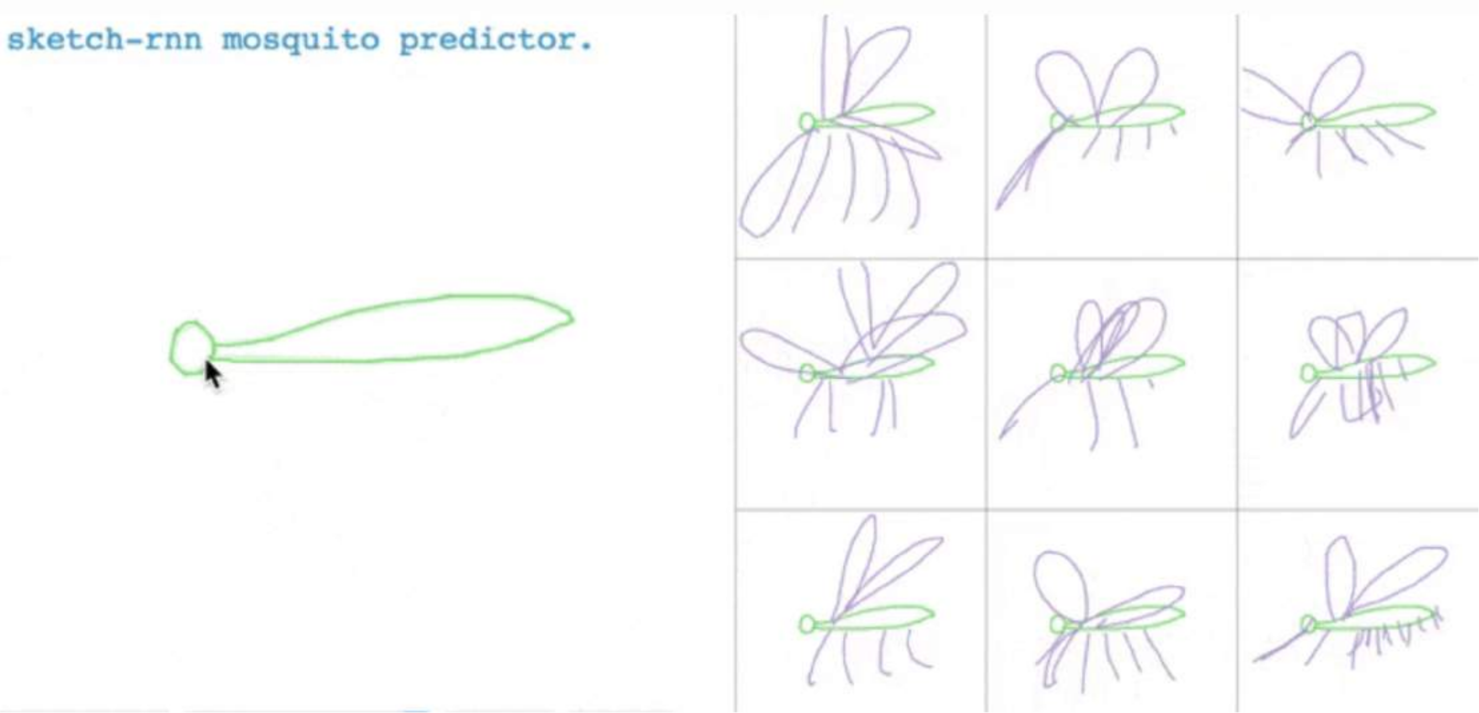
Computer Vision

Handwriting completion:
…with Neural Networks ([link]())

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

SketchRNN:
Automated sketching ([link]())

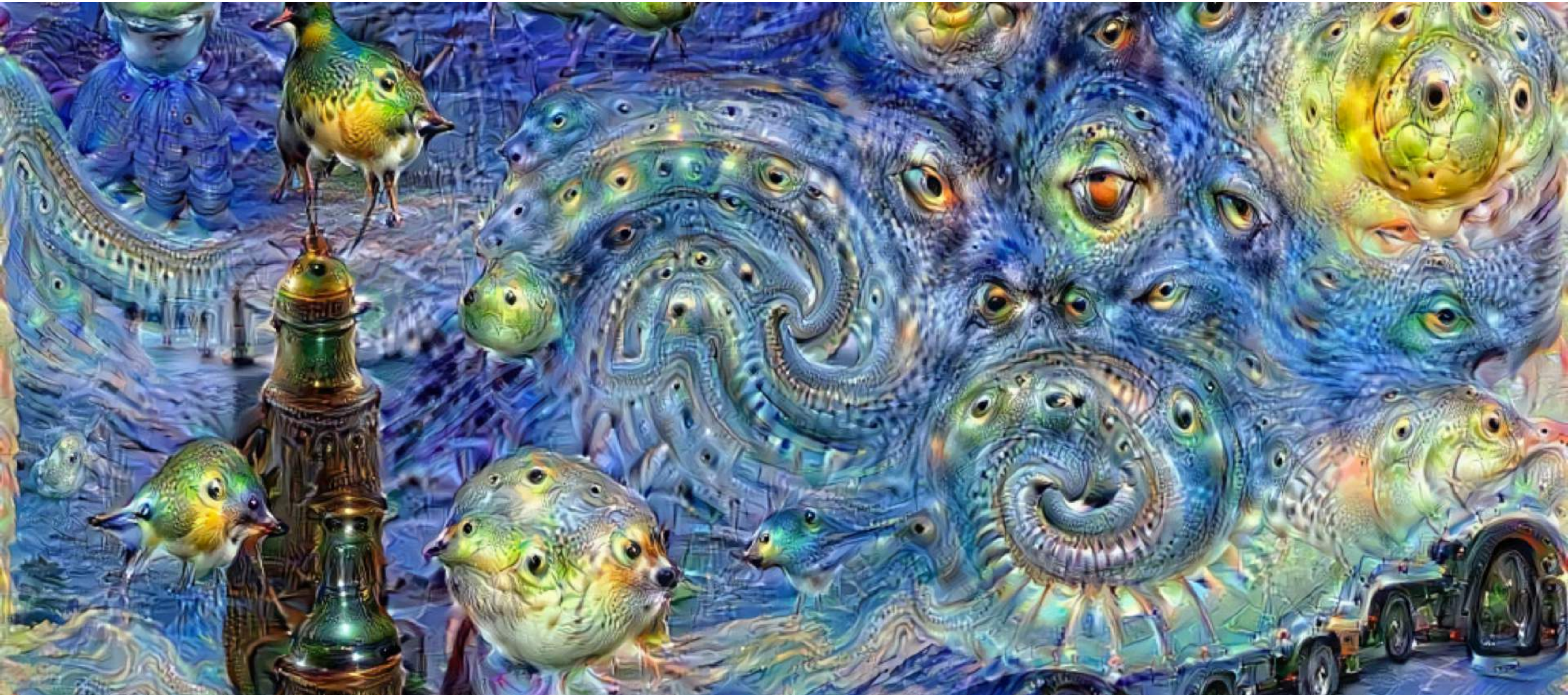
[Magenta Project]() (from Google Brain / tensorflow)



Computer Vision & Visual Arts

Deep Dream: Style Transfer and Abstract Art (link)

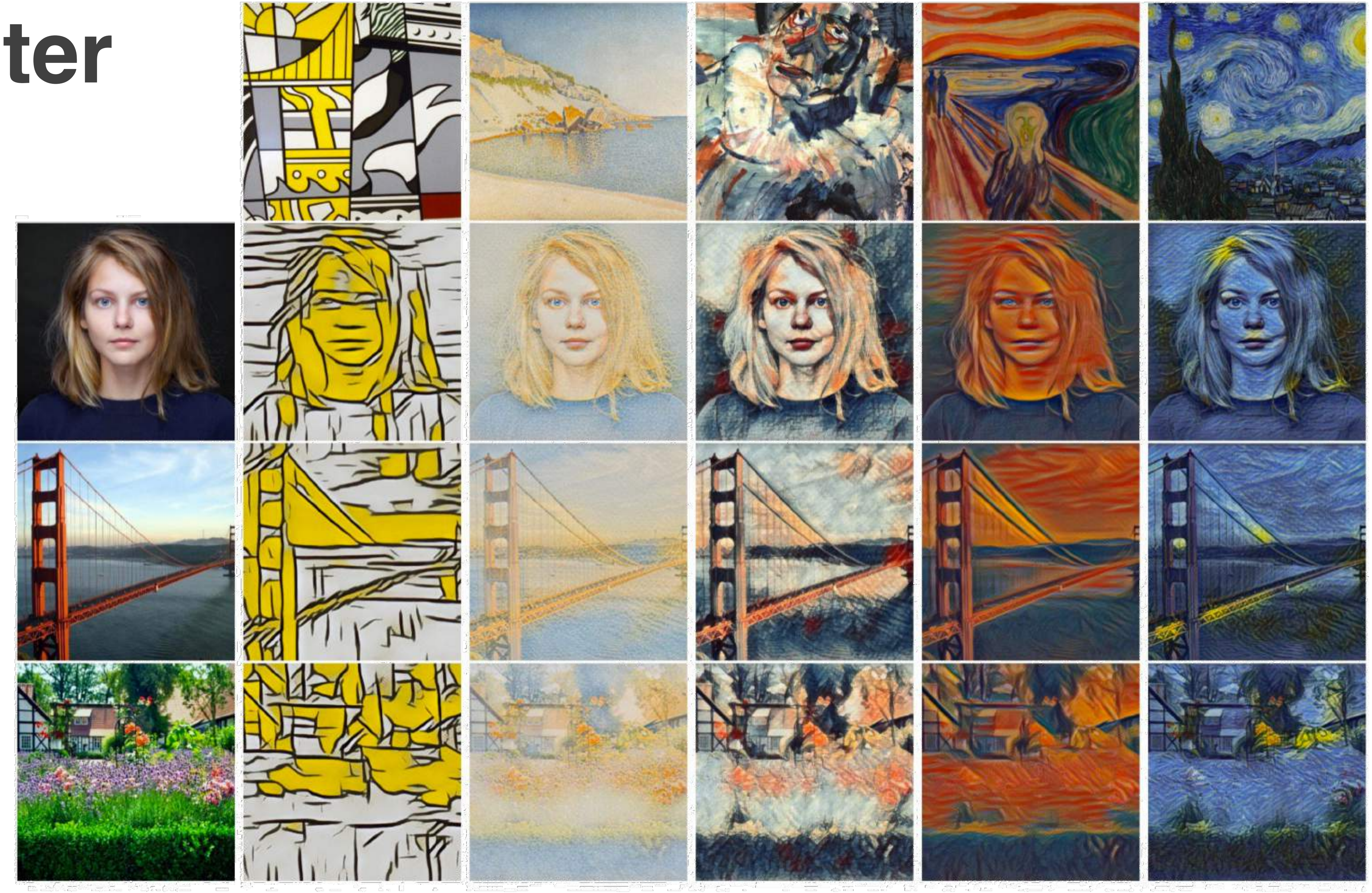
Originally developed by Alexander Mordvintsev from Google



Computer Vision

Style Transfer (link)

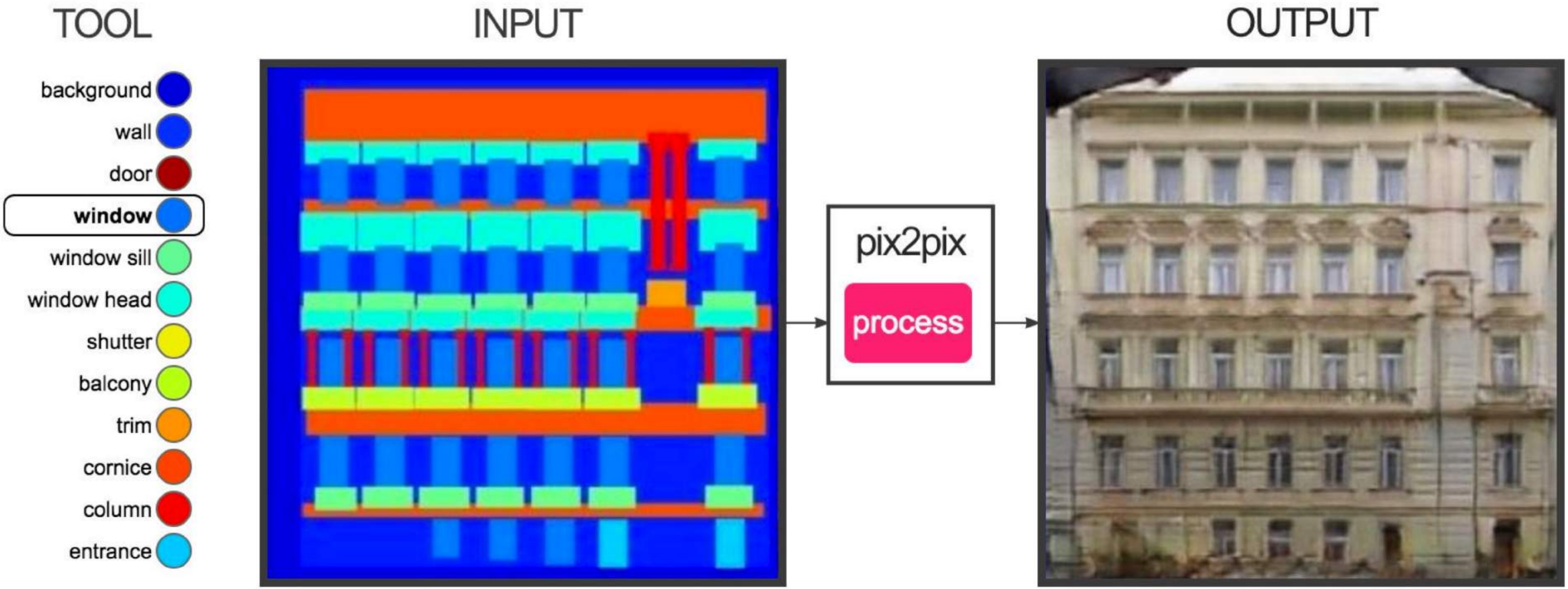
Dumoulin et al. 2016, A learned representation for artistic style



Computer Vision

Image-to-Image Translation (link)

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



Computer Vision

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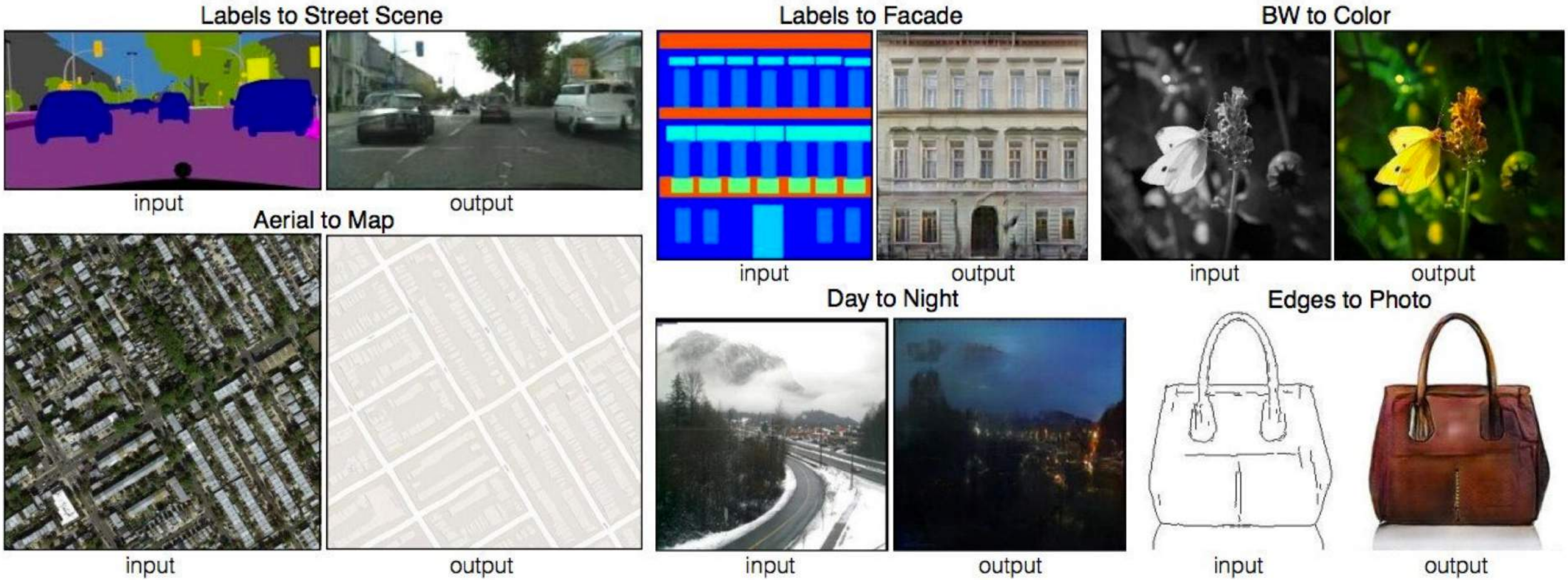
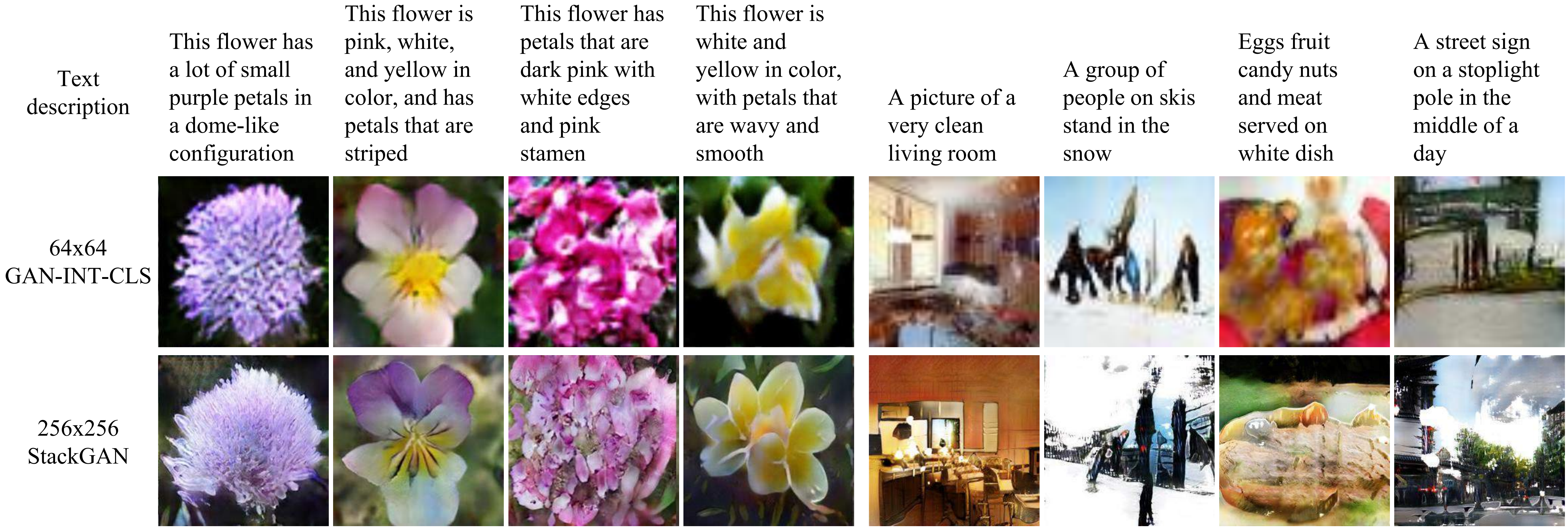


Computer Vision

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

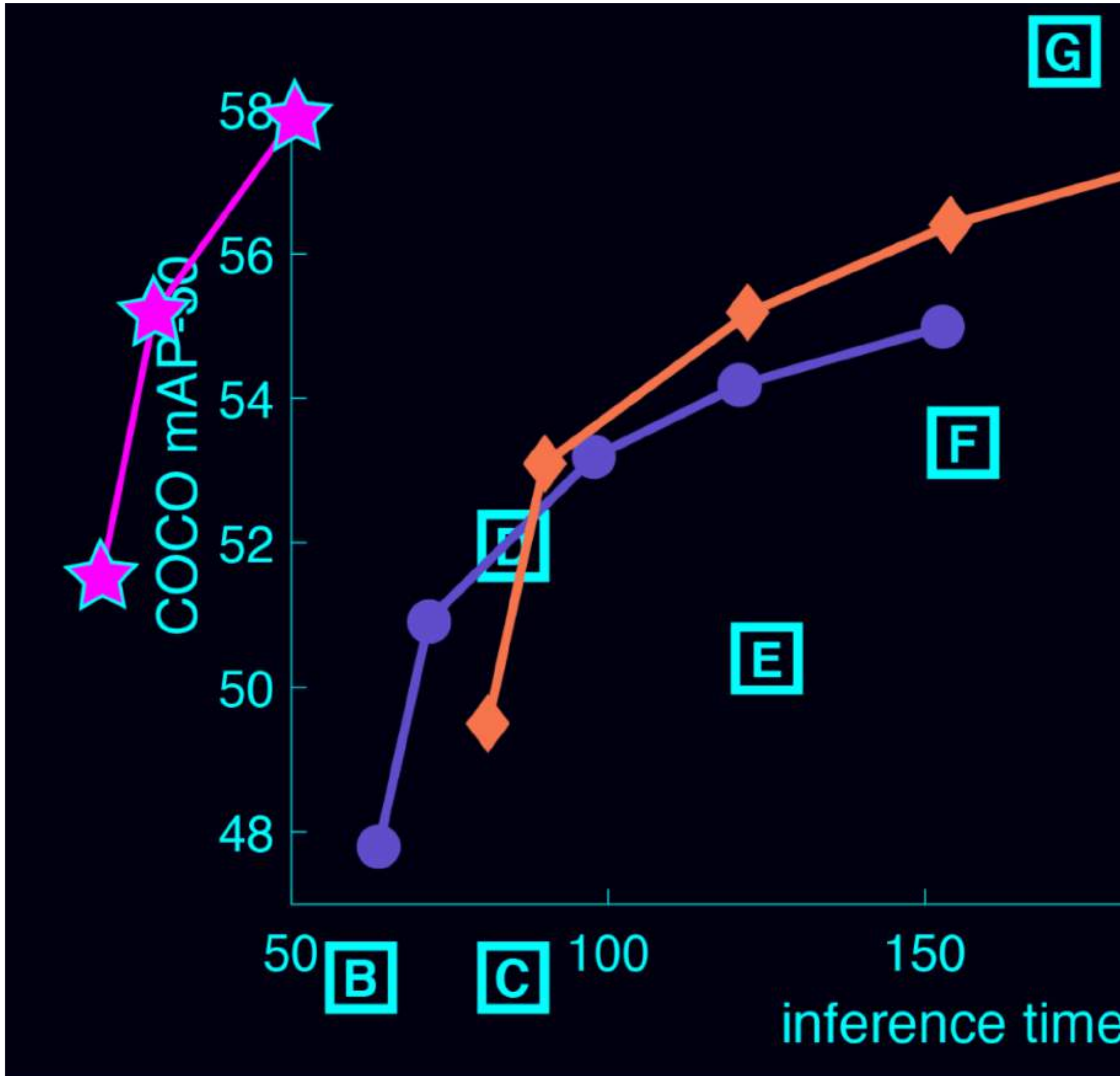
Computer Vision

YOLO: Real-time object identification (link)

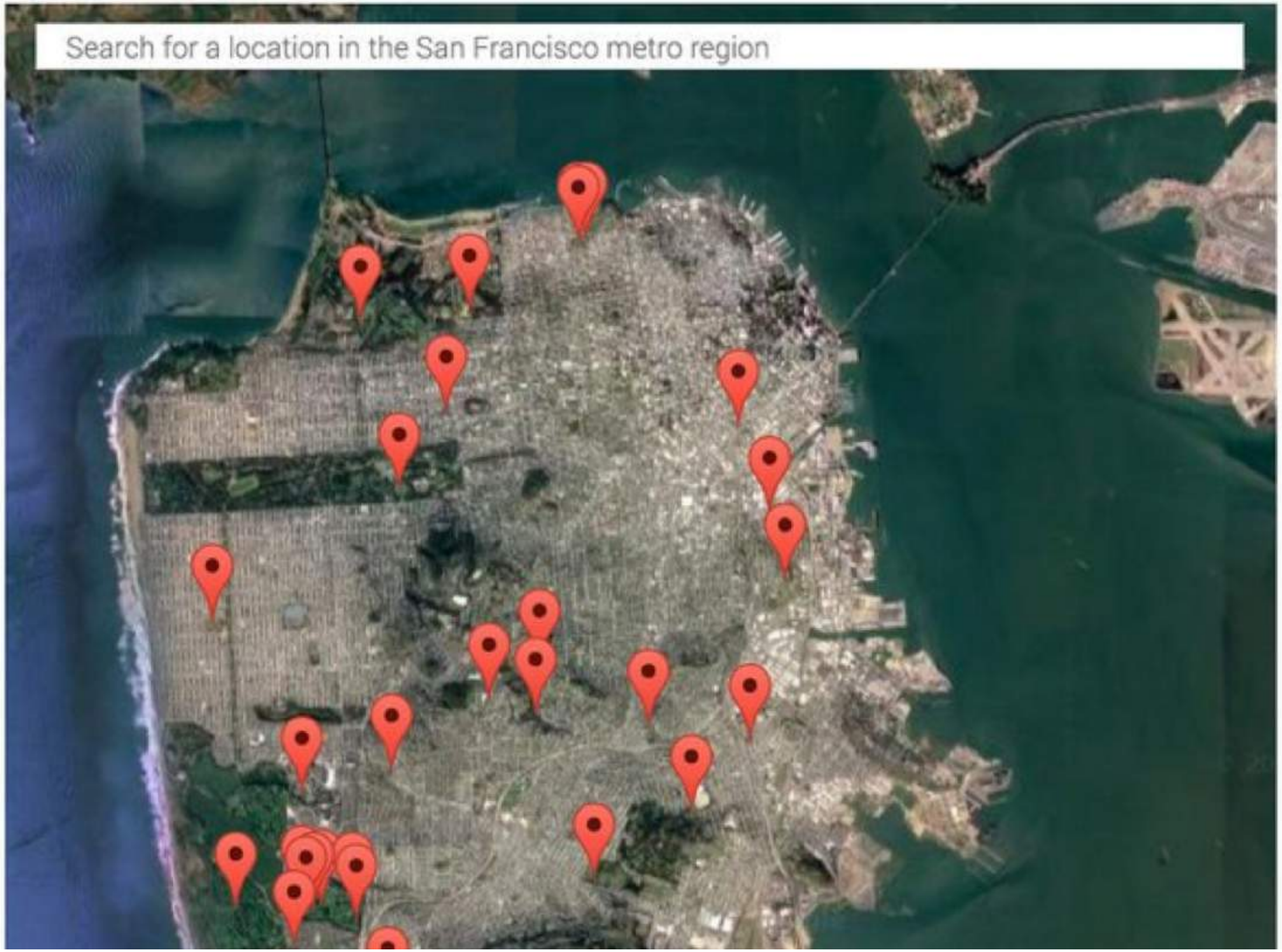
Redmon et al. 2016, You Only Look Once: Unified, Real-Time Object Detection

Example Video link

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



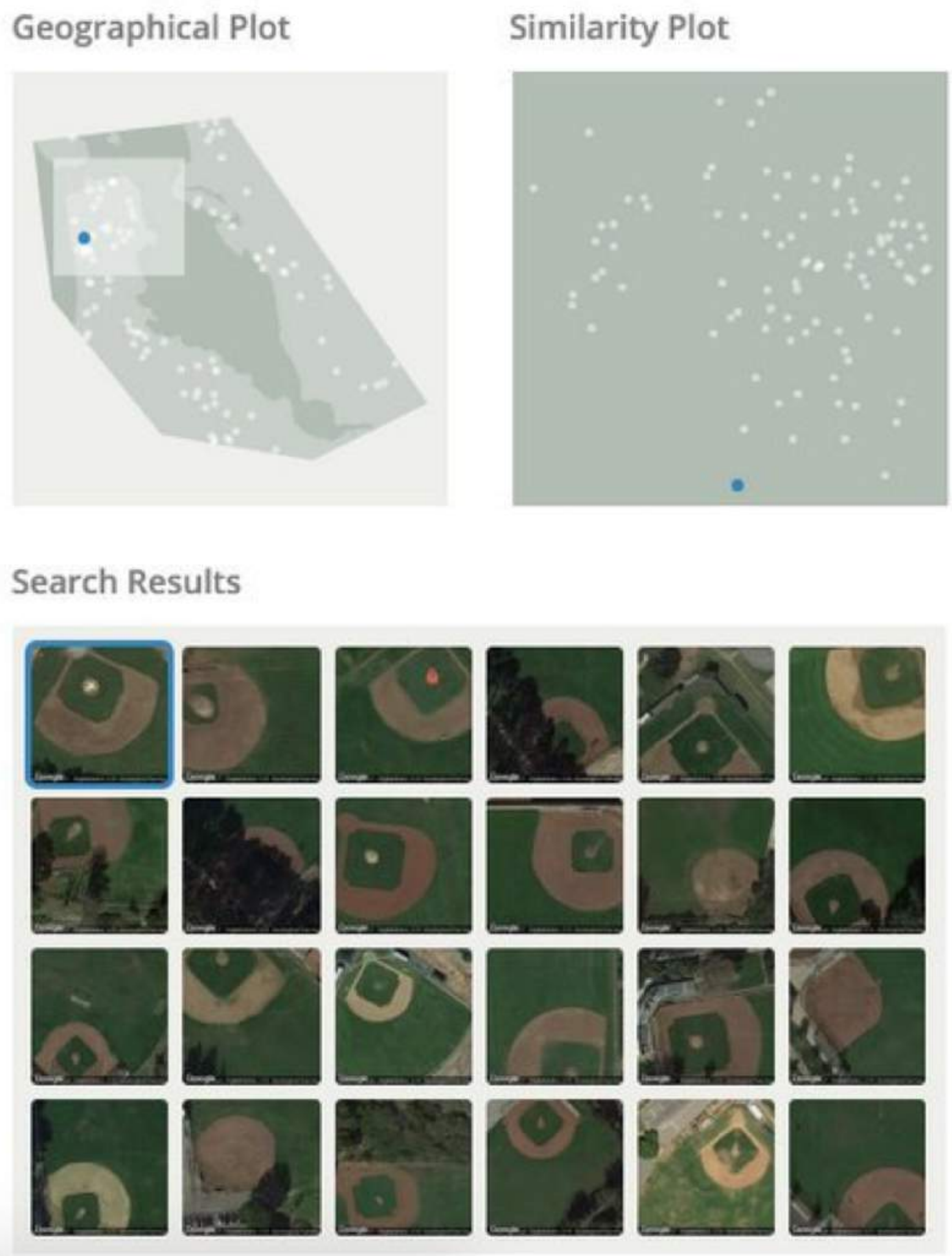
Method	mAP-50	time
[B] SSD321	45.4	61
[C] DSSD321	46.1	85
[D] R-FCN	51.9	85
[E] SSD513	50.4	125
[F] DSSD513	53.3	156
[G] FPN FRCN	**59.1**	172
RetinaNet-50-500	50.9	73
RetinaNet-101-500	53.1	90
RetinaNet-101-800	57.5	198
YOLOv3-320	51.5	**22**
YOLOv3-416	55.3	29
YOLOv3-608	57.9	51



Geospatial Image Analysis

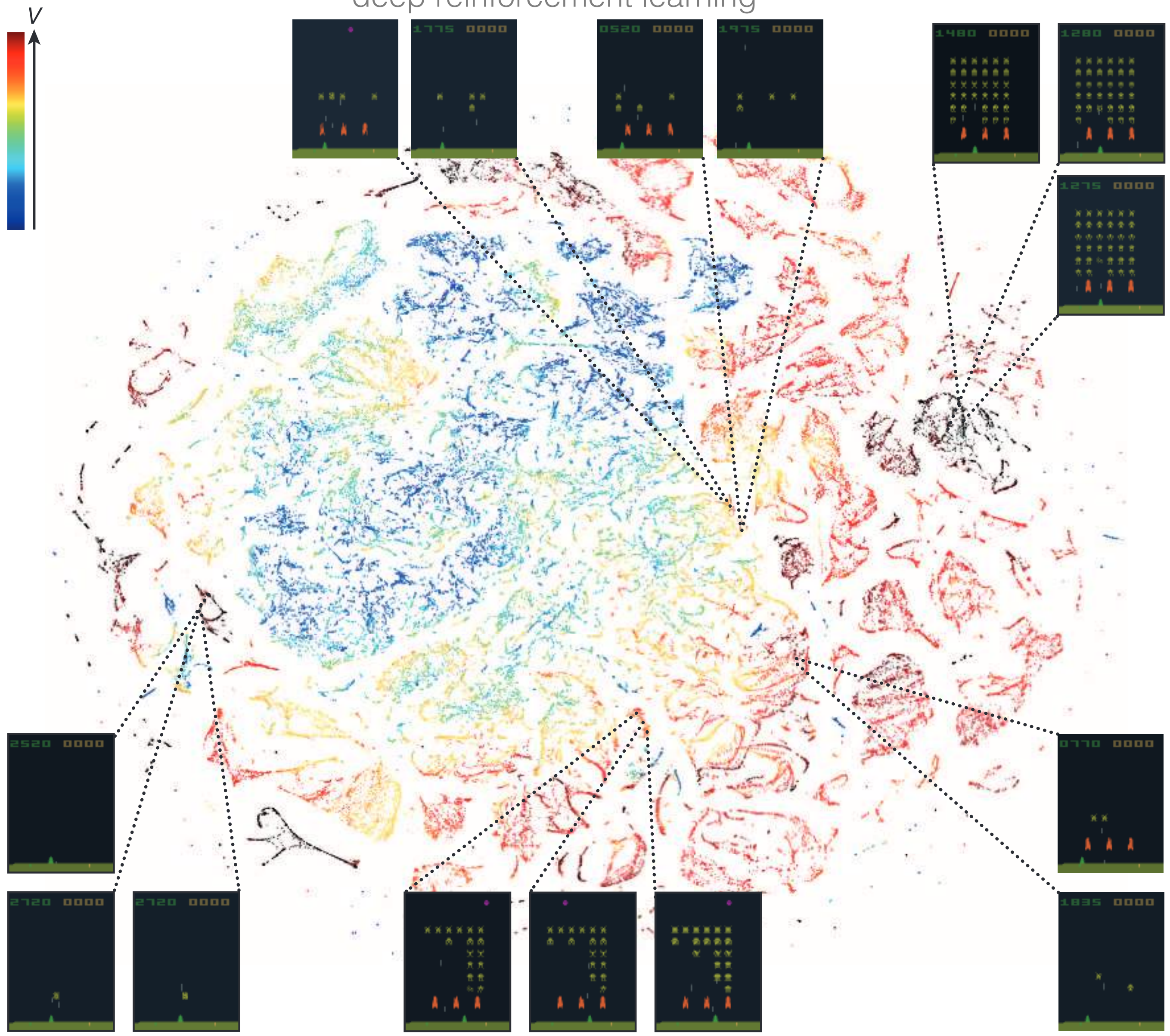
TerraPattern (link) [Levin, Newbury, McDonald et al.]

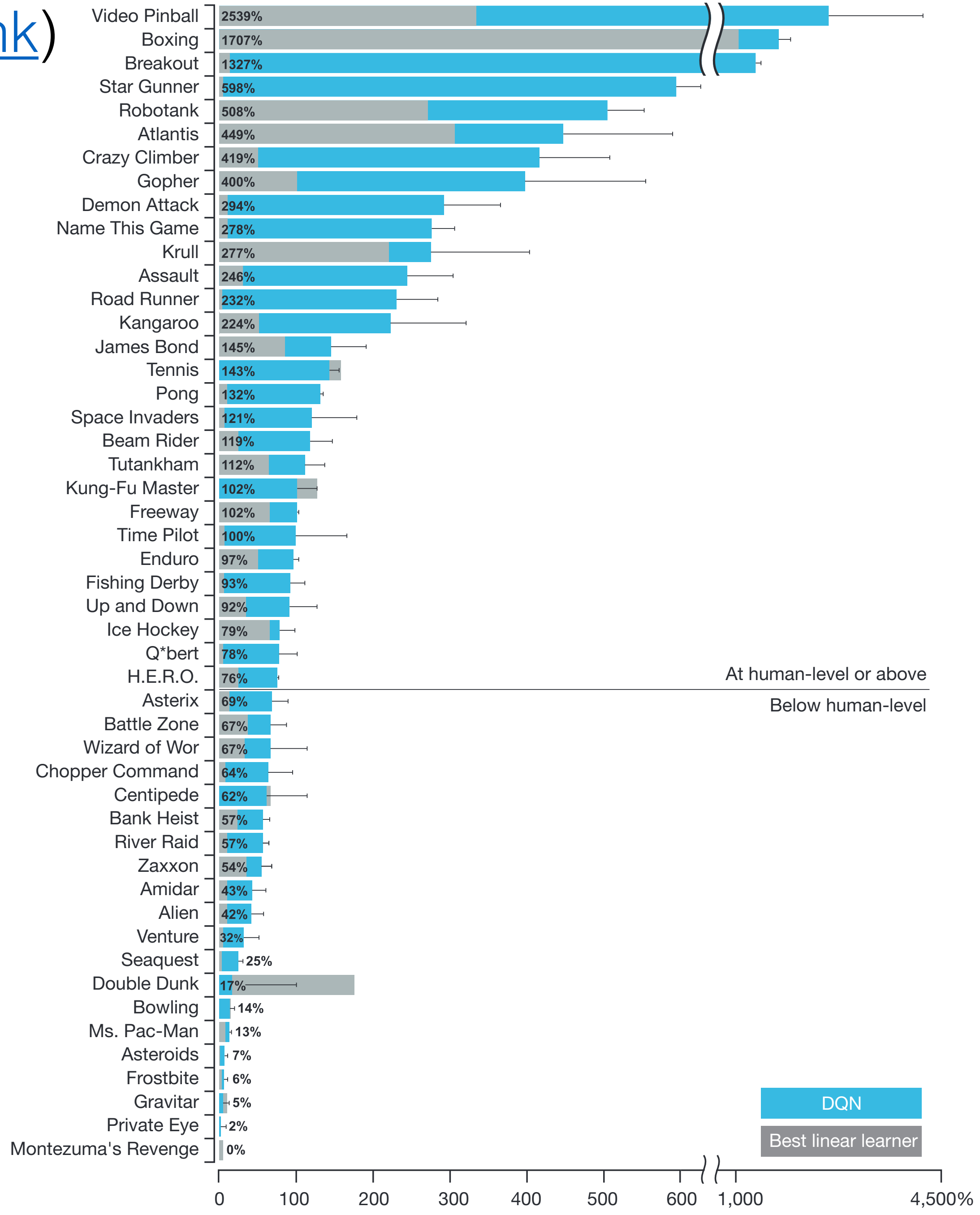
…similar tool available from Descartes Labs (link)



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

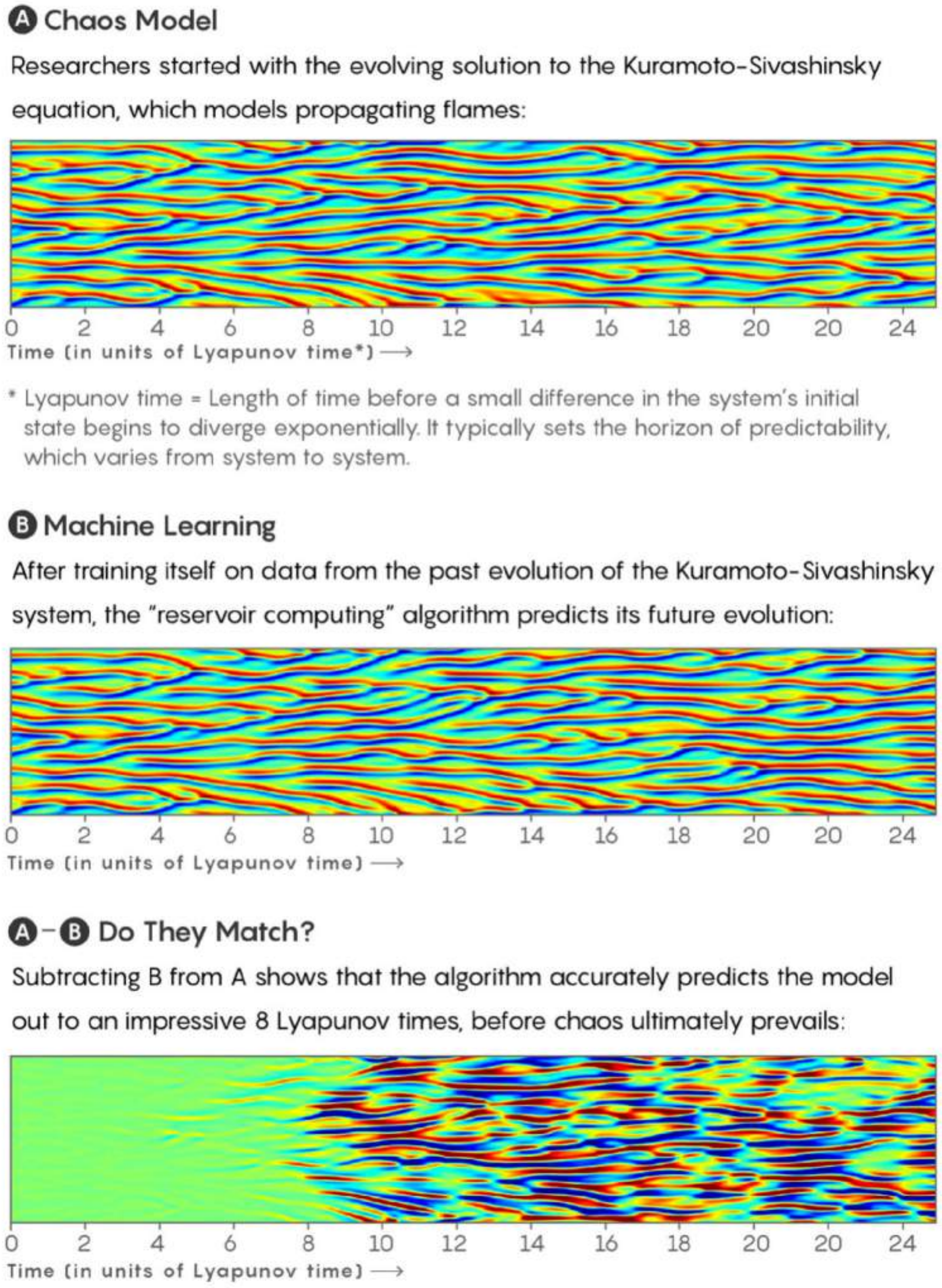
Other applications

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)

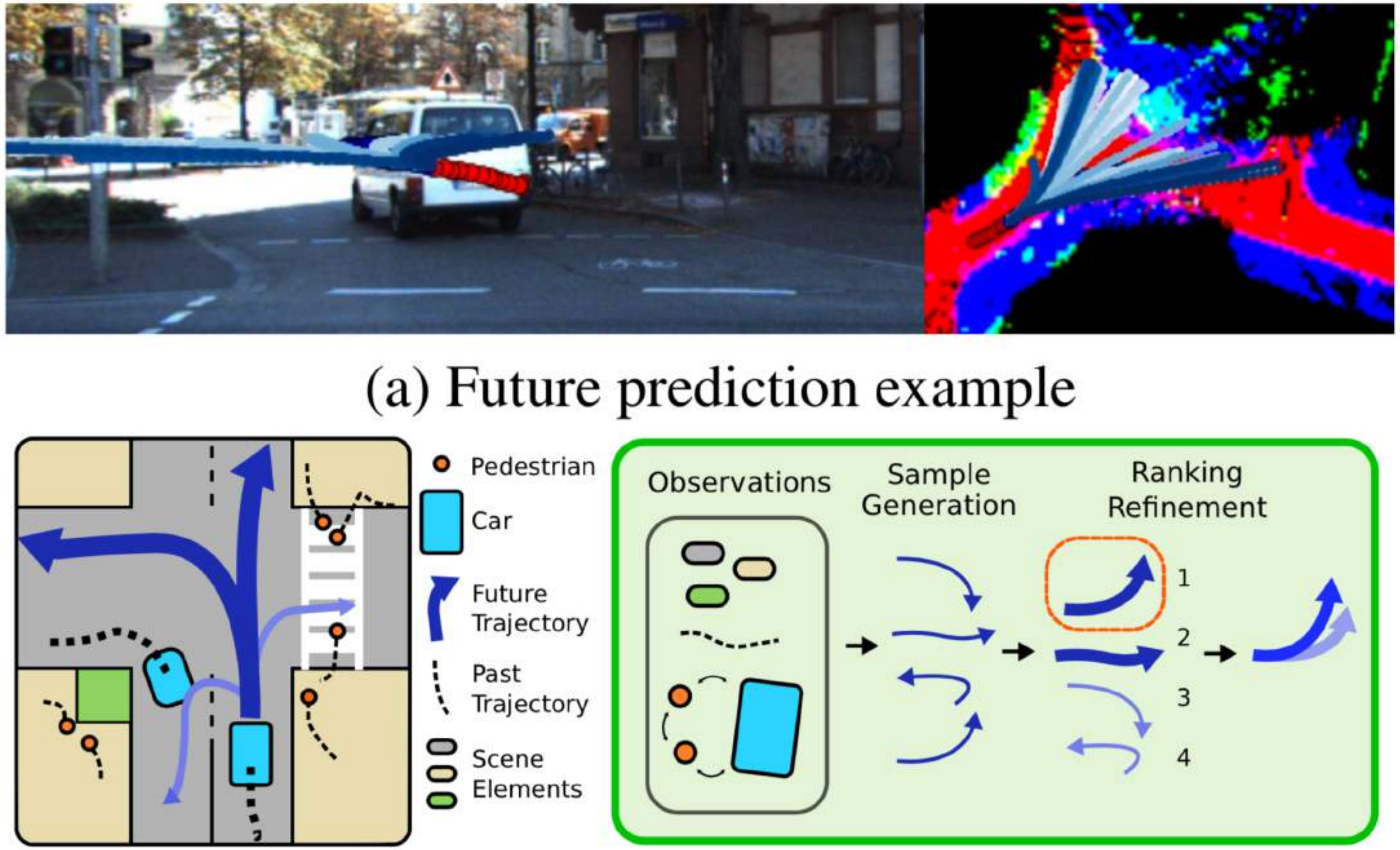
- Weather prediction
- Heart attack prediction (monitoring cardiac arrhythmias)
- Monitoring neuronal firing patterns for signs of neuron spikes
- Predicting solar flares



Other applications

Machine translation (link)
Vaswani et al. 2017, Attention Is All You Need

Self-driving cars (link)
Lee et al. 2017, DESIRE: Distant Future Prediction in Dynamic Scenes with Interacting Agents



(a) Future prediction example

(b) Workflow of *DESIRE*

Open source frameworks

Tensorflow (link)

Framework for implementing graphical models, such as neural networks

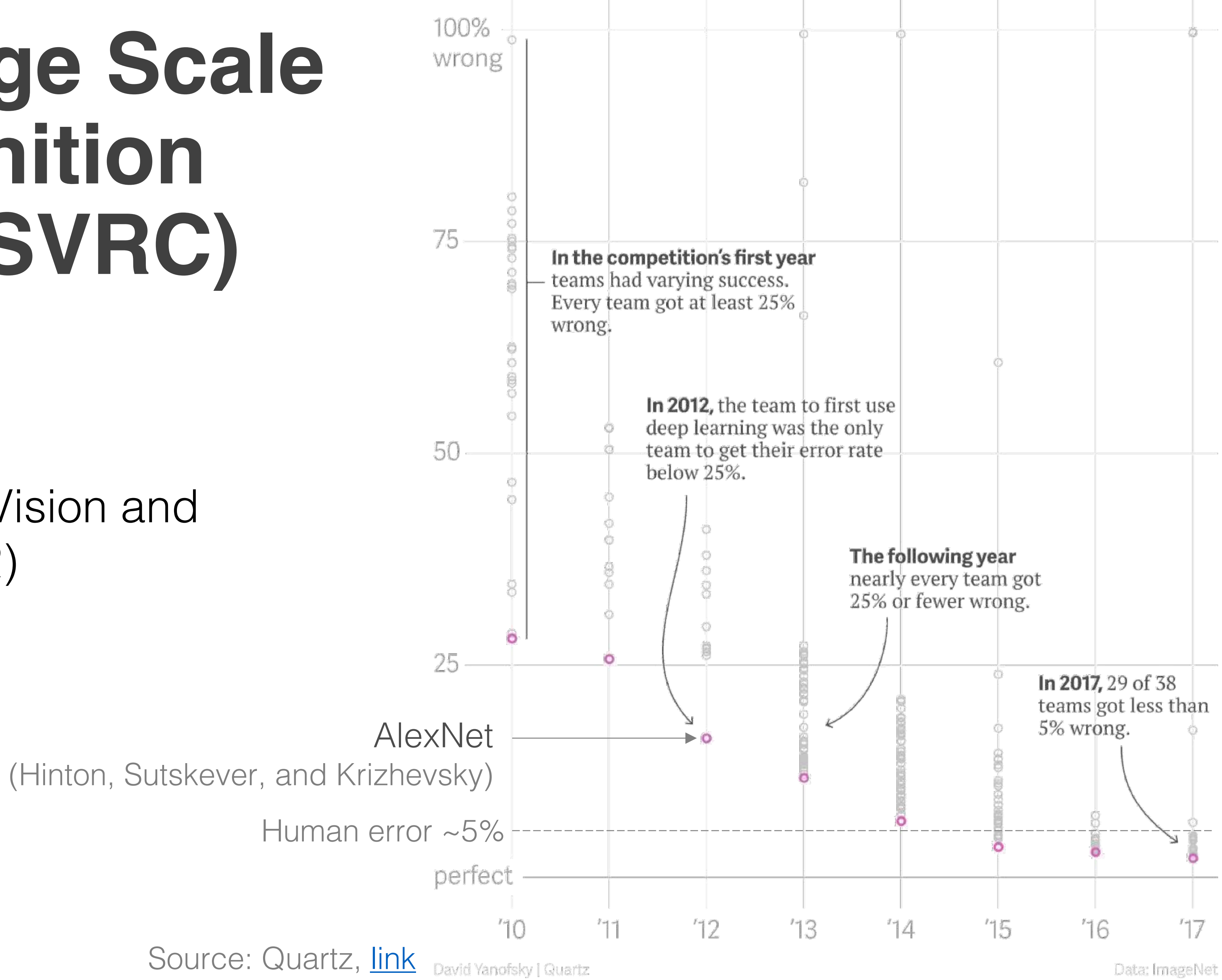
OpenAI (link)

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

ImageNet Large Scale Visual Recognition Challenge (ILSVRC)

Fei-Fei Li et al. 2010 (link)

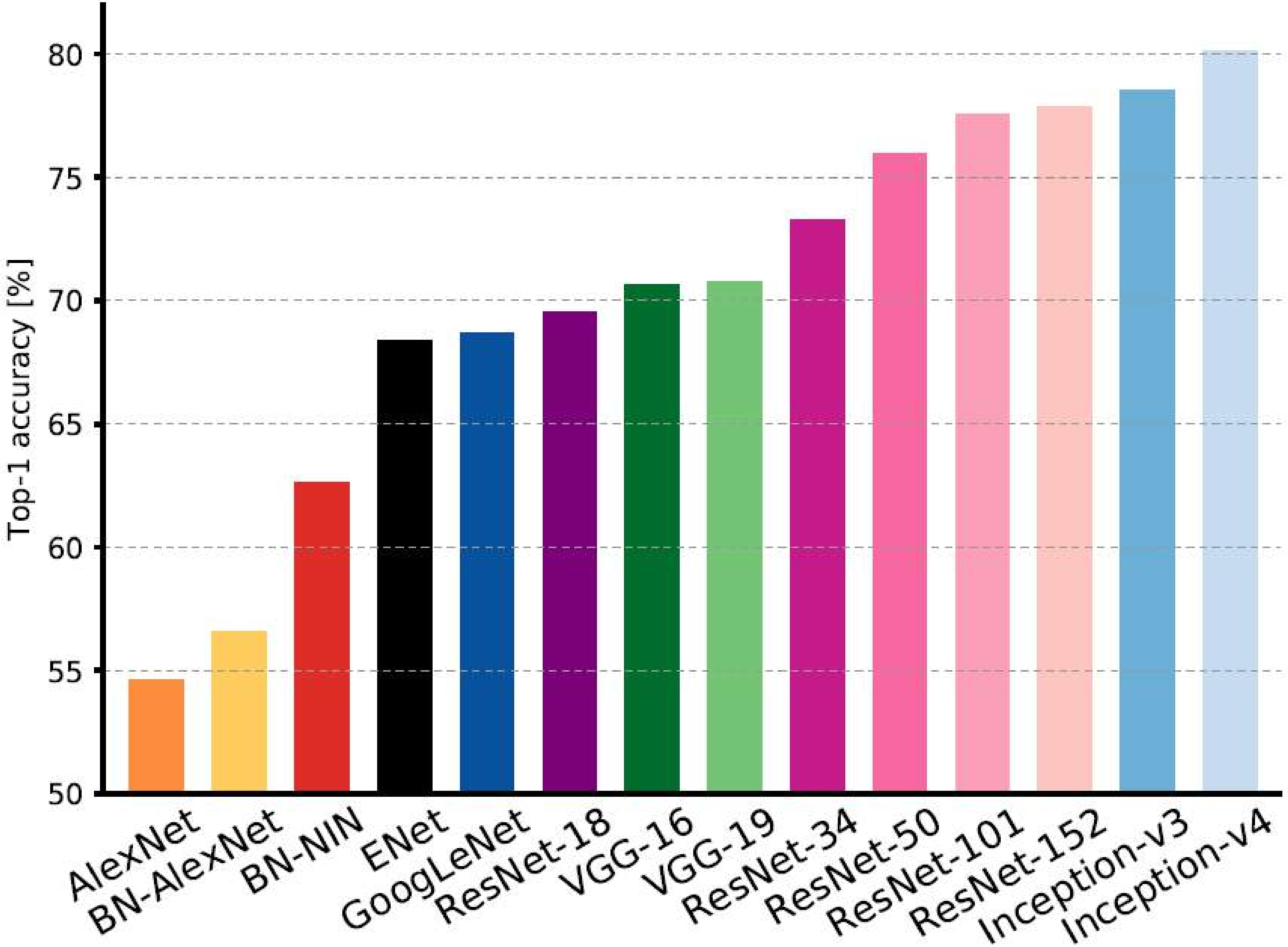
Competition at:
Conference on Computer Vision and Pattern Recognition (CVPR)



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)

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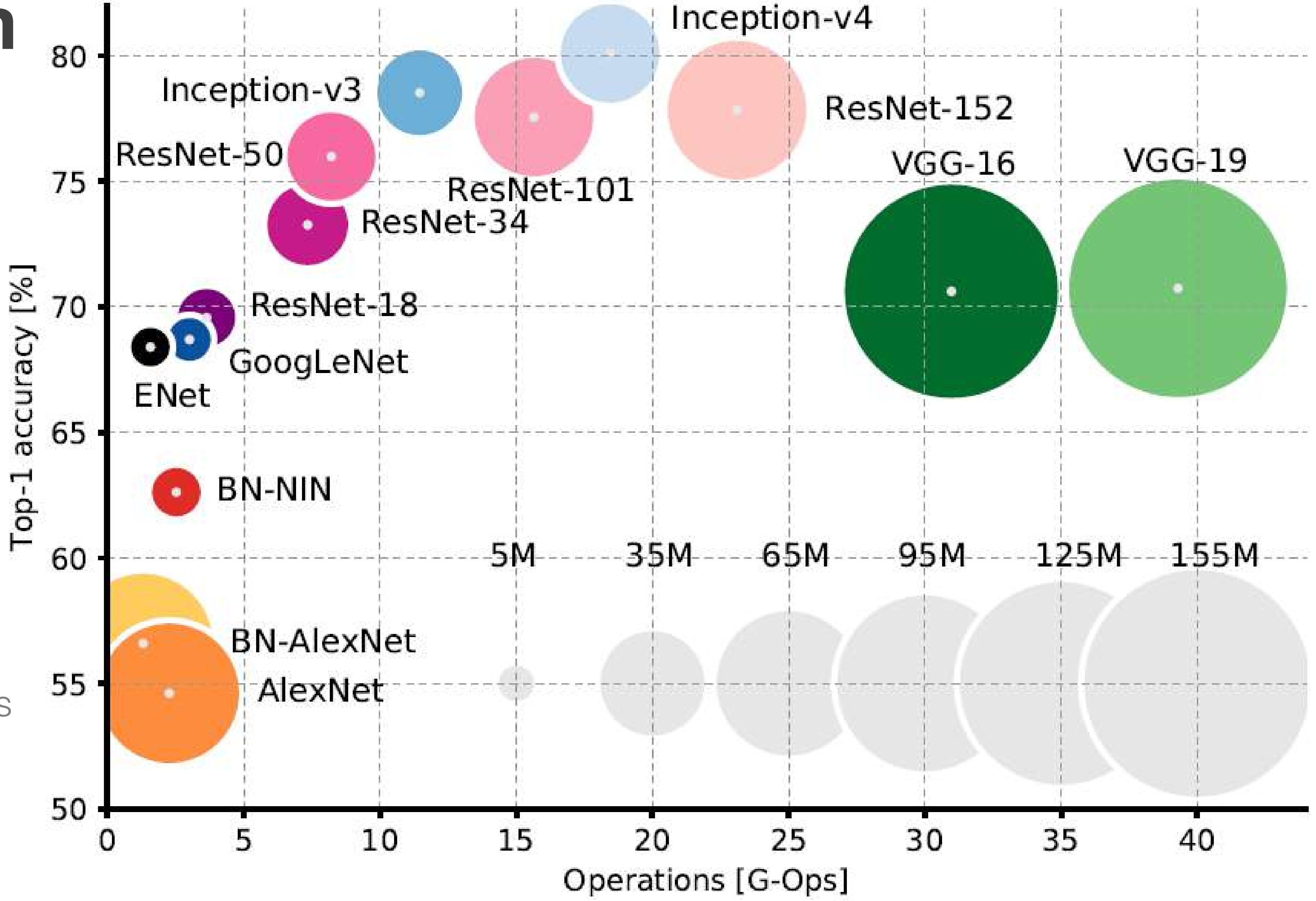

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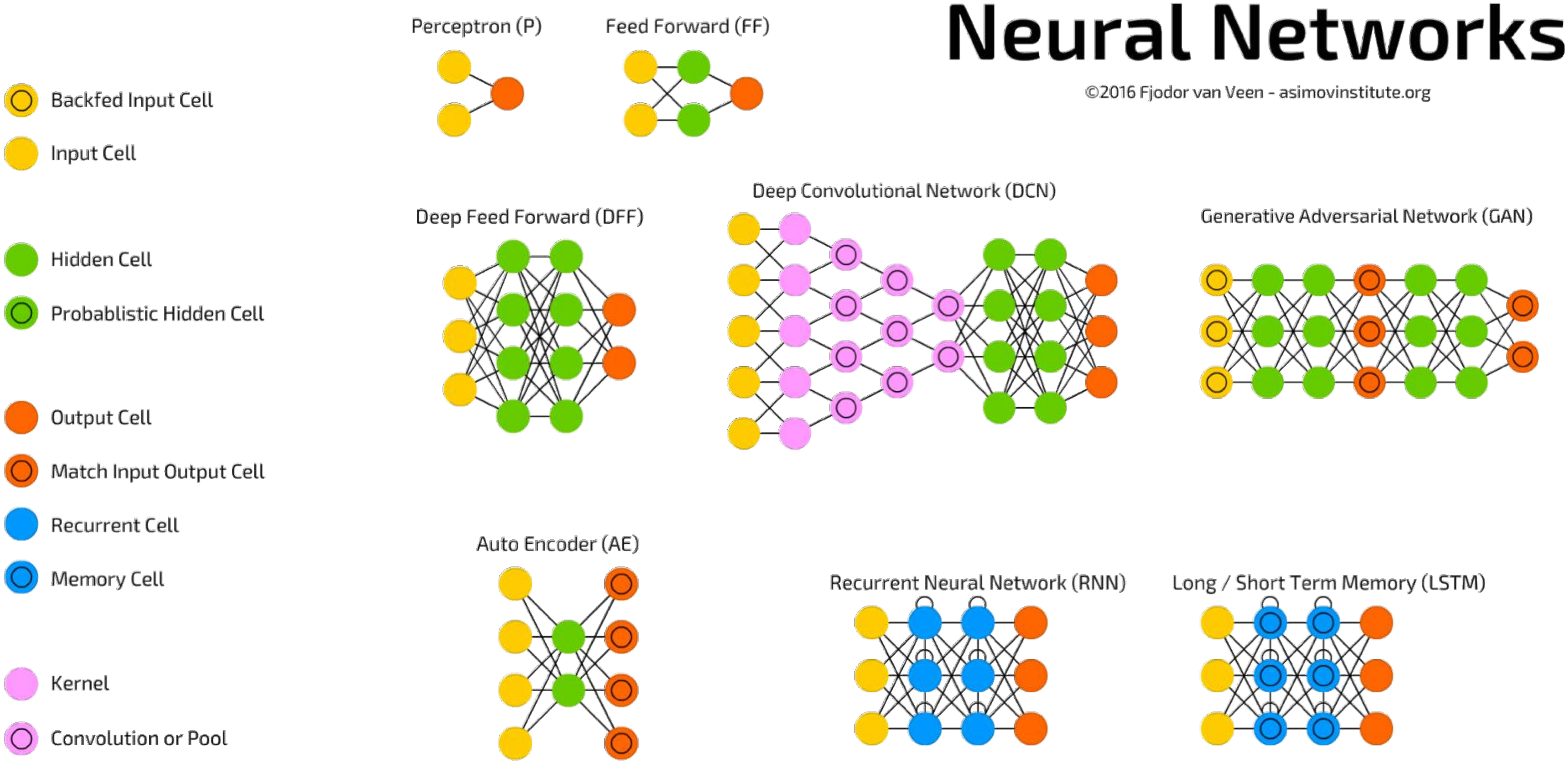


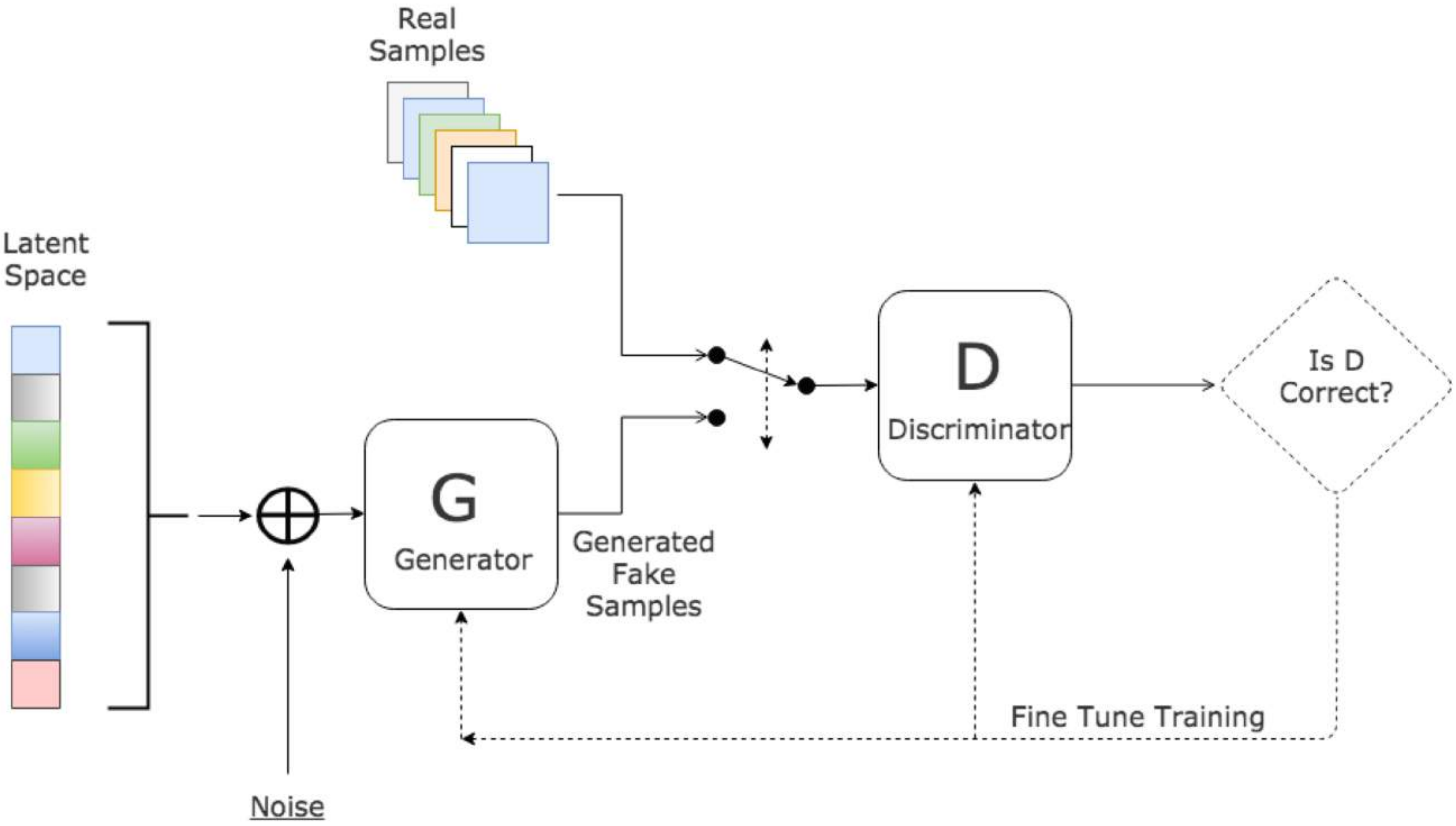
van Veen, 2016, The Azimov Institute (link)

Hinton's Capsule Networks... (link)

Generative Adversarial Networks

Generative Adversarial Nets (link)

Goodfellow et al. 2014

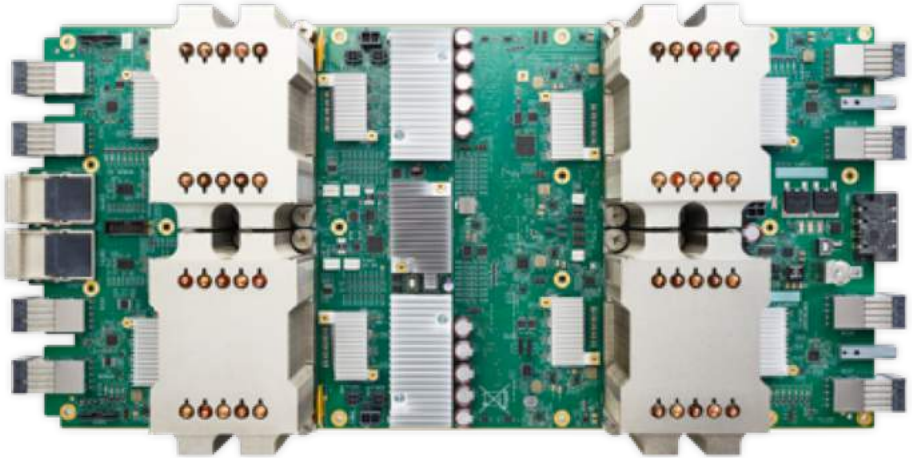


Hitawala 2018
Comparative Study on
Generative Adversarial
Networks

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

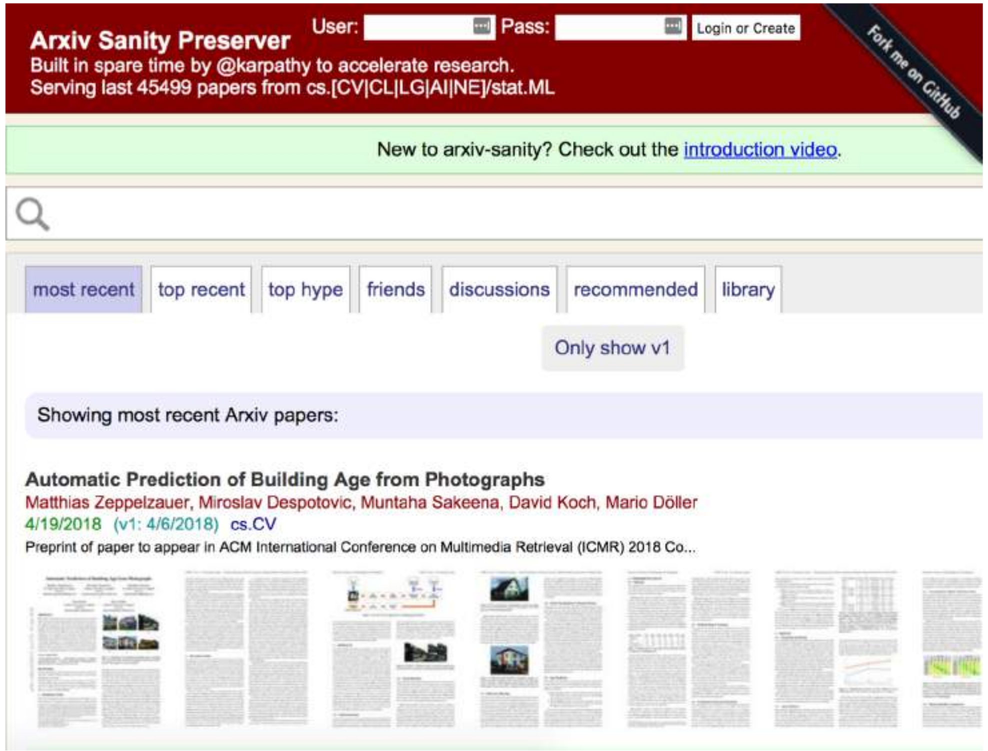
- Applied Stochastic Processes
- Computational Data Analysis
- Introduction to Statistical Methods
- Modeling and Scientific Computing
- Modern Nonparametric Theory and Methods
- Probability and Statistical Models
- Statistical Case Studies

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

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

What to read

Arxiv (link) (Arxiv sanity-preserver)



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

Weekly newsletters:
Data Machina (link)
Data Elixir (link)

Conferences:
International Conference on Machine Learning (ICML) (link)
Neural Information Processing Systems (NIPS) (link)
International Conference on Learning Representations (ICLR) (link)

People to know & read about in Machine Learning

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

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