

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

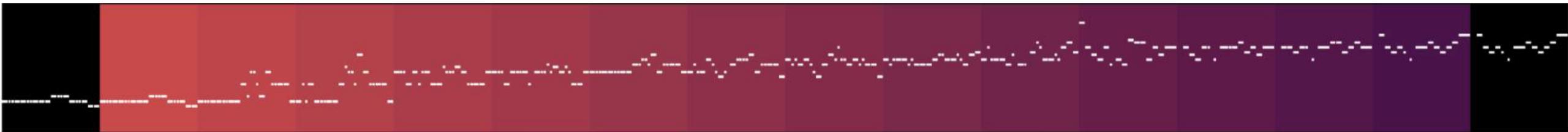
Dynamic Programming
Policy Evaluation
Policy Improvement
Policy Iteration
Value Iteration
Generalized policy iteration
Monte Carlo Control
Model free / model-based learning

Topics we covered

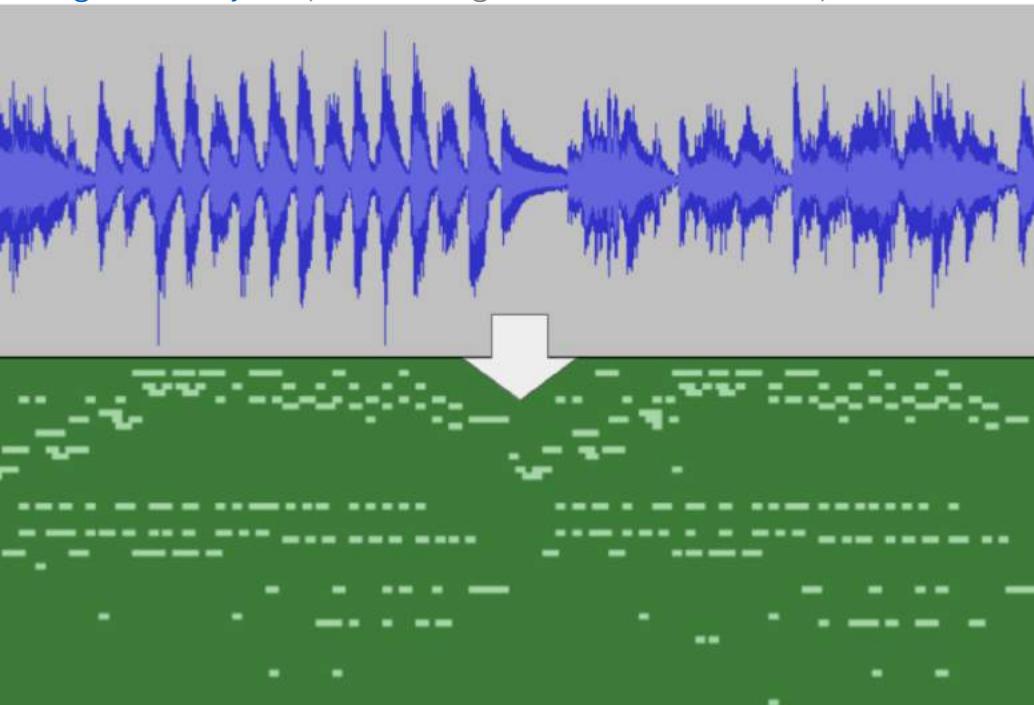
Machine Learning Applications

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

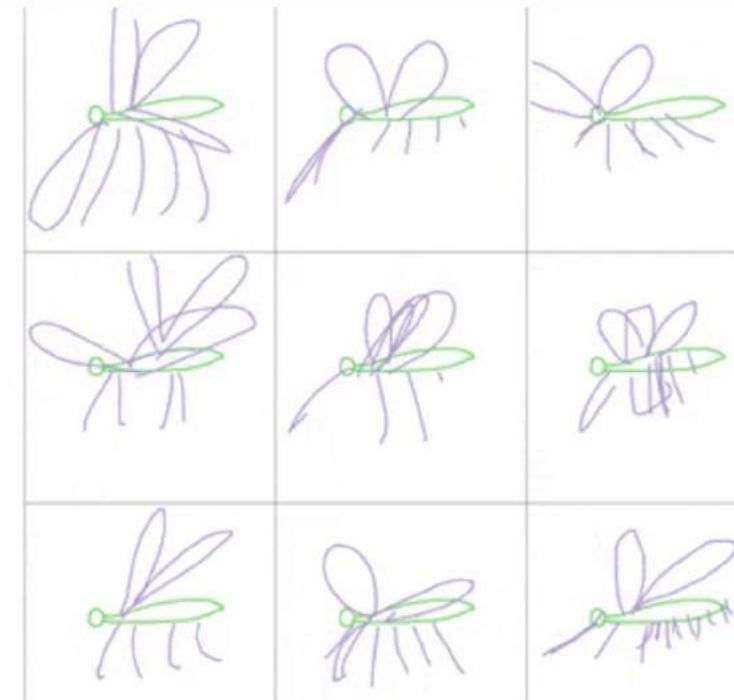
Handwriting completion:
...with Neural Networks ([link](#))

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



SketchRNN:
Automated sketching ([link](#))
[Magenta Project](#) (from Google Brain / tensorflow)

sketch-rnn mosquito predictor.



Computer Vision & Visual Arts

Deep Dream: Style Transfer and Abstract Art ([link](#))

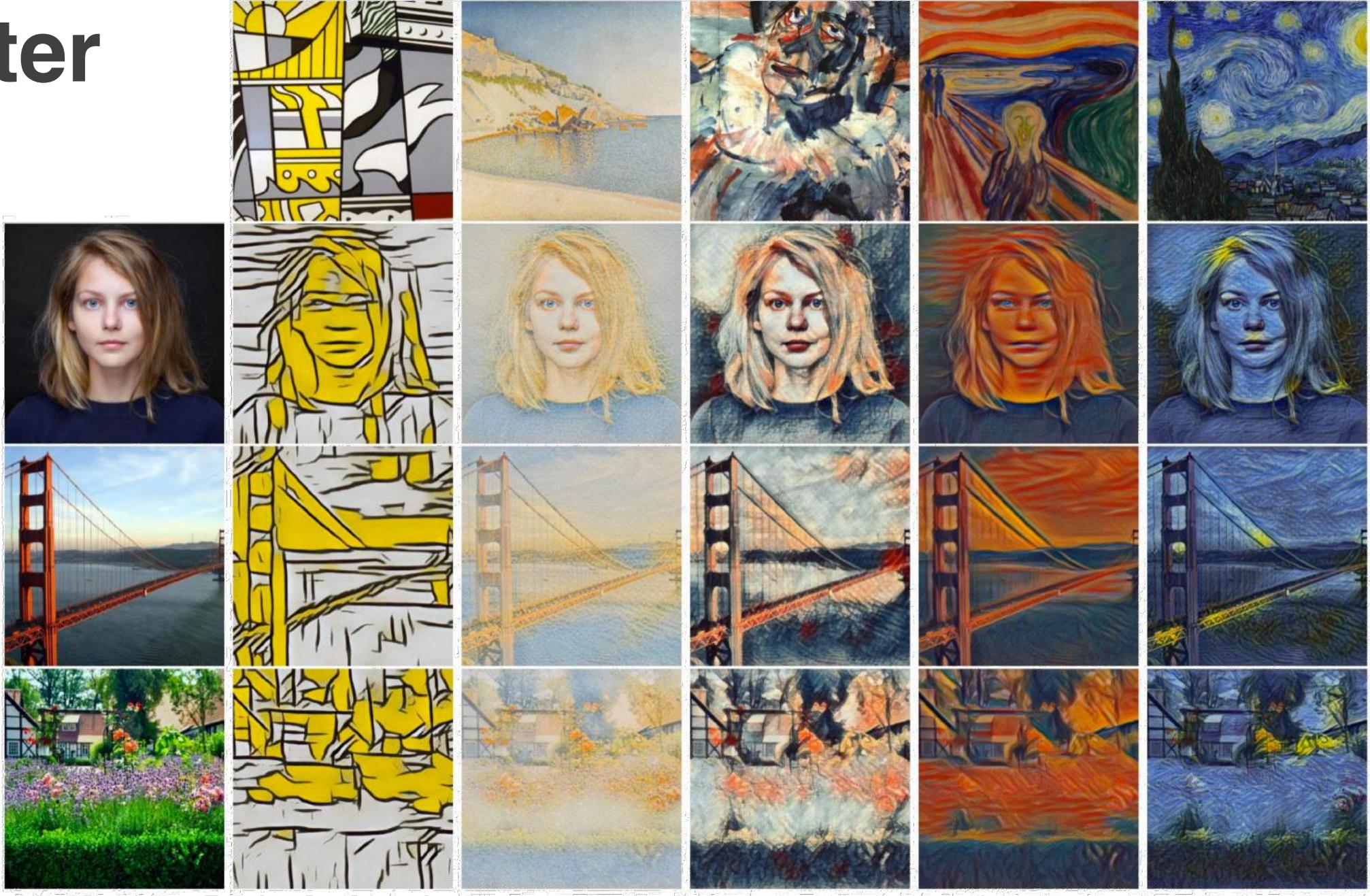
Originally developed by Alexander Mordvintsev from Google



Computer Vision

Style Transfer
([link](#))

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



Computer Vision

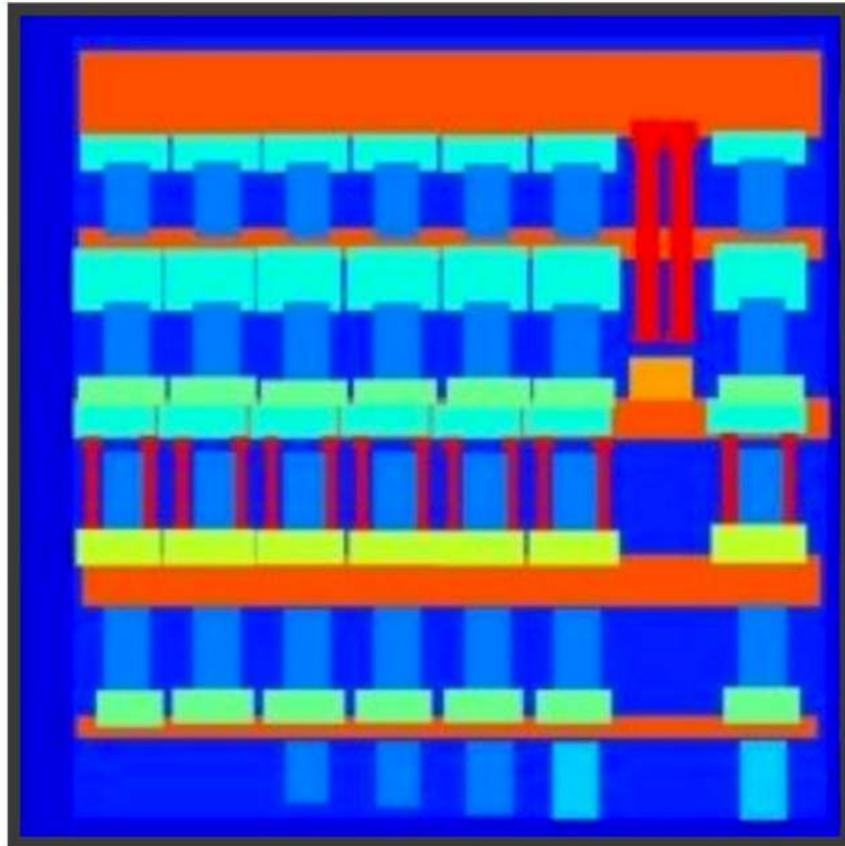
Image-to-Image Translation ([link](#))

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

TOOL

- background
- wall
- door
- window**
- window sill
- window head
- shutter
- balcony
- trim
- cornice
- column
- entrance

INPUT



pix2pix
process

OUTPUT

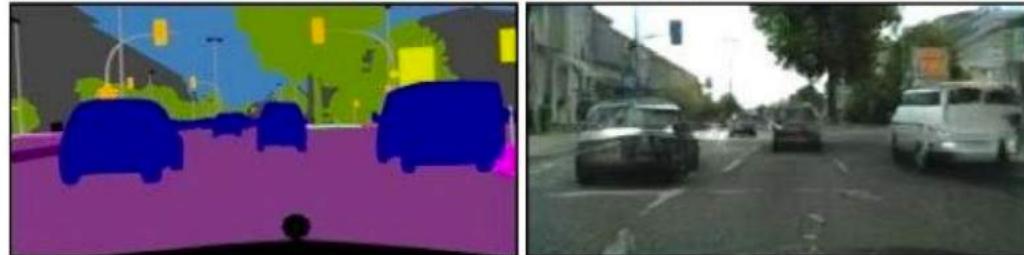


Computer Vision

Image-to-Image Translation ([link](#))

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

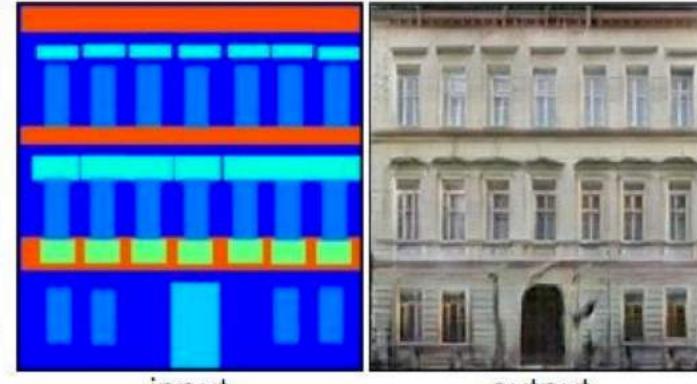
Labels to Street Scene



input

output

Labels to Facade



input

output

BW to Color



input

output

Aerial to Map



input

output

Day to Night



input

output

Edges to Photo



input

output

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

Text description	This flower has a lot of small purple petals in a dome-like configuration	This flower is pink, white, and yellow in color, and has petals that are striped	This flower has petals that are dark pink with white edges and pink stamen	This flower is white and yellow in color, with petals that are wavy and smooth	A picture of a very clean living room	A group of people on skis stand in the snow	Eggs fruit candy nuts and meat served on white dish	A street sign on a stoplight pole in the middle of a day
64x64 GAN-INT-CLS								
256x256 StackGAN								

Computer Vision

These
images are
all synthetic

Image Synthesis ([link](#))

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



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

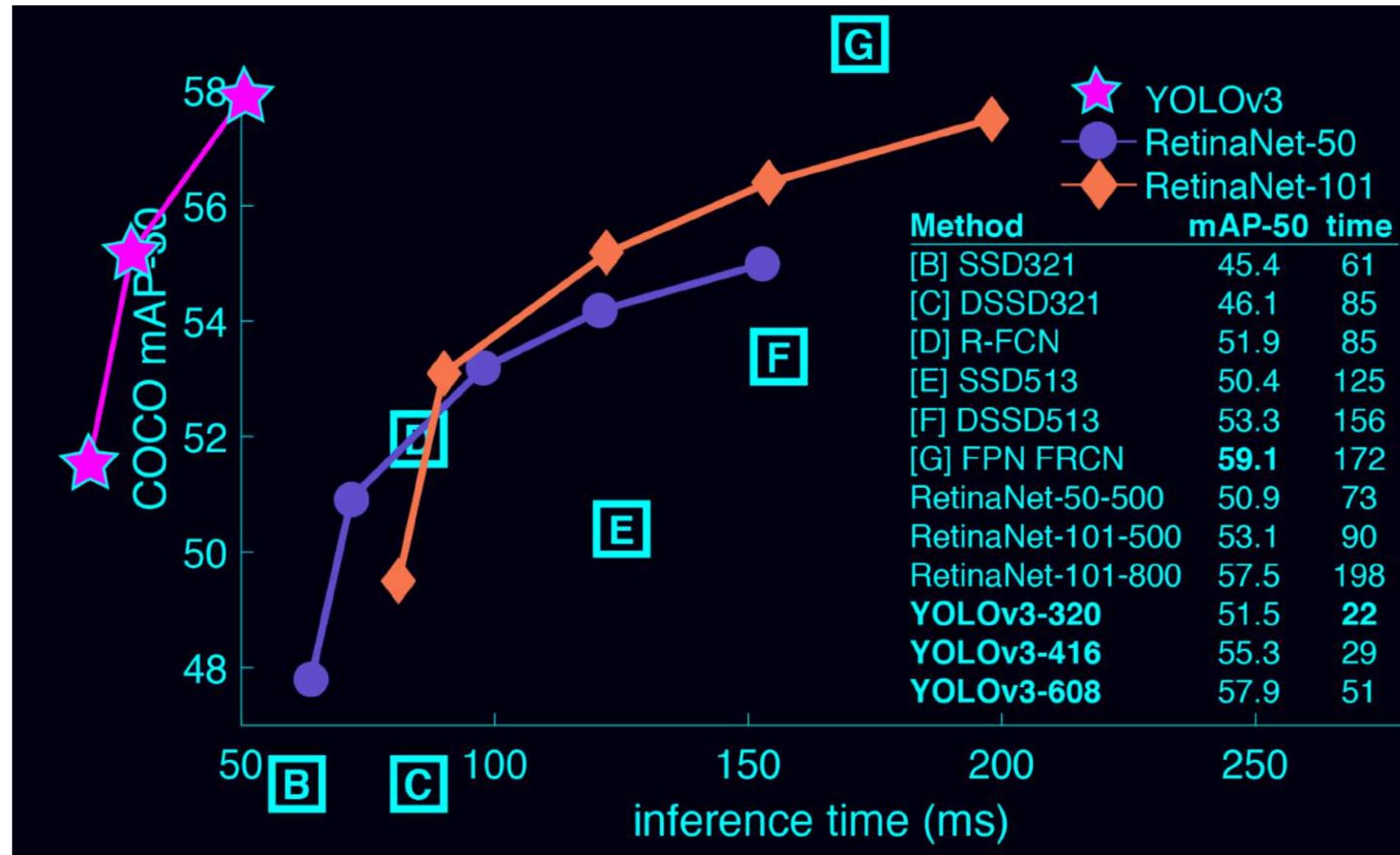
Computer Vision

YOLO: Real-time object identification ([link](#))

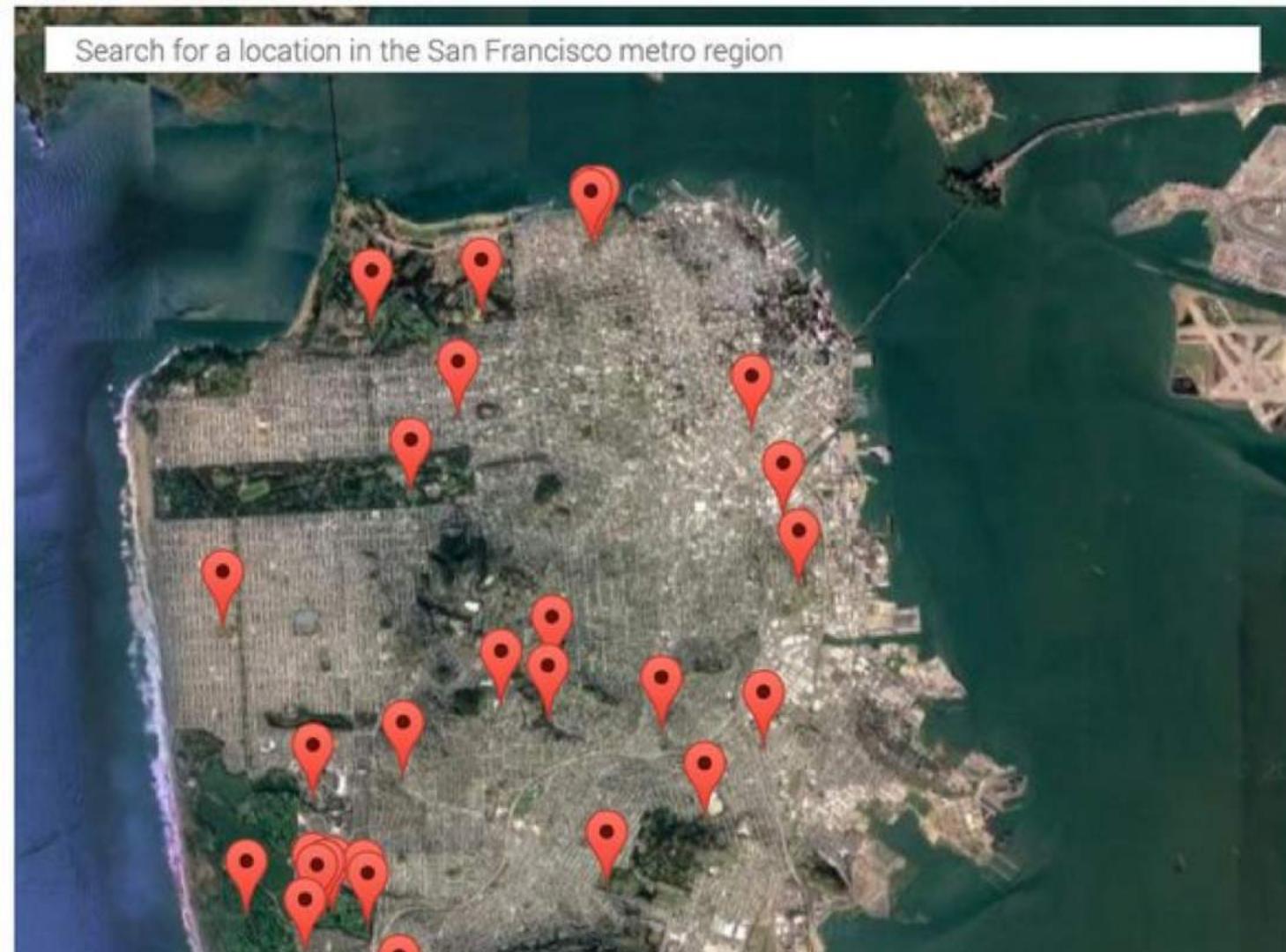
Redmon et al. 2016, You Only Look Once: Unified, Real-Time Object Detection

Example Video [link](#)

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



Search for a location in the San Francisco metro region



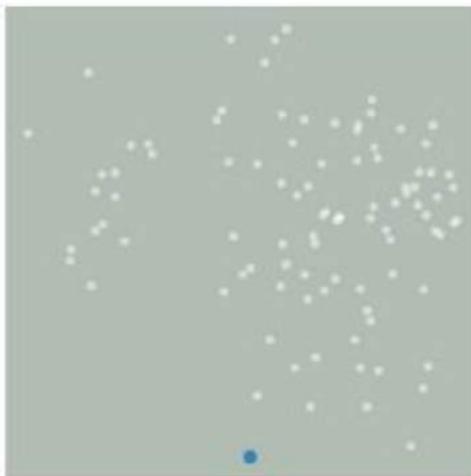
Geospatial Image Analysis

TerraPattern ([link](#)) [Levin, Newbury, McDonald et al.]
...similar tool available from Descartes Labs ([link](#))

Geographical Plot



Similarity Plot



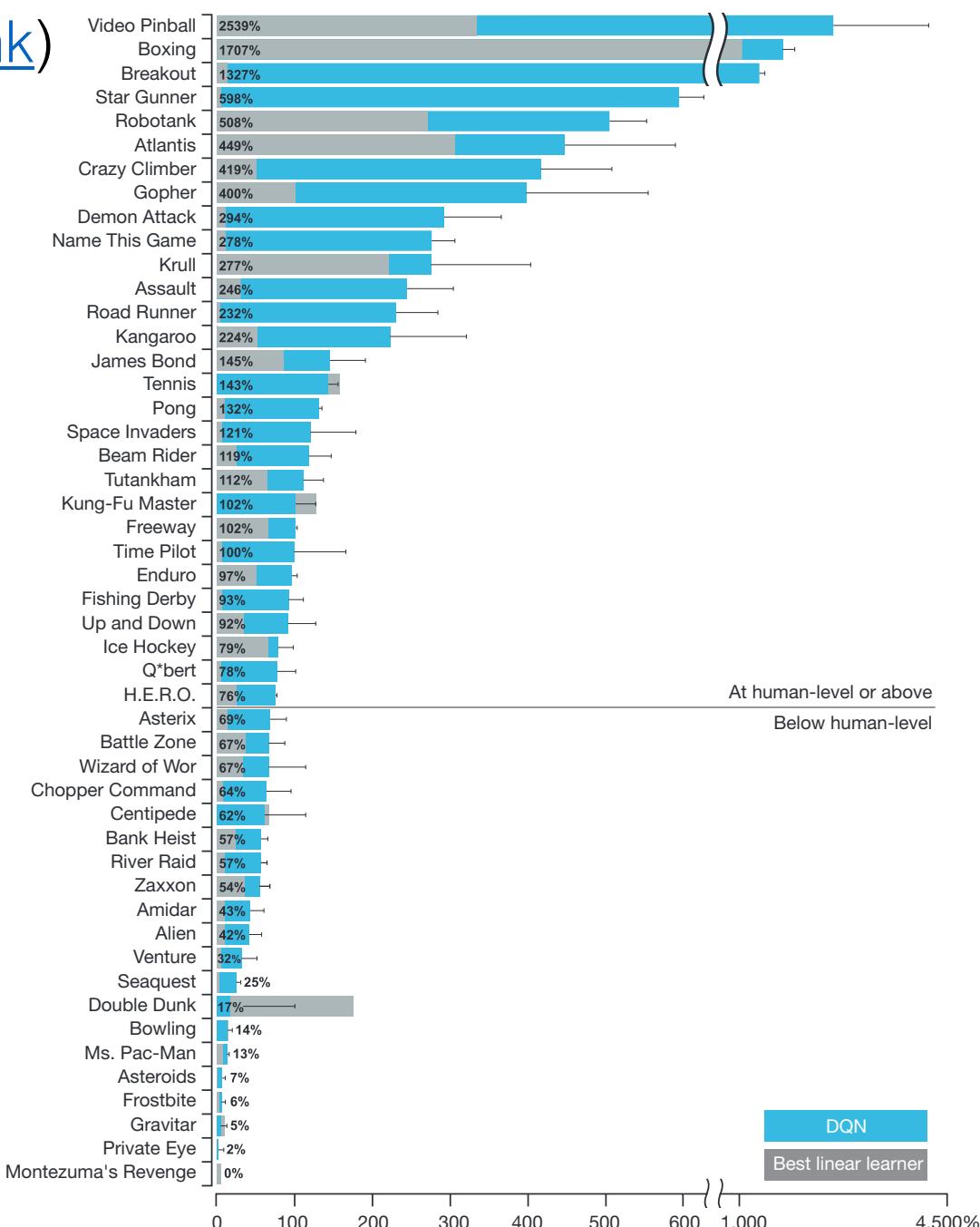
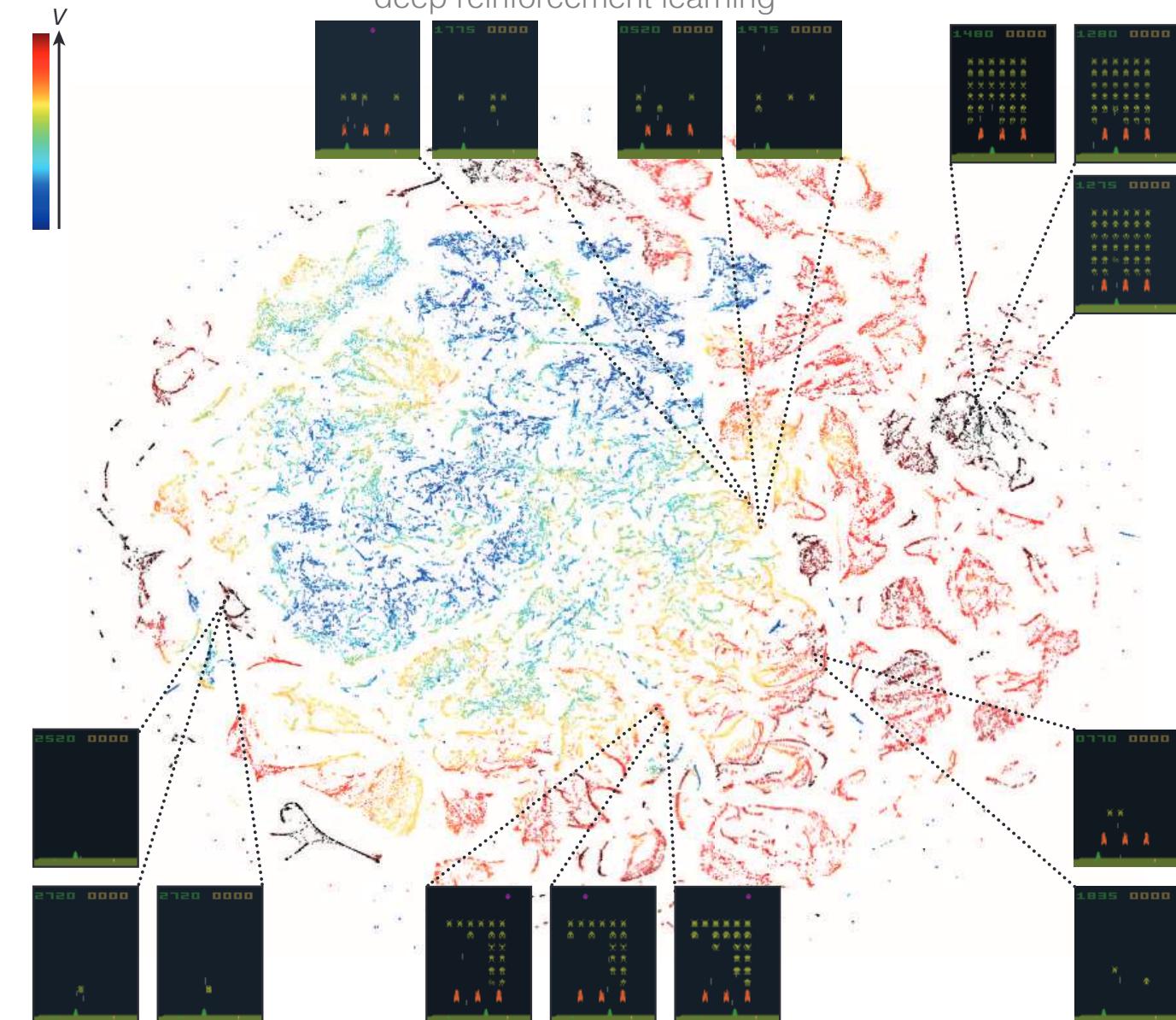
Search Results



Games

Reinforcement Learning for Atari ([link](#))

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



Games

Learning Go
starting from
random play

Mastered in
24 hours

Did the same
with Chess

AlphaZero ([link](#))

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



Other applications

Forecasting Chaos ([link](#))

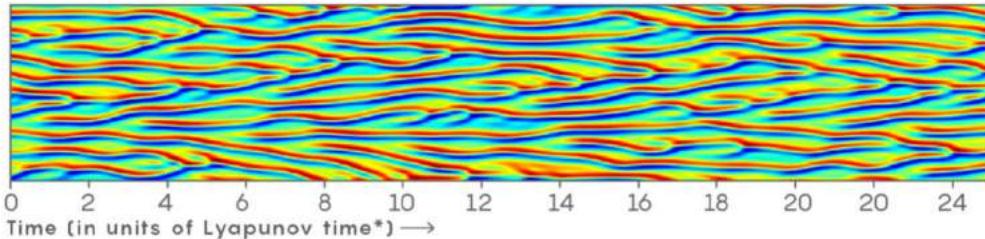
Pathak et al. 2017, Model-Free Prediction of Large Spatiotemporally Chaotic Systems from Data: A Reservoir Computing Approach

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

A Chaos Model

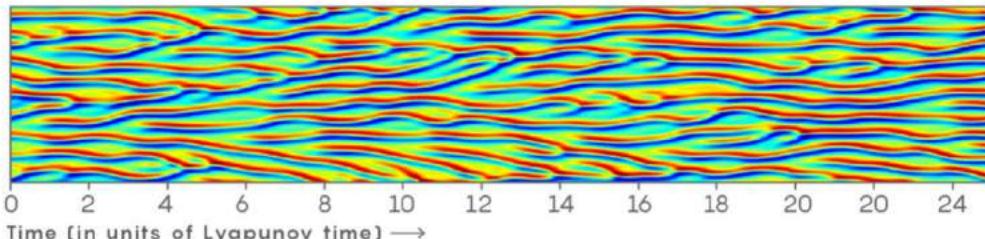
Researchers started with the evolving solution to the Kuramoto-Sivashinsky equation, which models propagating flames:



* Lyapunov time = Length of time before a small difference in the system's initial state begins to diverge exponentially. It typically sets the horizon of predictability, which varies from system to system.

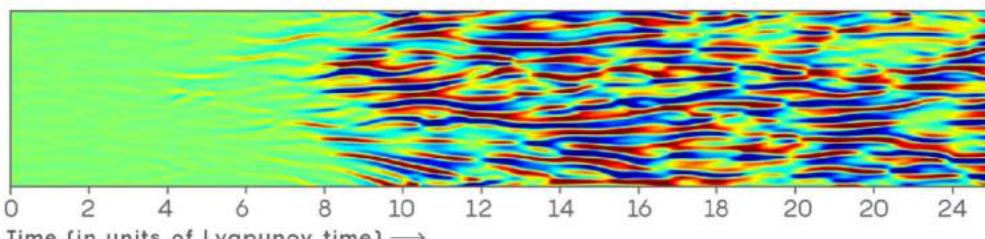
B Machine Learning

After training itself on data from the past evolution of the Kuramoto-Sivashinsky system, the "reservoir computing" algorithm predicts its future evolution:



A - B Do They Match?

Subtracting B from A shows that the algorithm accurately predicts the model out to an impressive 8 Lyapunov times, before chaos ultimately prevails:



Other applications

Machine translation ([link](#))

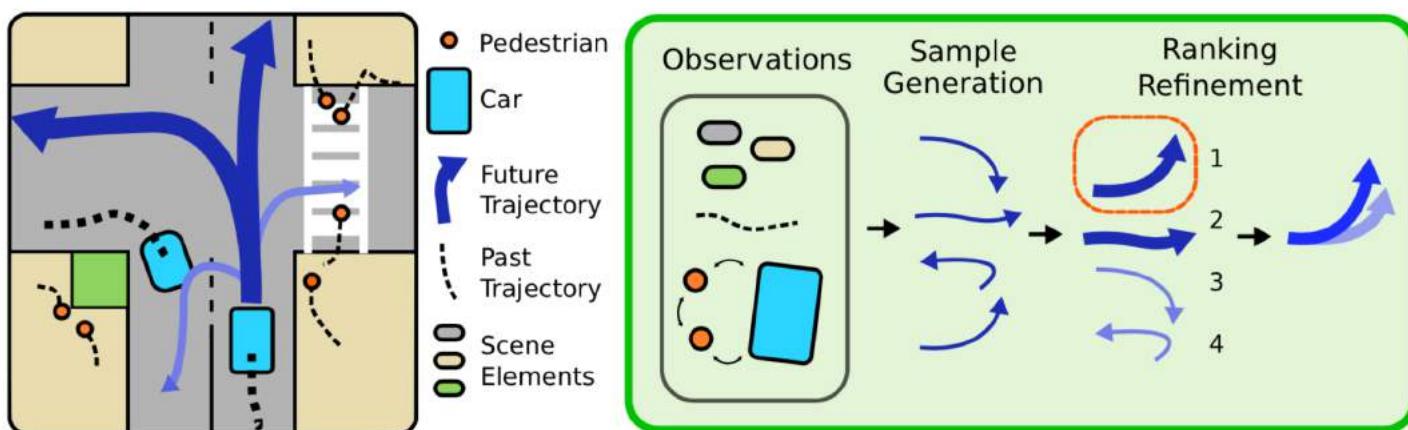
Vaswani et al. 2017, Attention Is All You Need



(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

OpenAI ([link](#))

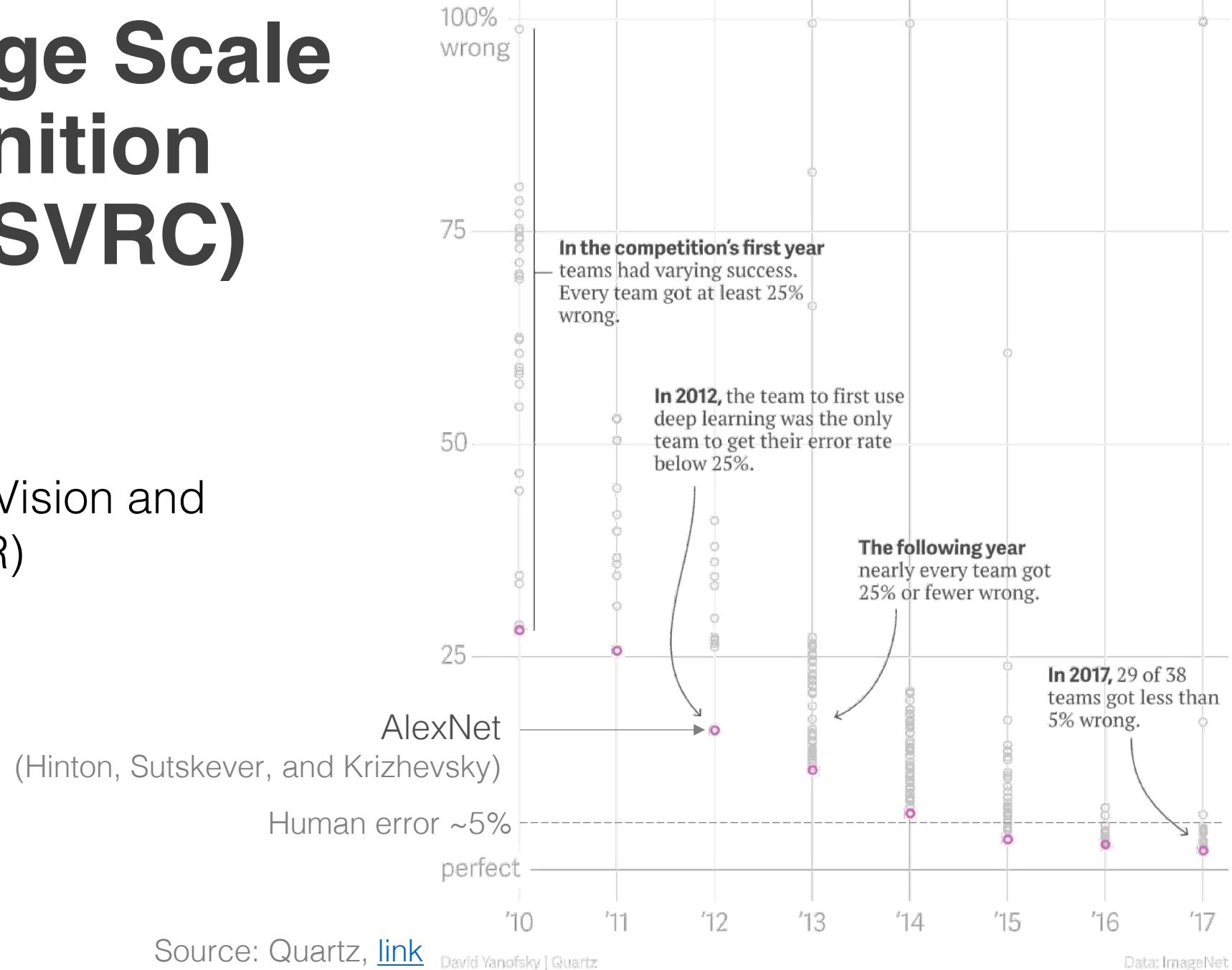
OpenAi Gym is a toolkit for developing and
comparing reinforcement learning algorithms



ImageNet Large Scale Visual Recognition Challenge (ILSVRC)

Fei-Fei Li et al. 2010 ([link](#))

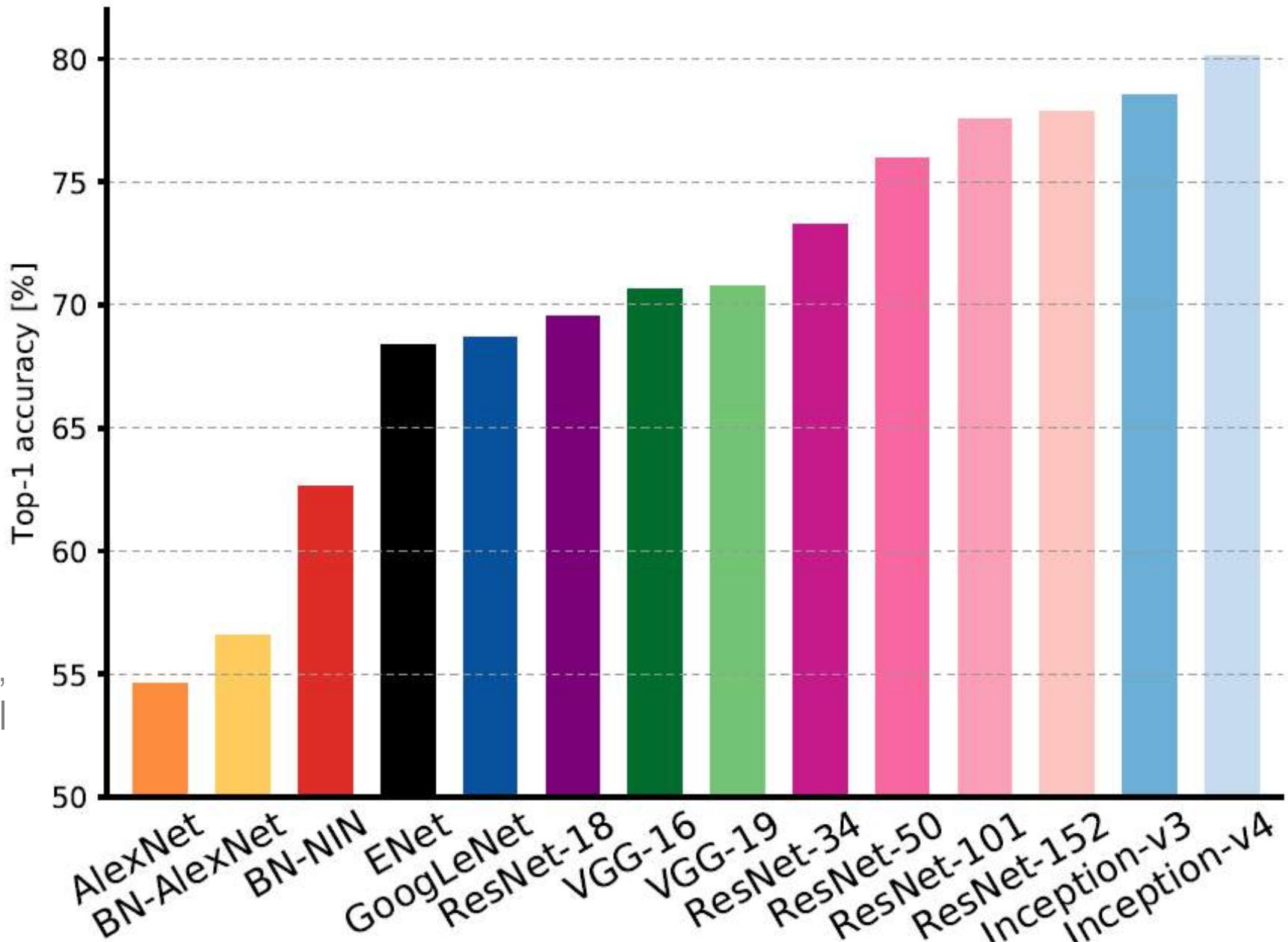
Competition at:
Conference on Computer Vision and
Pattern Recognition (CVPR)



Comparison of deep learning techniques

On the ImageNet data

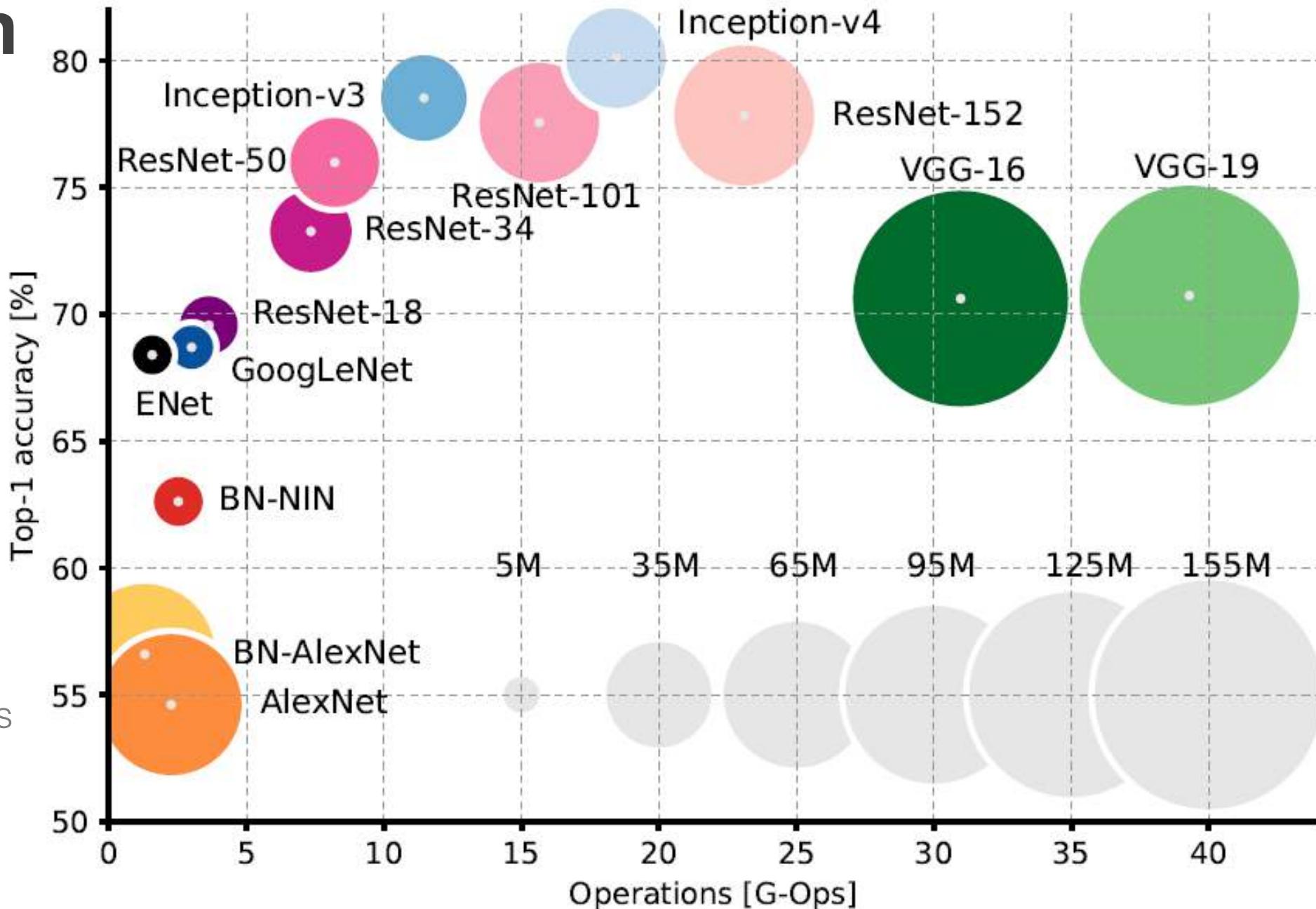
Canziani, Culurcillo, and Paszke,
2017, An analysis of deep neural
network models for practical
applications ([link](#))



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

©2016 Fjodor van Veen - asimovinstitute.org

○ Backfed Input Cell

○ Input Cell

● Hidden Cell

○ Probabilistic Hidden Cell

○ Output Cell

○ Match Input Output Cell

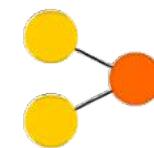
● Recurrent Cell

○ Memory Cell

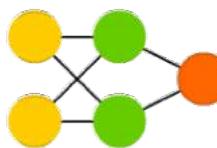
● Kernel

○ Convolution or Pool

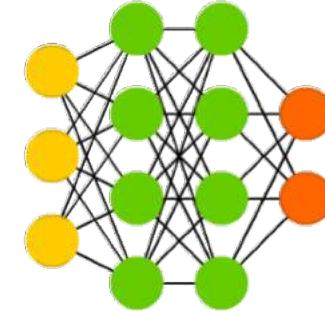
Perceptron (P)



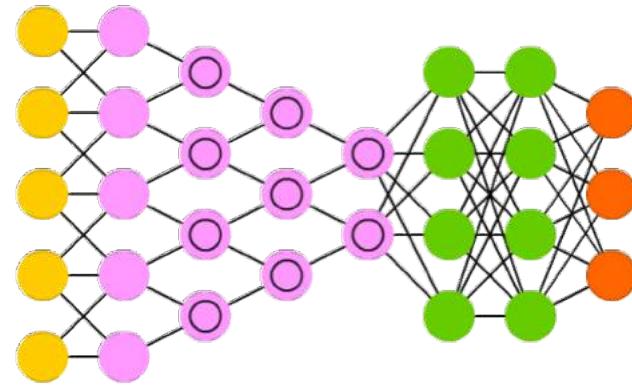
Feed Forward (FF)



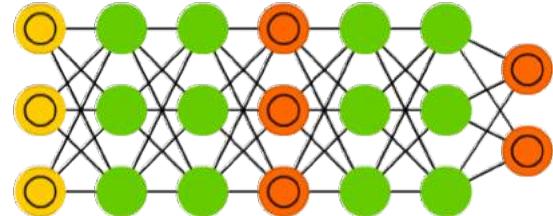
Deep Feed Forward (DFF)



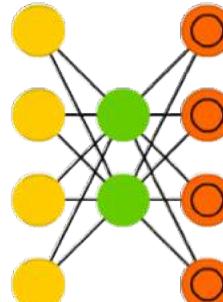
Deep Convolutional Network (DCN)



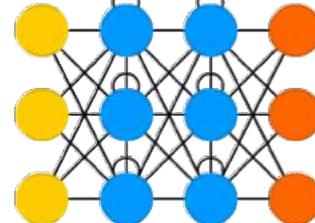
Generative Adversarial Network (GAN)



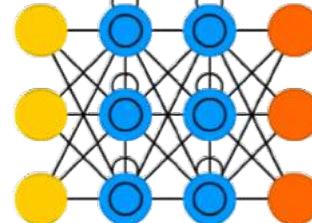
Auto Encoder (AE)



Recurrent Neural Network (RNN)



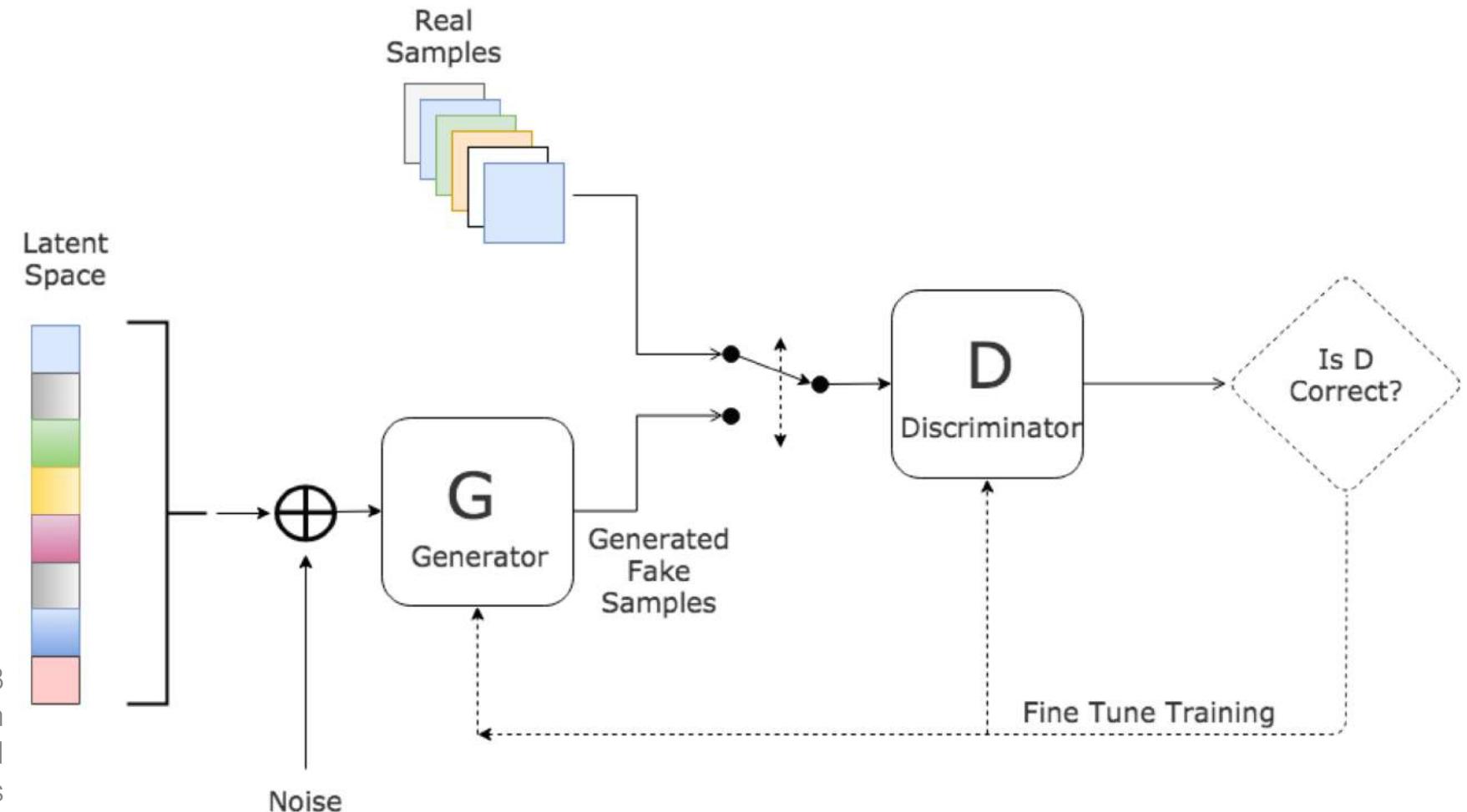
Long / Short Term Memory (LSTM)



Generative Adversarial Networks

Hitawala 2018
Comparative Study on
Generative Adversarial
Networks

Generative Adversarial Nets ([link](#))
Goodfellow et al. 2014

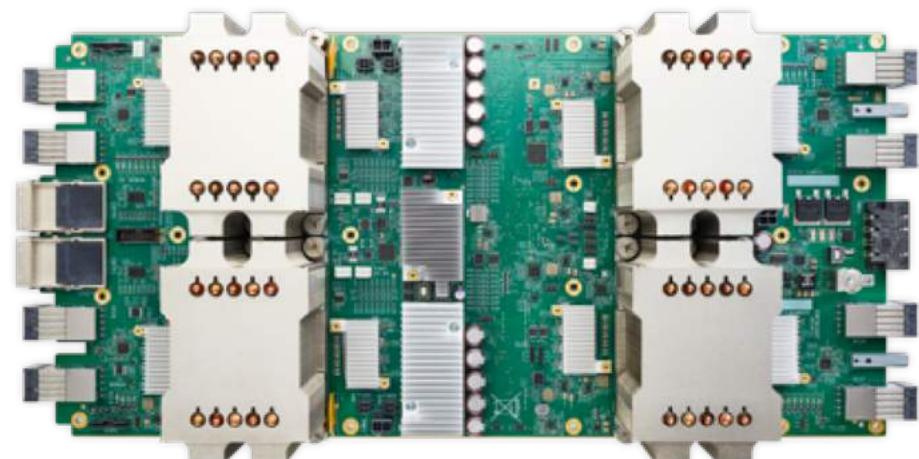


Hardware

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

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](#))

Arxiv ([link](#)) (Arxiv sanity-preserved)

The screenshot shows the homepage of the Arxiv Sanity Preserver. At the top, there is a login form with fields for 'User:' and 'Pass:', and buttons for 'Login' and 'Create'. Below the login is a banner stating 'Arxiv Sanity Preserver' and 'Built in spare time by @karpathy to accelerate research. Serving last 45499 papers from cs.[CV|CL|LG|AI|NE]/stat.ML'. A 'Fork me on GitHub' button is in the top right corner. A green header bar at the top has the text 'New to arxiv-sanity? Check out the [introduction video](#)'. Below the header is a search bar with a magnifying glass icon. Underneath the search bar is a row of buttons for filtering results: 'most recent' (which is highlighted in blue), 'top recent', 'top hype', 'friends', 'discussions', 'recommended', and 'library'. To the right of these buttons is a link 'Only show v1'. A purple bar below the buttons says 'Showing most recent Arxiv papers:'. Below this, a single research paper is previewed. The title is 'Automatic Prediction of Building Age from Photographs' by Matthias Zeppelzauer, Miroslav Despotovic, Muntaha Sakeena, David Koch, and Mario Döller. It was submitted on 4/19/2018 (v1: 4/6/2018) and is listed under cs.CV. The preview shows the abstract, authors, and several thumbnail images of building photographs.

Jeffrey Hinton
Google &
U. of Toronto

Backpropagation for
neural nets. Won
ImageNet
Competition in 2012.



Image: Toronto Star

Yann LeCunn
Facebook & NYU

Creator of the LeNet,
Optical Character
Recognition, and
CNNs



Image: Facebook Research

Fei-Fei Li
Stanford Artificial
Intelligence Lab

Creator of ImageNet,
works in computer
vision



Image: Twitter

Andrew Ng
Baidu & Stanford

Founder of Google
Brain, co-founder of
Coursera



Image: Twitter

Yoshua Bengio
Université de
Montréal

Deep learning expert



Image: Université de Montréal

David Silver
DeepMind

Deep reinforcement
learning



Image: Business Insider UK

Andrej Karpathy
Tesla (formerly
OpenAI)

CNNs for computer
vision and natural
language processing



Image: Stanford

Ian Goodfellow
Google Brain

Creator of generative
adversarial networks



Image: Michael Dukakis Institute

**People to know &
read about in
Machine Learning**

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