Lecture 01

Introduction to Machine learning

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Agenda

Brief history of technological revolutions

Future technologies

Definitions

Formulation of the problem

Definitions

ML applications

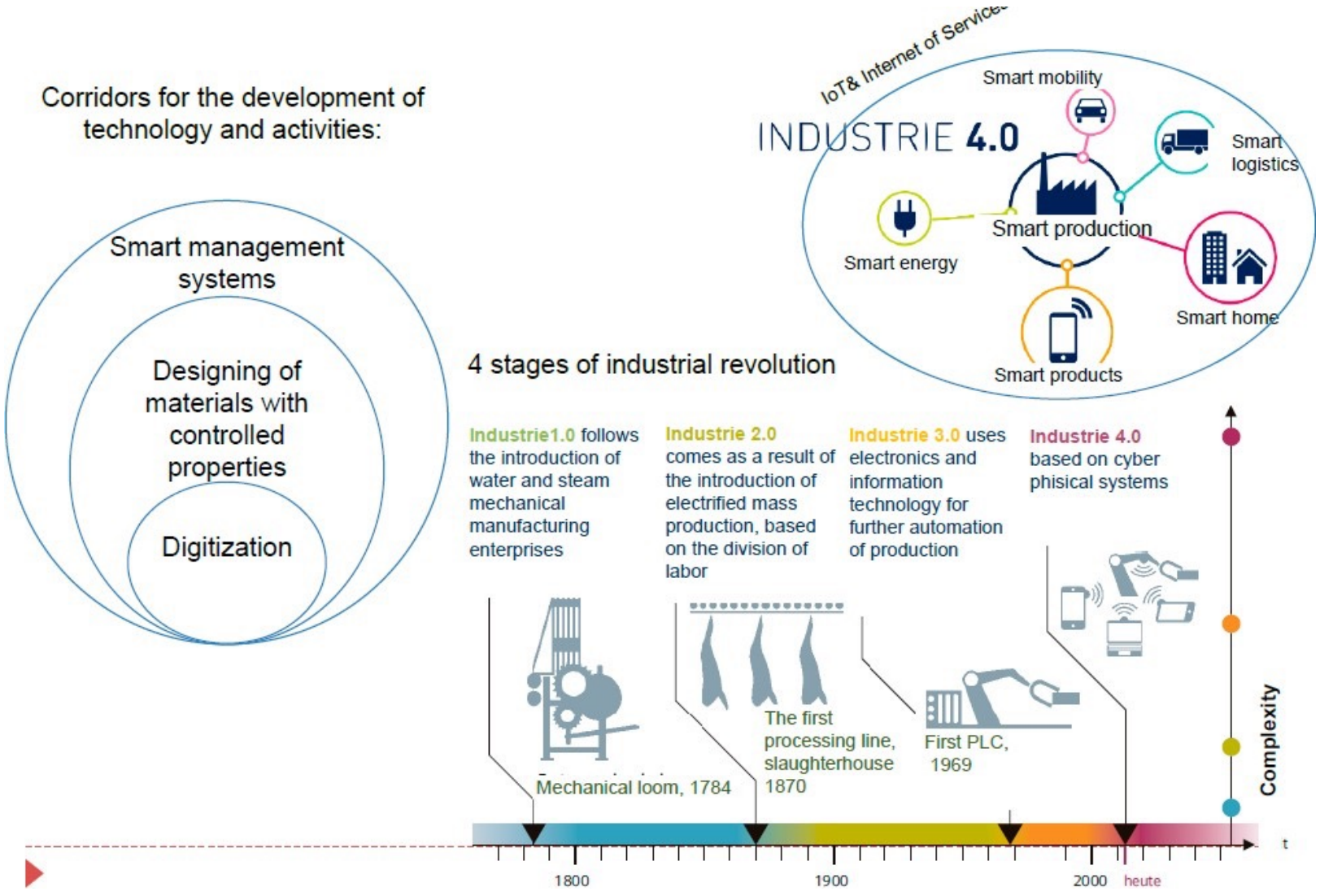
Methods of ML

Industrial revolutions

	«I» IR XVII century	II IR XVIII – XIX	III IR XIX – XX	IV IR XXI
Technologies	▸ wood ▸ peat burn ▸ wind energy	▸ Iron, steel ▸ coal burn ▸ steam ▸ surgery, anesthesia ▸ agriculture machines	▸ plastic ▸ oil, electricity ▸ cars, airplains ▸ satellites ▸ antibiotics, early diagnosis ▸ mineral fertilizers	▸ 3D printing & materials ▸ thin films ▸ clean energy ▸ robots ▸ small satellites ▸ organic agriculture
	 	 	  	 
	Netherlands	*England*	*USA*	

[1] http://www.tv2.tomsk.ru/sites/www.tv2.tomsk.ru/files/mobil.jpg

Industry 4.0


Corridors for the development of technology and activities:
Smart management systems
Designing of materials with controlled properties
Digitization
IoT& Internet of Services
INDUSTRIE 4.0
Smart mobility
Smart logistics
Smart production
Smart energy
Smart home
Smart products
4 stages of industrial revolution
Industrie1.0 follows the introduction of water and steam mechanical manufacturing enterprises
Industrie 2.0 comes as a result of the introduction of electrified mass production, based on the division of labor
Industrie 3.0 uses electronics and information technology for further automation of production
Industrie 4.0 based on cyber phisical systems
Mechanical loom, 1784
The first processing line, slaughterhouse 1870
First PLC, 1969
Complexity
t
1800
1900
2000
heute

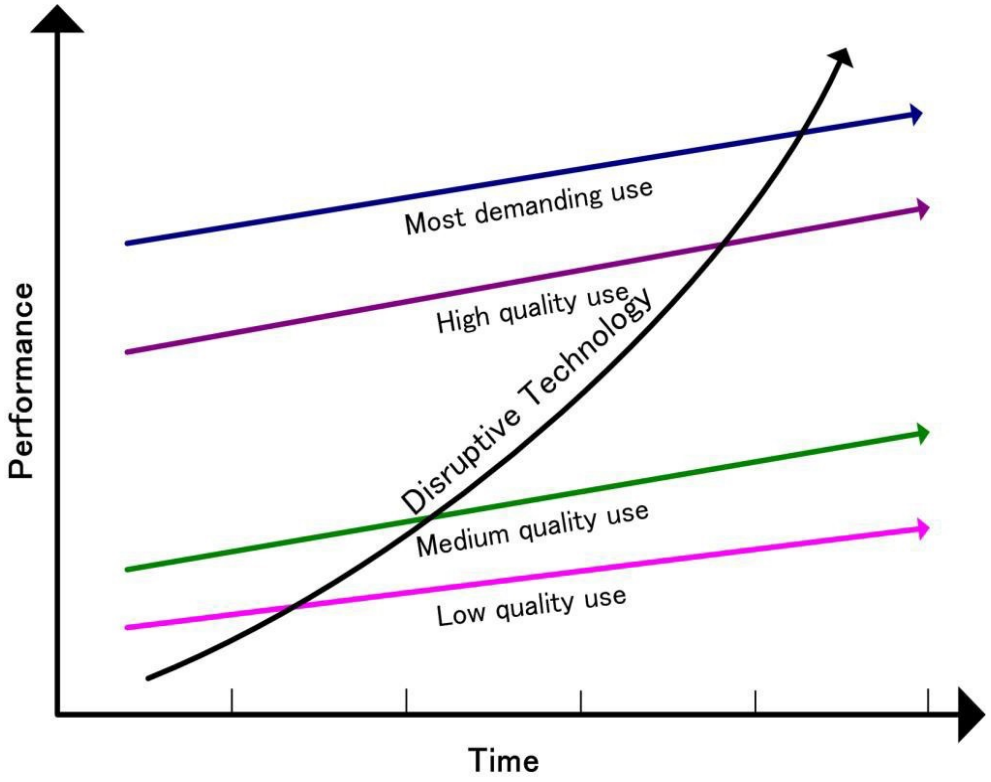
Labor productivity

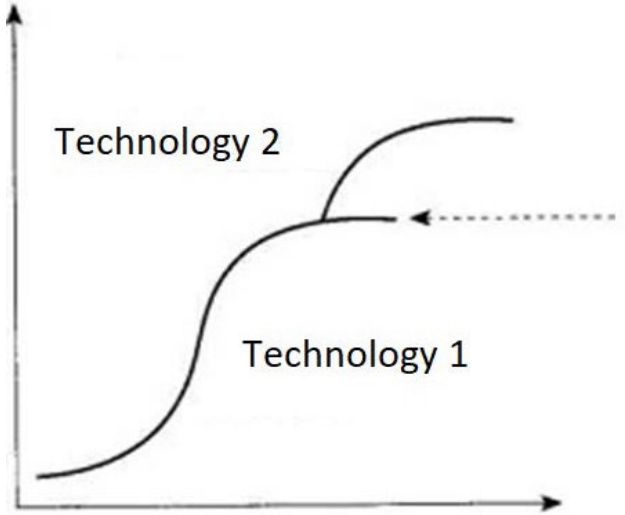
Assessment of the growth of labor productivity from the development of new technologies in production

Steam engine	Early robotics	IT	Robots, AI, ML
1850-1910	1993-2007	1995-2005	2015-2065
Growth in labor productivity per year			
0,3%	0,4%	0,6%	0,8 - 1,4%

[1] McKinsey & Company, http://www.mckinsey.com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works

Disruptive technologies

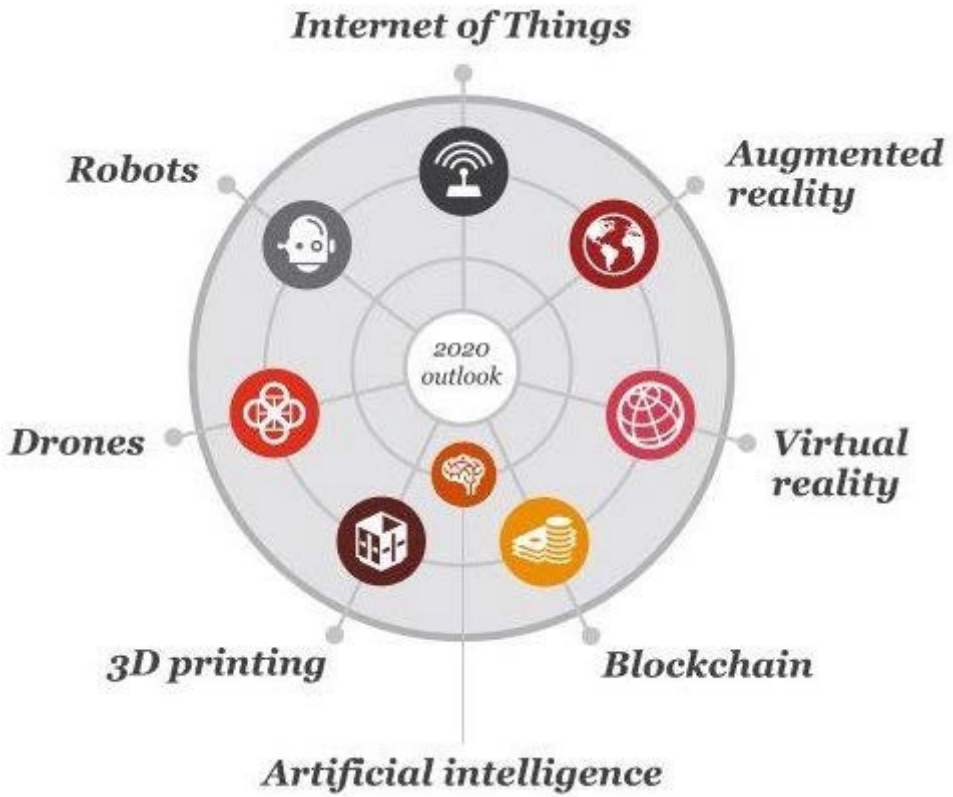




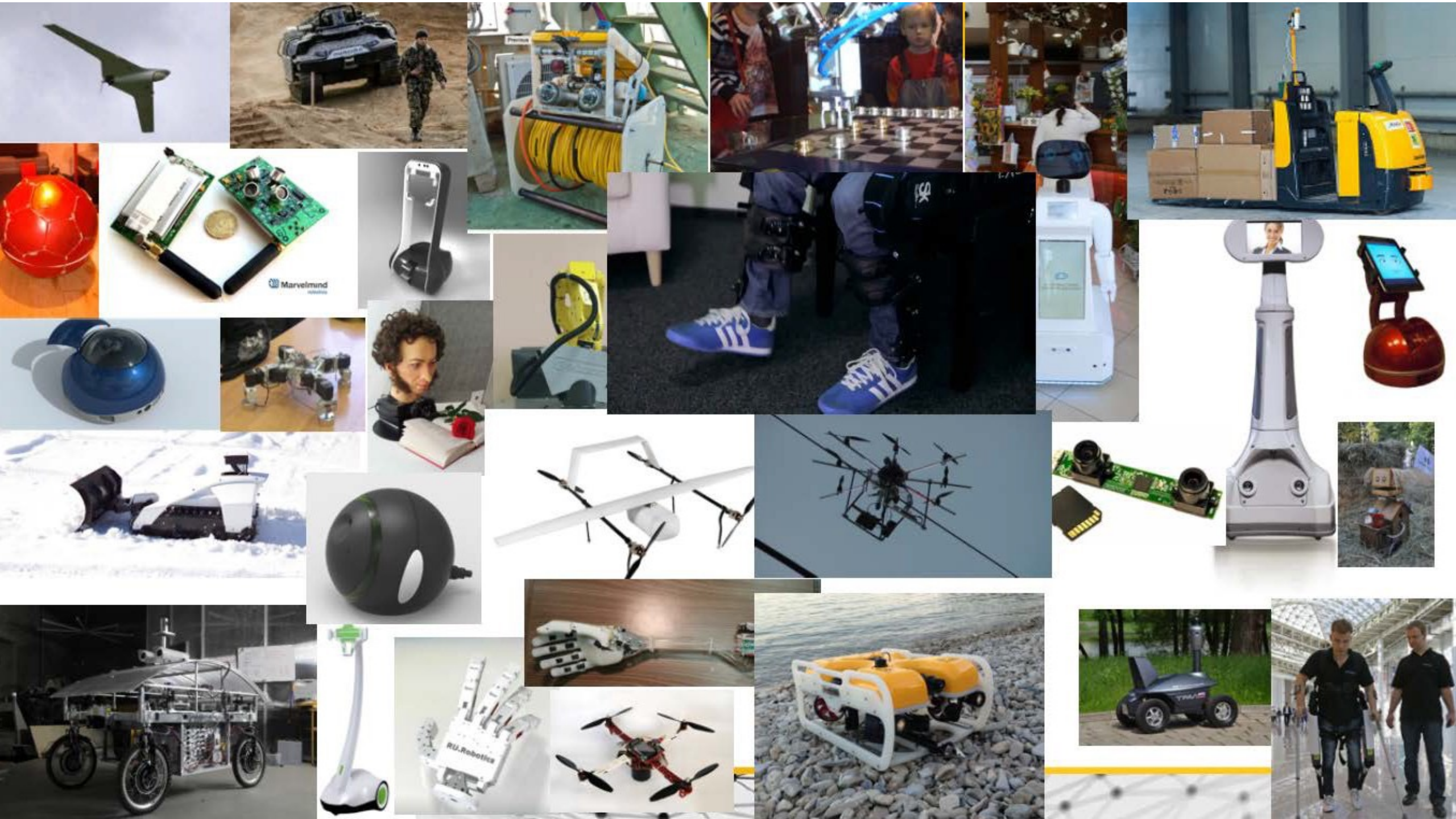
Clayton Cristensen

Problems of transformation

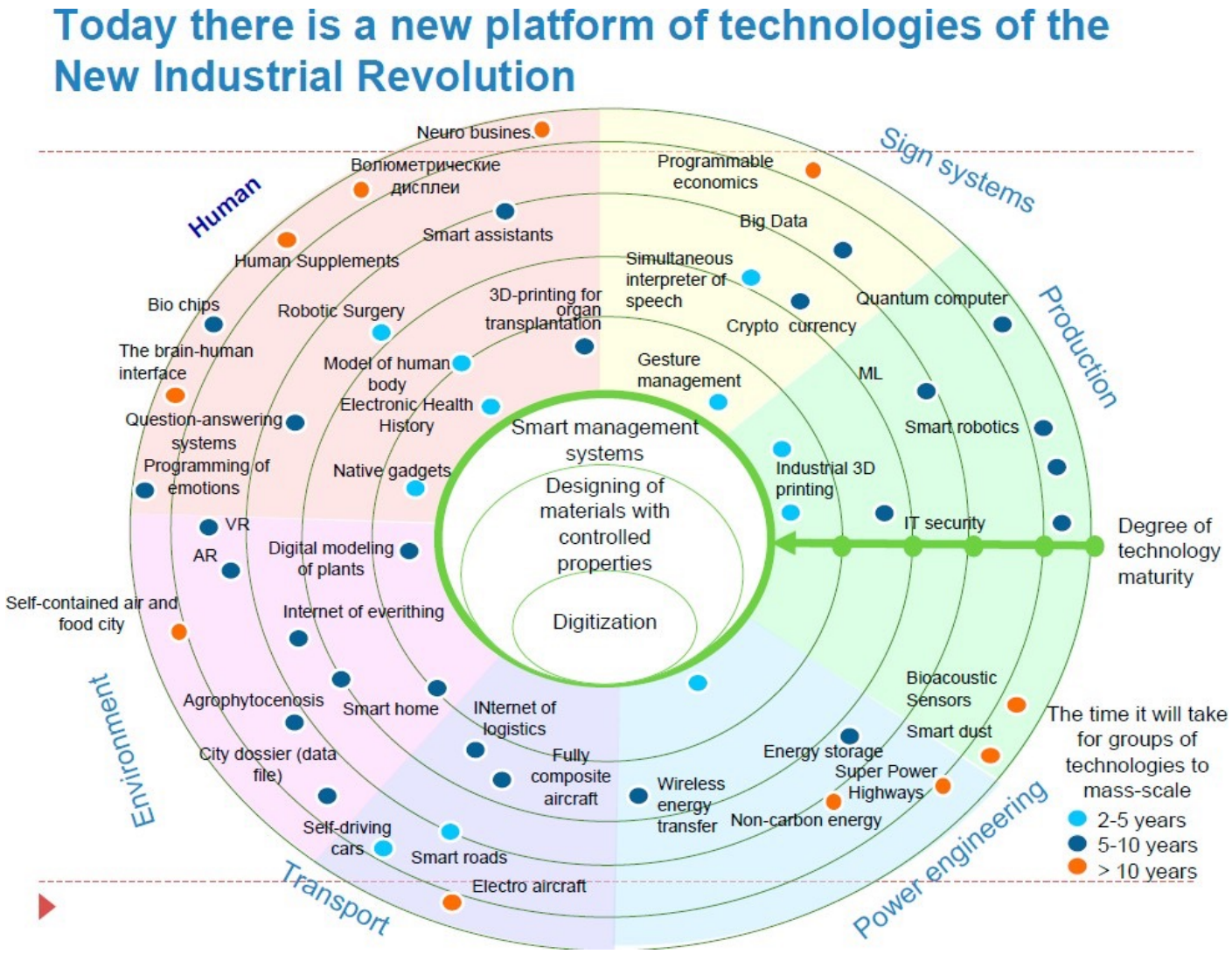
The essential 8 technologies



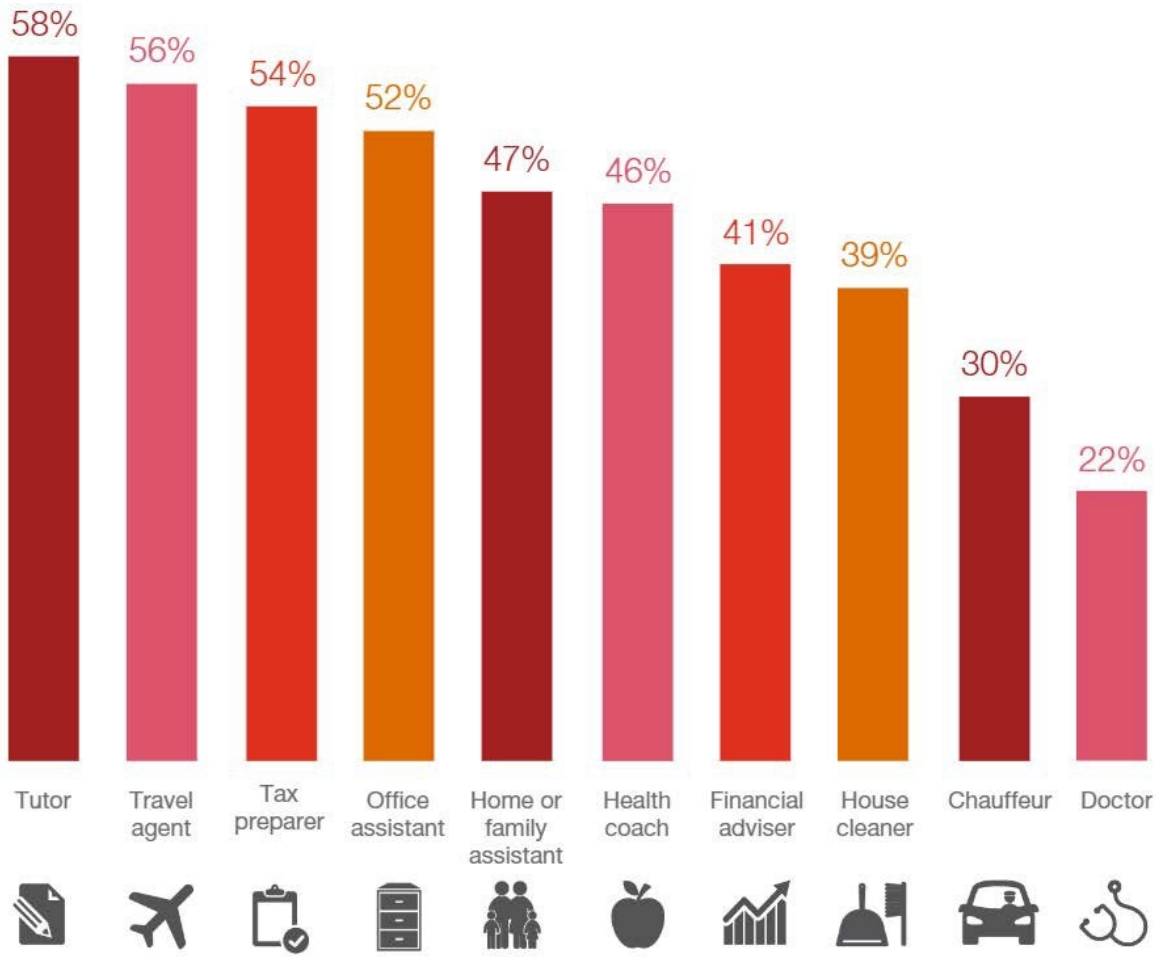
https://pwc.blogs.com/ceoinsights/2016/08/a-guide-to-the-essential-eight-emerging-technologies.html


Marvelmind
RU.Robotics

Modern technologies



"In the next five years, I can see AI replacing humans as a..."



http://pwcartificialintelligence.com/

AI winter & spring

1940—1960: first neural networks

1970—1990: «winter of AI»

1980—2000: algorythms for the second AI spring

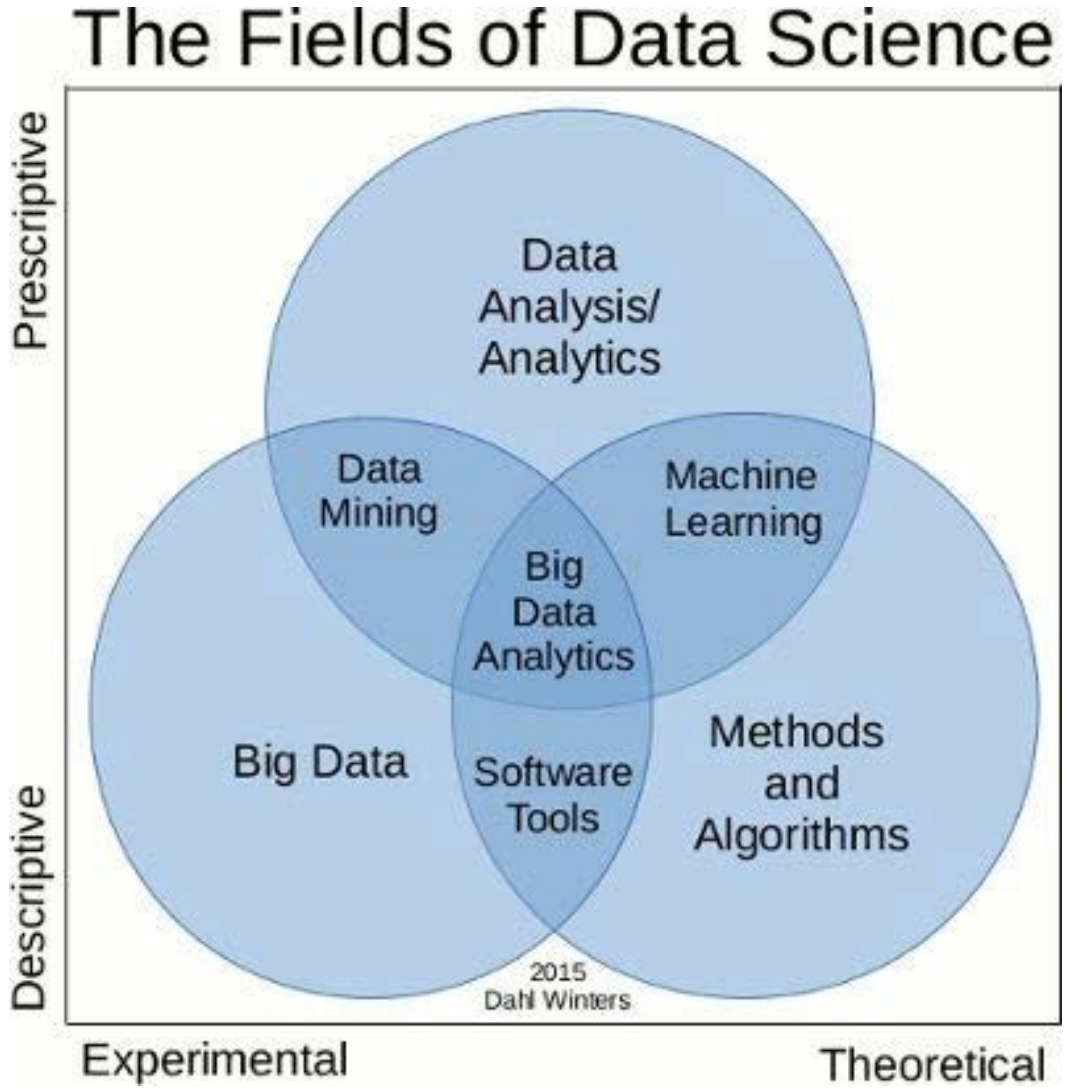
2010+ — spectacular examples of AI

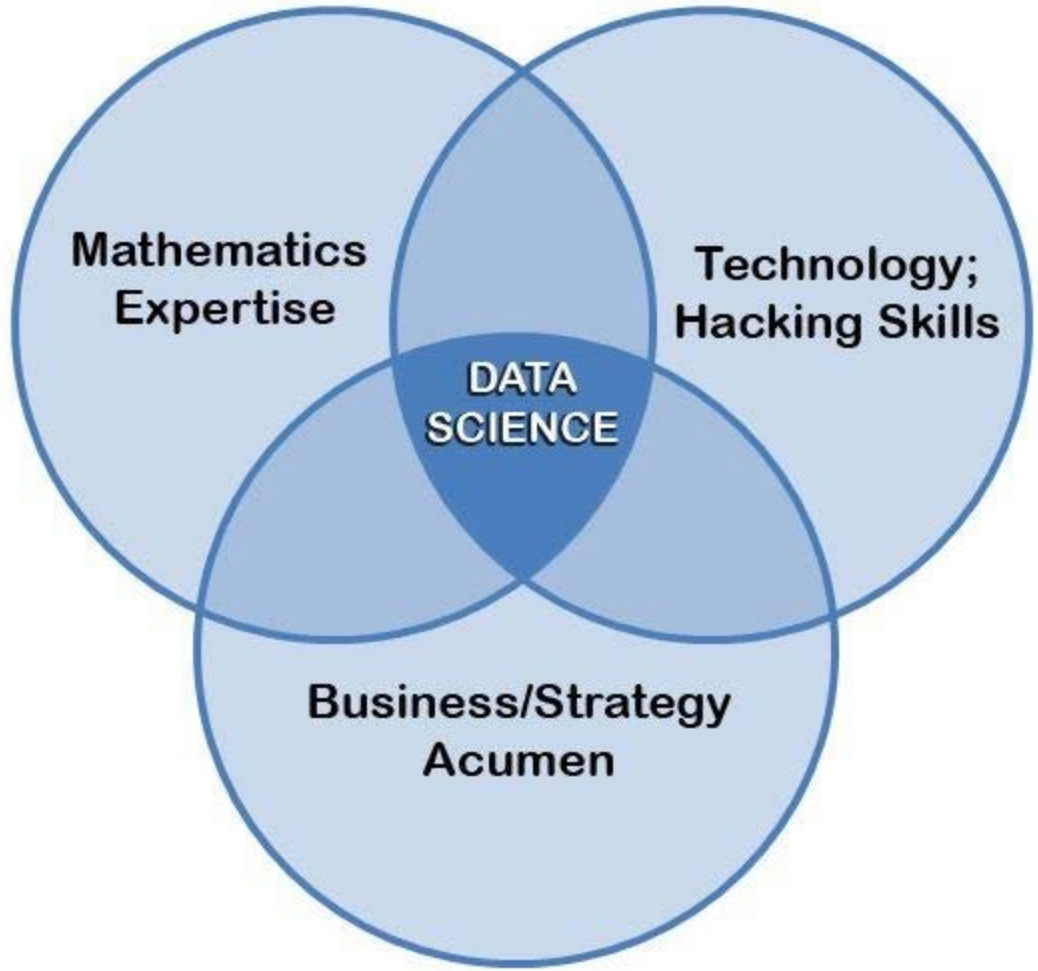
2016+ — investment and media boom

ML definition

Machine Learning:

- Machine learning is a topic of an artificial intelligence, a mathematical discipline that uses mathematical statistics, numerical optimization methods, probability theory, discrete analysis, to extract knowledge from data.
- Field of study that gives computers the ability to learn without being explicitly programmed. (Arthur Samuel, 1959)


The Fields of Data Science
Prescriptive
Descriptive
Experimental
Theoretical
Data Analysis/ Analytics
Data Mining
Machine Learning
Big Data Analytics
Big Data
Software Tools
Methods and Algorithms
2015
Dahl Winters


Mathematics
Expertise
Technology;
Hacking Skills
DATA
SCIENCE
Business/Strategy
Acumen

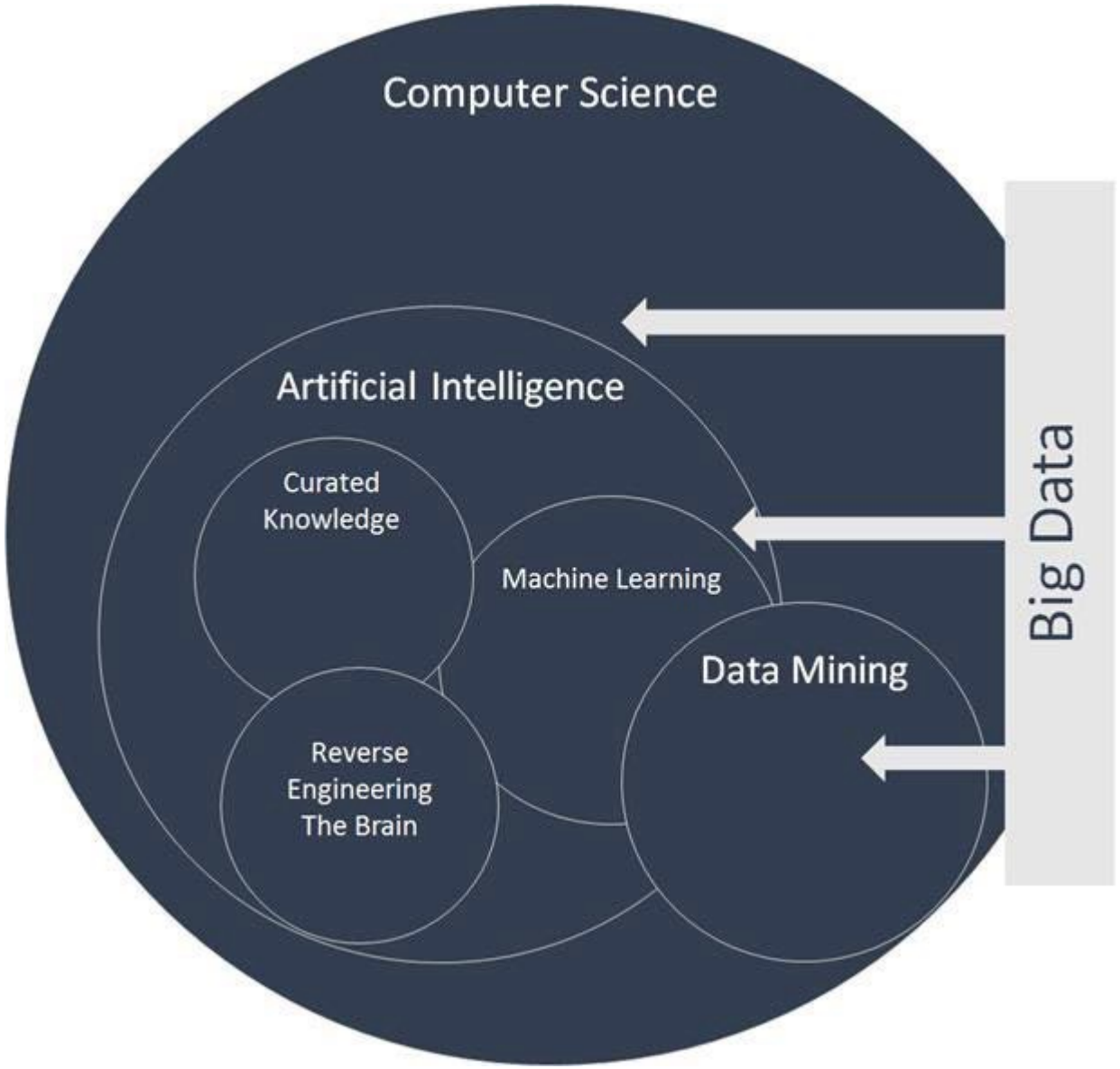
Data mining key features

- Data can be inaccurate, incomplete, heterogeneous, indirect, and at the same time have huge volumes;
- Data analysis algorithms themselves may have the ability to learn from precedents;
- Processes of raw data processing into information require non-trivial automation.

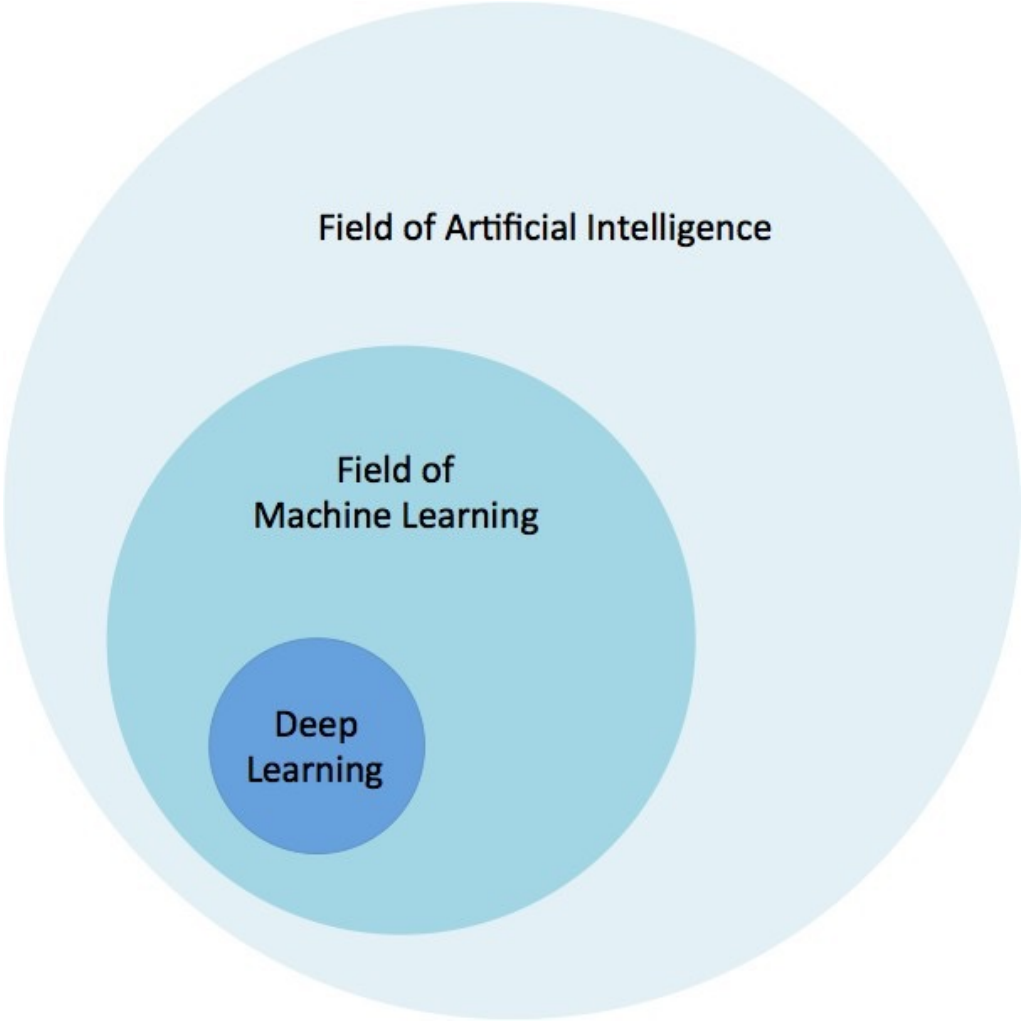
Data mining key features

Over the past decades, significant efforts in the field of Data Mining have focused on the creation of specialized algorithms capable of performing the same tasks during linear or even logarithmic time without significant loss of accuracy.

Data mining key features



Data mining key features



Data mining key features

A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E.

(T. Mitchell)

Data mining key approaches

There are two types of learning:

- Precedent training
- Deductive training

Data mining key features

The purpose of precedent training is to generalize or gain knowledge about the "law of nature."

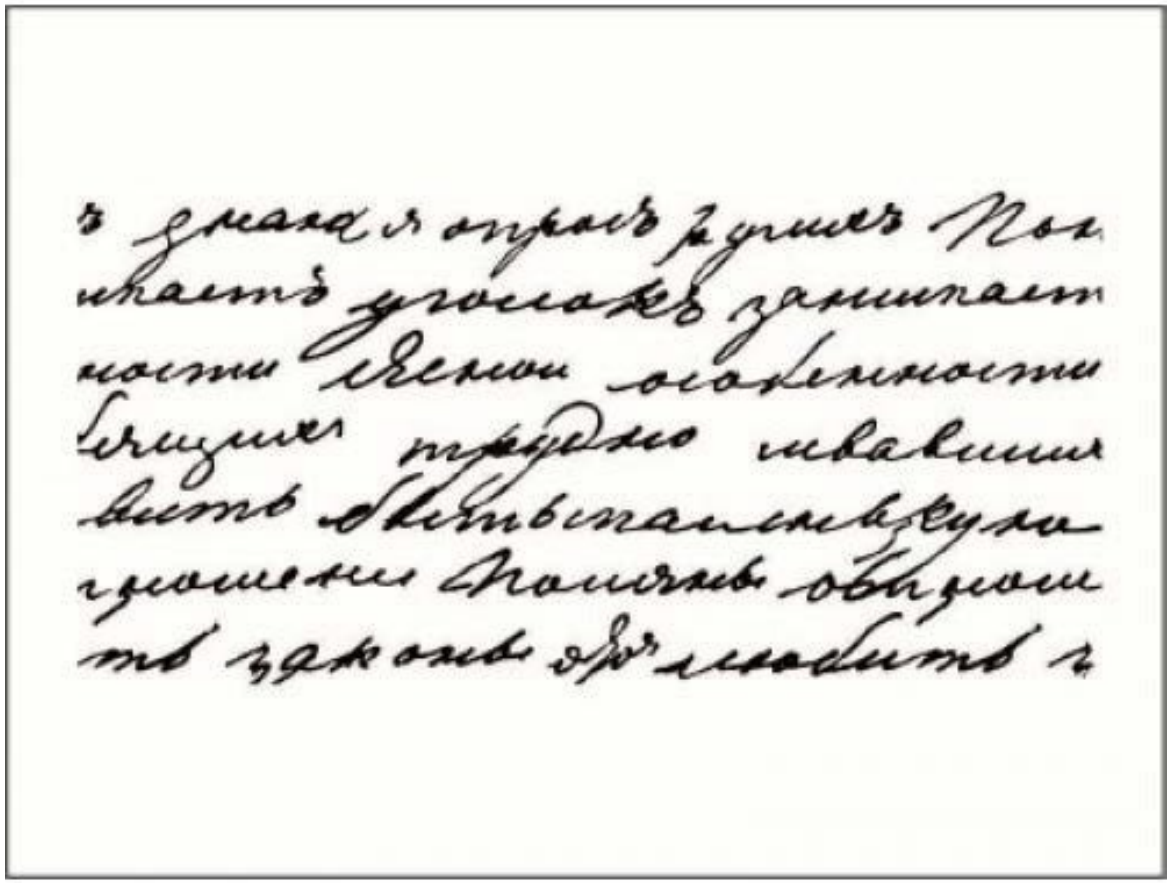
Data mining key features

SPHINX OF BLACK QUARTZ JUDGE MY VOW

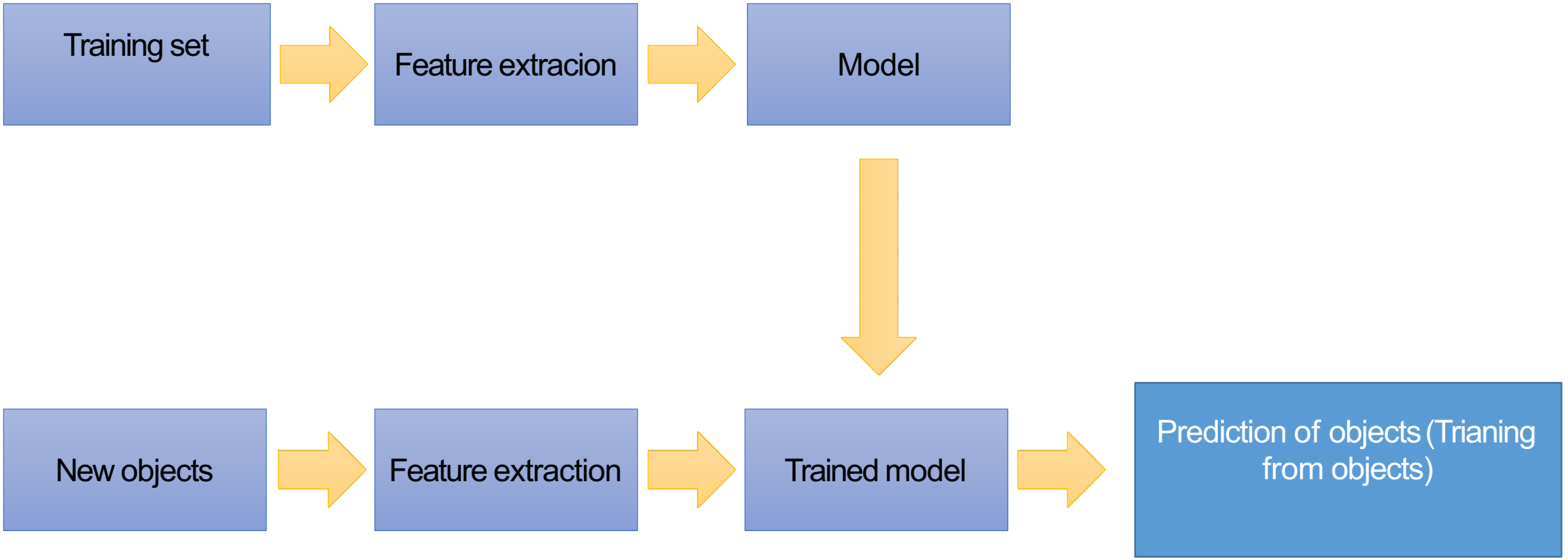
Sphinx of black quartz judge my vow

ABCDEFGHabcdefhg

0123456789/!@#$%



Data mining key features



ML task definition

Machine learning:

- What is an object X(what features) and what is an answer Y?
- How to build a model M?
- How can we make an approximation of Y from X with M?

ML task definition

Input data types:

- Image
- Text
- Sound
- GEO data
- Timeseries
- Datasheet

Generalization

Generalization error (also known as the **out-of-sample error**) is a measure of how accurately an algorithm is able to predict outcome values for previously unseen data

In a learning problem, the goal is to develop a function $f(x)$ that predicts output values y based on some input data x. The expected error, $I[f_n]$ of a particular function f_n over all possible values of x and y is:

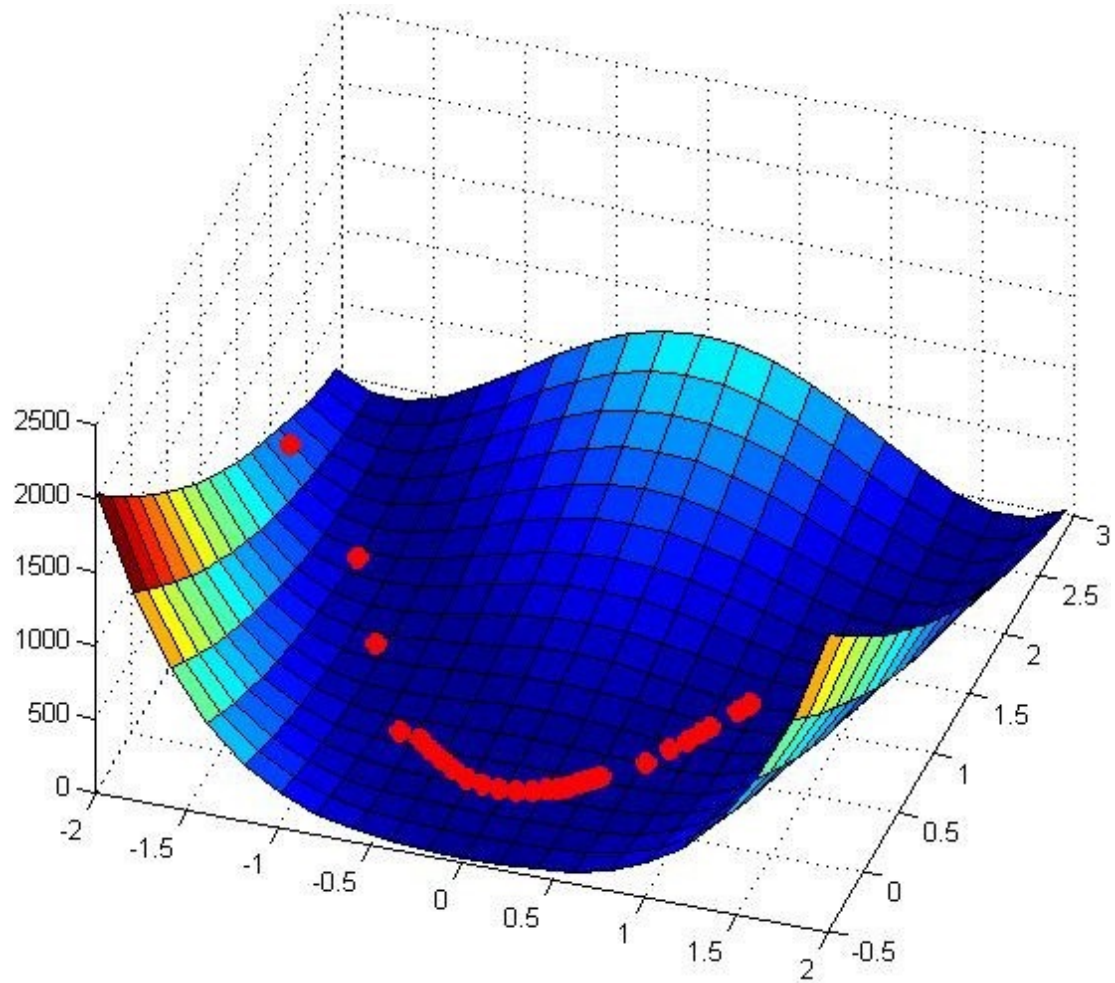
$$I[f_n] = \int_{X \times Y} V(f_n(x), y) \rho(x, y) dx dy,$$

where V denotes a loss function and $\rho(x, y)$ is the unknown joint probability distribution for x and y.

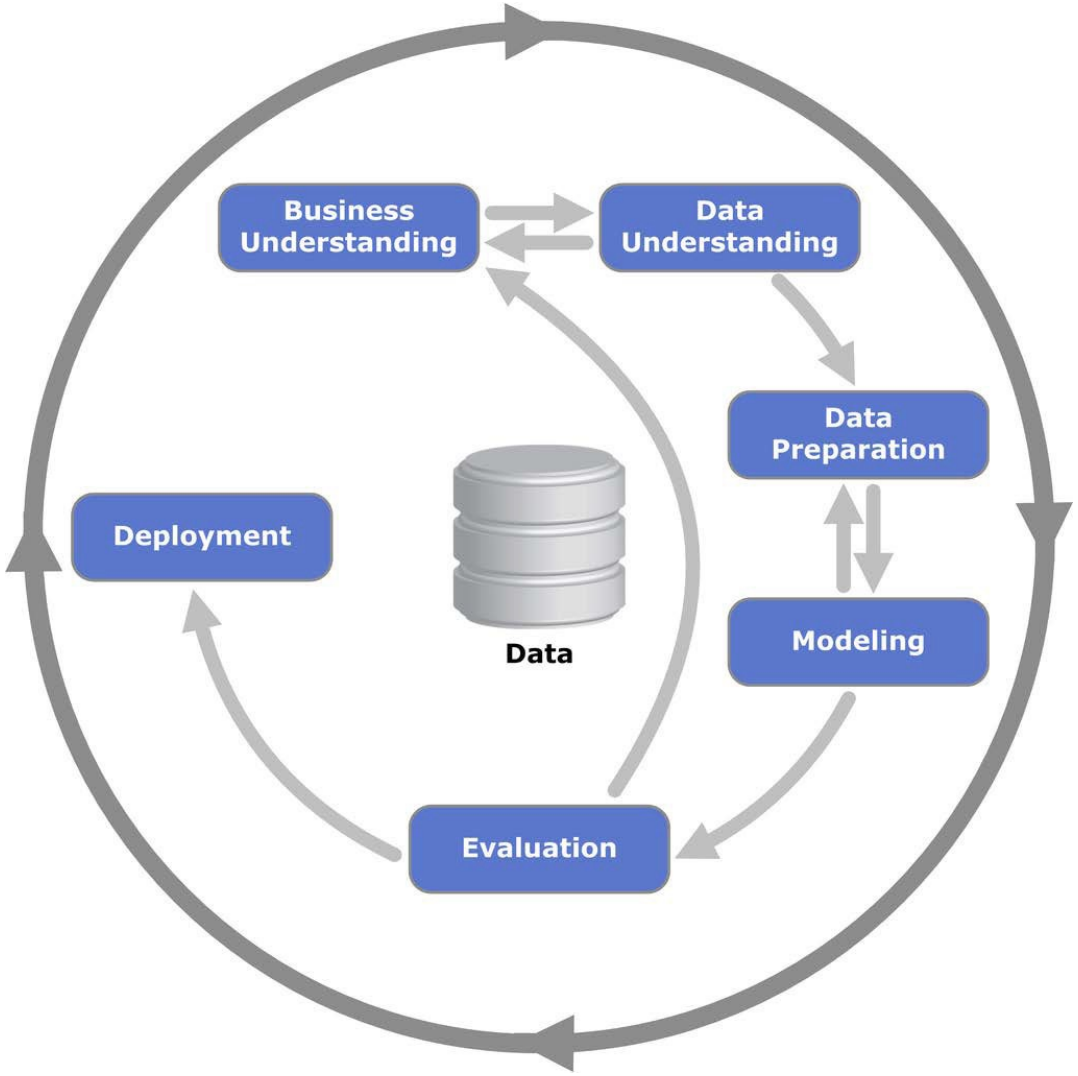
Without knowing the joint probability distribution, it is impossible to compute $I[f]$. Instead, we can compute the empirical error on sample data. Given n data points, the empirical error is:

$$I_S[f_n] = \frac{1}{n} \sum_{i=1}^{n} V(f_n(x_i), y_i)$$

Gradient descent



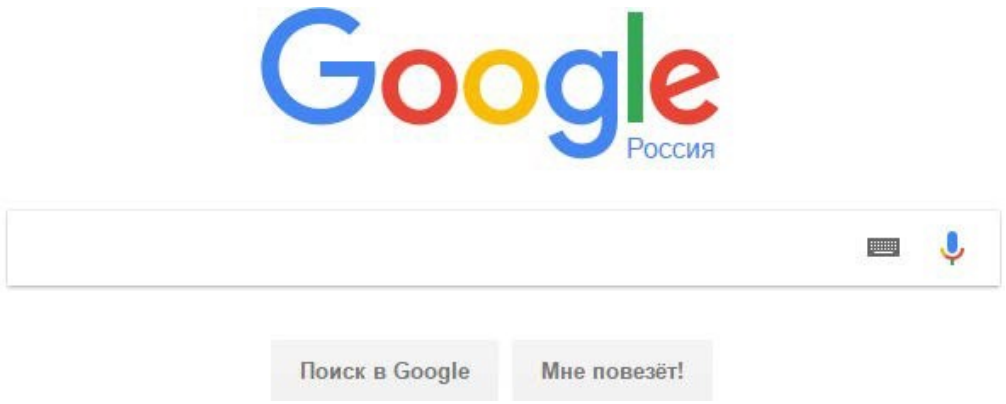
CRISP-DM methodology

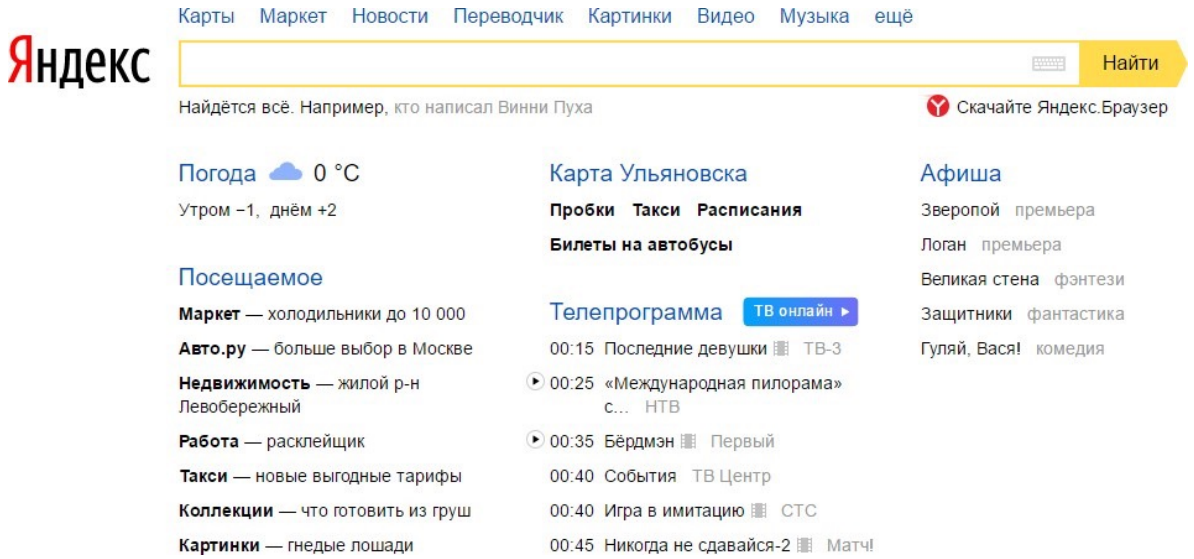


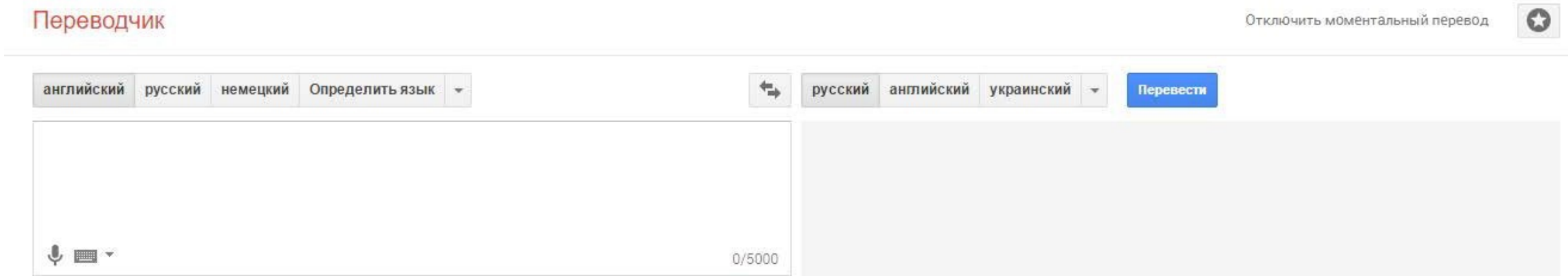
Appliances of ML

Automation control	Bioinformatics	Stock technical analysis	Image generation	Speech generation
Text generation	Categorizing documents	Credit scoring	Medical diagnosis	Detection of fraud
Spam detection	Learning ranking in information search	Searching potential customers	Predicting customer care	Decision-making
Predicting time series	Gesture recognition	Image recognition	Speech recognition	Pecognition of handwriting
Recognition of physical activity	Technical diagnostics	Financial supervision	Chemoinformatics	

ML application

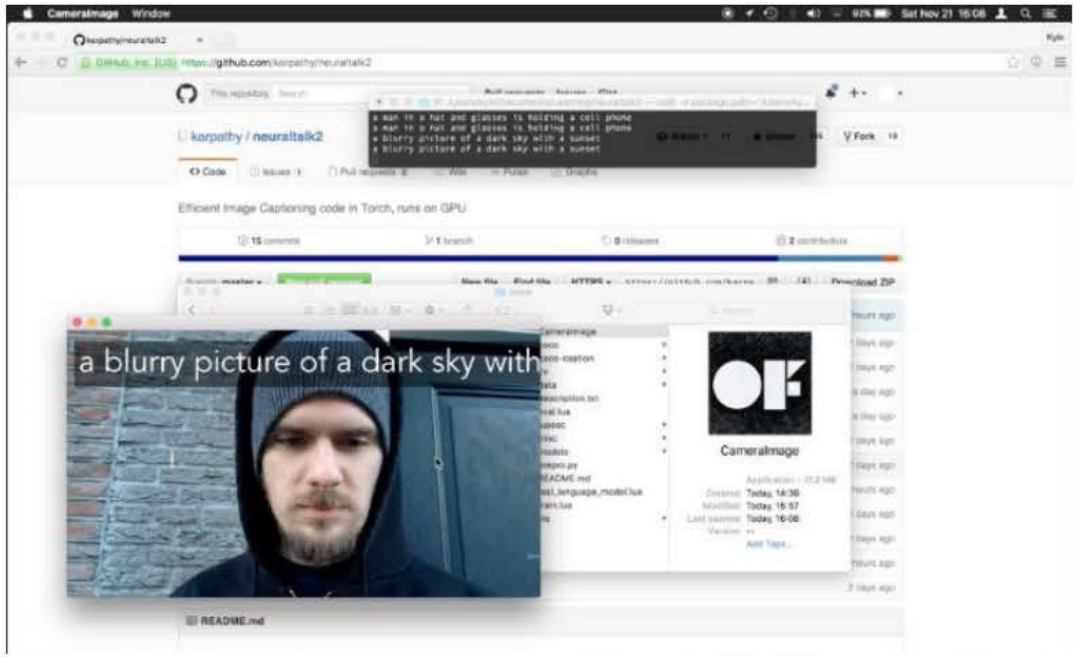






ML application

NeuralTalk




a man is playing tennis on a tennis court


a train is traveling down the tracks at a train station


a cake with a slice cut out of it


a bench sitting on a patch of grass next to a sidewalk

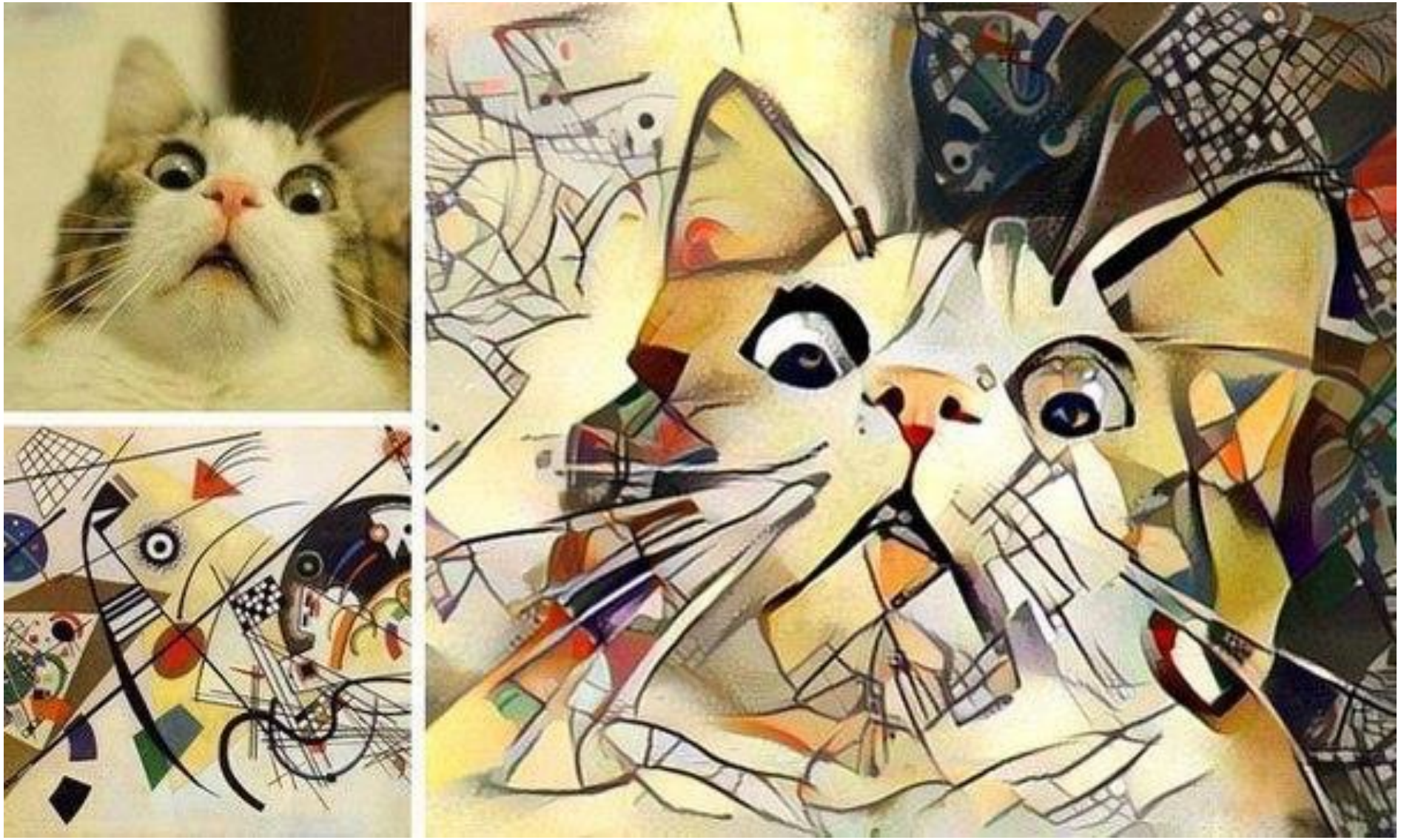
https://github.com/karpathy/neuraltalk2

https://vimeo.com/14649200

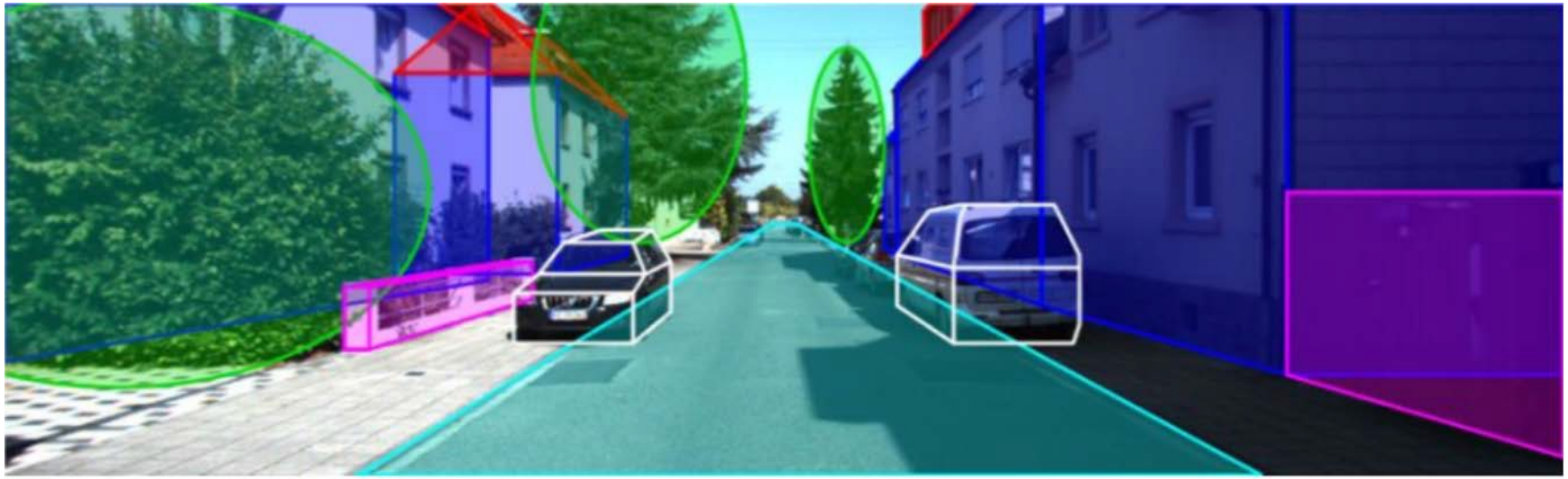
ML application

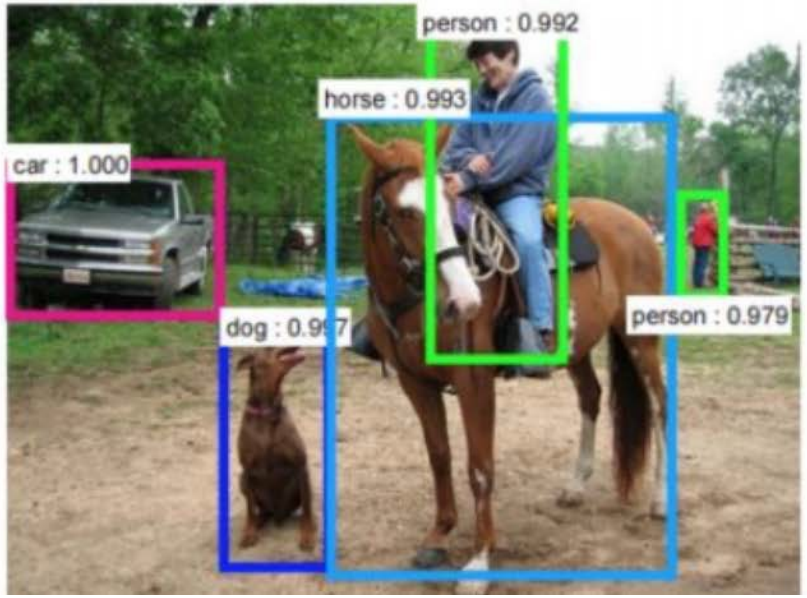
ML application

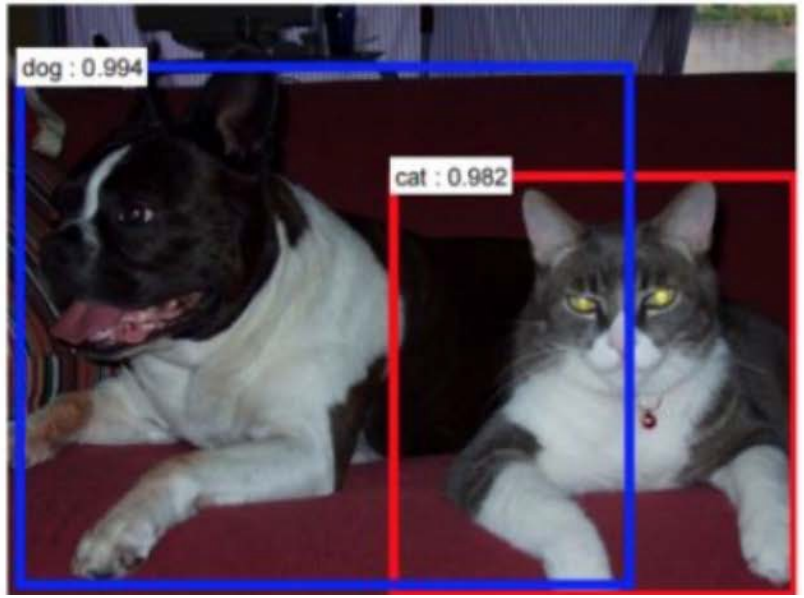
ML application. Generative models



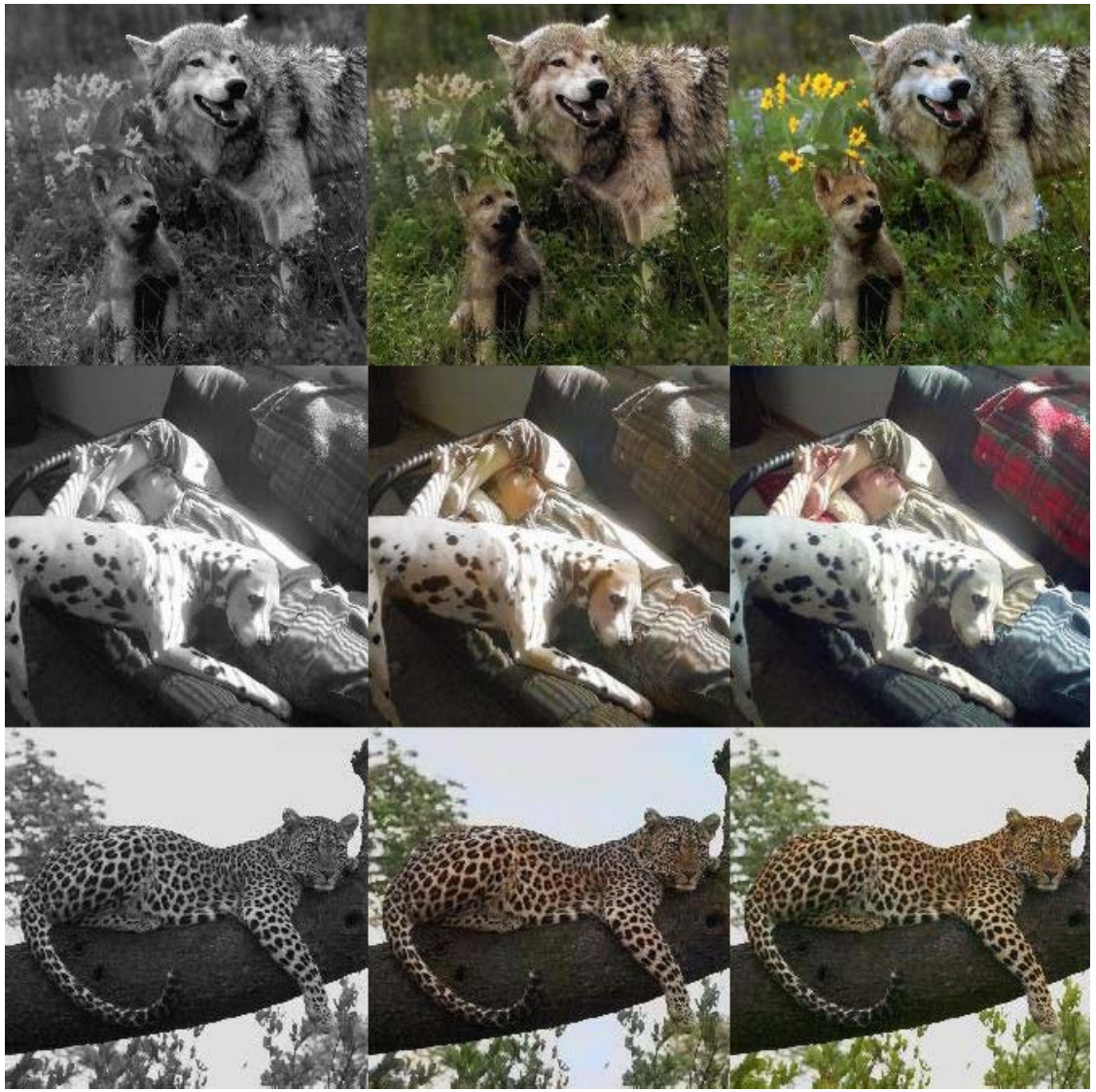
ML application







ML application. Colorization



ML applications. Labeling

"girl in pink dress is jumping in air."

"black and white dog jumps over bar."

"young girl in pink shirt is swinging on swing."

"man in blue wetsuit is surfing on wave."

"little girl is eating piece of cake."

"baseball player is throwing ball in game."

"woman is holding bunch of bananas."

"black cat is sitting on top of suitcase."

Transport systems

Route planning
Logistic control
Robotization

Energy

Planning and management of production and distribution of energy
Consumption management

Medical care

Automation of primary diagnostics
Decision making for diagnoses, treatment and follow-up
Medical data mining
Medical robots
Epidemic forecast
Genetic analysis

Financial services

Forecasting
Antifraud
Credit scoring
Management of risks
Professional bank assistants

E-commerce

Demand forecasting
Demand management and recommend systems
Logistics

Agriculture

Monitoring (global)
Farming
Robotization of agricultural equipment
Analysis and planning of consumption and production of products, equipment

National security

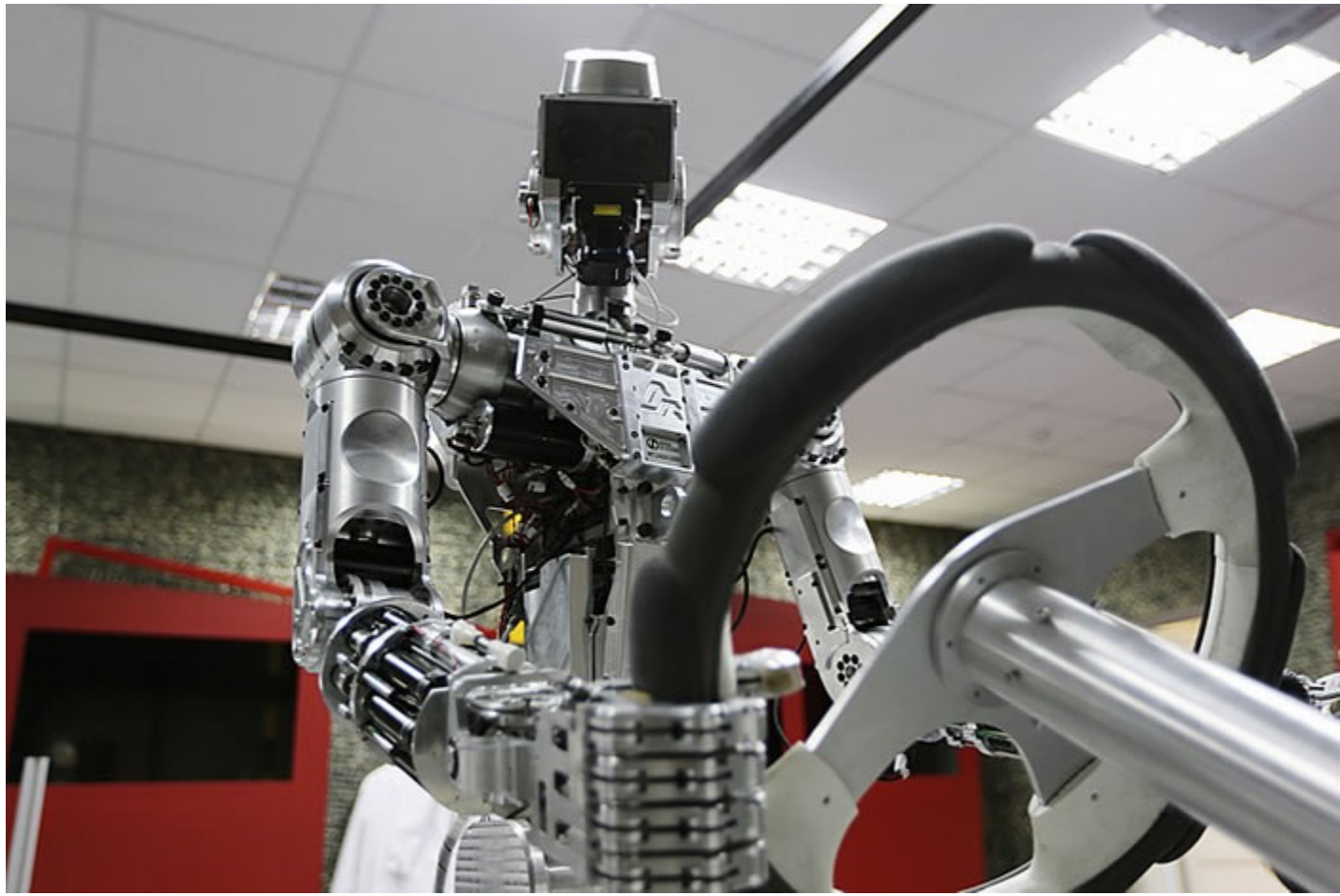
Intelligent analysis and risk prediction
Anti-terrorism

Education

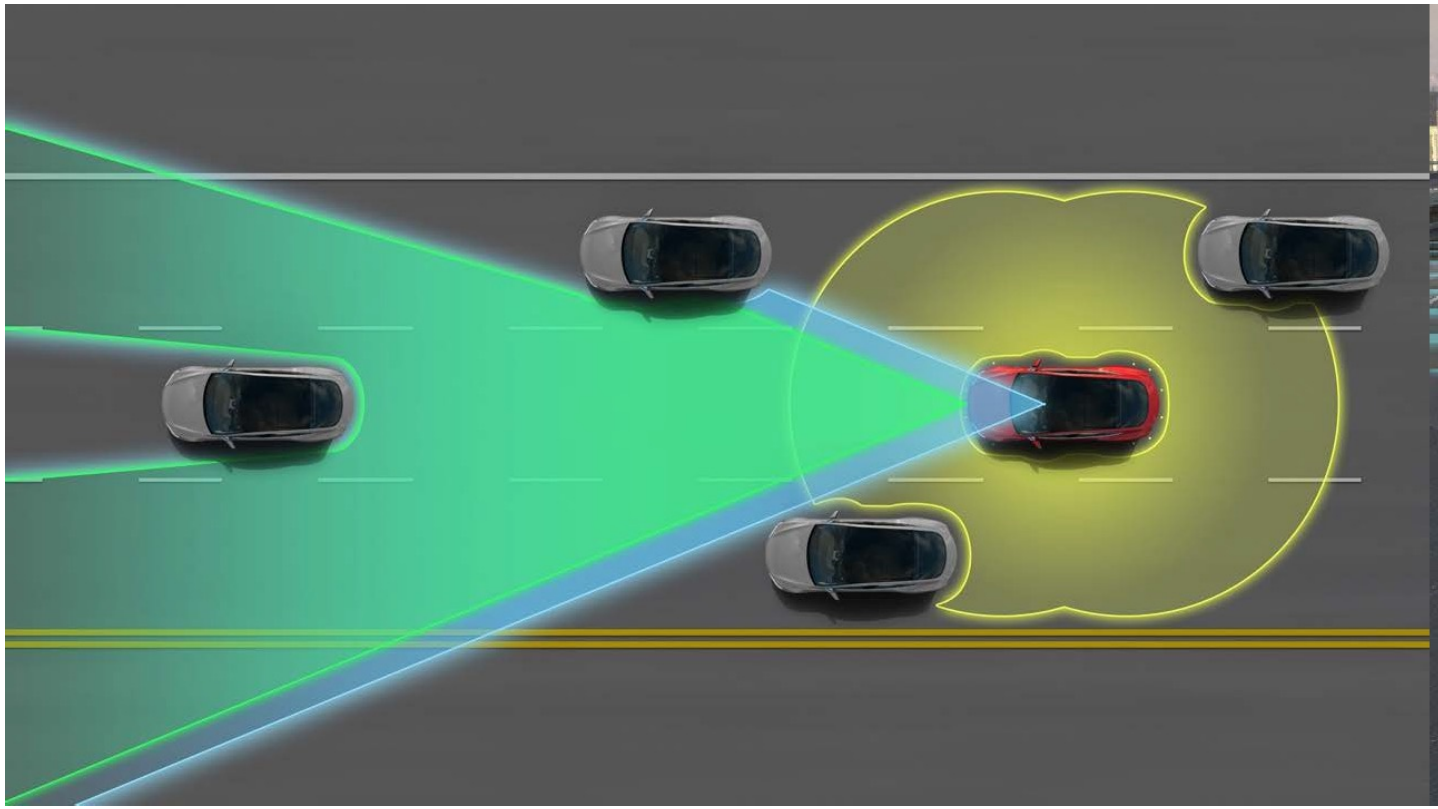
Individualization of the training process
Online training
Forecasting needs
Assistants

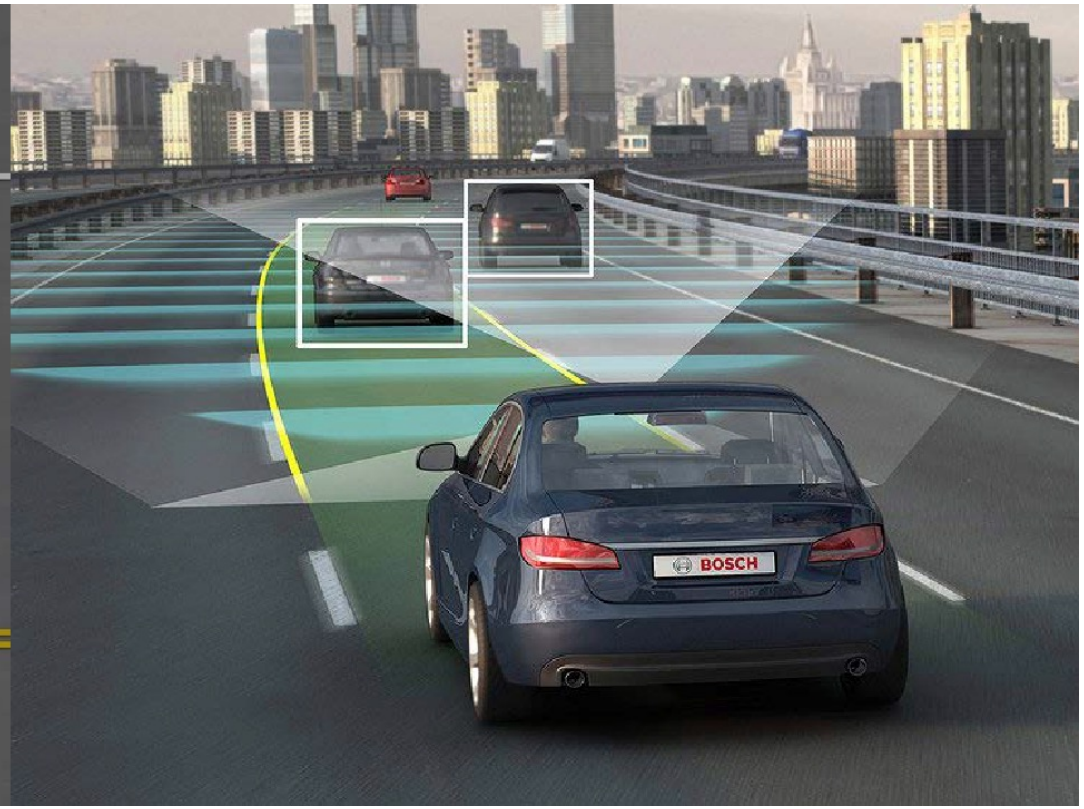
Defence

Planning
Decision making
Robots and coalitions



ML application





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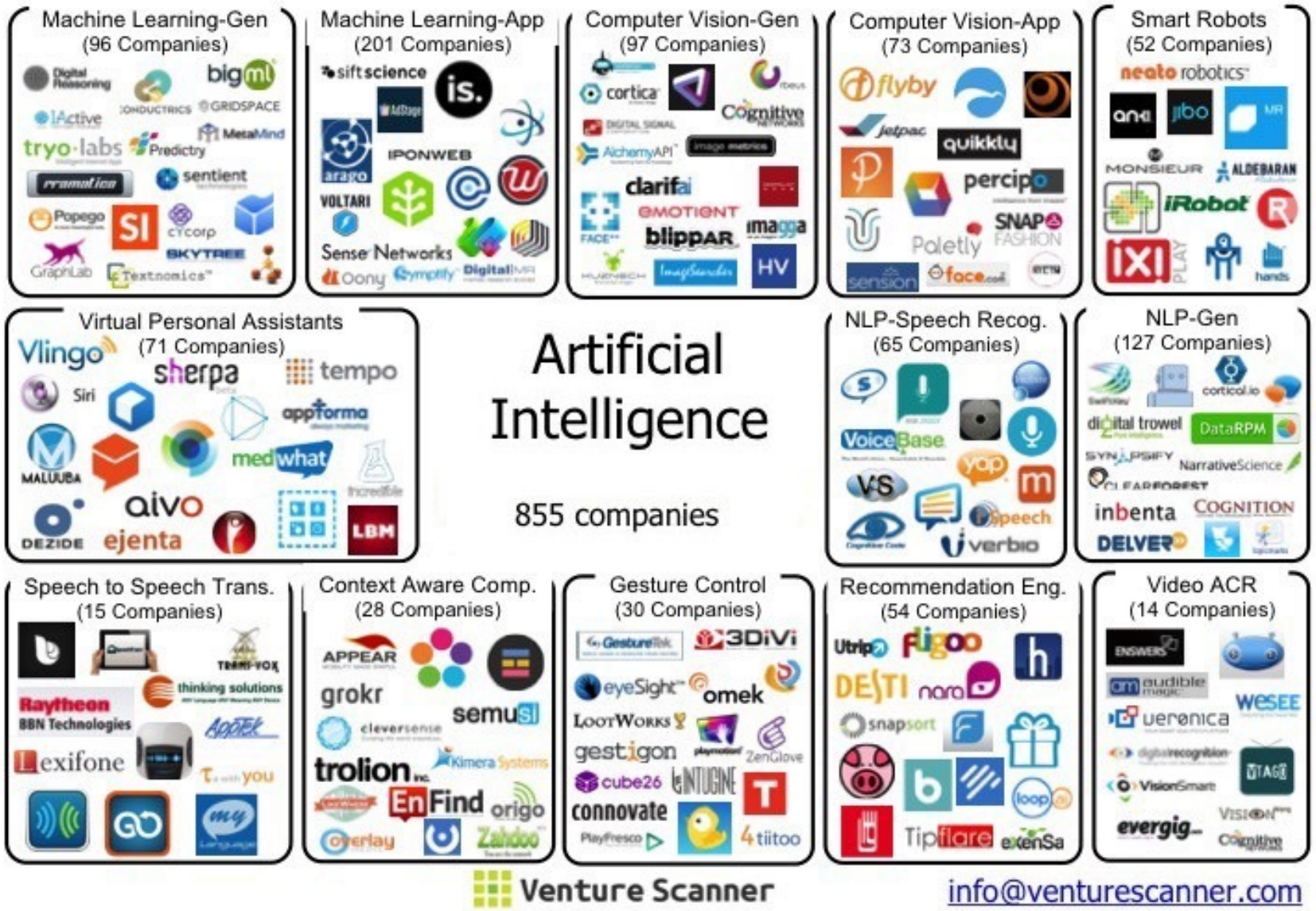

ML tasks types

1. Supervised learning:
    - Classification
    - Regression
    - Learning to rank
    - forecasting
2. Uunsupervised learning:
    - Clustering
    - Association rules learning
    - Outliers detection
3. Reinforcement learning
4. Meta-learning or learning-to-learn
5. Portfolio selection
6. Collaborative filtering
7. …

Approaches and methods

- Regression
- Bayesian inference
- Decision trees
- Neural networks
- K-nearest neighbors
- Principal component analysis
- Support vector machines
- Genetic algorythms

Tools

1. Python, R, Matlab, …
2. IPython Notebook, PyCharm
3. Tensor Flow, Keras, Theano, Scikit-Learn
4. CNTK
5. Torch
6. Caffe
7. Apach Spark
8. Azure

Automation

- Automation controls the processes, but the person is responsible for processes.
- G. Kasparov: “I played strange chess, not the kind to which I am used to, I tried to use our human advantages over the machine. But if I loose a trump card, I am doomed."
- Dangerous Conflict: Operators may rely on automation tools and, when faced with an unexpected problem, try to ignore it, rather than turn the automation off and switch to manual control. On the other hand, people can mistake the definition of a dangerous or threatening situation, mistaking it for safe.
- A new type of failure appears, associated not with equipment breakdowns, but with inadequate operation of automation in the diagnosis of on-board systems.

A.Kostin, 2001. https://old.computerra.ru/197252/

Principles of Human-Computer Interaction

- P. Fitts: the principle of advantageous opportunities: functions of a person and automation tools should be assigned depending on whose advantages will be better used in the performance of the control task
- N.Jordan. Allocation of functions **between man and machines** in automated systems. Journal of Applied Psychology, 47 (3) (1963): it is not necessary to distribute functions, but to organize the joint activity of man and machine in such a way as to mutually reinforce their functions. Complementarity can be expressed both in ensuring the optimal difficulty of the activity, and in redundancy, duplication of a machine by a person in the event of failures in its operation by switching to a manual control mode.
- N. D. Zavalova, B. F. Lomov and V. A. Ponomarenko. The principle of mutual redundancy of the operator and automation tools: semi-automatic control modes should be the main mode and should be selected based on the assessment of the adequacy of the use of quantitative criteria in automation programs, and automatic and manual ones should be considered as backup mode for insurance of the operator and automation

Links

- [ML course by Andrew Ng](https://www.coursera.org/learn/machine-learning)
- [ML course by Dmitry Efimov](https://github.com/diefimov/MTH594_MachineLearning)
- [ML course by OpenData Science](https://github.com/Yorko/mlcourse.ai)
- [MIT Deep learning](https://github.com/lexfridman/mit-deep-learning)
- https://github.com/qati/DeepLearningCourse
- https://github.com/roebius/deeplearning_keras2
- https://github.com/enggen/Deep-Learning-Coursera
- https://github.com/fchollet/deep-learning-with-python-notebooks