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What is Machine Learning and what can it be used for

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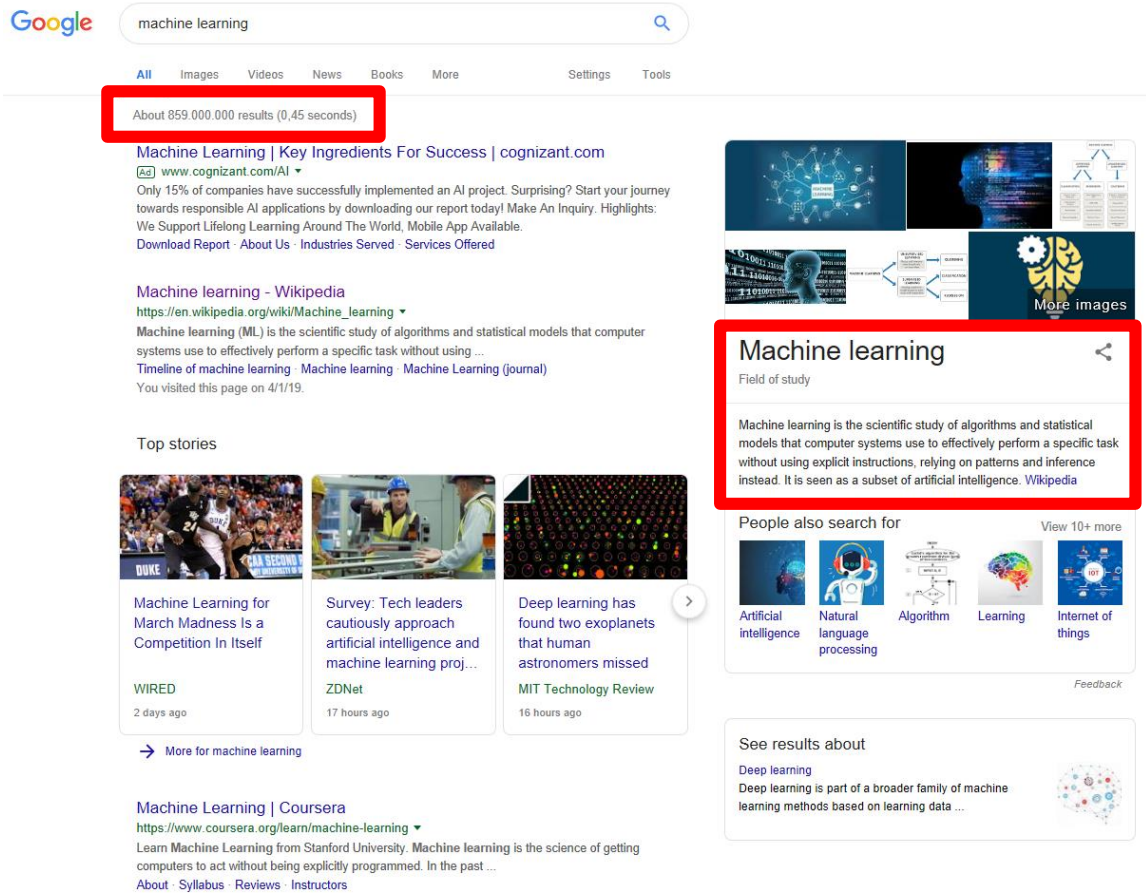
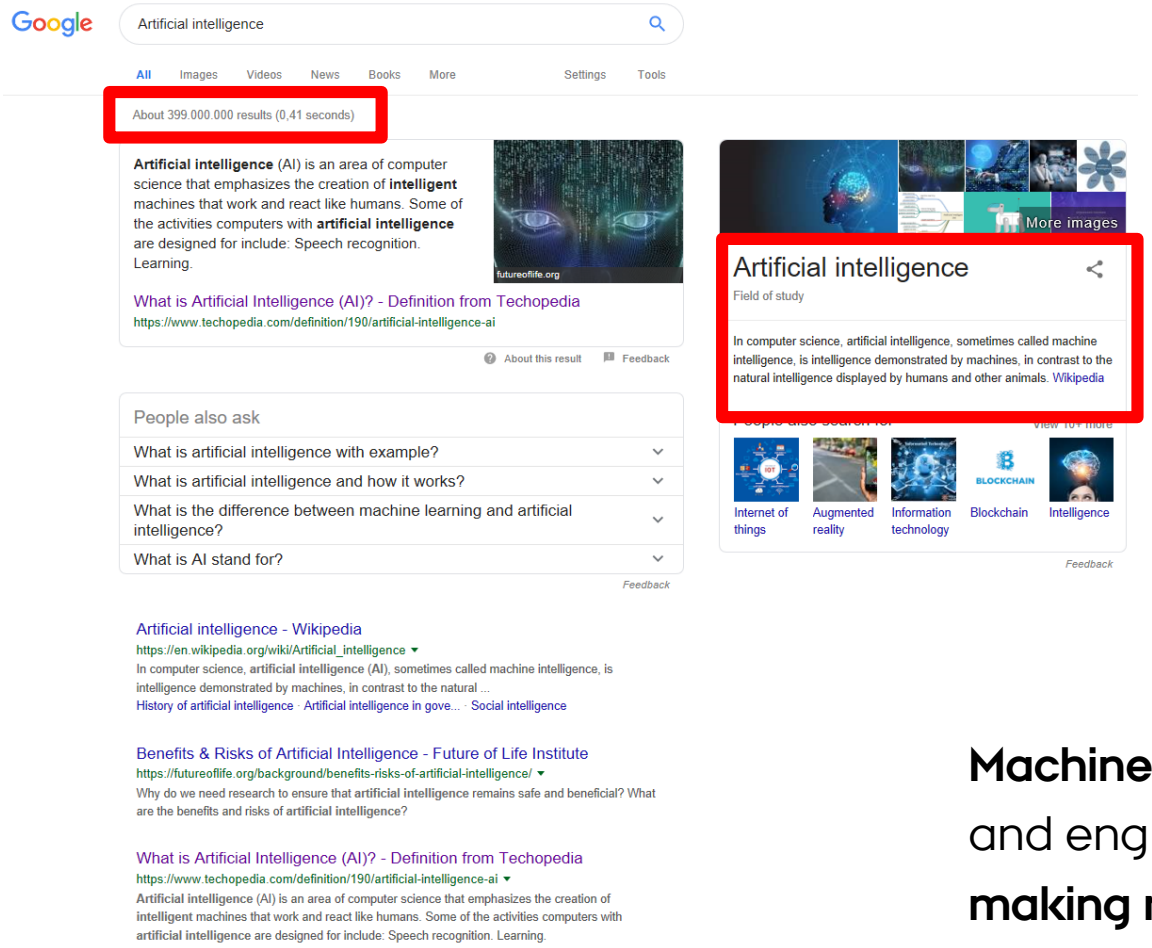
What is Machine Learning?



Machine Learning is the scientific study of algorithms and statistical models that computer systems use to **effectively perform a specific task without using explicit instructions**, relying on *patterns* and *inference* instead. It is seen as a subset of Artificial Intelligence.

What is Artificial Intelligence?



In computer science, Artificial Intelligence, sometimes called Machine Intelligence, is **intelligence demonstrated by machines**, in contrast to the natural intelligence displayed by humans and other animals.

Machine Learning is the field of science and engineering studying the process of **making machines intelligent**.

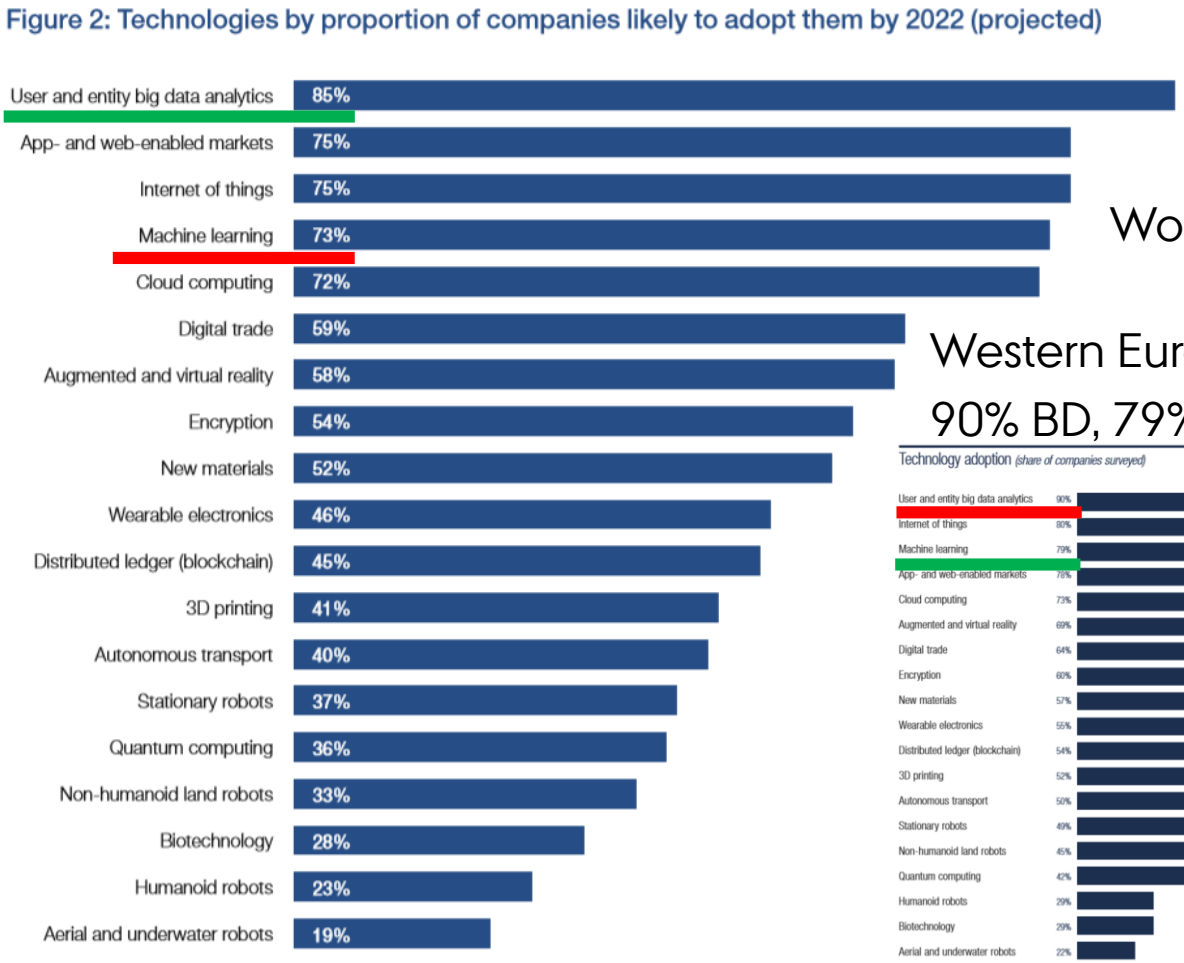
Impact of ML and AI in industry

Trends set to positively impact business growth up to 2022
Increasing adoption of new technology
Increasing availability of big data
Advances in mobile internet
Advances in artificial intelligence
Advances in cloud technology
Shifts in national economic growth
Expansion of affluence in developing economies
Expansion of education
Advances in new energy supplies and technologies
Expansion of the middle classes

Source: Future of Jobs Survey 2018, World Economic Forum.

World Economic Forum: http://reports.weforum.org/future-of-jobs-2018/

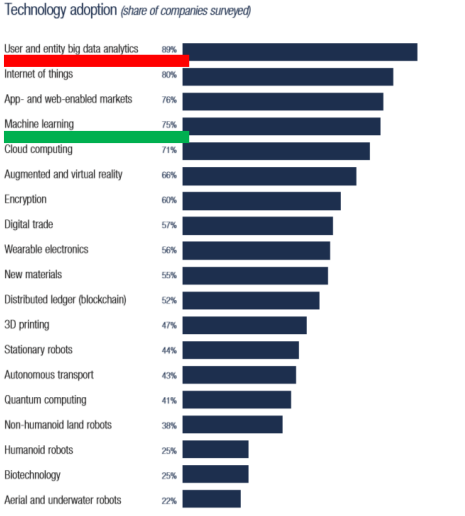
Impact of ML and AI in industry



World-wide: 85% BD, 75% ML

Western Europe:
90% BD, 79% ML

USA:
89% BD, 75% ML



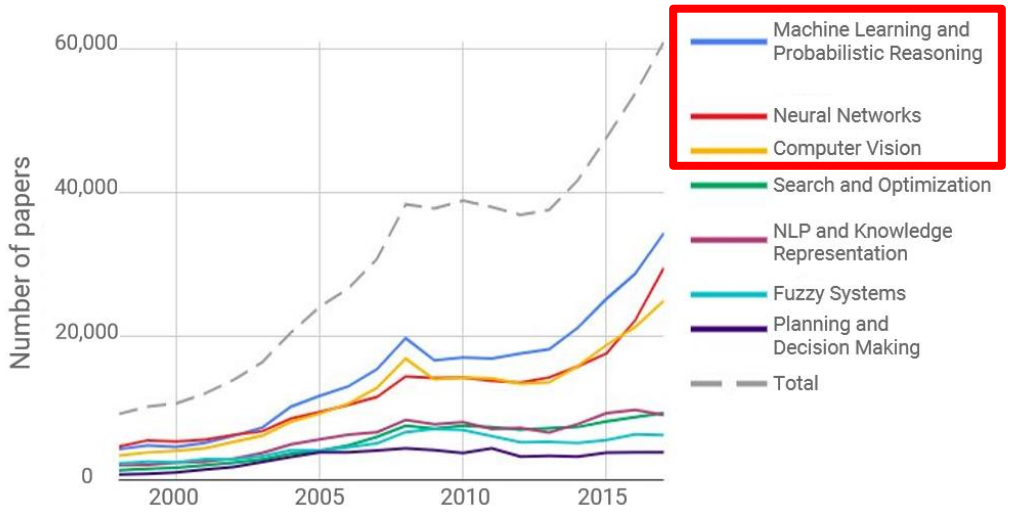
World Economic Forum: http://reports.weforum.org/future-of-jobs-2018/

Attracting more researchers to work on ML & AI

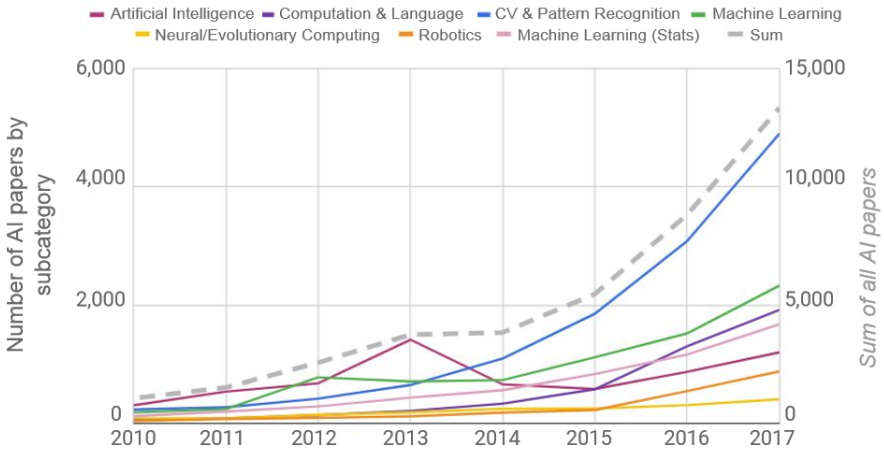
New research results

› Exponential growth of papers focusing on and using ML, its subfields and connected topics

Number of AI papers on Scopus by subcategory (1998–2017)
Source: Elsevier



Number of AI papers on arXiv by subcategory (2010–2017)
Source: arXiv



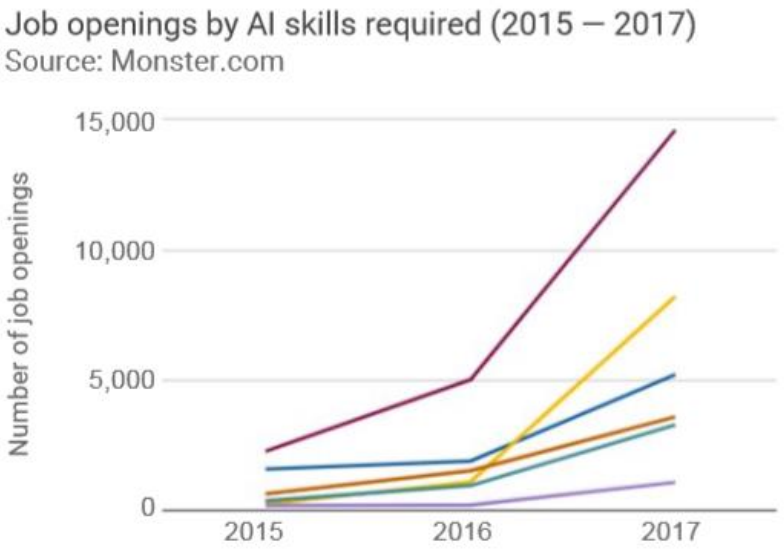
AI Index 2018: http://cdn.aiindex.org/2018/AI%20Index%202018%20Annual%20Report.pdf

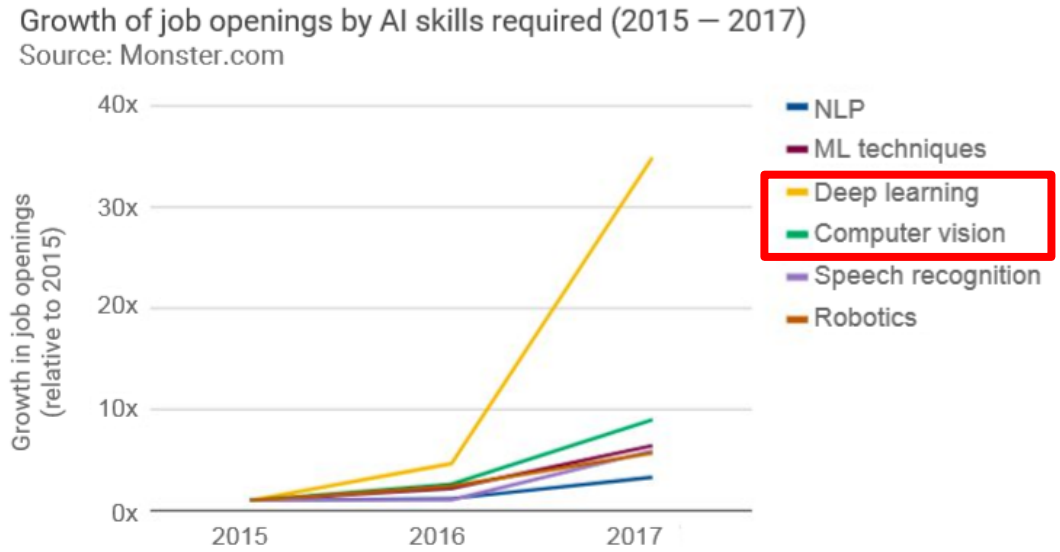
Need for more ML & AI scientists-engineers

Job openings for AI scientists/engineers

› Machine Learning is an essential skill

› Deep Learning is the most active topic





AI Index 2018: http://cdn.aiindex.org/2018/AI%20Index%202018%20Annual%20Report.pdf

The current Machine Learning paradigm

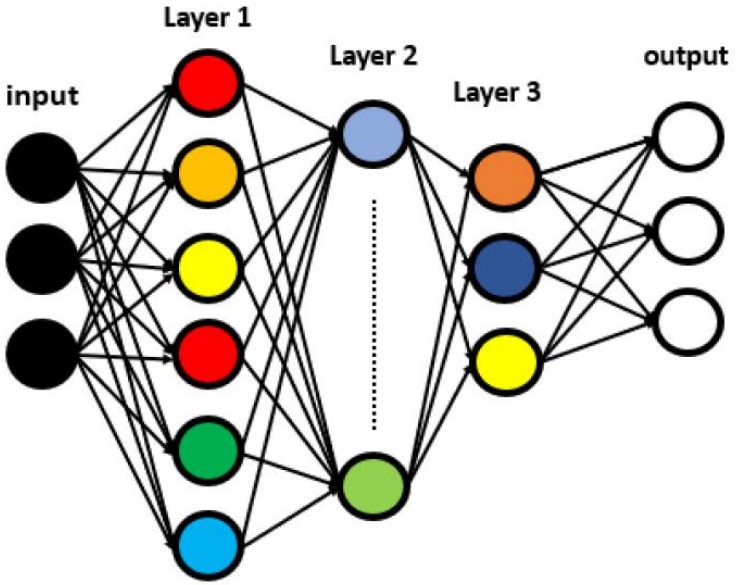
Deep Learning

- Machine Learning architectures which are formed by **multiple hierarchical transformation/mapping levels**, the parameters of which are **jointly optimized to achieve a goal** expressed in the form of an optimization function **defined on the training data** (and usually annotations of it)
- During the last seven years, they have achieved impressive performance in a wide range of applications.

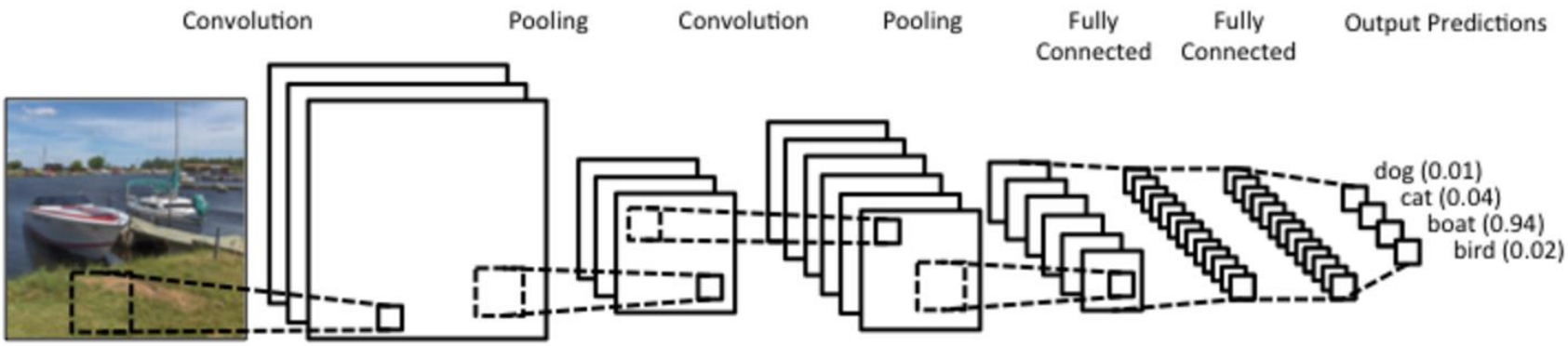
What DL model to use? Many decisions to make:

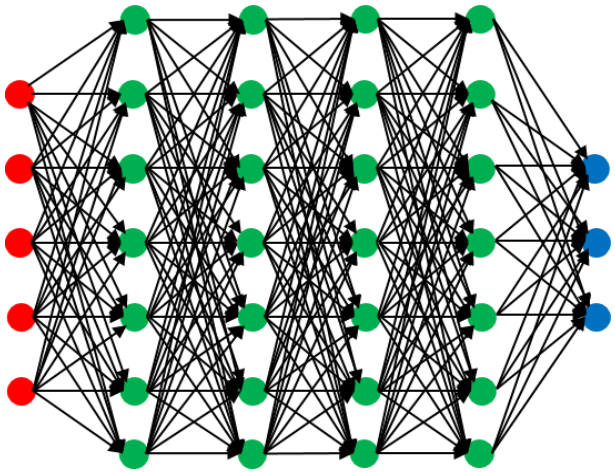
- Topology, type of neurons, optimization tricks, etc.

Some design patterns become standard, but not necessarily optimal for a new problem



Deep Learning





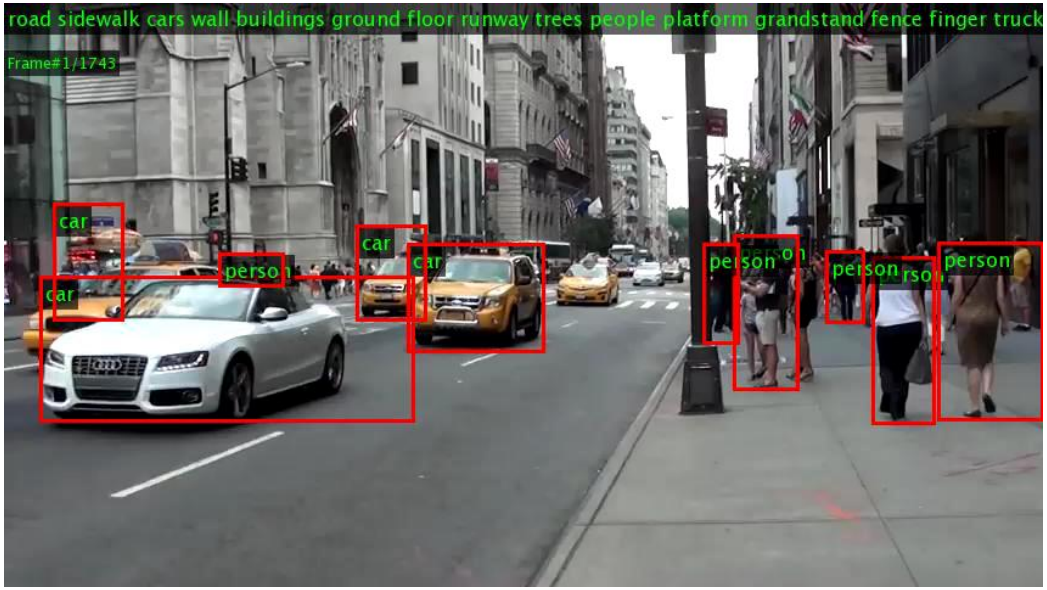
Automatic learning of data representations of increased level of abstraction at different layers of the Deep Learning model.

Let the DL model define which is the information needed for achieving the best performance on the specific task.

Applications of ML/DL

Problems which attracted public attention:

› General scene and object detection/recognition



NSF-CVDI 2015

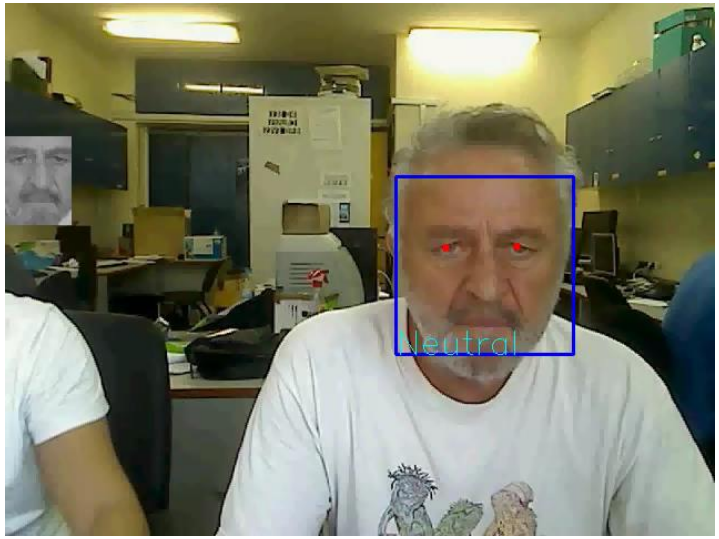
M. Waris, A. Iosifidis and M. Gabbouj, "CNN-based Edge Filtering for Object Proposals", Neurocomputing, 2017

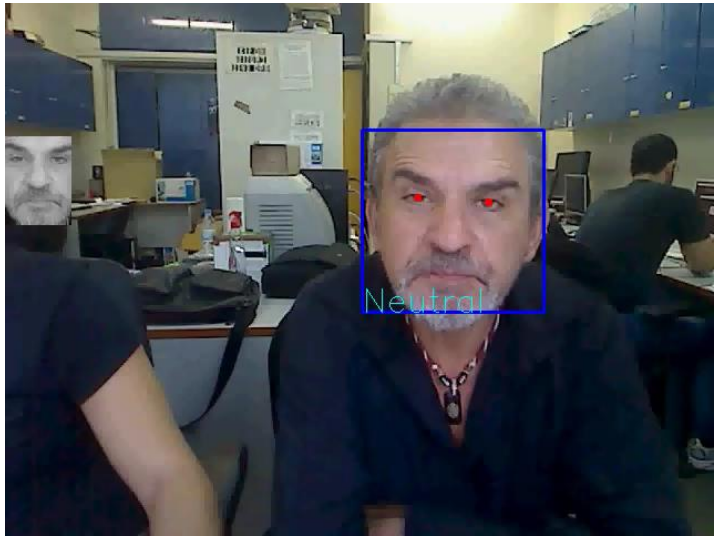
Applications of ML/DL

Problems which didn't receive much public attention yet:

› Face analysis

MOBISERV FP7





A. Iosifidis and M. Gabbouj, "Class-Specific Kernel Discriminant Analysis revisited: further analysis and extensions", IEEE Transactions on Cybernetics, 2017

A. Iosifidis and M. Gabbouj, "Scaling up Class-Specific Kernel Discriminant Analysis for large-scale Face Verification", IEEE Transactions on Information Forensics and Security, 2016

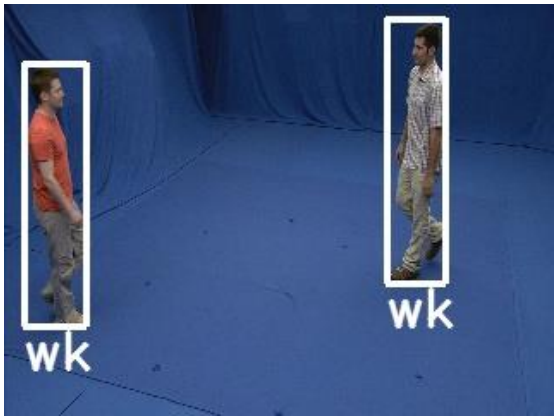
A. Iosifidis, A. Tefas and I. Pitas, "Class-specific Reference Discriminant Analysis with application in Human Behavior Analysis", IEEE Transactions on Human-Machine Systems, 2015

Applications of ML/DL

Problems which didn't receive much public attention yet:

- Face analysis
- Action recognition

MOBISERV FP7



F. Patrona, A. Iosifidis, A. Tefas, N. Nikolaidis and I. Pitas, "Visual Voice Activity Detection in the Wild", IEEE Transactions on Multimedia, 2016

A. Iosifidis, A. Tefas and I. Pitas, "Distance-based Human Action Recognition using optimized class representations", Neurocomputing, 2015

A. Iosifidis, A. Tefas and I. Pitas, "View-invariant action recognition based on Artificial Neural Networks", IEEE Transactions on Neural Networks and Learning Systems, 2012

Applications of ML/DL

Problems which didn't receive much public attention yet:

- Face analysis
- Action recognition
- Action recognition in smart home environments

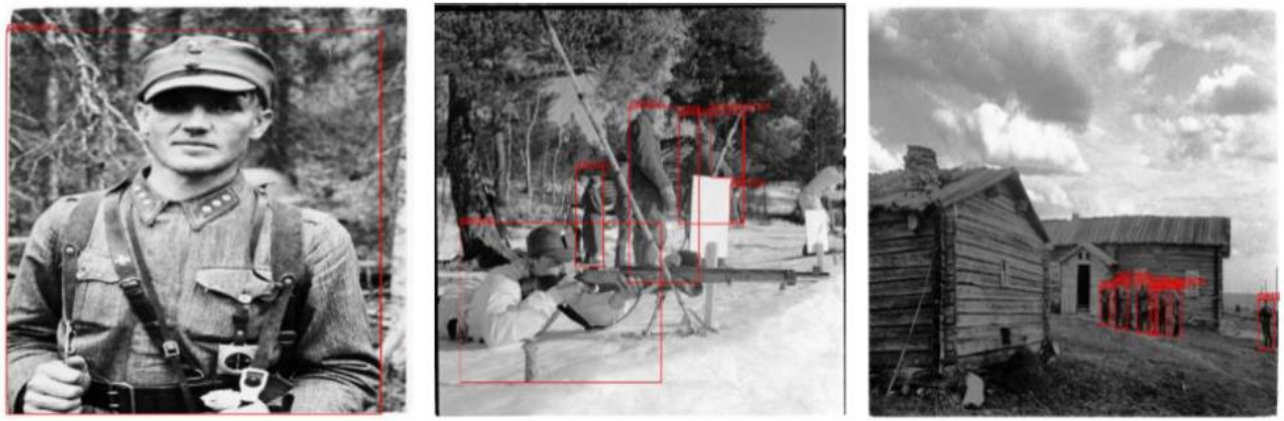
MOBISERV FP7

A. Iosifidis, E. Marami, A. Tefas, I. Pitas and K. Lyroudia, "The MOBISERV-AIIA Eating and Drinking multi-view database for vision-based assisted living", J-IHMSP, 2015.

Applications of ML/DL

Problems which didn't receive much public attention yet:

- Face analysis
- Action recognition
- Historic visual data analysis



(a) A close-up photo (b) A mid-range photo (c) An overview photo

Figure 2. Examples of photos taken from different distance ranges and the corresponding bounding boxes

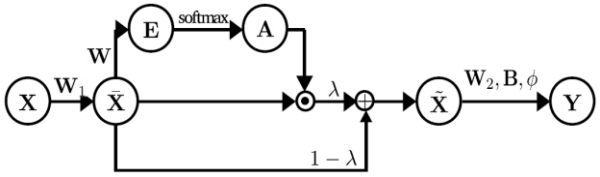
K. Chumachenko, A. Mannisto, A. Iosifidis and J. Raitoharju, "Machine Learning based Analysis of Finnish World War II Photographers", 2019

Time-series analysis

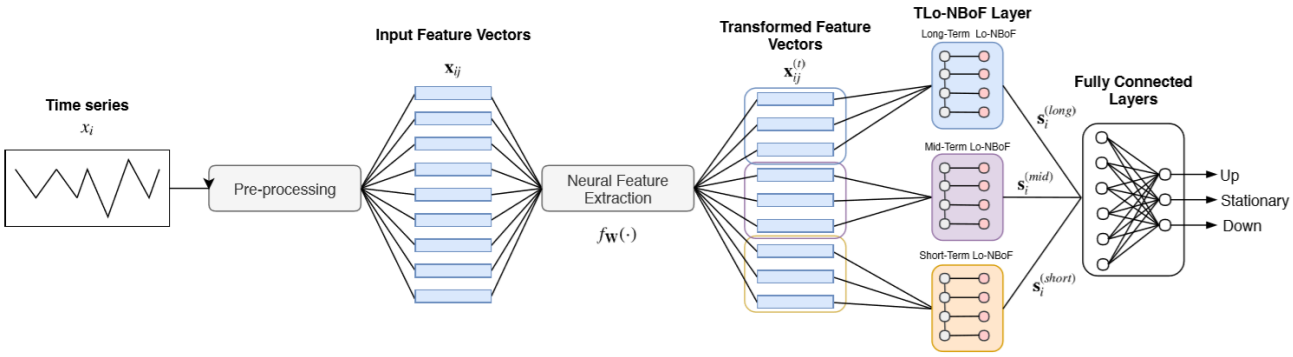
Proposal of new types of DL models

› Exploiting properties of the input data, e.g. time-series data

Temporal Attention-augmented Bilinear Network



Temporal Logistic Neural Bag-of-Features with Long- and Short-Term memory



D.T. Tran, A. Iosifidis, J. Kanniainen and M. Gabbouj, "Temporal Attention augmented Bilinear Network for Financial Time-Series Data Analysis", IEEE Transactions on Neural Networks and Learning Systems, 2019

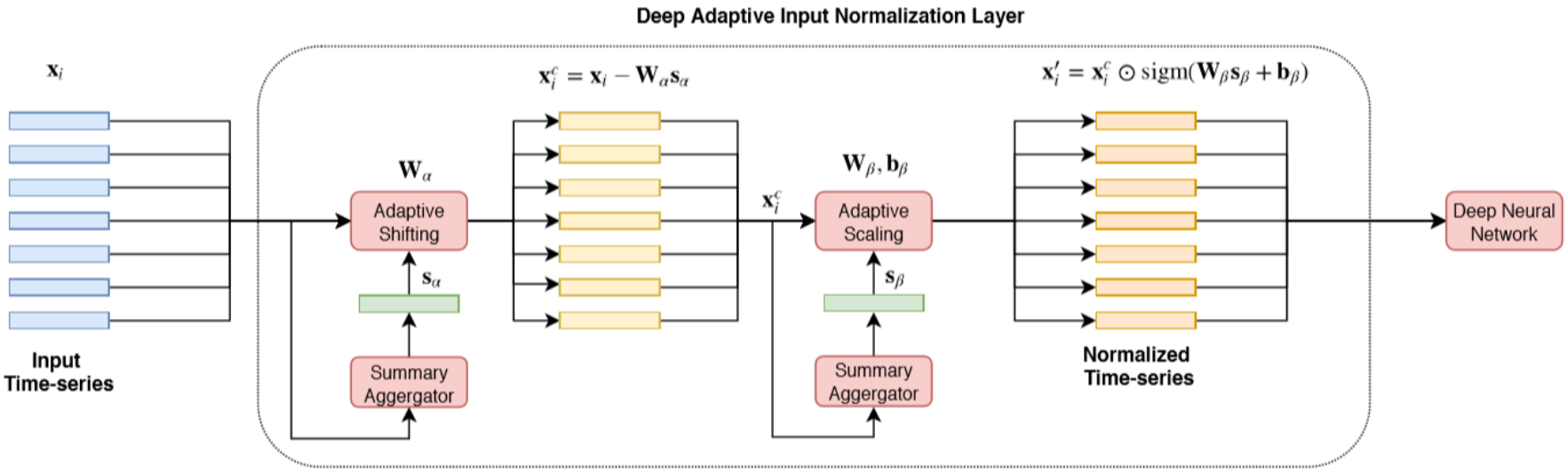
N. Passalis, A. Tefas, J. Kanniainen, M. Gabbouj and A. Iosifidis, "Temporal Bag-of-Features Learning for Predicting Mid Price Movements using High Frequency Limit Order Book Data", IEEE Transactions on Emerging Topics in Computational Intelligence, 2019

Time-series analysis

Proposal of new types of data registration for DL models

› Automatic data-driven based pre-processing of data

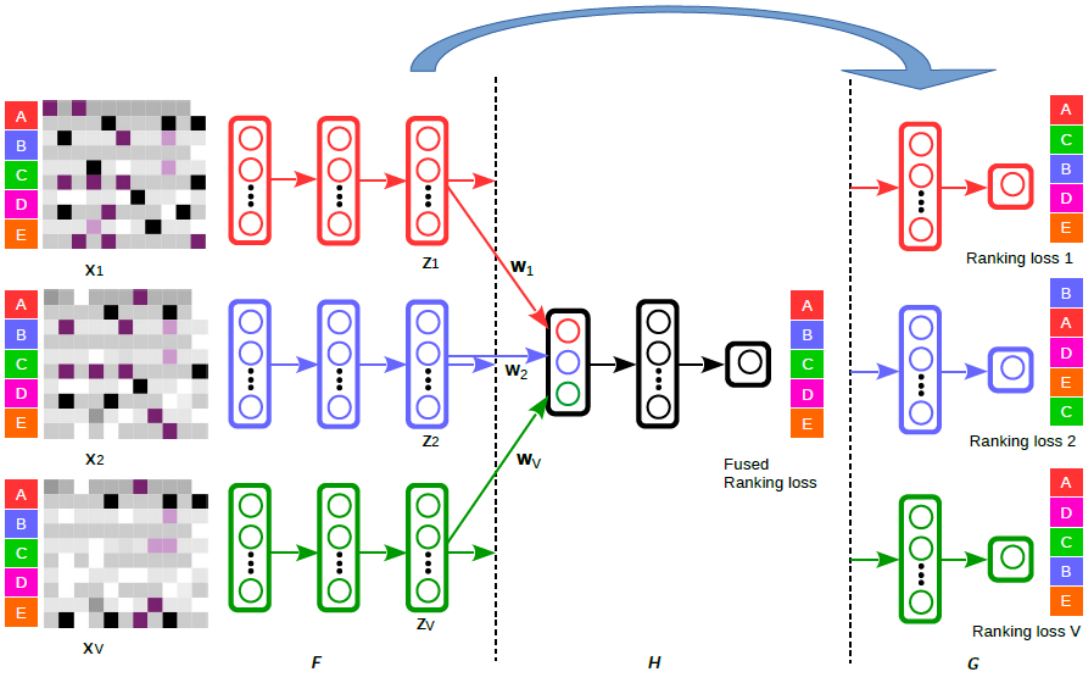
Adaptive Input Normalization of DL models for time-series data



N. Passalis, A. Tefas, J. Kanniainen, M. Gabbouj and A. Iosifidis, "Deep Adaptive Input Normalization for Time Series Forecasting", IEEE Transactions on Neural Networks and Learning Systems, 2019

Recommendation systems

Multi-faceted and multi-objective data ranking



Safety/hazard Assessment

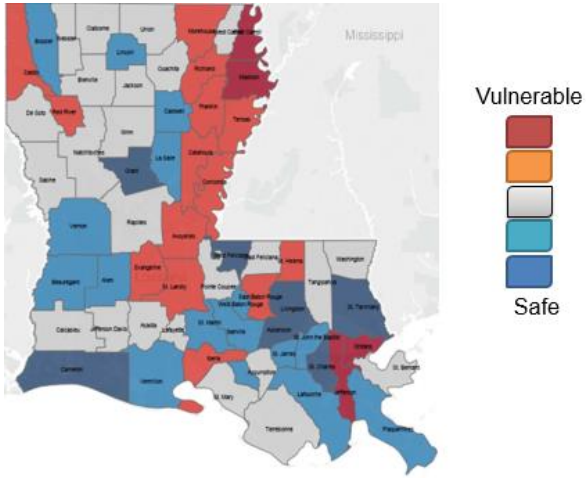


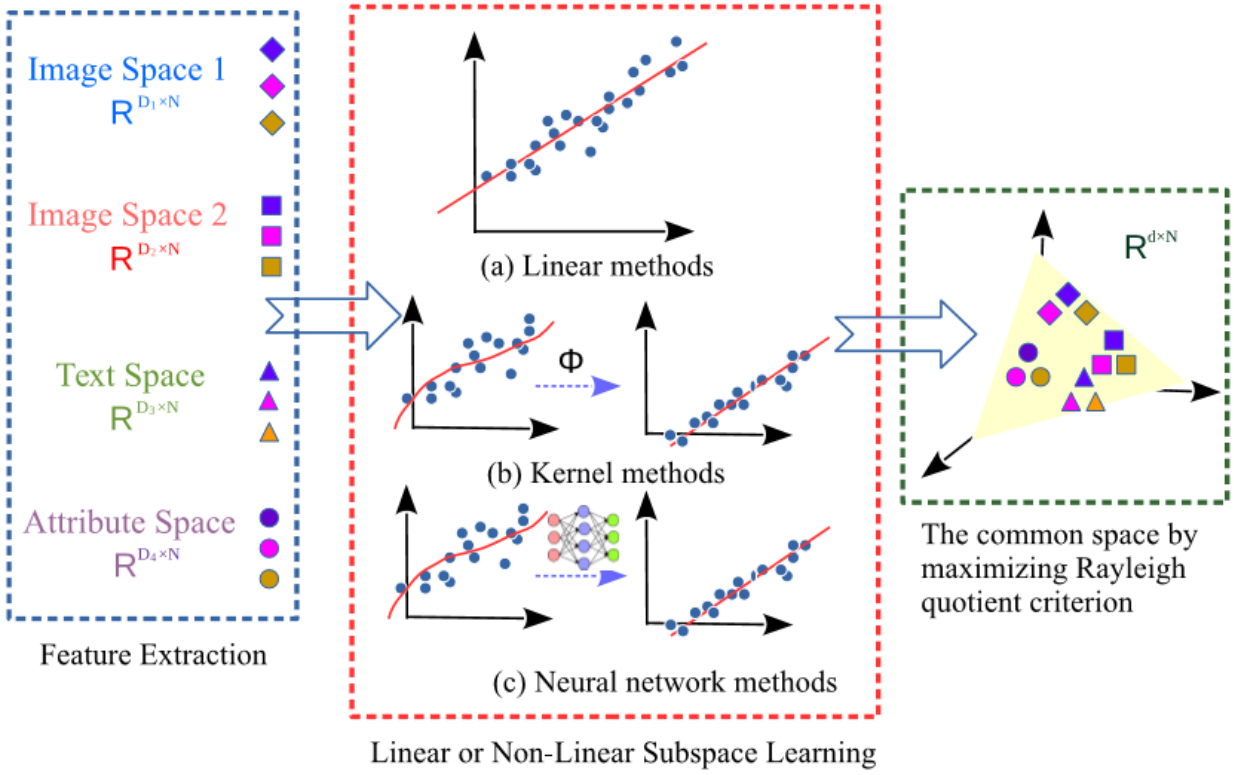
TABLE 1: Average Prediction Results (%) on 3 University Ranking Datasets in 2015.

Methods	Kendal's tau	Accuracy
Best Single View	65.38	-
Feature Concat	35.10	-
LMvCCA [5]	86.04	94.49
LMvMDA [5]	87.00	94.97
MvDA [6]	85.81	94.34
SmVR [8]	80.75	-
DMvCCA [5]	70.07	93.20
DMvMDA [5]	70.81	94.75
MvCCAE (*ours*)	75.94	94.01
MvMDAE (*ours*)	81.04	94.85
DMvDR (*ours*)	**89.28**	**95.30**

G. Cao, A. Iosifidis, M. Gabbouj, V. Raghavan and R. Gottumukkala, "Deep Multi-view Learning to Rank", IEEE Transactions on Knowledge and Data Engineering, 2019

Multi-view/modal Data Analysis

Generalized Multi-view Embedding

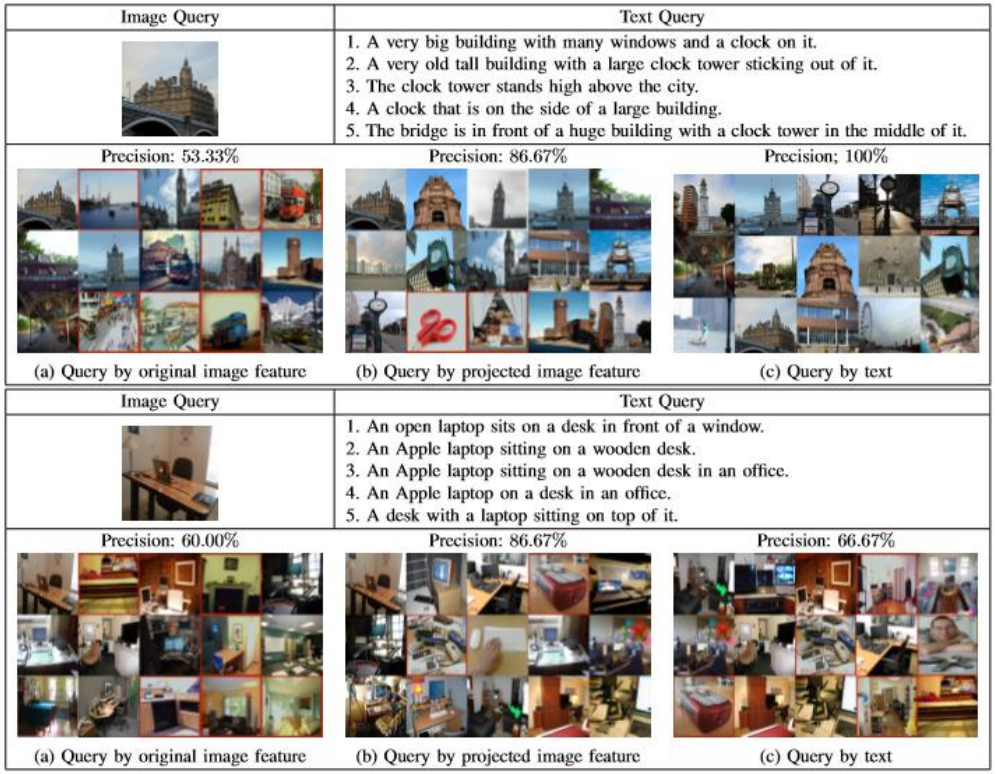


G. Cao, A. Iosifidis, K. Chen and M. Gabbouj, "Generalized Multi-view Embedding for Visual Recognition and Cross -modal Retrieval", IEEE Transactions on Cybernetics, 2018

Multi-view/modal Data analysis

Image and Text (I2T and T2I) Retrieval

NSF-CVDI 2016



G. Cao, A. Iosifidis, K. Chen and M. Gabbouj, "Generalized Multi-view Embedding for Visual Recognition and Cross -modal Retrieval", IEEE Transactions on Cybernetics, 2018

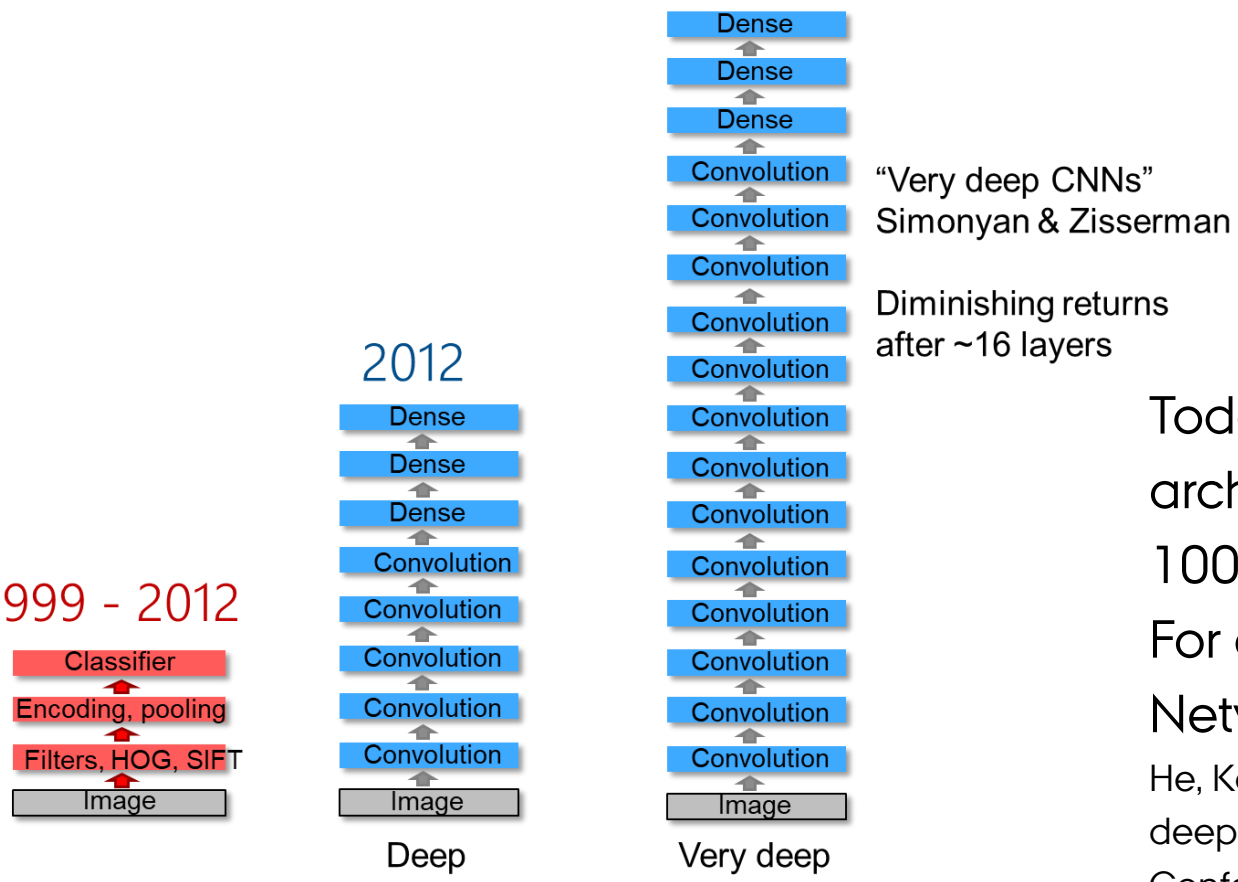
Is DL easy to train and deploy?

Challenges

- High dependence on large and pre-processed (annotated) data sets
- Enormous number of computations
  - long training and evaluation times
  - need for GPU powered computers
- Need for human expertise to define the most suitable type of DL model for the specific problem
- Highly specialized solutions which cannot be easily employed in other problems

Neural networks in Computer/Robotic Vision

Architectures



"Very deep CNNs"
Simonyan & Zisserman

Diminishing returns
after ~16 layers

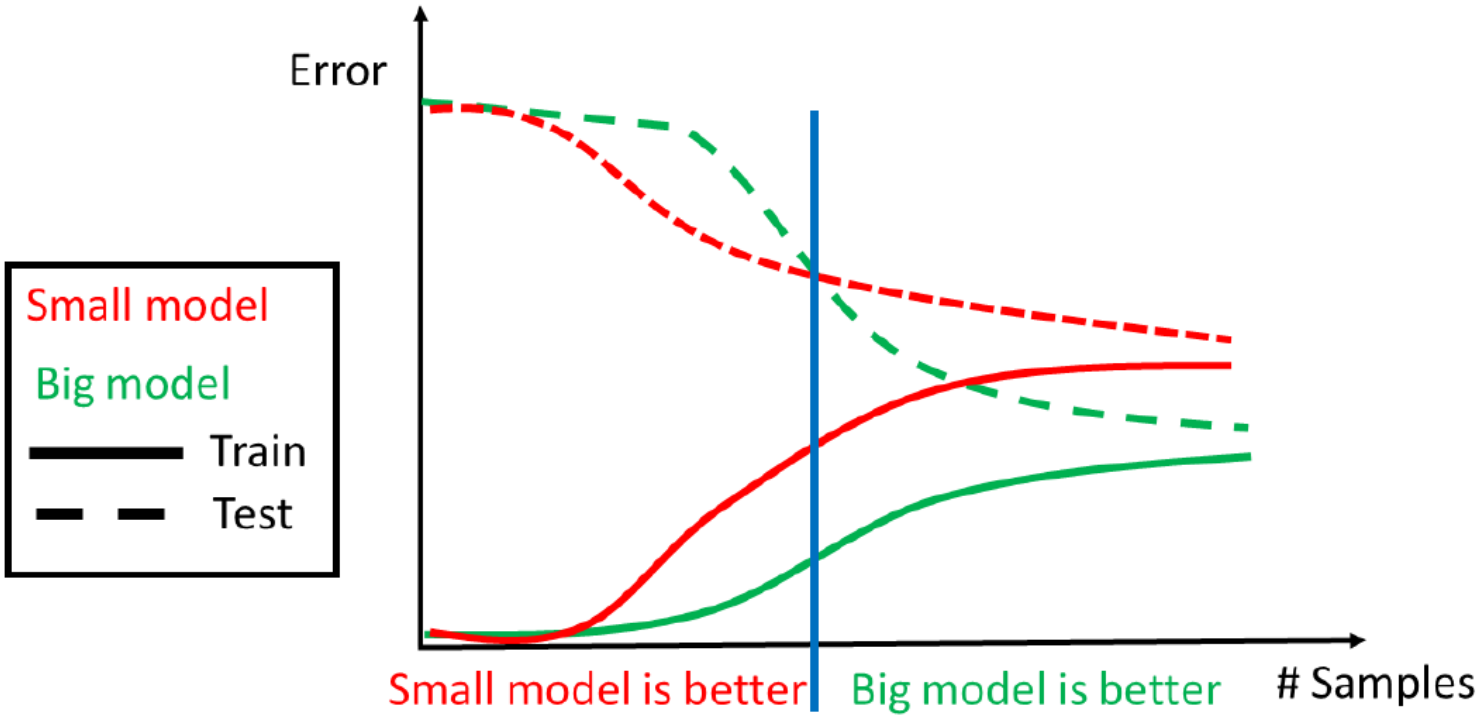
Today there exist network architectures with more than 100 convolution layers!

For example Residual Networks with 1000 layers in:

He, Kaiming, et al. "Identity mappings in deep residual networks." Proc. European Conference on Computer Vision. 2016

The role of Big Data in ML and CV solutions

Shallow vs. Deep Learning models

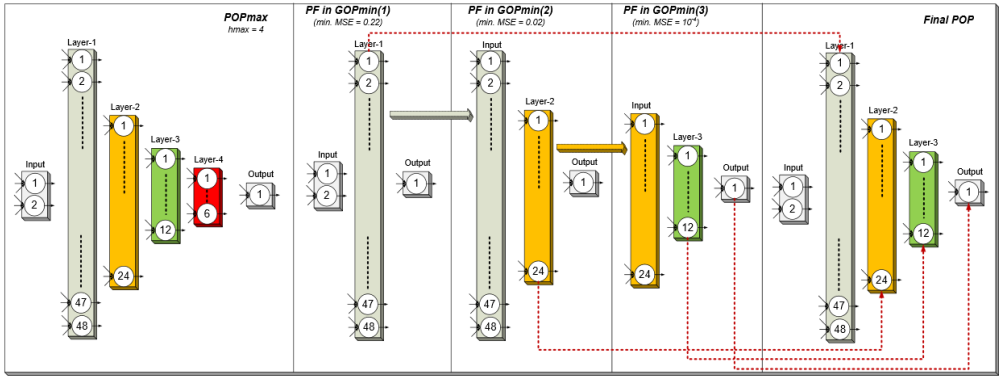


Automatic network design

Data-driven DL model learning

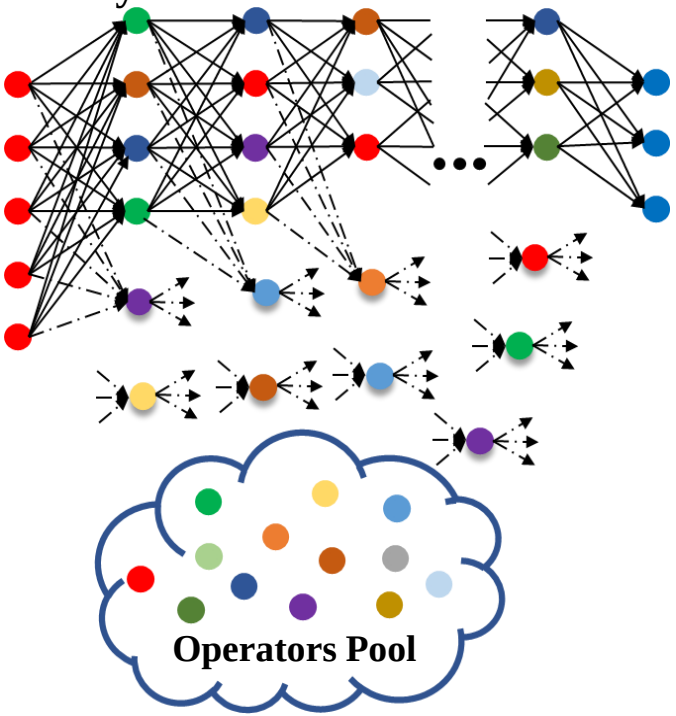
- Automatic training of the structure and the parameters of the DL model
- Data having the form of vectors and tensors

Progressive Operational Perceptrons



Heterogeneous Multilayer Generalized Operational Perceptron

Layers and neurons selection

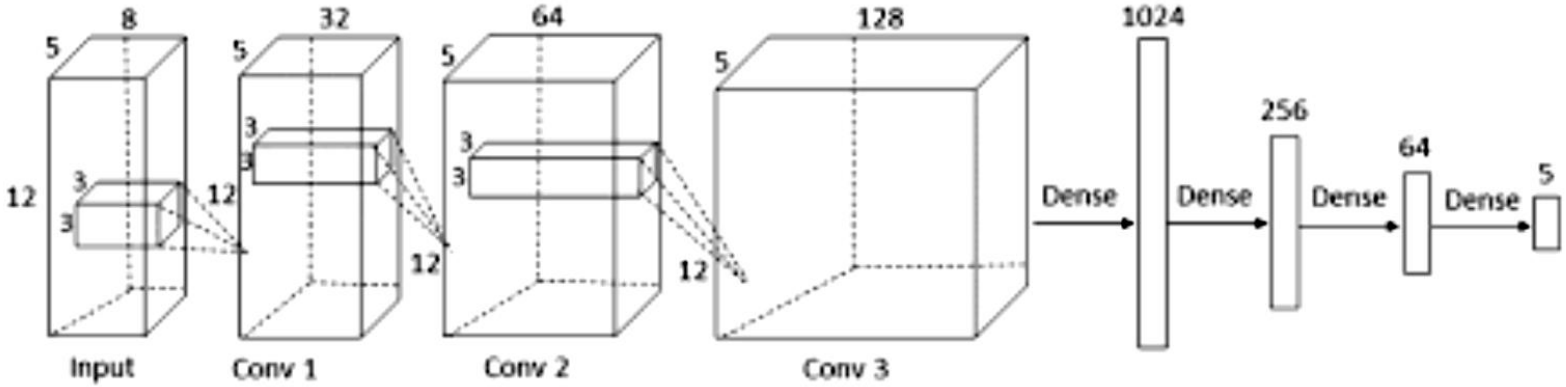


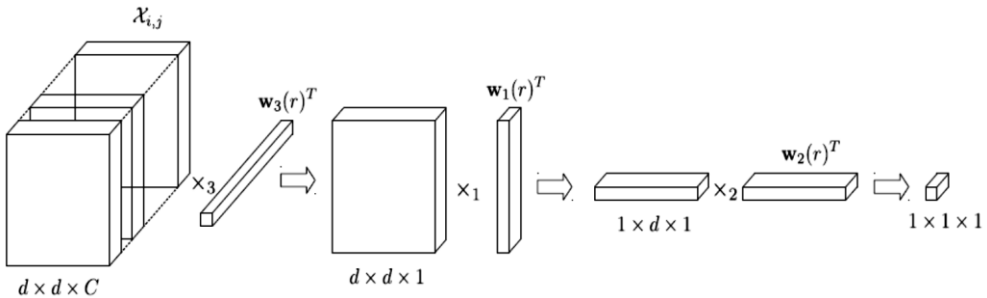
S. Kiranyaz, T. Ince, A. Iosifidis and M. Gabbouj, "Progressive Operational Preceptrons", Neurocomputing, 2017

D.T. Tran, S. Kiranyaz, M. Gabbouj and A. Iosifidis, "Heterogeneous Multilayer Generalized Operational Perceptron", IEEE Transactions on Neural Networks and Learning Systems, 2019

Acceleration of DL models

Exploitation of ideas from statistical Machine Learning for increasing efficiency of DL models

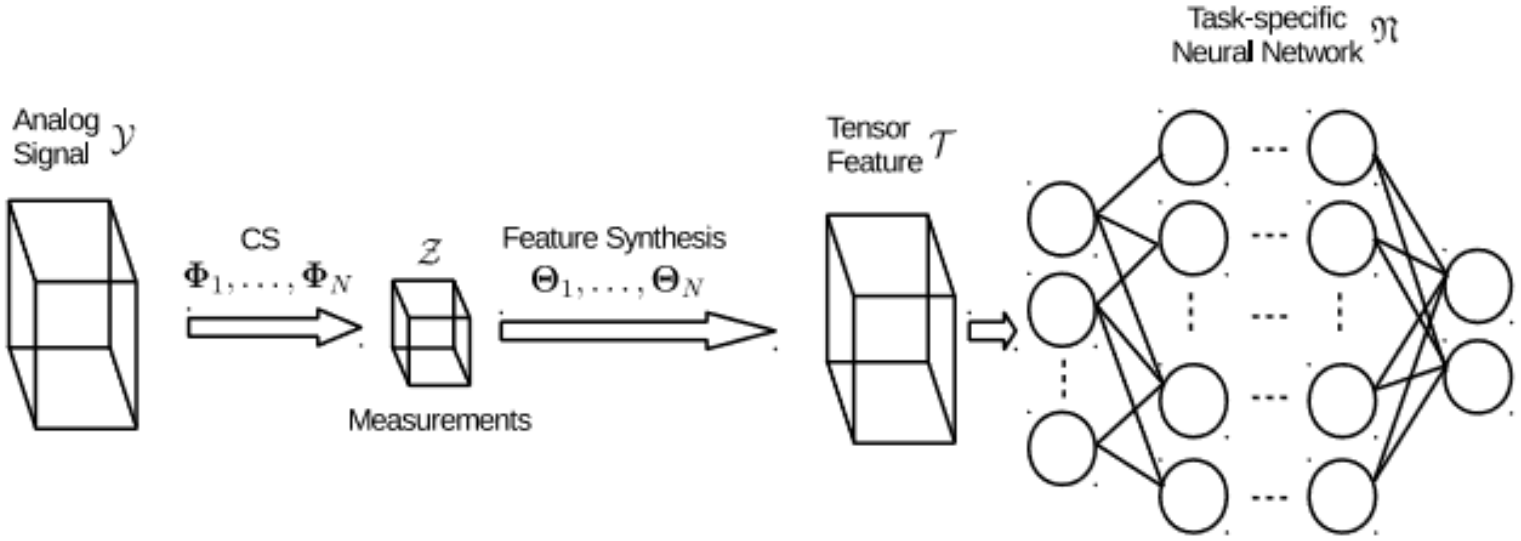




D.T. Thanh, A. Iosifidis and M. Gabbouj, "Improving Efficiency in Convolutional Neural Network with Multilinear Filters", Neural Networks, 2018

Efficient DL models

When computations need to be done on a server (not on the robotic platform) efficient end-to-end compression, transmission and recognition can be applied



D.T. Tran, M. Yamac, A. Degerli, M. Gabbouj and A. Iosifidis, "Multilinear Compressive Learning", arXiv: 1905.07481, 2019

Data-Driven Analytics group at ENG

More information can be found in our websites:

- Work in several topics of Machine Learning
- Implementations in several applications, including
  - human behavior analysis
  - financial data analysis
  - Computer Vision for Bioscience
  - …

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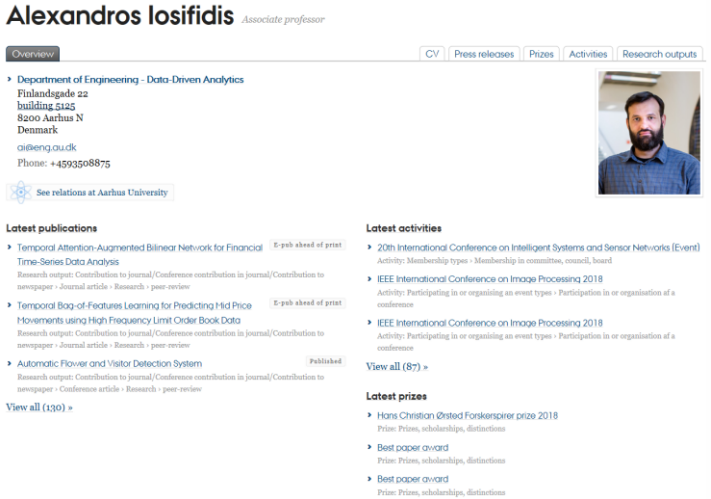
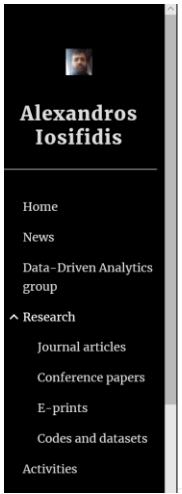
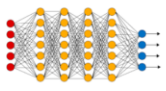
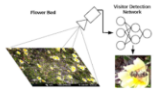
sites.google.com/view/iosifidis






Machine Learning


Computer Vision


Bioscience

Computational Finance

Publications

- Journal articles
- Conference papers
- E-prints

Codes and datasets

- Codes
- Datasets

If you are unable to find any of my papers, you are welcome to contact me.

Data-Driven Analytics group at ENG

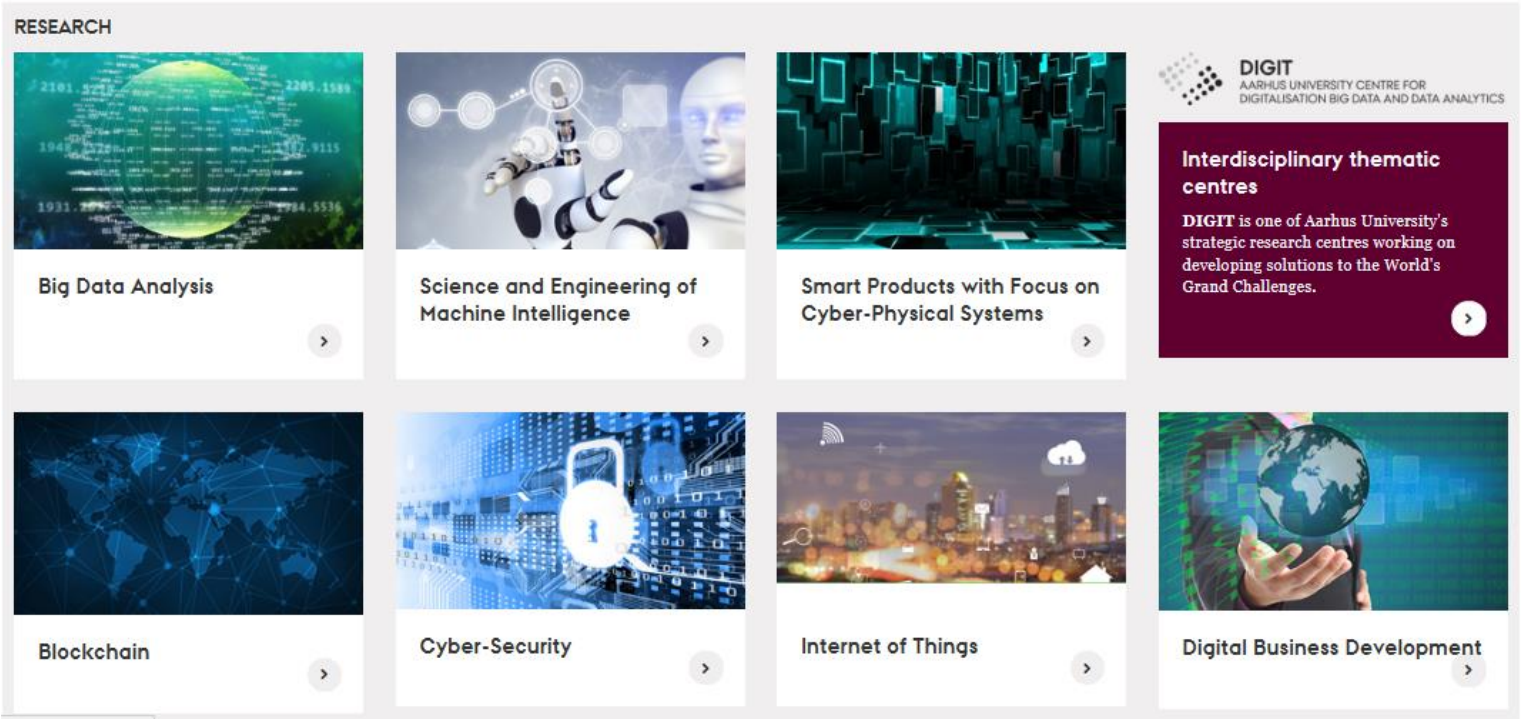
Current funding

- **OpenDR**:
  - H2020-RIA project (2020-2022) targeting to create the first Deep Learning toolkit for efficient solutions of Robotic problems (including visual data and sensor time-se
- **DISPA**:
  - IRFD project (2019-2022) targeting at financial market time-series analysis for inter-stock predictive analytics
- **Interpretable Deep Learning**:
  - DIGIT project (2019-2022) targeting the proposal of new interpretable Deep Learning method
- **Industrial PhD**:
  - Project (2019-2023) targeting the proposal of new Deep Learning methods for weather forecasting
- **Efficient DL for UAVs**:
  - AU-ST project (2018-2022) targeting the proposal of new efficient Deep Learning methods for Computer Vision in drones

Aarhus University Centre for Digitalisation, Big Data and Data Analytics

Collaboration between the Departments

› Engineering
› Computer Science
› Mathematics



http://digit.au.dk/

Thank you for your attention!