LESSON 24

Machine Learning Software and Cloud Services

Designing for Industry 4.0 applications




Outline 1/2

Introduction to Machine learning
Software and Toolboxes

- Cloud (external resources)
  - SaaS
  - Machine Learning as a Service (MLaaS)

Google Cloud

Azure Machine Learning

aws

amazon web services™

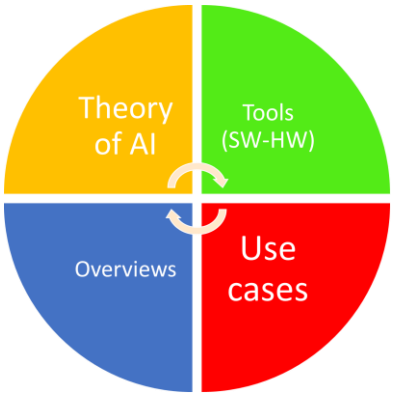
Outline 2/2

- Applications of Intelligent Vision Systems
  - Industry 4.0
  - Ambient Intelligence and Domotics
  - Supply Chain
  - Environmental
- Appendix (not in the exam)

THEORY

Machine Learning SW

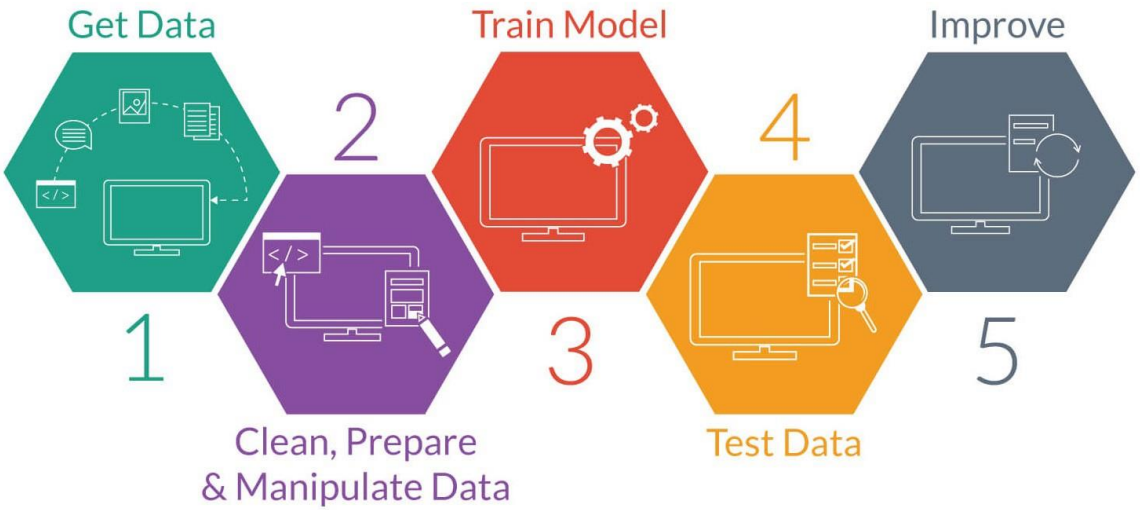
The tools and libraries you need

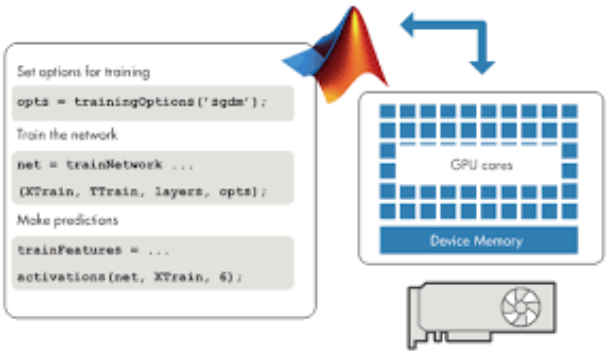


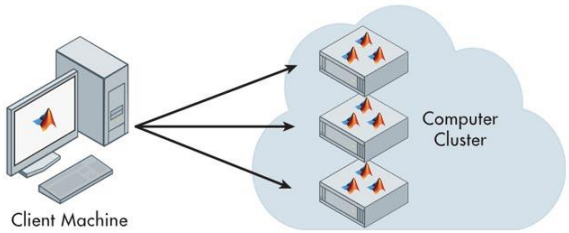
SW: How and where?

Deployment

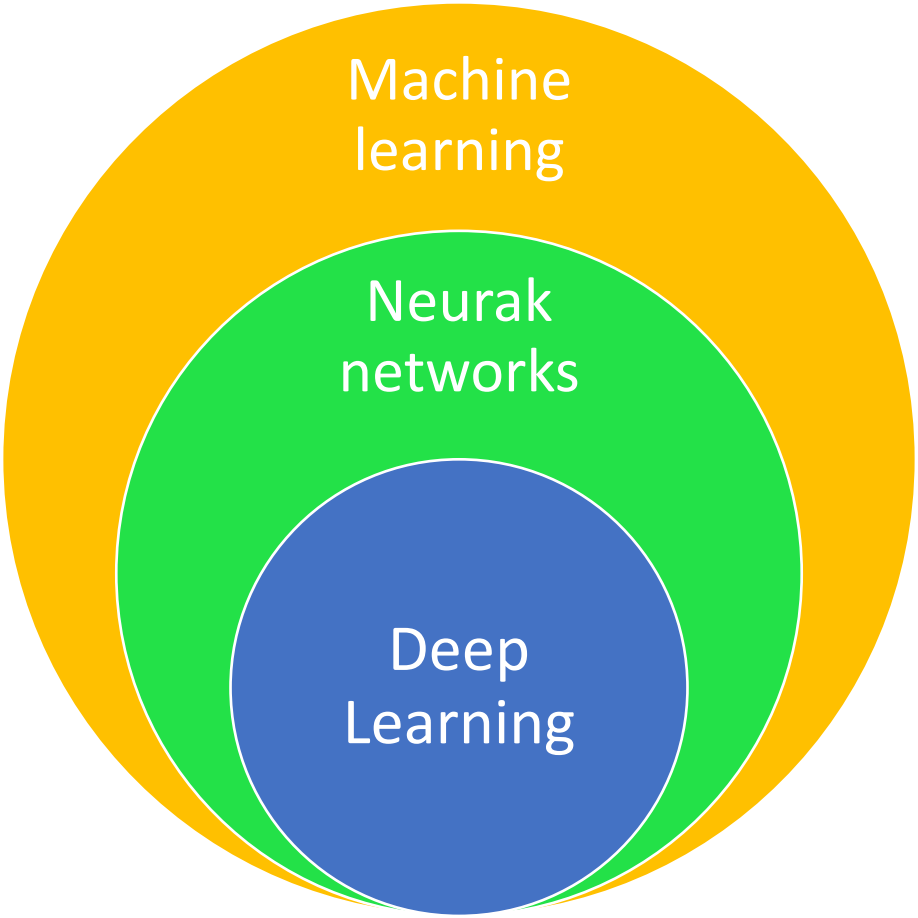
Needed in all steps!





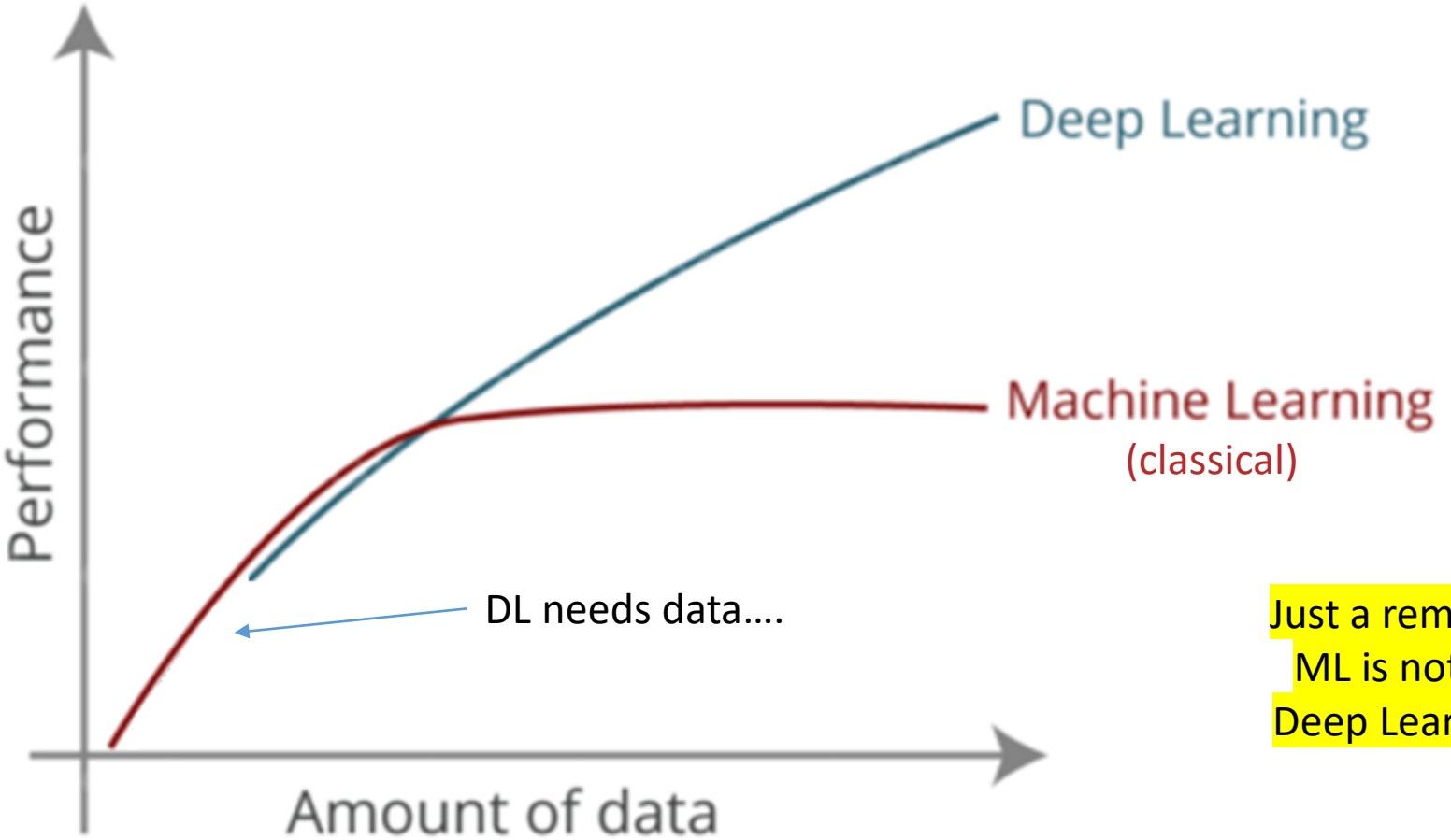


Machine Learning and Deep Learning



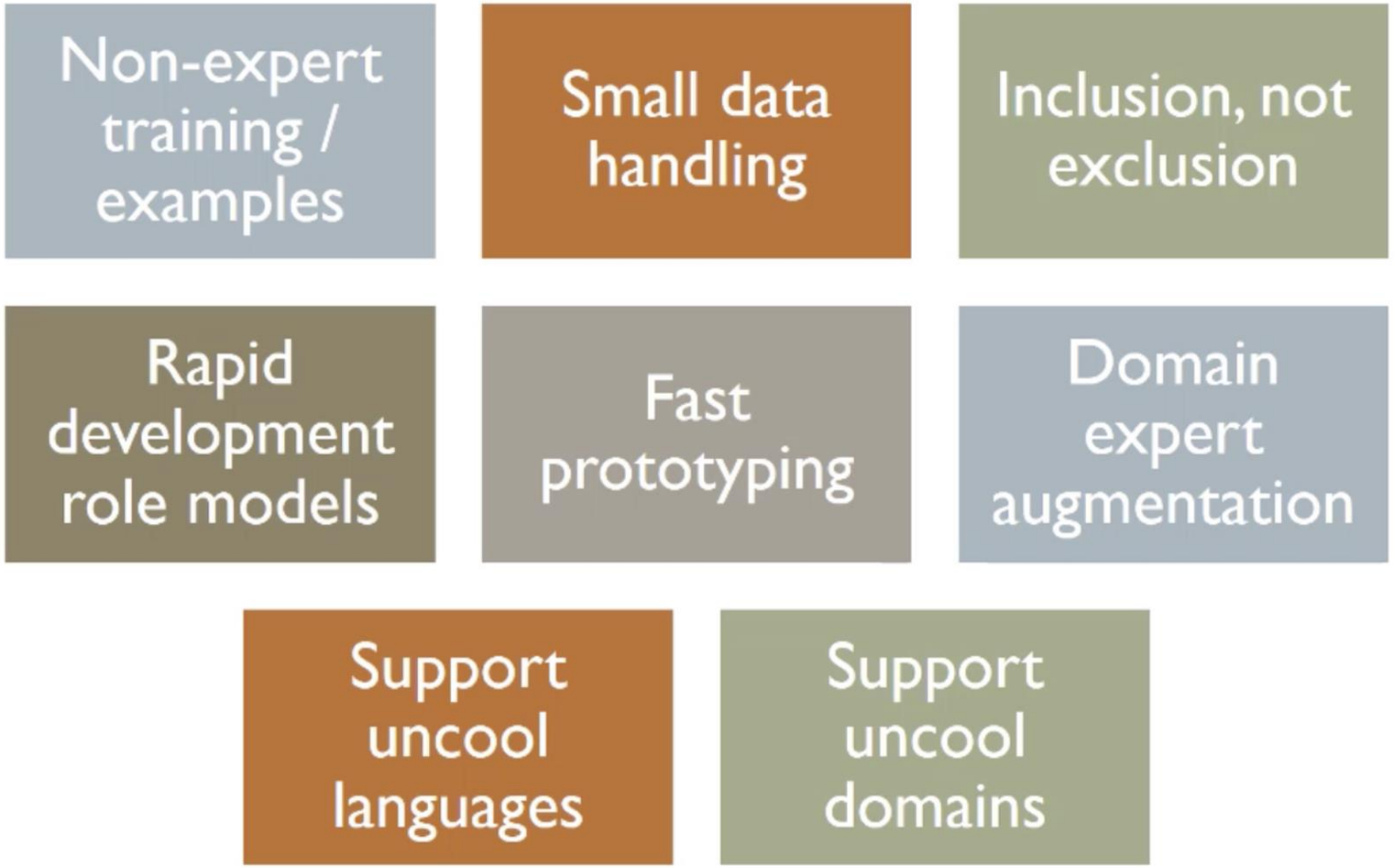
Just a reminder: ML is not just Deep Learning..

Classical ML and DeepLearning data need



Just a reminder:
ML is not just
Deep Learning..

SW tools: what you may need



Discussion …..

SW libraries and toolboxes

- Hunderds of ML toolboxes are now avaiblaes
- **Deeplearning** tools
  - Apache Singa
  - Amazon Machine Learning
  - Azure ML Studio
  - Caffe
  - H2O
  - Massive Online Analysis (MOA)
  - MLlib (Spark)
- mlpack,
- Matlab toolboxes
- Pattern
- Scikit-Learn
- Shogun
- low
- Theano
- Torch
- Veles

Deep Learn toolboxes comparison

Restricted Boltzmann machine
Deep belief network

Software	Creator	Initial release	Software license[a]	Open source	Platform	Written in	Interface	OpenMP support	OpenCL support	CUDA support	Automatic differentiation[1]	Has pretrained models	Recurrent nets	Convolutional nets	RBM/DBNs	Parallel execution (multi node)	Actively developed
BigDL	Jason Dai (Intel)	2016	Apache 2.0	Yes	Apache Spark	Scala	Scala, Python			No		Yes	Yes	Yes			
Caffe	Berkeley Vision and Learning Center	2013	BSD	Yes	Linux, macOS, Windows[2]	C++	Python, MATLAB, C++	Yes	Under development[3]	Yes	Yes	Yes[4]	Yes	Yes	No	?	No[5]
Chainer	Preferred Networks	2015	BSD	Yes	Linux, macOS	Python	Python	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No[6]
Deeplearning4j	Skymind engineering team; Deeplearning4j community; originally Adam Gibson	2014	Apache 2.0	Yes	Linux, macOS, Windows, Android (Cross-platform)	C++, Java	Java, Scala, Clojure, Python (Keras), Kotlin	Yes	No[7]	Yes[8][9]	Computational Graph	Yes[10]	Yes	Yes	Yes	Yes[11]	Yes
Dlib	Davis King	2002	Boost Software License	Yes	Cross-platform	C++	C++, Python	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	
Flux	Mike Innes	2017	MIT license	Yes	Linux, MacOS, Windows (Cross-platform)	Julia	Julia			Yes	Yes	Yes[12]	Yes	Yes	No	Yes	Yes
Intel Data Analytics Acceleration Library	Intel	2015	Apache License 2.0	Yes	Linux, macOS, Windows on Intel CPU[13]	C++, Python, Java	C++, Python, Java[13]	Yes	No	No	Yes	No		Yes		Yes	
Intel Math Kernel Library	Intel		Proprietary	No	Linux, macOS, Windows on Intel CPU[14]		C[15]	Yes[16]	No	No	Yes	No	Yes[17]	Yes[17]		No	
Keras	François Chollet	2015	MIT license	Yes	Linux, macOS, Windows	Python	Python, R	Only if using Theano as backend	Can use Theano, Tensorflow or PlaidML as backends	Yes	Yes	Yes[18]	Yes	Yes	No[19]	Yes[20]	Yes
MATLAB + Deep Learning Toolbox	MathWorks		Proprietary	No	Linux, macOS, Windows	C, C++, Java, MATLAB	MATLAB	No	No	Train with Parallel Computing Toolbox and generate CUDA code with GPU Coder[21]	Yes[22]	Yes[23][24]	Yes[23]	Yes[23]	Yes	With Parallel Computing Toolbox[25]	Yes
Microsoft Cognitive Toolkit (CNTK)	Microsoft Research	2016	MIT license[26]	Yes	Windows, Linux[27] (macOS via Docker on roadmap)	C++	Python (Keras), C++, Command line,[28] BrainScript[29] (.NET on roadmap[30])	Yes[31]	No	Yes	Yes	Yes[32]	Yes[33]	Yes[33]	No[34]	Yes[35]	No[36]
Apache MXNet	Apache Software Foundation	2015	Apache 2.0	Yes	Linux, macOS, Windows,[37][38] AWS, Android,[39] iOS, JavaScript[40]	Small C++ core library	C++, Python, Julia, Matlab, JavaScript, Go, R, Scala, Perl, Clojure	Yes	On roadmap[41]	Yes	Yes[42]	Yes[43]	Yes	Yes	Yes	Yes[44]	Yes
Neural Designer	Artelnics	2014	Proprietary	No	Linux, macOS, Windows	C++	Graphical user interface	Yes	No	Yes	Analytical differentiation	No	No	No	No	Yes	Yes
OpenNN	Artelnics	2003	GNU LGPL	Yes	Cross-platform	C++	C++	Yes	No	Yes	?	?	No	No	No	?	
PlaidML	Vertex.AI, Intel	2017	Apache 2.0	Yes	Linux, macOS, Windows	Python, C++, OpenCL	Python, C++	?	Some OpenCL ICDs are not recognized	No	Yes	Yes	Yes	Yes		Yes	Yes

Software	Creator	Initial release	Software license[a]	Open source	Platform	Written in	Interface	OpenMP support	OpenCL support	CUDA support	Automatic differentiation[71]	Has pretrained models	Recurrent nets	Convolutional nets	RBM/DBNs	Parallel execution (multi node)	Actively developed

https://en.wikipedia.org/wiki/Comparison_of_deep_learning_software

Open Computing Language is a framework for writing programs that execute across heterogeneous platforms consisting of central processing units (CPUs), graphics processing units (GPUs), digital signal processors (DSPs), field-programmable gate arrays (FPGAs) and other processors or hardware accelerators

Automatic differentiation (auto-differentiation, simply autodiff…) is a set of techniques to evaluate the derivative of a function specified by a computer program.

Deep Learn toolboxes comparison (II)

Software	Creator	Initial release	Software license[a]	Open source	Platform	Written in	Interface	OpenMP support	OpenCL support	CUDA support	Automatic differentiation[71]	Has pretrained models	Recurrent nets	Convolutional nets	RBM/DBNs	Parallel execution (multi node)	Actively developed
PlaidML	Vertex.AI, Intel	2017	Apache 2.0	Yes	Linux, macOS, Windows	Python, C++, OpenCL	Python, C++	?	Some OpenCL ICDs are not recognized	No	Yes	Yes	Yes	Yes		Yes	Yes
PyTorch	Adam Paszke, Sam Gross, Soumith Chintala, Gregory Chanan (Facebook)	2016	BSD	Yes	Linux, macOS, Windows	Python, C, C++, CUDA	Python, C++, Julia	Yes	Via separately maintained package[45][46]	Yes	Yes	Yes	Yes	Yes		Yes	Yes
Seq2SeqSharp	Zhongkai Fu	2018	BSD	Yes	Linux, macOS, Windows	C#, C, C++, CUDA	C#	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Apache SINGA	Apache Software Foundation	2015	Apache 2.0	Yes	Linux, macOS, Windows	C++	Python, C++, Java	No	Supported in V1.0	Yes	?	Yes	Yes	Yes	Yes	Yes	
TensorFlow	Google Brain	2015	Apache 2.0	Yes	Linux, macOS, Windows,[47][48] Android	C++, Python, CUDA	Python (Keras), C/C++, Java, Go, JavaScript, R,[49] Julia, Swift	No	On roadmap[50] but already with SYCL[51] support	Yes	Yes[52]	Yes[53]	Yes	Yes	Yes	Yes	Yes
Theano	Université de Montréal	2007	BSD	Yes	Cross-platform	Python	Python (Keras)	Yes	Under development[54]	Yes	Yes[55][56]	Through Lasagne's model zoo[57]	Yes	Yes	Yes	Yes[58]	No
Torch	Ronan Collobert, Koray Kavukcuoglu, Clement Farabet	2002	BSD	Yes	Linux, macOS, Windows,[59] Android,[60] iOS	C, Lua	Lua, LuaJIT,[61] C, utility library for C++/OpenCL[62]	Yes	Third party implementations[63][64]	Yes[65][66]	Through Twitter's Autograd[67]	Yes[68]	Yes	Yes	Yes	Yes[59]	No
Wolfram Mathematica	Wolfram Research	1988	Proprietary	No	Windows, macOS, Linux, Cloud computing	C++, Wolfram Language, CUDA	Wolfram Language	Yes	No	Yes	Yes	Yes[69]	Yes	Yes	Yes	Yes[70]	Yes
Software	Creator	Initial release	Software license[a]	Open source	Platform	Written in	Interface	OpenMP support	OpenCL support	CUDA support	Automatic differentiation[71]	Has pretrained models	Recurrent nets	Convolutional nets	RBM/DBNs	Parallel execution (multi node)	Actively developed

https://en.wikipedia.org/wiki/Comparison_of_deep_learning_software

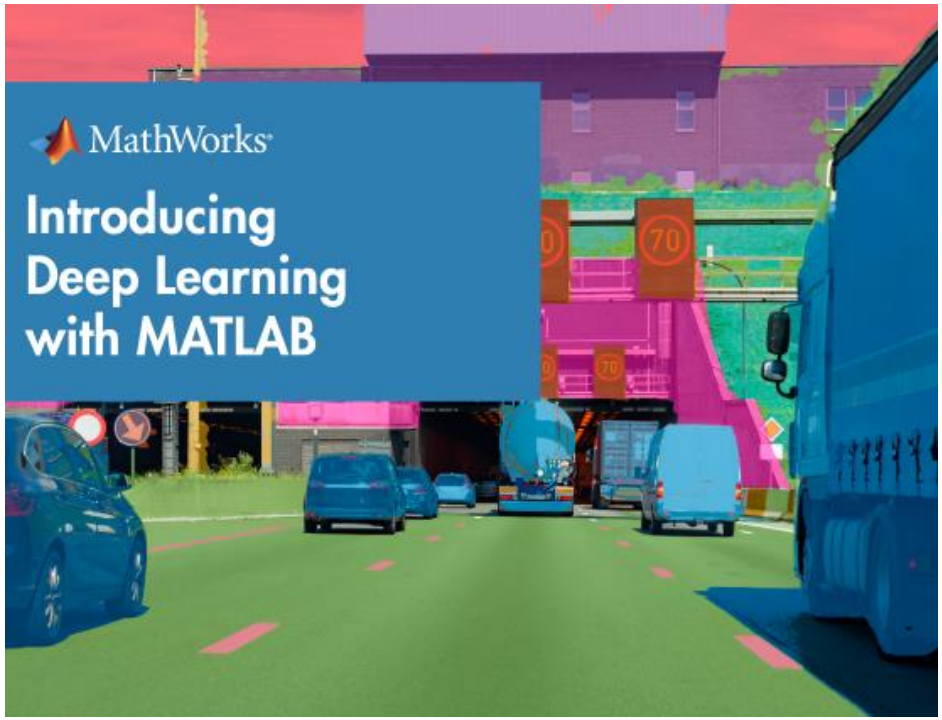
The Matlab ML toolboxes

(Laboratory)

Not in the exam
but it is quite good for
your knowledge and skills

Matlab toolbox

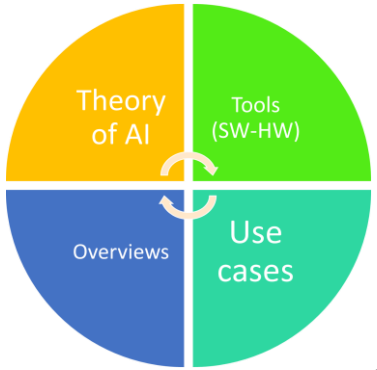
- Please refere to **Lesson24_ML_SW_toolboxes_2_Matlab.pdf**



Toolboxes

Cloud Services for ML

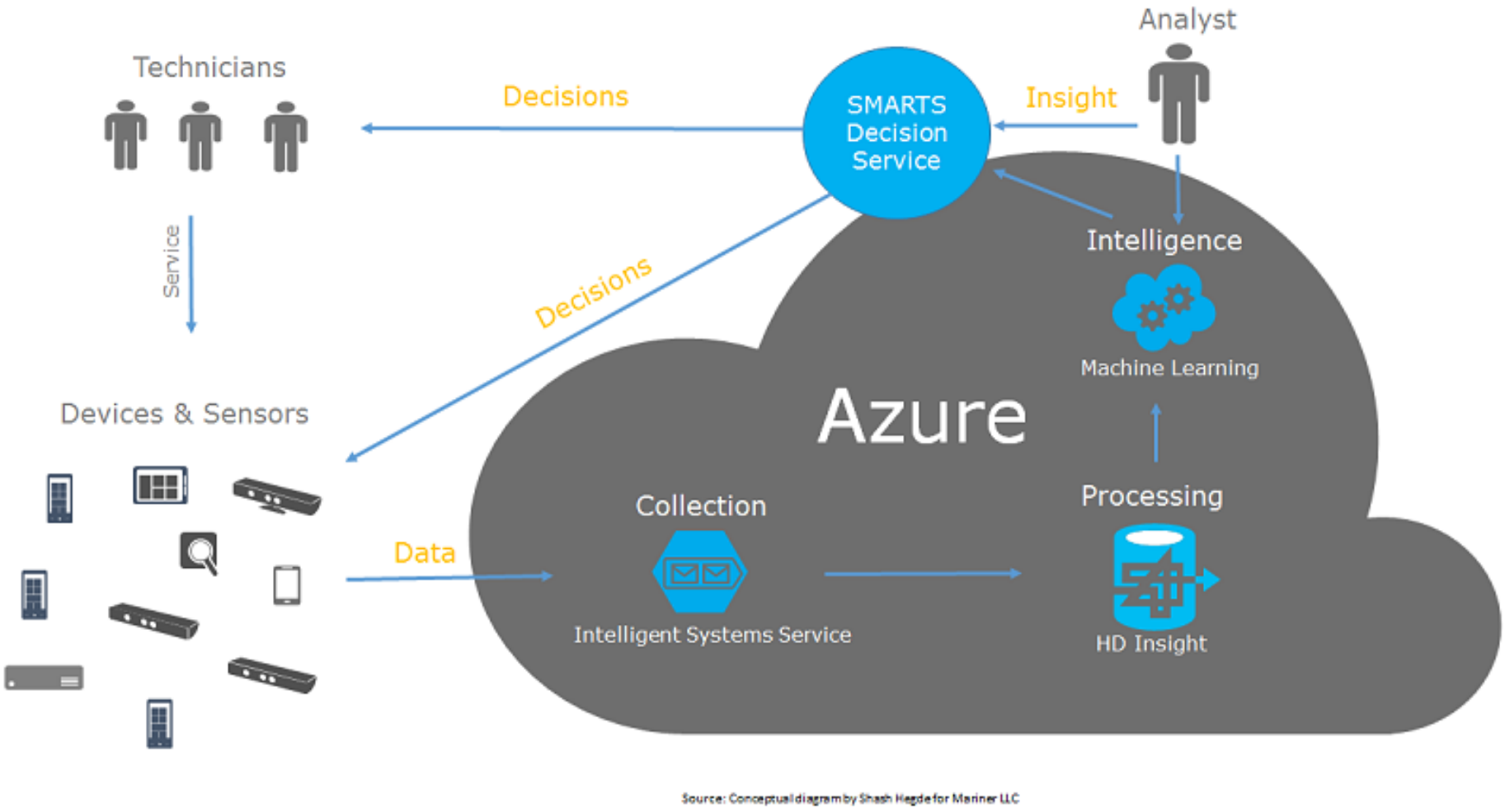
Machine Learning as a Service (MLaaS)



Machine Learning "as a Service" (MLaaS)

- Machine learning as a service is an umbrella definition of automated and semi-automated cloud platforms that cover most infrastructure task such as
  - Data pre-processing
  - Model training
  - Model evaluation
  - Dataset management
- Prediction results can be bridged for example with your internal IT infrastructure through REST APIs.

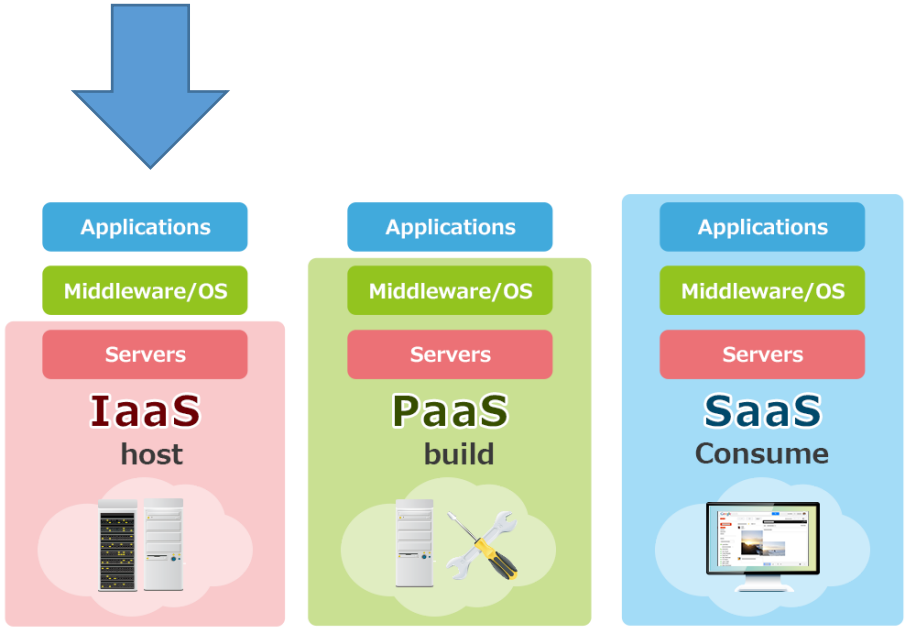
An example: the MS Azure



Source: Conceptual diagram by Shash Hegde for Mariner LLC

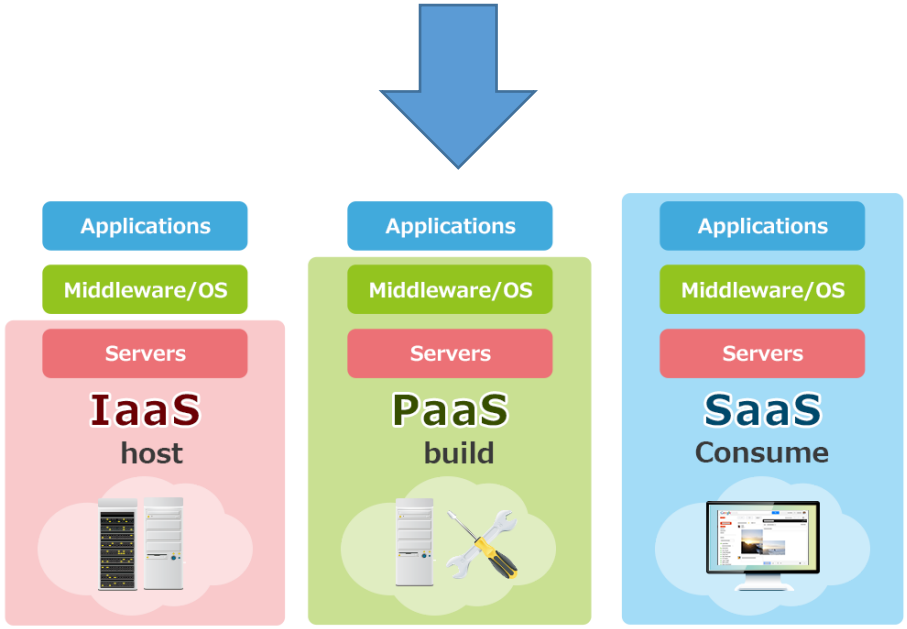
Cloud services: the 3-Tiers model: IaaS

- **Infrastructure as a service (IaaS)**
- A vendor provides clients pay-as-you-go access to
  - storage,
  - networking,
  - servers and
  - other computing resources in the cloud



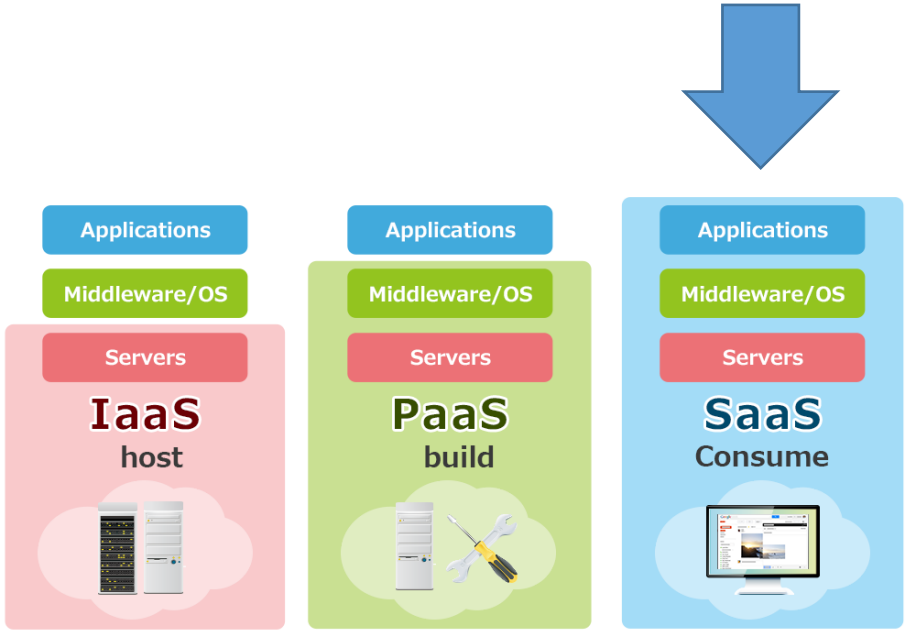
Cloud services: the 3-Tiers model: PaaS

- **Platform as a service (PaaS)**
- A service provider offers access to a cloud-based environment in which users can build and deliver applications.
- The provider supplies underlying infrastructure.



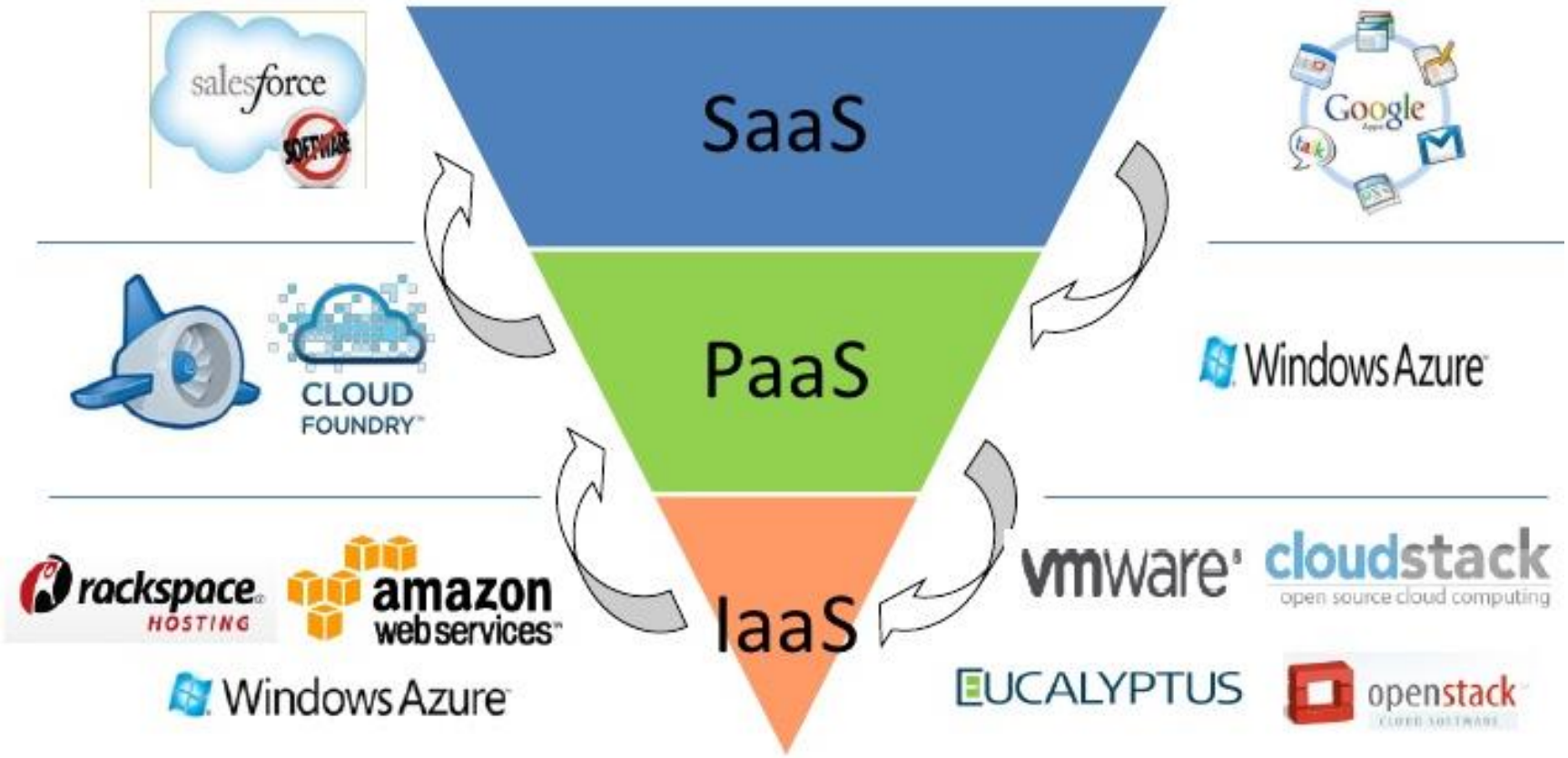
Cloud services: the 3-Tiers model: SaaS

- **Software as a service (SaaS)**
- A service provider delivers software and applications through the internet.
- Users subscribe to the software and access it via the web or vendor APIs.



Cloud services: the 3-Tiers model

Note: Things are changing quickly …



3 leading cloud MLaaS services

- They allow for fast model training and deployment with little to no data science expertise:
  - Azure Machine Learning (MS)
  - Amazon Machine Learning services
  - Google Cloud AI

High-level APIs

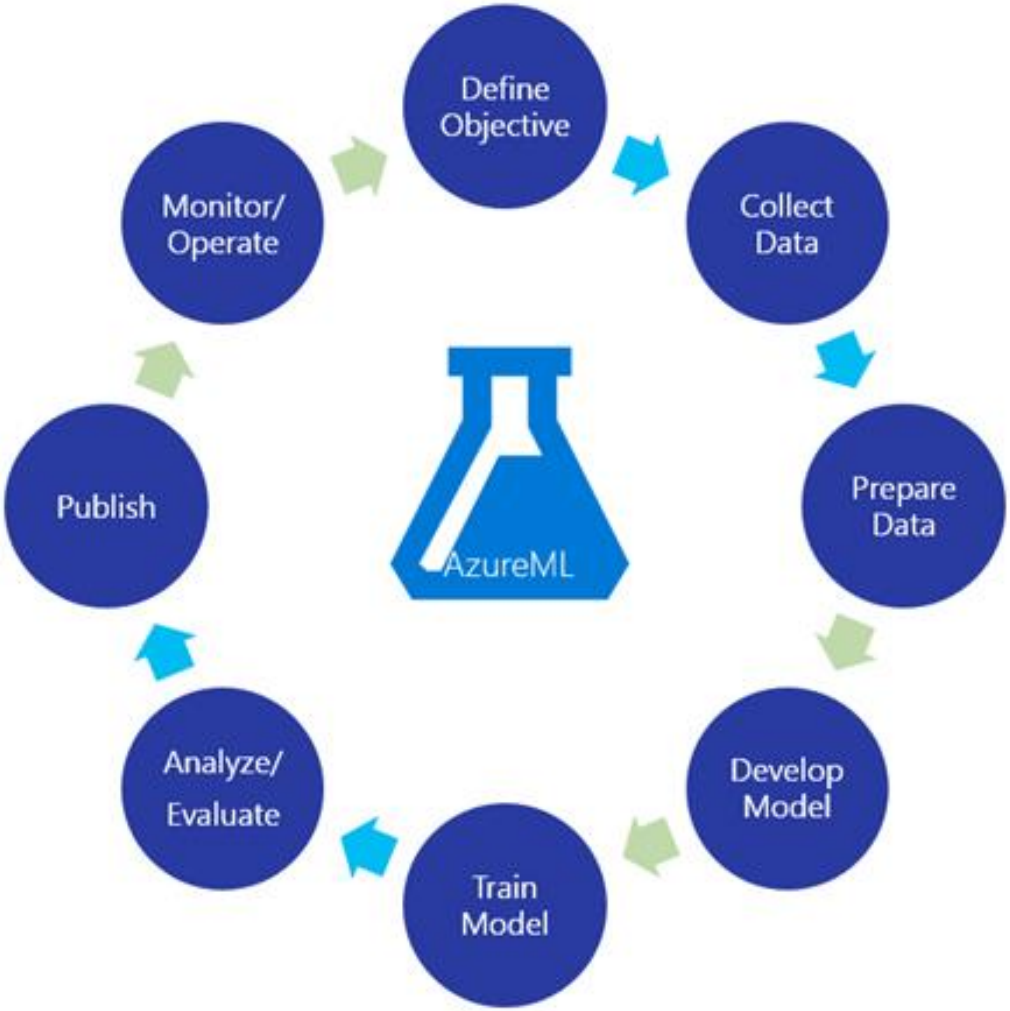
- Easy: feed your data to the trained models and get results!
- APIs don’t require machine learning expertise at all (….more or less…).
- Three large groups:
  1. Text recognition, translation, and textual analysis
  2. Image + video recognition and related analysis
  3. Other, that includes specific uncategorized services

Microsoft Azure

Azure Machine Learning

Microsoft Azure Machine Learning Studio

Azure Machine Learning



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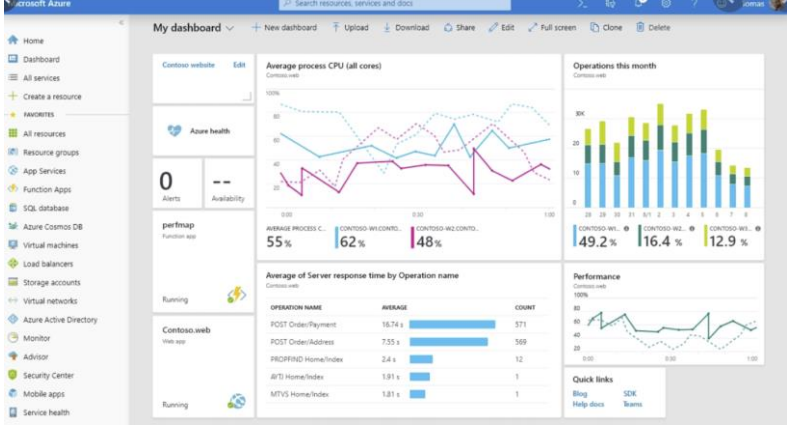
Features



- Steep learning curve.
- Supports workflow graphical interface
- Hundreds of methods that address
  - *classification (binary+multiclass)*
  - *anomaly detection*
  - *regression*
  - *recommendation*
  - *text analysis*
  - *clustering* algorithm (K-means)
  - …




Amazon Machine Learning

Amazon Machine Learning

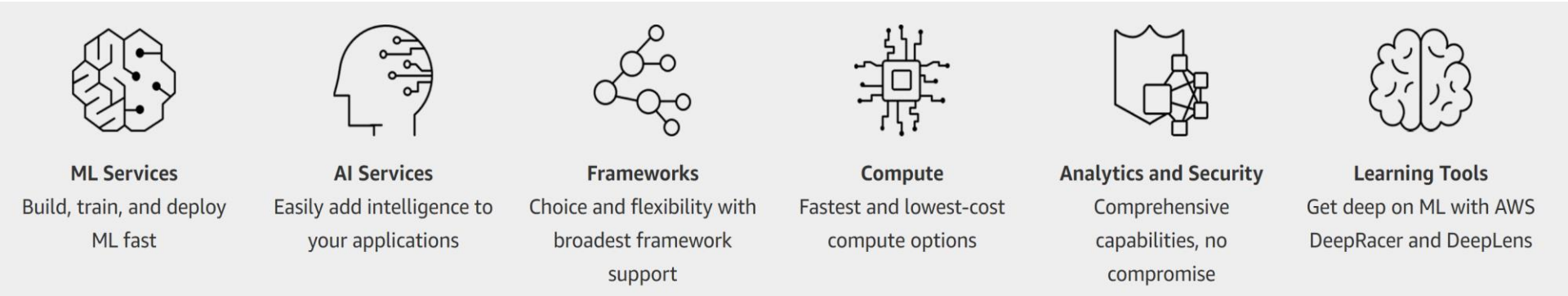
- Two levels:
  - **Predictive analytics**
  - **SageMaker** (tool for data scientists).

- Amazon Machine Learning for **predictive analytics**
  - Is one of the most automated solutions on the market
  - The best fit for deadline-sensitive operations.
  - Load data from multiple sources
    - Amazon RDS,
    - Amazon Redshift,
    - CSV files,
    - etc.
  - All data preprocessing operations are performed automatically (not always is a good thing…it's an error-prone approach)
    - Automatic categorical/ numerical recongnition
    - Automatic data preprocessing (dimensionality reduction and whitening).

Browse the site of the producer for updated information

Amazon SageMaker and frameworks-based services

- A Machine Learning environment
  - Simplify the work of the data scientist
  - Quick model building and deployment
  - Simplify data exploration and analysis
  - Built-in algorithms that are optimized for large datasets and computations in distributed systems.



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Amazon SageMaker and frameworks-based services (2)

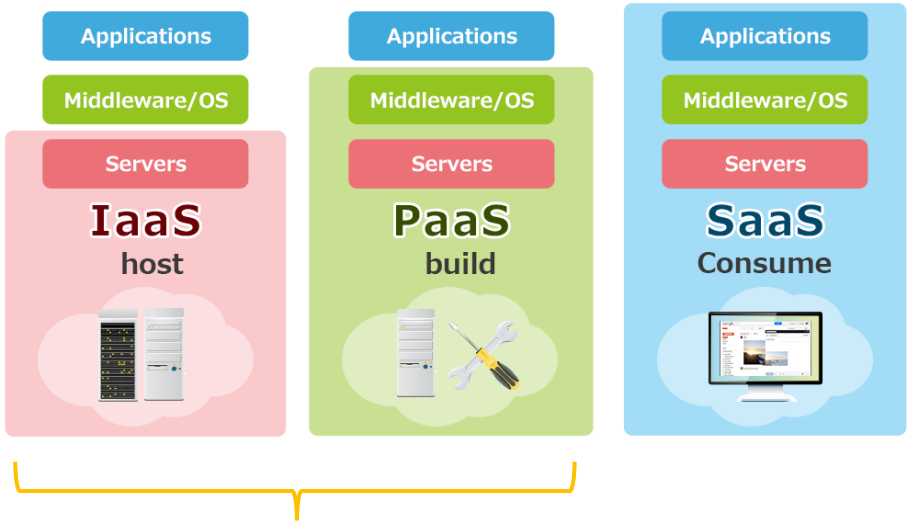
Just few examples….

- Linear learner, a supervised method for *classification* and *regression*
- Factorization machines for *classification* and *regression* designed for sparse datasets
- XGBoost is a supervised **boosted trees** algorithm that increases prediction accuracy in *classification*, *regression,* and *ranking* by combining the predictions of simpler algorithms
- **Image classification** based on ResNet, which can also be applied for transfer learning
- Seq2seq is a supervised algorithm for **predicting sequences** (e.g. translating sentences, converting strings of words into shorter ones as a summary, etc.)
- **K-means** is an unsupervised learning method for ***clustering* tasks**
- **PCA** for dimensionality reduction
- Latent Dirichlet allocation is an unsupervised method used for finding categories in documents
- Neural topic model (NTM) is an unsupervised method that explores documents, reveals top ranking words, and defines the topics (users can't predefine topics, but they can set the expected number of them)

Google Cloud Machine Learning Engine

Google Cloud Machine Learning Engine

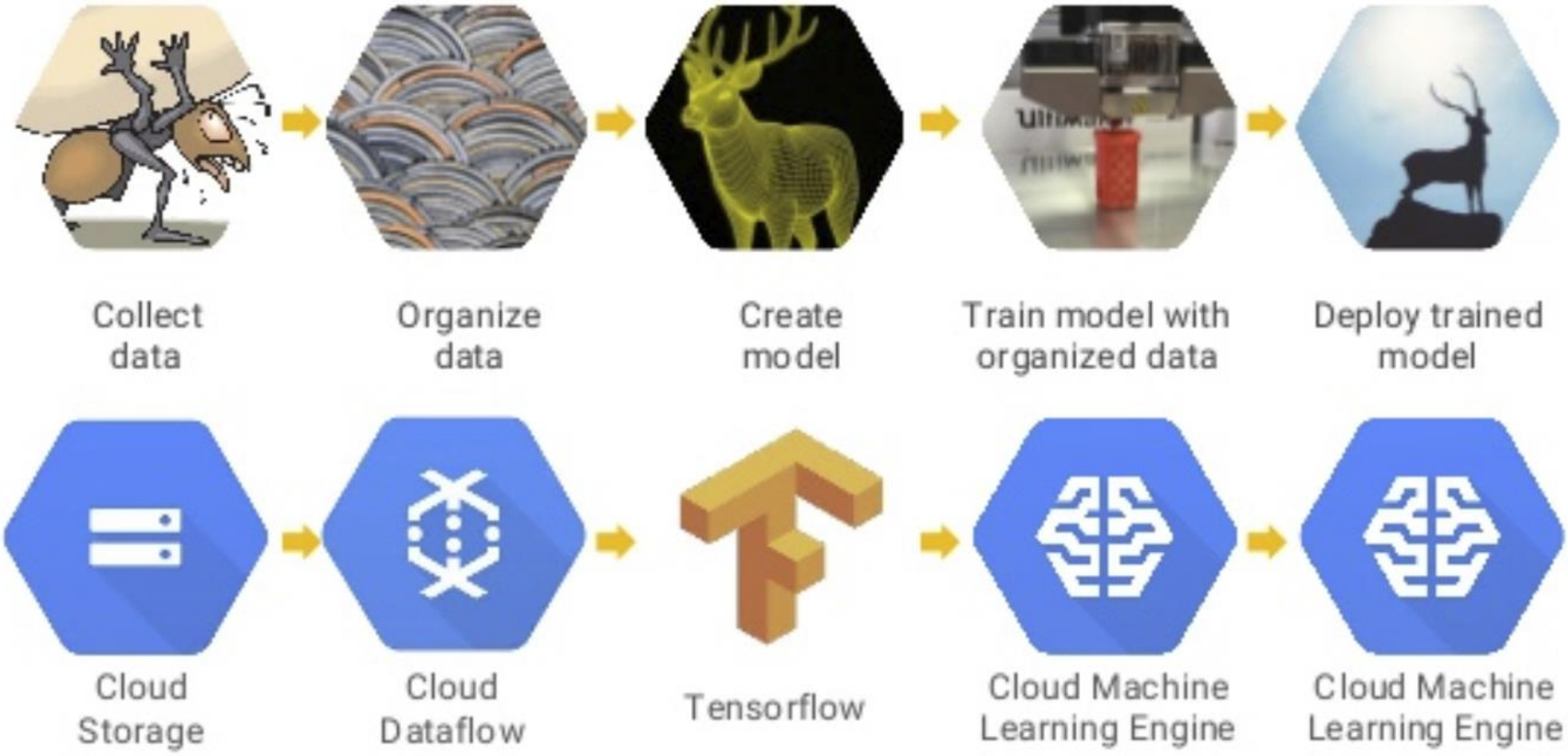
- The combination of **TensorFlow** and **Google Cloud service** achieves different solutions
  - *infrastructure-as-a-service*
  - *platform-as-a-service*



Google ML Engine

- For experienced data scientists
- Very flexible,
- Typically: Cloud infrastructure +TensorFlow as a machine learning driver (similar to SageMake)
- TensorFlow (Google open source machine learning library)
  - Not (yet completely) ML-as-a-service….
  - No visual interface
  - Steep learning curve!
    - The library is also targeted at software engineers

Design step in **Google Cloud service**



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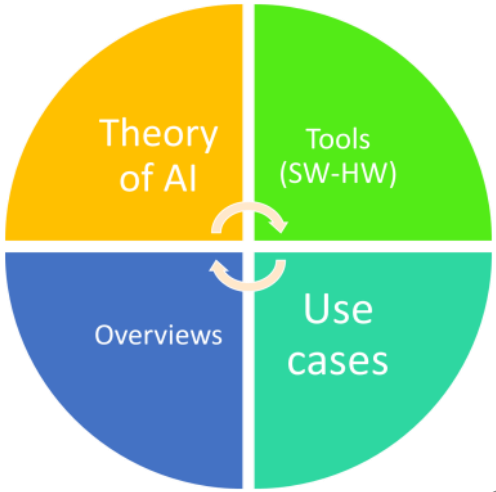
Overview

Introduction to intelligent vision systems



Intelligent systems for Robotics (1)

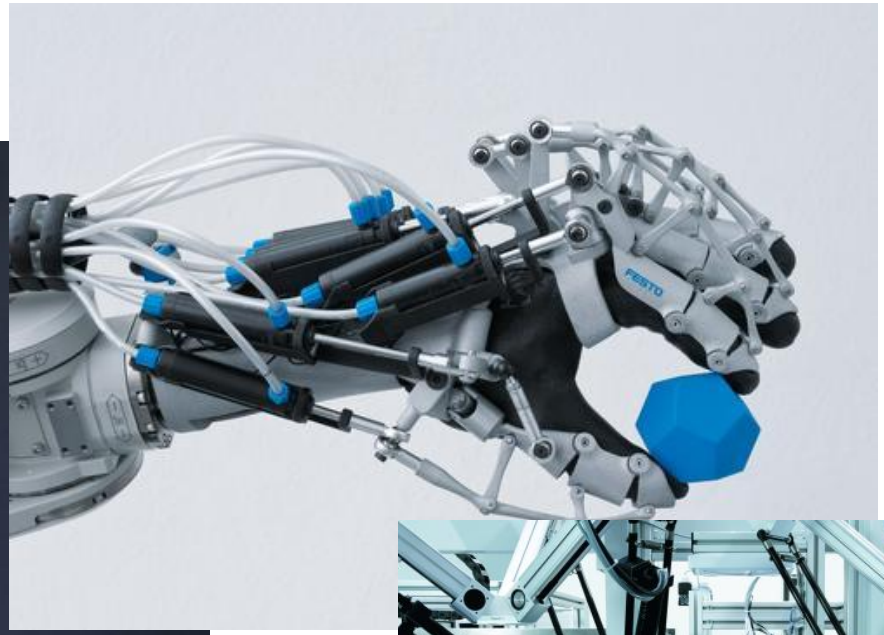
- Automatic machines that perform various tasks that were previously done by humans
- Example:
  - Industrial robots (pick and place, cutting, welding)
  - Pilot-less combat airplanes
  - Land-mine hunters
  - Autonomous vacuum-cleaners
- Components: Body structure, actuators, power-source, sensors, controller (the AI-based part)

Intelligent systems for Robotics

(2)

Industrial applications

General purpose



Trajectories optimization, haptics, sensors, improved controllers, vision systems, co-working, …

Many of them are using cameras

Methods and applications: Control

Control of a plant

Applications of intelligent system for control of industrial processes, industrial automation, robotic systems, complex products, power distribution grids, automotive and transport systems.

Control of a position

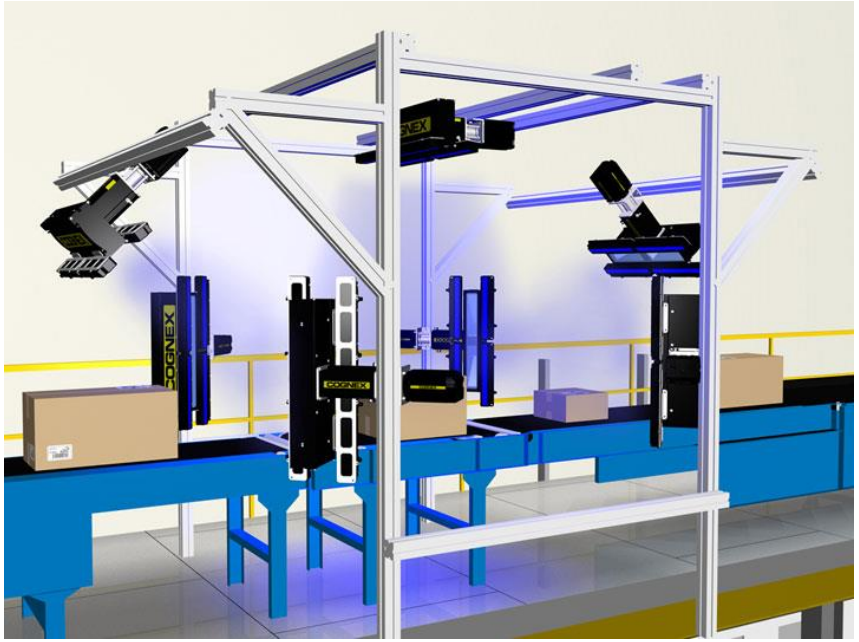
Stability Control

Intelligent vision systems

- Environment, Quality, Inspection, Production, Security, …

Complex scenarios to be managed

Non ideal inputs and changes in time



Smart Cars

- Identification of the driver
- Driving assistance
- Autonomous driving
- Security/Surveillance
- Automatic settings …

Smart Entertainement Systems / Domotics

- Identification
- Profiling (adult/kid/dog/cat)
- Security
- …





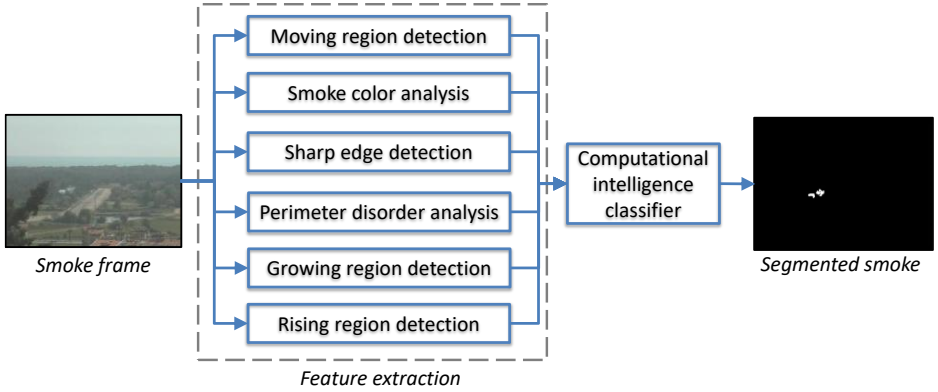
Smart city

- Intelligent Traffic Management
- Anomality detection
- Crime prevention
- Security/Surveillance
- Profiling (adult/kid)
- …

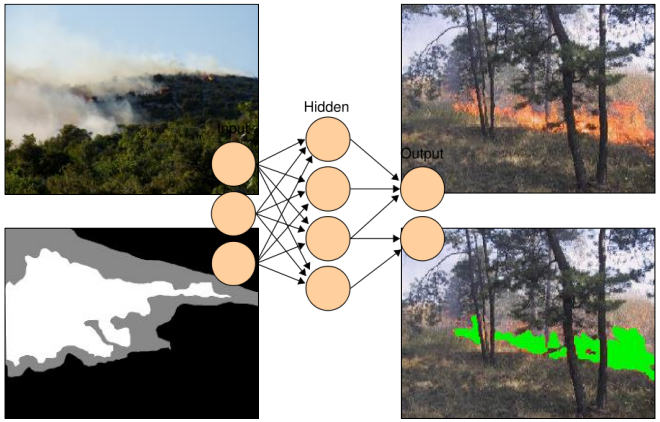
Environmental applications: Wildfire smoke detection

- Problem in regions with hot climate and extensive vegetation
- Current techniques require large infrastructure and human inspection
- Innovative computer vision approach
  - Visible light
  - Low quality frames
  - Limited hardware power
  - Different environments
  - Distinctive features:
    - Static
    - Dynamic
  - Computational intelligence
- Flexible: can learn new environments!

STEP 1: Feature extraction (by the designer)



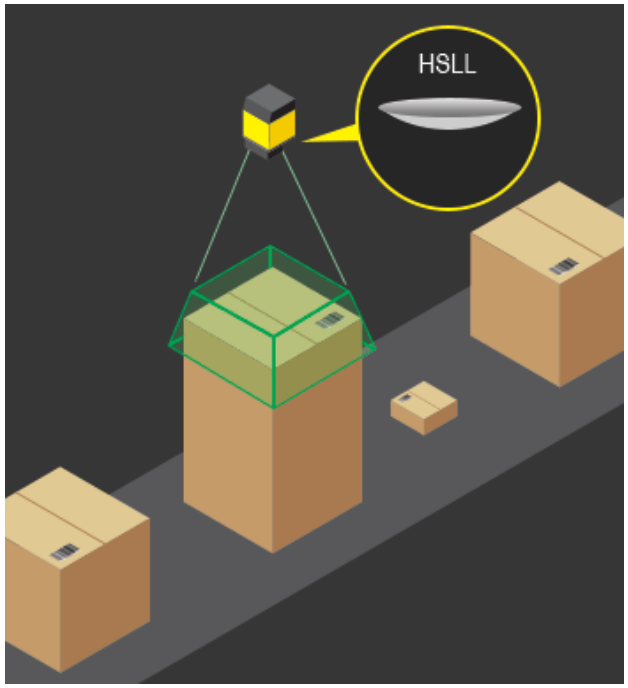
STEP 2: classification with NN

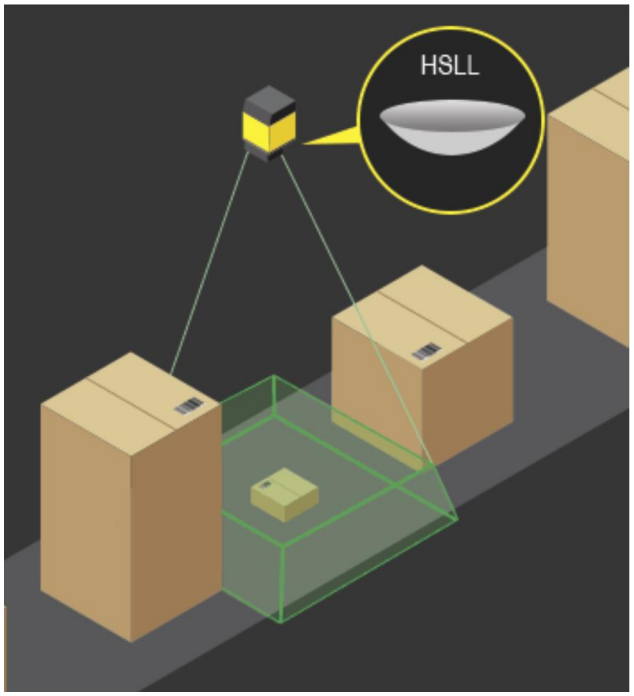


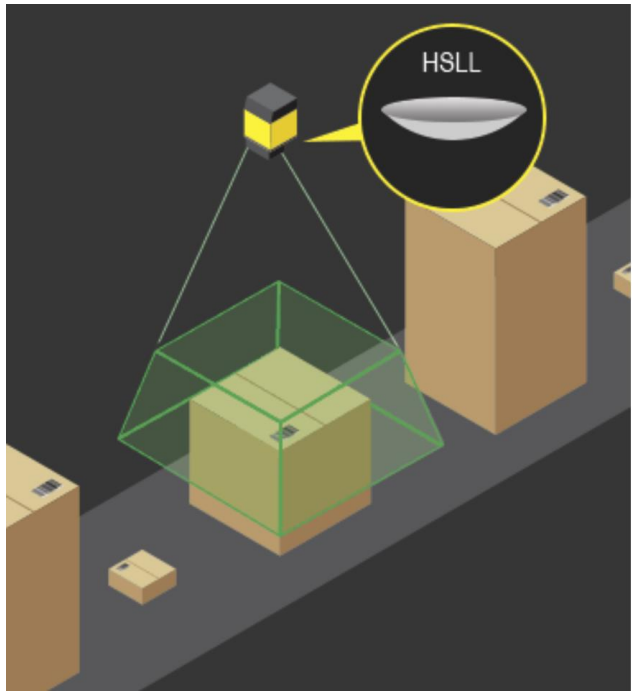
Methods and applications: Logistics

Liquid lens + AI in logistics

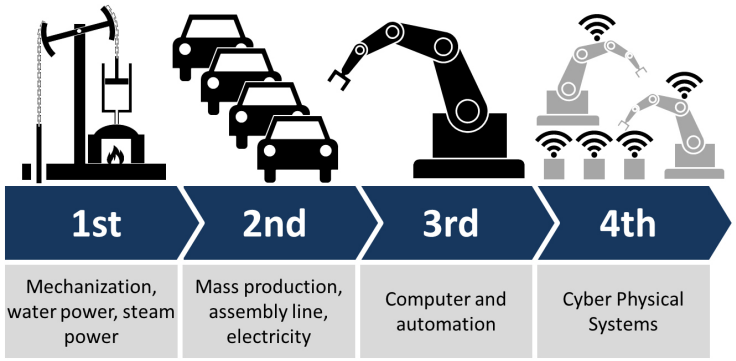
- On a convoyer belt the bar codes can be effectively scanned by chaning the focal of the optics
  + Deep Learning OCR → correct identification







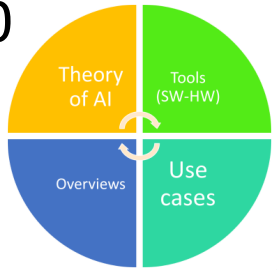


Overview

Industry 4.0

Features needed to create applications within Industry 4.0



All sector are investing within Industry 4.0

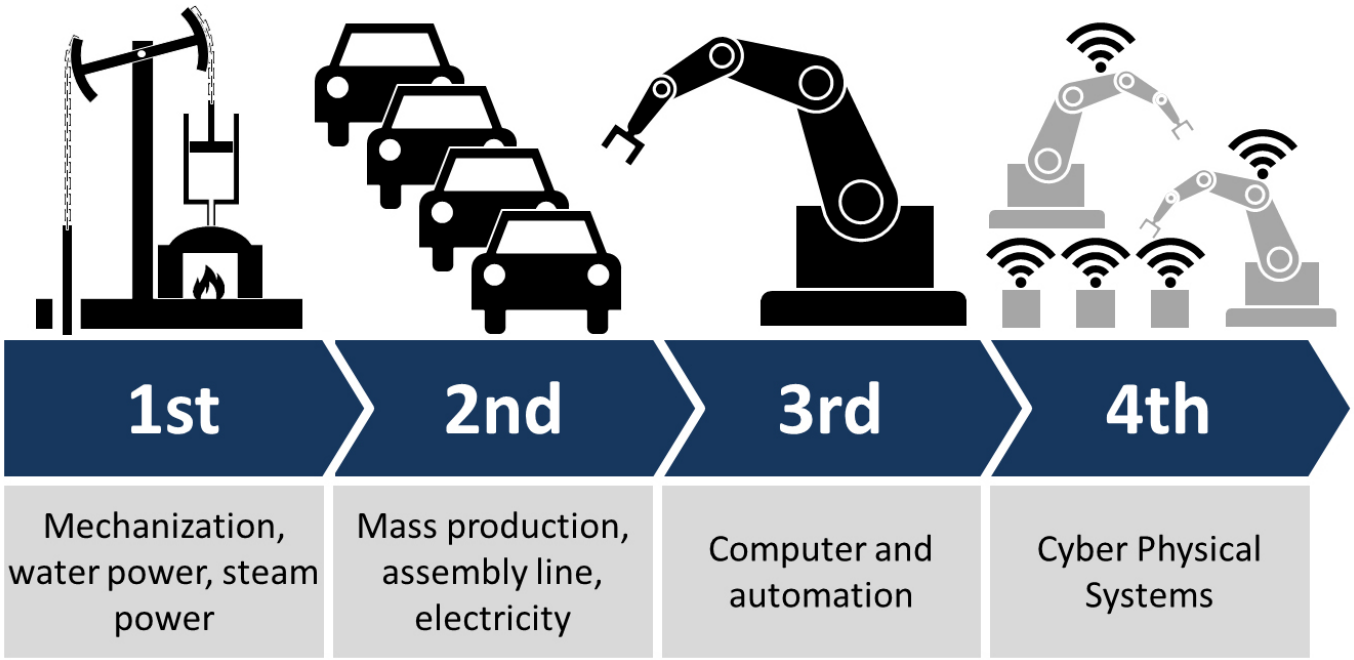
In brief…. Technologies/Architectures/Machines/Sensors/IoT devices with augmented (wireless) connectivity, connected to a system that can represent the entire production line and make decisions on its own

Many funding program within Industry 4.0 are available

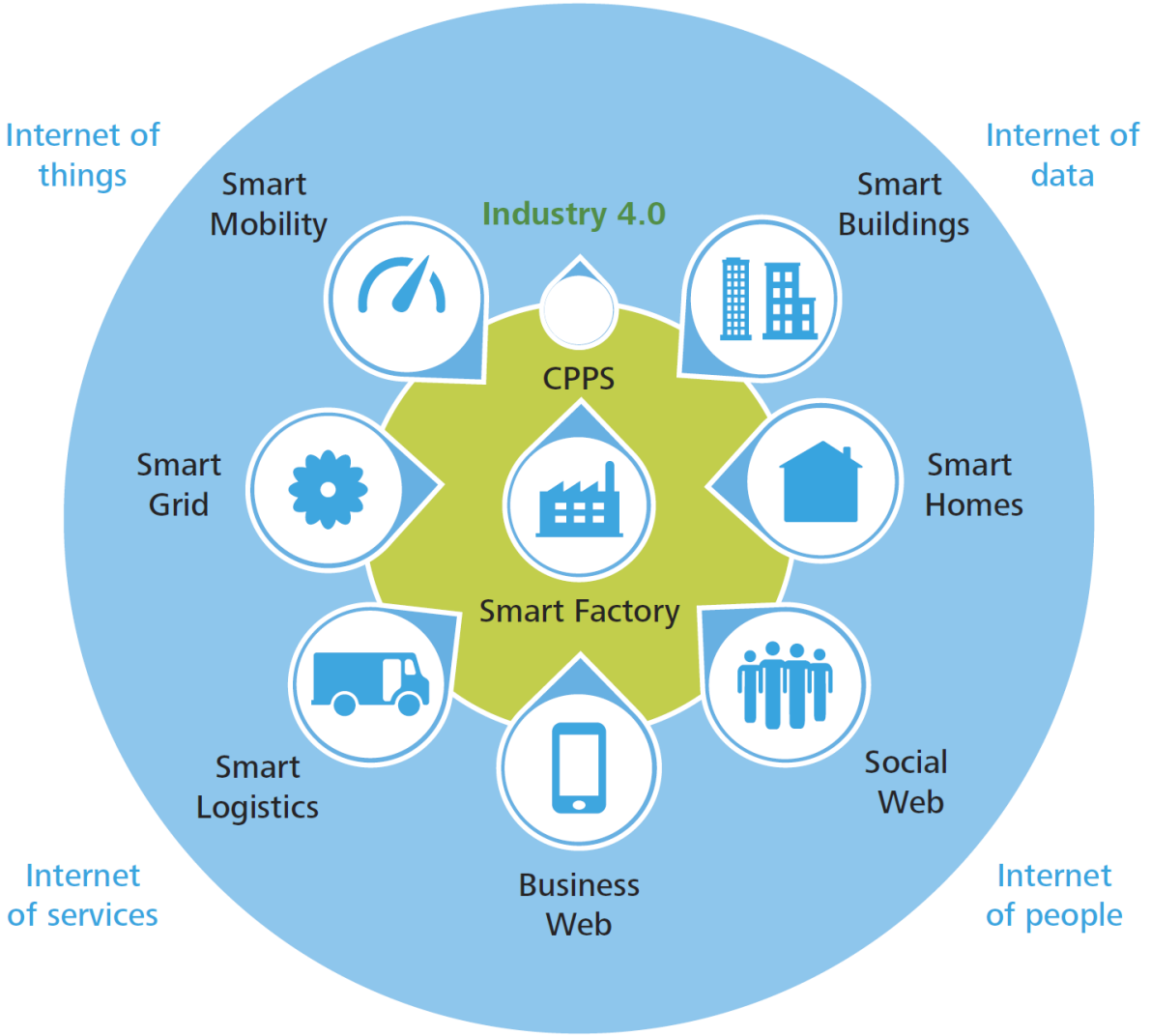
Industry 4.0

The topic of the course…..

- Stands for highly intelligent connected processes and systems created through digital networked data communication.



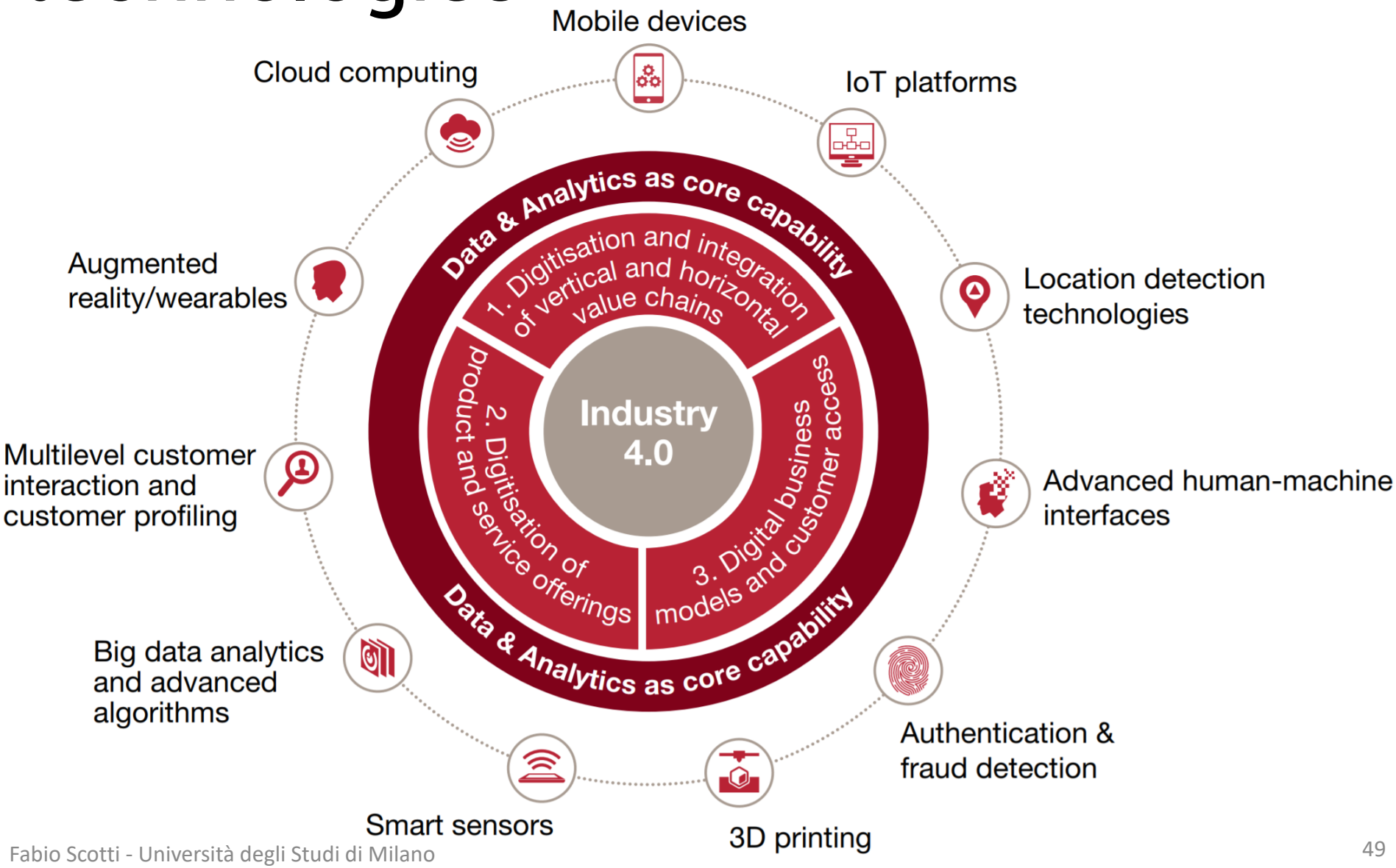
The I4.0 environment



(IoP) is the new infrastructure we need to create to enable people to communicate with each other using their own devices directly without relying on any trusted third party to establish the connection

PWC report «Building the digital enterprise»

I4.0: Contributing digital technologies



In case you will leading the design of a system with Industry 4.0 funds, keep it in mind..

Industry 4.0 Design principles (1-2)

- To be compliant to the Industry 4.0 funds…
- Interoperability:
  - The ability of machines, devices, sensors, and people to **connect and communicate with each other** via the Internet of Things (IoT) or the Internet of People (IoP).
- Information transparency:
  - The ability of information systems to create a virtual copy of the physical world by enriching digital plant models with sensor data. This requires the aggregation of raw sensor data to higher-value context information.

Industry 4.0
Design principles (3-4)

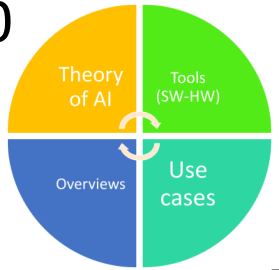
- Improved technical assistance:
  - The ability of assistance systems to support humans by aggregating and visualizing information comprehensibly for making informed decisions and solving urgent problems on short notice (exploiting the ability of cyber physical to conduct tasks that are unpleasant, too exhausting, or unsafe for their human co-workers).
- Decentralized decisions:
  - The ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomously as possible.
  - Only in the case of exceptions, interferences, or conflicting goals, are tasks delegated to a higher level.




Overview

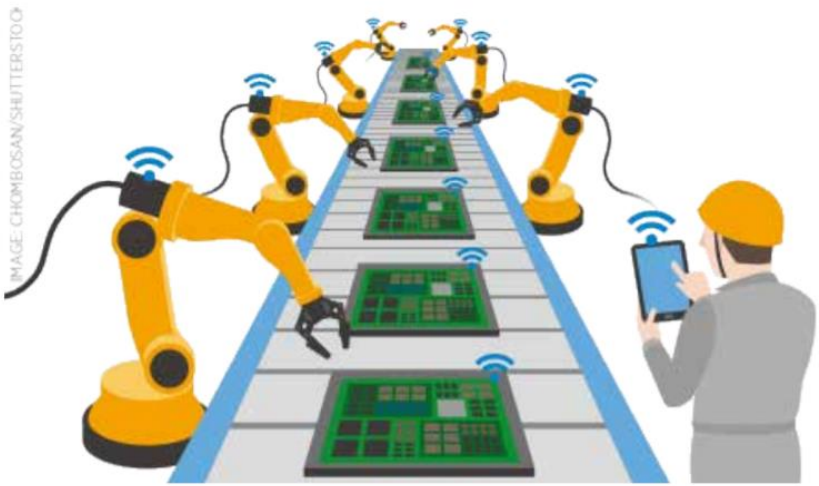
Industrial Intelligent Vision Systems

Features needed to create applications within Industry 4.0



Intelligent Vision System

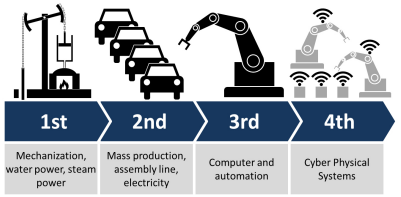
- Industrial cameras continue to become smaller and more affordable, even as performance constantly improves.
- Machine Vision Imaging Systems, together with ever-expanding networking capabilities, opens up this potential for new applications and further advancing Industry 4.0.



Cameras as tireless process auditors

Industrial cameras in production

Intelligent Vision System for Industry 4.0



- They are the ***eyes*** that capture the process and proved feed back via image processing software.
- Throughout all steps of manufacturing (from the inspection of raw materials and production monitoring to final inspections and quality assurance) industrial vision cameras are being used across all industries and **are an indispensable part of achieving efficiency and high quality standards** (*).

(*) WHITE PAPER: Industrial Cameras in Industry 4.0 for Efficient Production www.baslerweb.com

History... today

2005-2006
- Machine Vision Cameras
- VGA to 3MP and Linescan
- Camera Link and FireWire Interfaces

2007-2008
- Smart Vision System
- DSP, Image Processing Library, Interactive GUI for Programming

2009-2013
- Smart Camera / Smart Sensor
- Embedded DSP
- Fully Integrated Functionality

2018-2020
- Smart cameras with FPGA
- With onboard deep neural network
- Measurements
- OCR + QR + Barcode adv. techniques

Industrial vision systems
Sensors and smart cameras

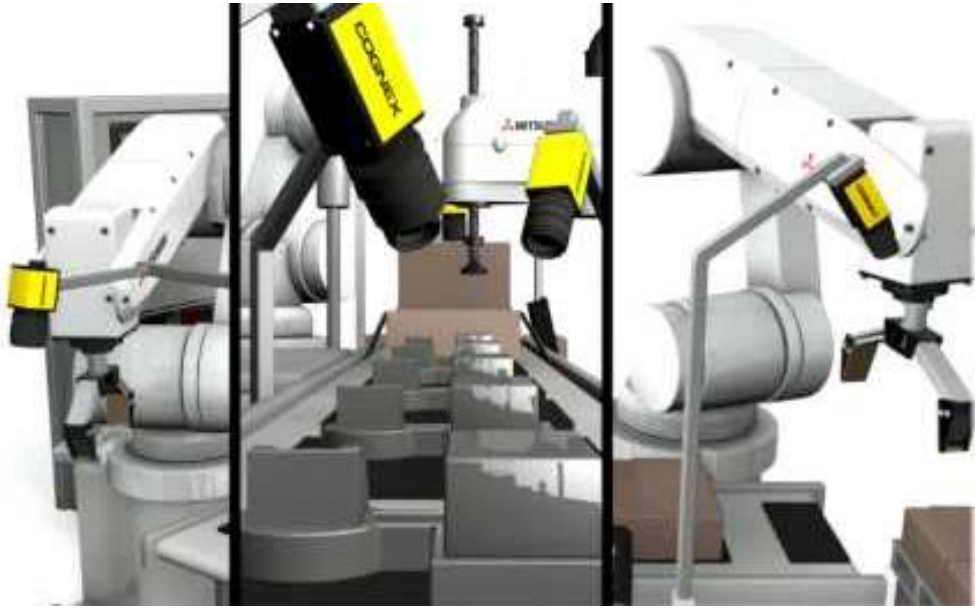
3D laser profilometer

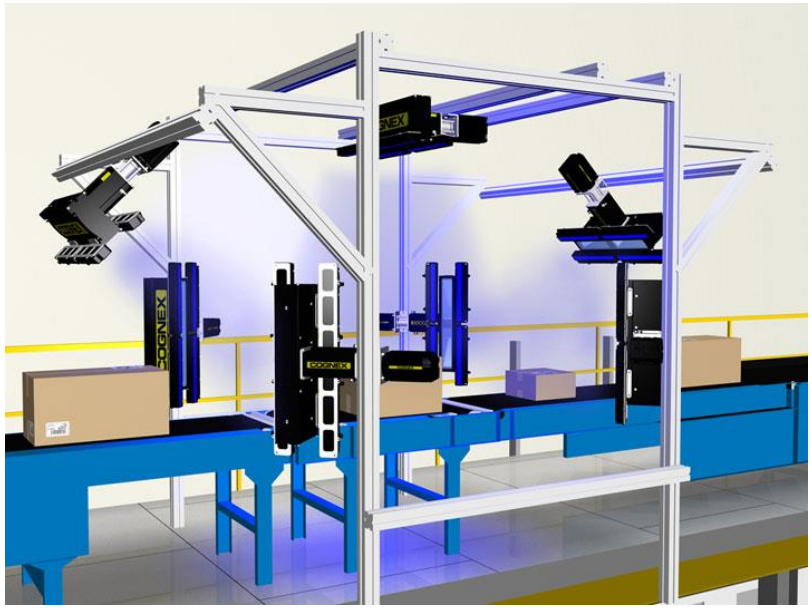
Onboard processing = Smart camera

Camera

Industrial Vision Systems

- Quality, Inspection, Production, Security





Along the complete production chain

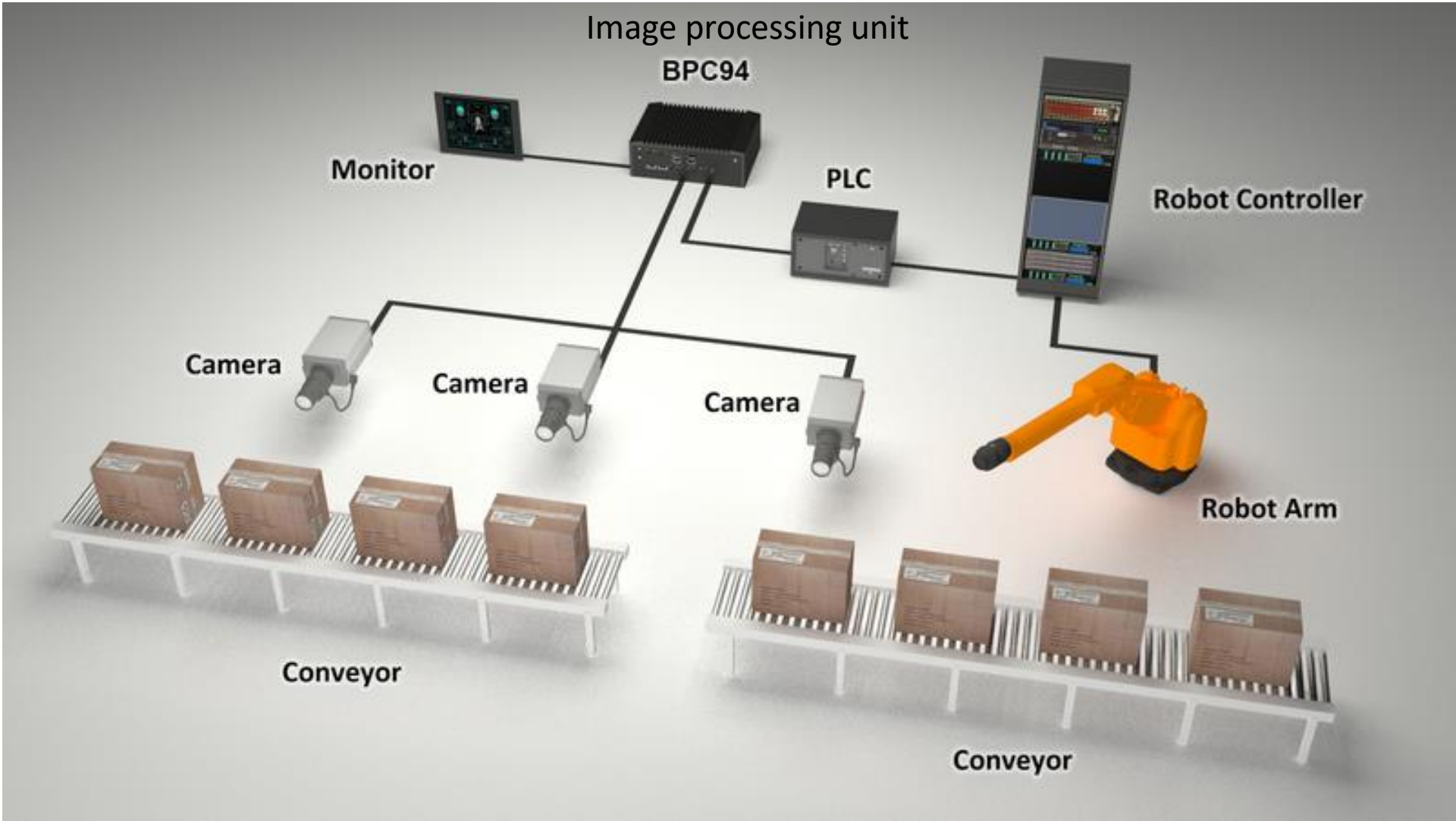
The basic setup

Illumination systems

HW+SW
(+ deep models)

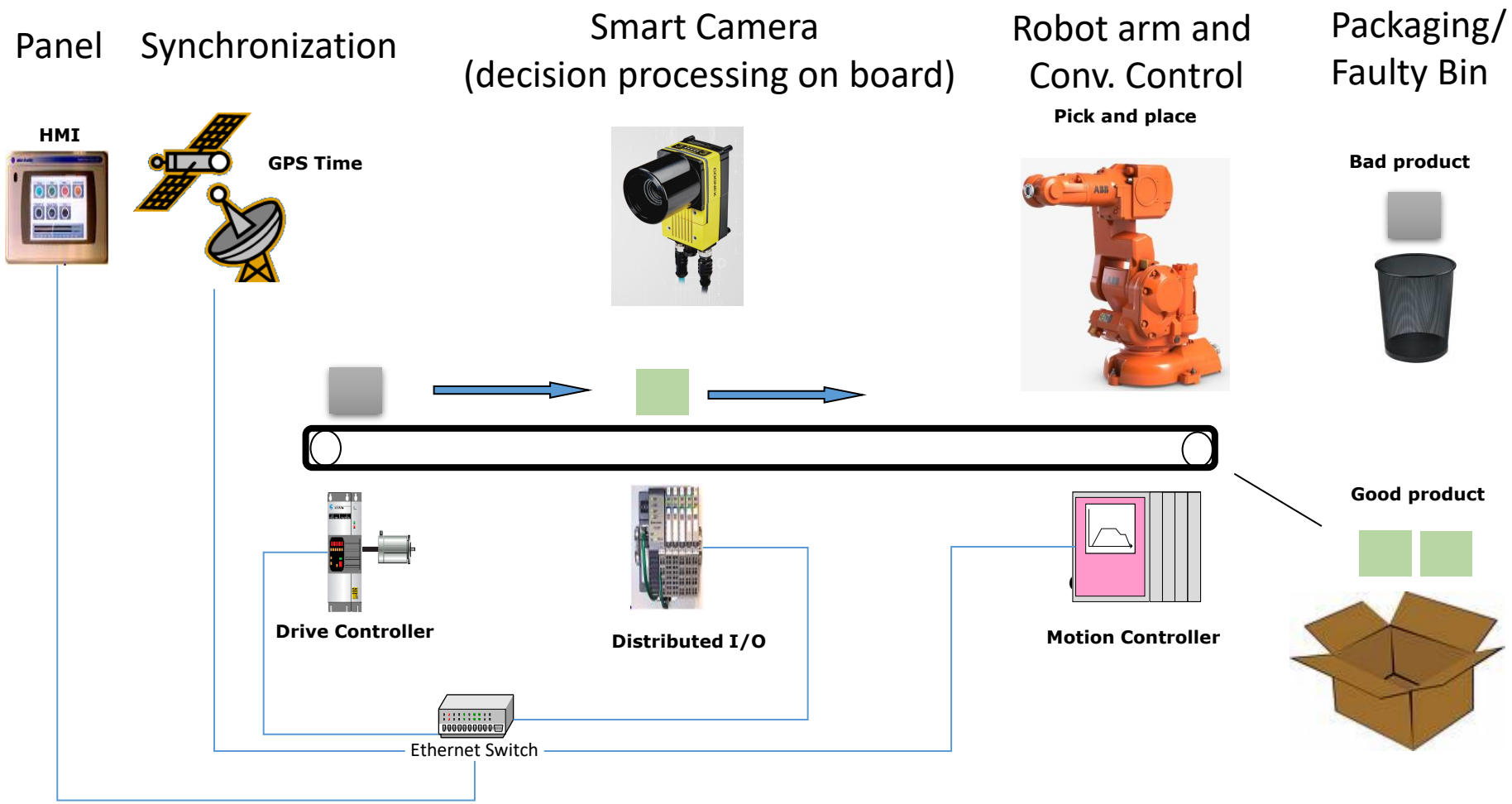
Classification
Measurements
Quality assessment

Industrial Vision Environment

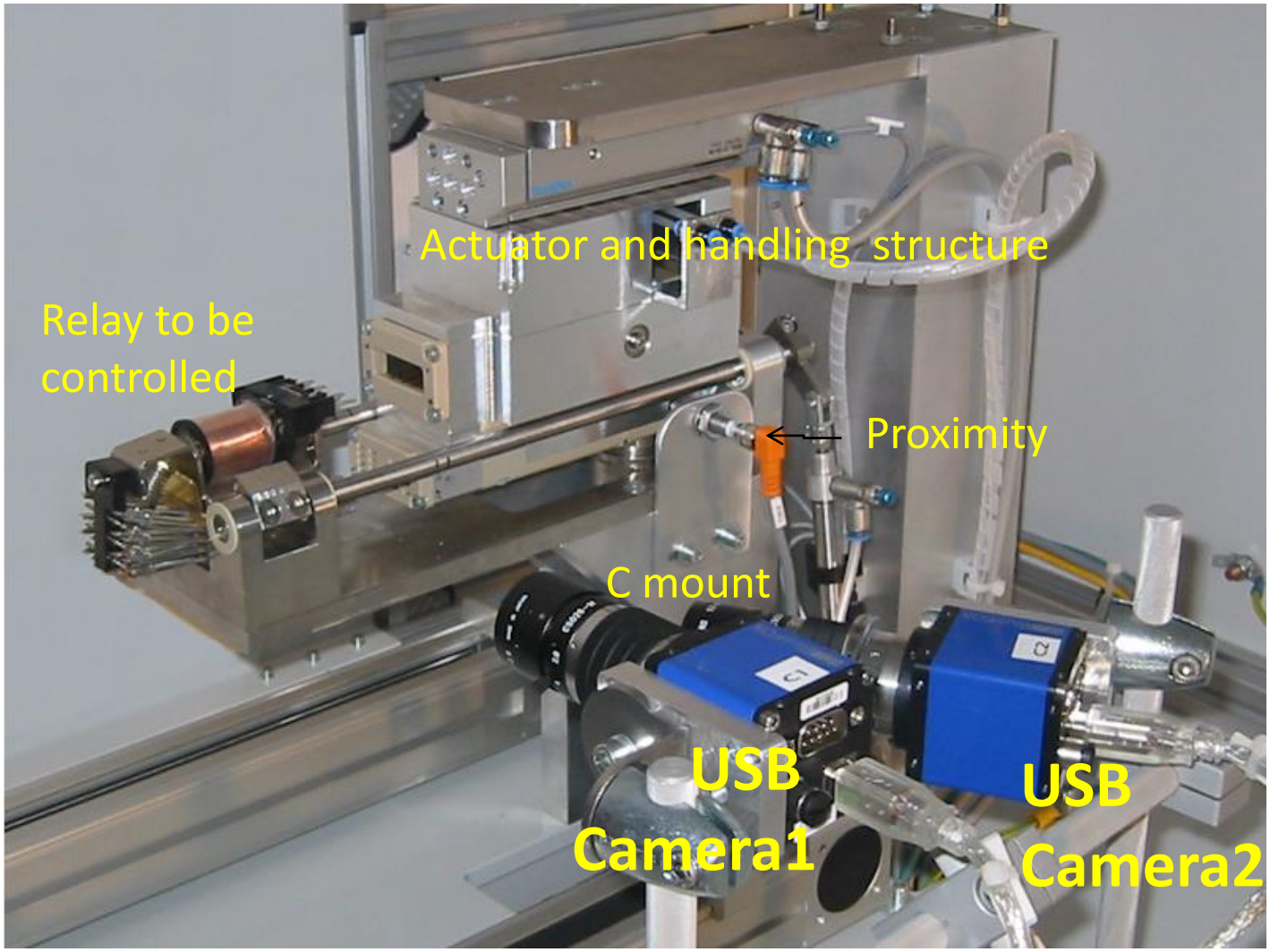


Automation Control Network Example

- **An intelligent system sorts defective parts off of a conveyor belt**
- **Network uses fieldbus protocols on a 10/100 Ethernet network with IEEE 1588 time synchronization support**

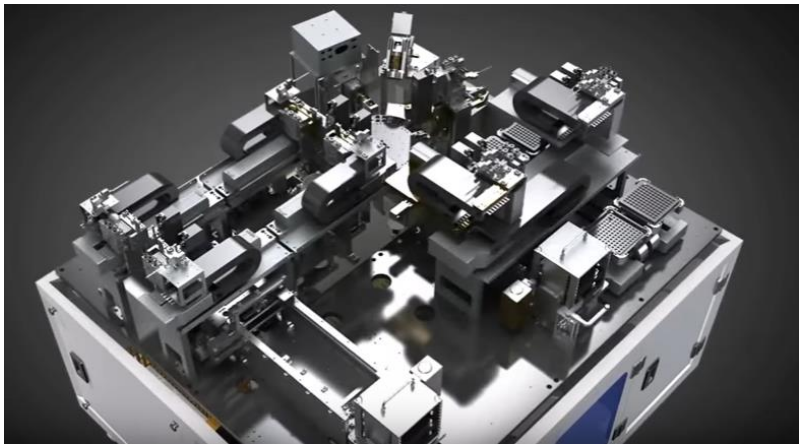


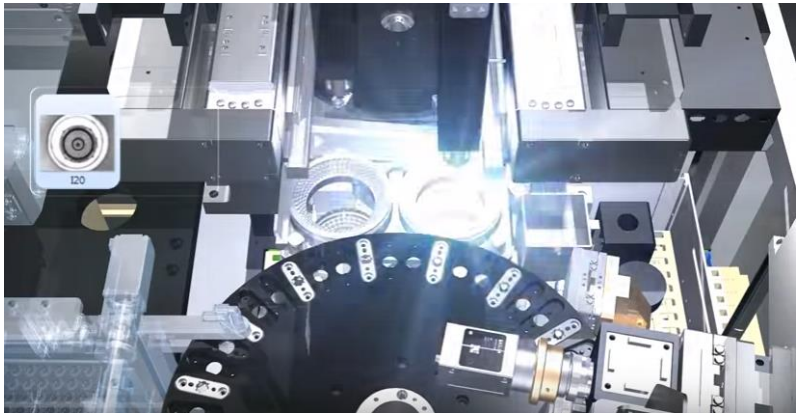
Example of industrial vision system: Relay contact measurement



Complete systems

100.000 – 200.000 EUR





Main points

- Applications of Intelligent Vision Systems
  - Industry 4.0
  - Ambient Intelligence and Domotics
  - Supply Chain
  - Environmental
- Intelligent Vision Systems
  - Object detection,
    Segmentation and Recognition
  - Classical, Deep and Hybrid solutions
  - Use cases
- Appendix: Industry 4.0 details (after this slide)

Thank you for your attention!

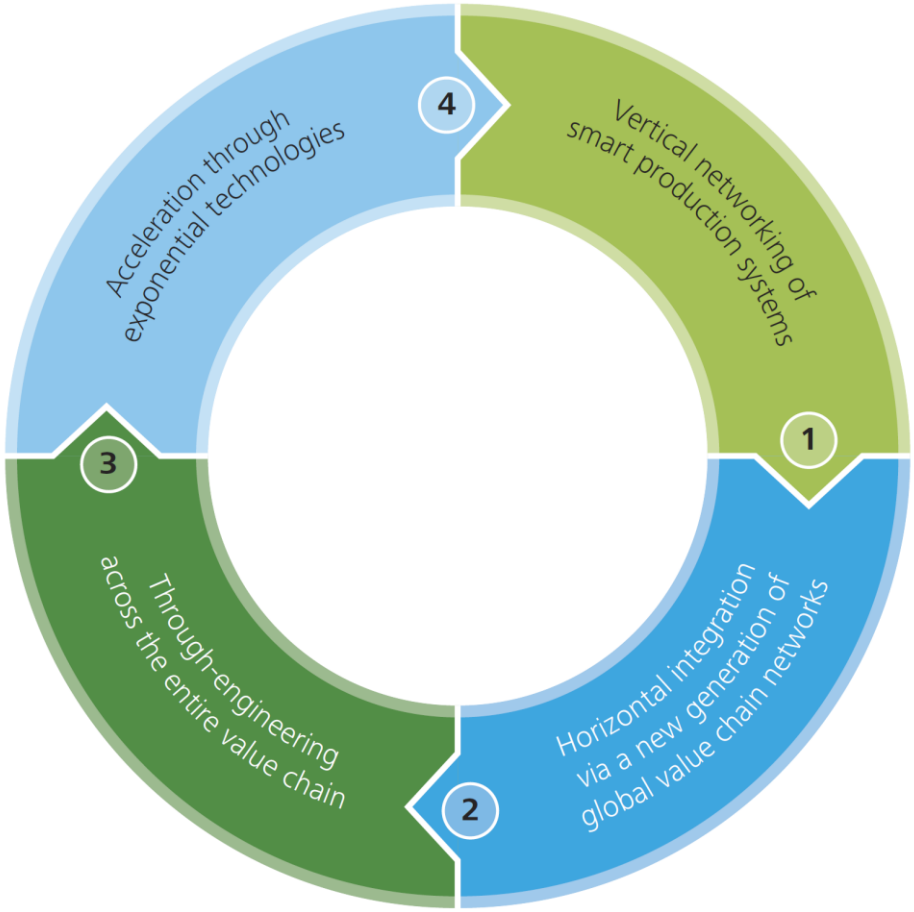
In case you need, write an email here:
fabio.scotti@unimi.it




Industry 4.0 Appendix

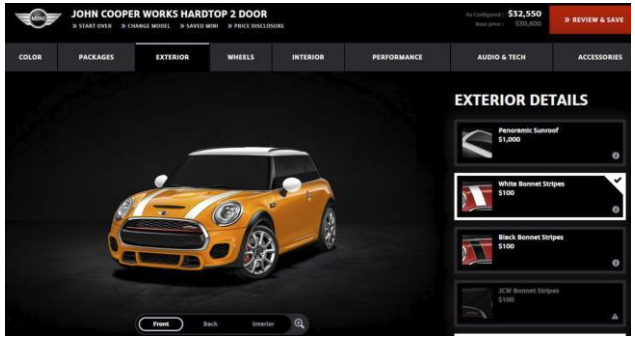
(not in the exam)

Industry 4.0
4 main synergic features



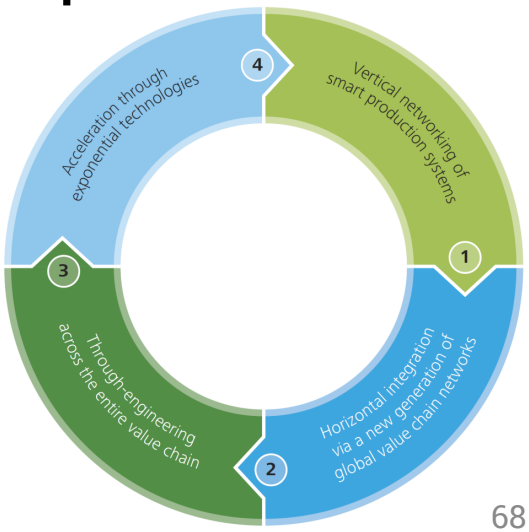
1) Vertical networking of smart production systems

- This vertical networking uses cyber-physical production systems (CPPSs) to enable plants to react rapidly to changes in demand or stock levels and to faults.
- Smart factories organize themselves and enable production that is customer-specific and personalized.



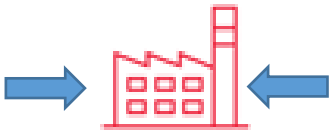
Customers/market

Production



Not in the exam

2) Horizontal integration via a new generation of global value chain networks



- Local and global networks provide networking via CPPSs from logistics, warehousing, production, marketing and sales.
- Networks are real-time optimized
  → transparency, flexibility to respond more rapidly to problems and faults facilitating better global optimization.
- The history of any part or product is logged and can be accessed at any time, ensuring constant traceability.

3) Through-engineering across the entire value chain

The development and manufacture of

- new products
- and production systems

is integrated and coordinated with product life cycles, enabling new synergies to be created between product development and production systems.

development ←→ manufacture ←→ product life cycles

Not in the exam

4) Acceleration through exponential technologies

- Industry 4.0 already requires automation solutions to be
  - highly **cognitive**
  - and highly **autonomous**
- To increase autonomy further still and to speed up individualisation and flexibilization:
  - Artificial intelligence
  - Advanced robotics
  - Sensor technology