ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Internet of Things (IoT) per Sensorizzazione: esempi su Manutenzione Predittiva

Evento online per CNA, 17 giugno 2024

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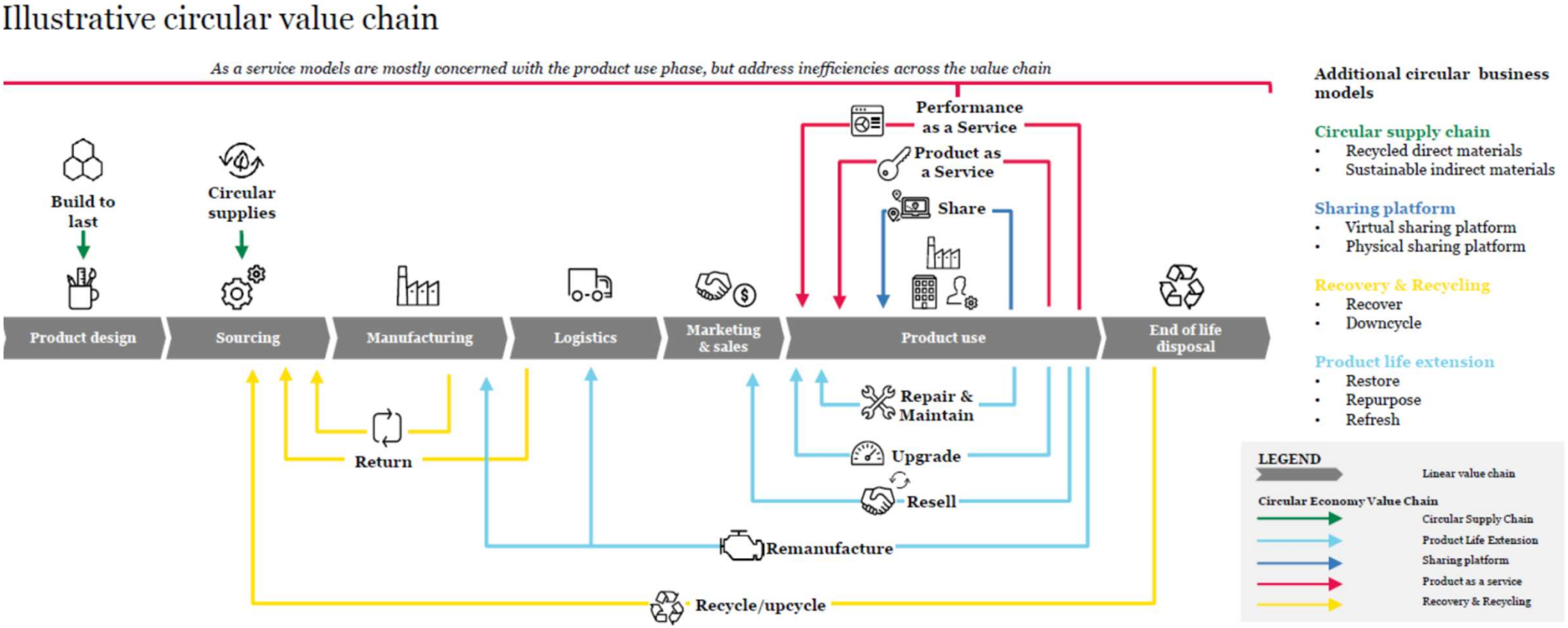
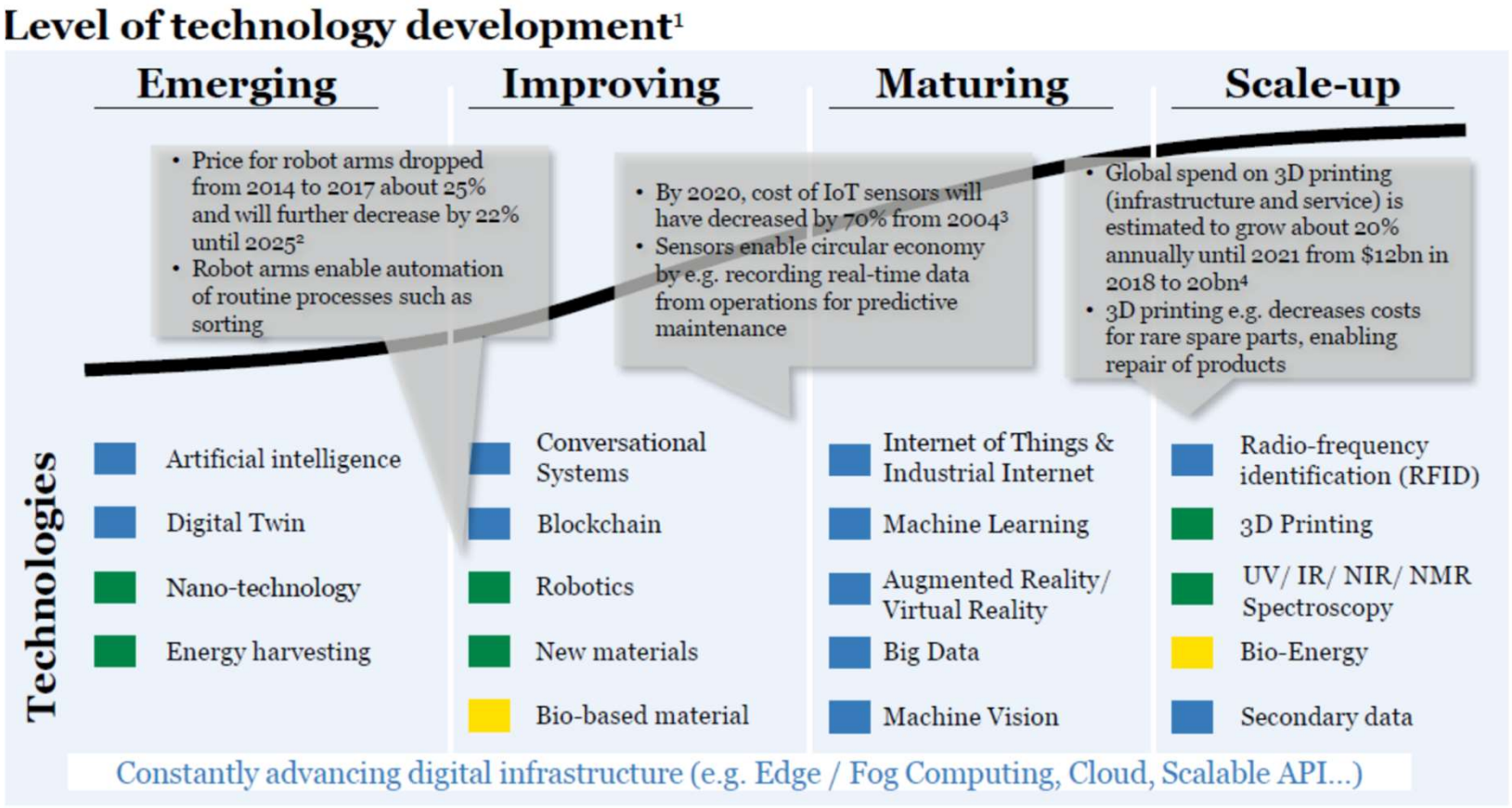
ICT Technologies for converting Circular Economy into Business Opportunities



Most circular opportunities are in the product use phase, bringing companies closer to their customers.

Converting Digital Transformation into Business Opportunities



Digital:
Technologies based on computer sciences, electronics and communication which make use of increasing information intensity and connectedness of physical resources

Physical:
Technologies based on basic property of materials, energy, forces of nature and their interaction

Biological:
Technologies based on biology, aspects including but not limited to biological systems, living organisms, or derivatives thereof, to make products and processes for specific use

Sources: 1: Accenture, Appendix 2 for more details, 2: IEEE Engineering360; 3: Bank of America, Merrill Lynch; 4: International Data Corporation (IDC)

Legend Type of technology: Digital, Physical, Biological

Digital Transformation and Return on Investment

Digital technologies (and in particular ***big data processing***) are crucial to enable the following goals:

- ***Industrial Efficiency***
  - Reduction of consumption of raw materials
  - Reduction of consumption of energy
  - Reduction of defects, reduction of non-compliance with quality reqs, …
- ***Personalization of products and services***
  - ***Lean manufacturing one-piece-flow*** vs mass production
- ***Advanced energy management***
  - Efficient exploitation and integration of renewables (storage, weather/consumption forecasts, energy digital markets, …)
  - Advanced smart electric grids (prosumption in localities, islanding, …)

Internet of Things - Use Cases

Smart Wearables

Smart Home

Smart City

Smart Agriculture

Connected Car

Health Care

Industry Automation

Smart Energy

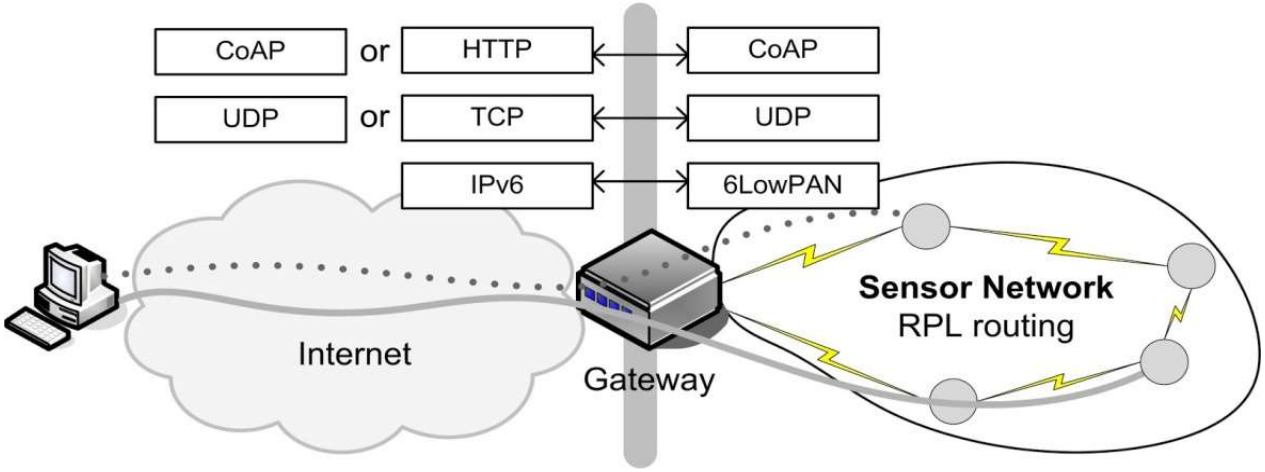
IoT Enabling Technologies

- Reduced **hardware** cost and size
  - from special-purpose to Commercial Off-The-Shelf (COTS)
- Pervasive and cheap **wireless communication**
  - from cables to large-bandwidth and/or wide-coverage wireless communication

actual game Changers so far, IMHO

- Consolidated and emerging **Web-based communication**
  - from close protocols to open standards, also applied in constrained devices
- **Standards**, to achieve interoperability
  - e.g., communication standards and data representation
- General purpose **horizontal solutions**
  - from SCADA to IoT platforms
- Automatic tools to **infer knowledge**
  - wide application of AI (Artificial Intelligence) techniques

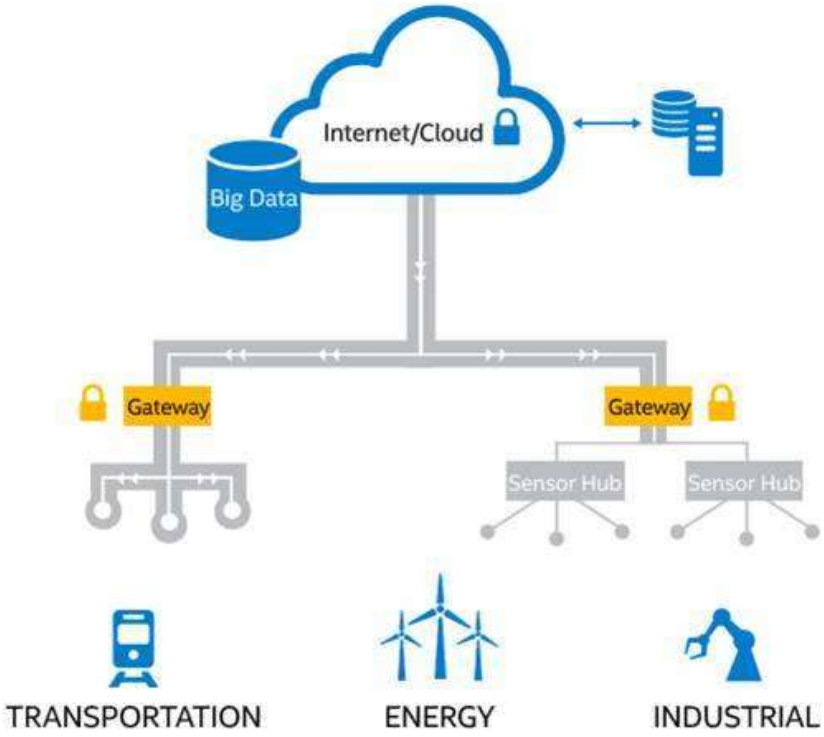
IoT - the General Idea



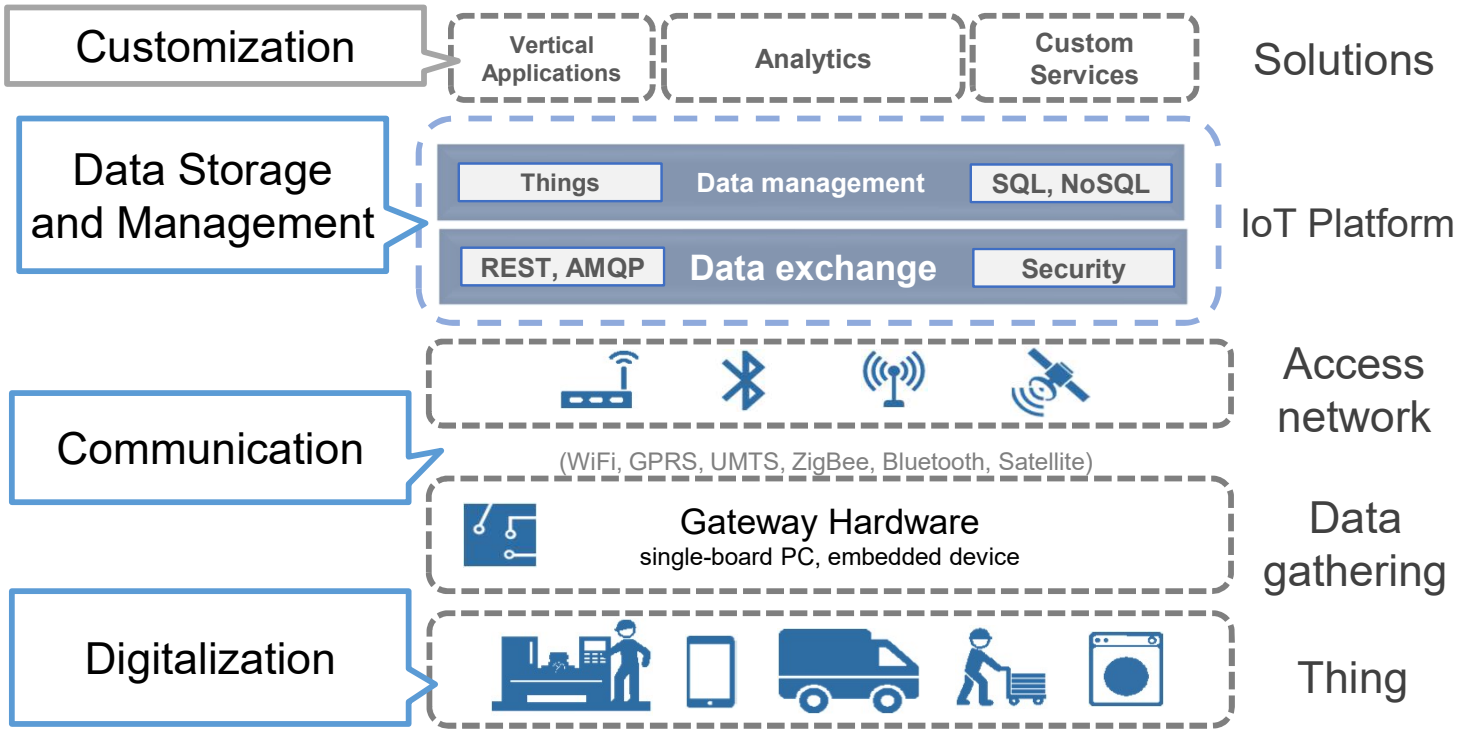
The general idea behind the (commonly accepted) vision of IoT consists in the extension of Internet protocols to Wireless Sensor Networks (WSNs), consisting of sensors as well as actuators

Typical Cloud-based IoT Architecture

- Several heterogeneous **things**, e.g., sensors and actuators
- Multiple **gateways** geographically close to sensors/actuators
  - directly interact with things
  - dispatch data to/from the Internet
- Server-side remote **applications** stored in the Cloud and managing data



IoT: Layered Middleware Platforms



Several IoT Platforms

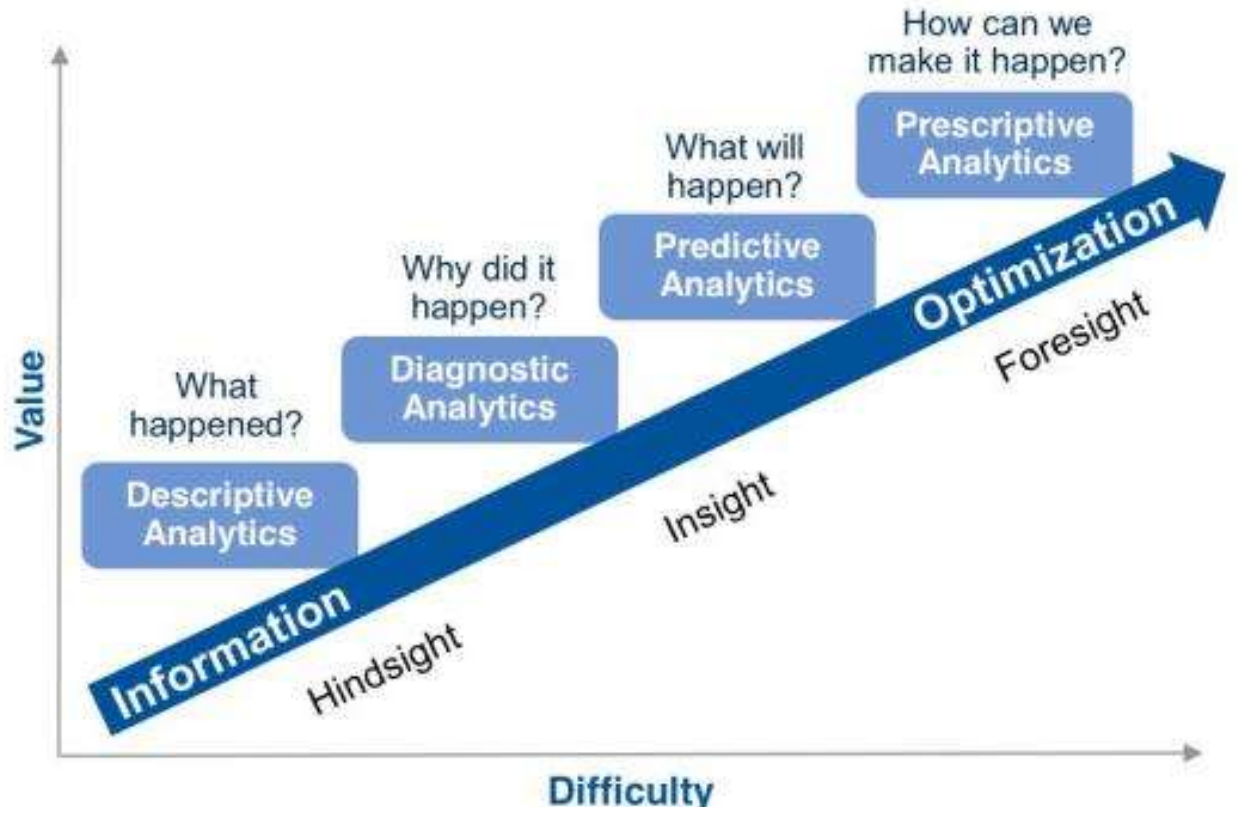
A possible selection:

- Amazon Web Services (AWS) IoT
- Microsoft Azure IoT Hub
- Mindsphere by Siemens
- EdgeXFoundry

And several others:

- Google Cloud Platform
- ThingWorx IoT Platform
- IBM Watson
- Carriots
- Kaa
- …

Example: Prescriptive maintenance for wind turbines



Credits to Data Science Association

Example: Prescriptive maintenance for wind turbines

Credits to Bonfiglioli

HW Architecture Overview "Handle the Data"

Accelerometer (HighDataRate)
Thermometer/HR
SoundLevel Meter (HighDataRate)
Magnetometer (HighDataRate)
Tachometer (HighDataRate)
Torquemeter
Oil Sensor
IPC KKWIND (global WTG system)
Data Processed (AI&ML Models output)

Max Streaming Data: **1,6** Gbyte
Per Day
Per wind Turbine
(With **Data Compression Strategy**)

Cloud

REST API "push"

Cloud
IOTWins HPC

REST API "get"

IODS

Turbine Control System

SCADA

IPC

PLC

Switch Ethernet

LTE

Bonfiglioli Edge GW

Smart Sensors Nodes

Torque Sensor (Gearbox)
(Torque and Tacho)

Custom **Bonfiglioli** Sensor (MOTOR)
(Mic / Acc / Mag / Temp / IO)

Oil Sensor (Gearbox)

YAW DRIVE

Custom **Bonfiglioli** Sensor (Gearbox)
(Mic / Accel / Temp)

Cloud
3rd Party

Cloud
ESI

Cloud
KKWIND

2

Prescriptive maintenance for wind turbine

Bonfiglioli
Forever Forward

Testbed #4

Predictive maintenance and production optimization for closure manufacturing

TESTBED #4 PREDICTIVE MAINTENANCE AND PRODUCTION OPTIMIZATION FOR CLOSURE MANUFACTURING

manufacturing

In complex closures manufacturing (spirits closures can have up to 15 different components) several production phases occur and different technologies and machinery are used.

This testbed will optimize production management and implement predictive maintenance for operation improvement and cost reduction.

Key features will be

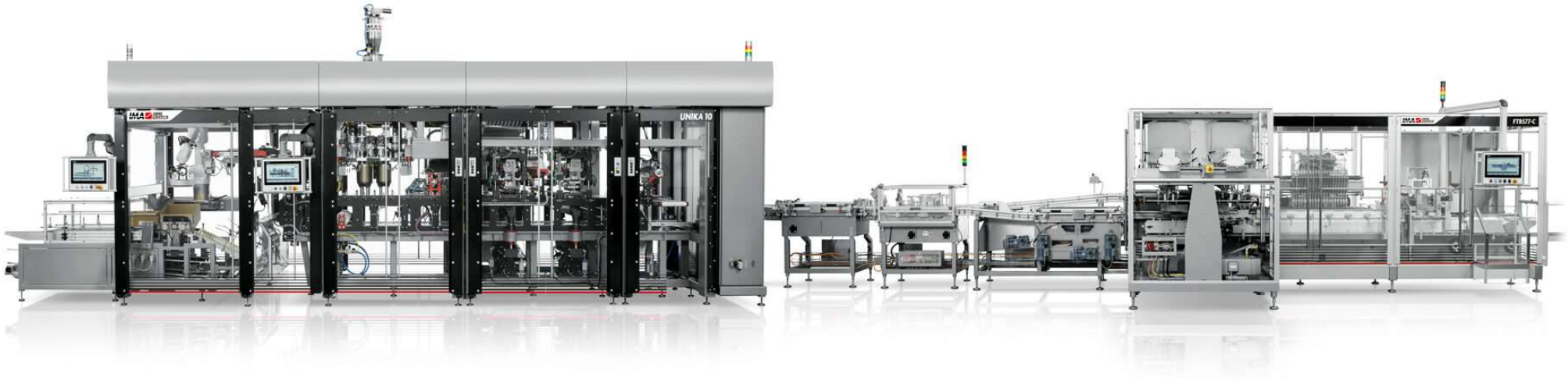
- the remote and real-time performance and status monitoring of all the industrial assets and the detection of anomalies;
- the improved scheduling process leveraging real-time data from the production floor, properly linking it to the scheduling ERP system for production optimization.

The testbed will foresee the design and deployment of redundant IoT modules able to

- to log data at high sample rates;
- to fuse data coming from a first pilot series of machines;
- to install a new module of the industrial IoT platform ThingWorx for predictive maintenance and performance improvement;
- to integrate a data-driven anomaly detection system.

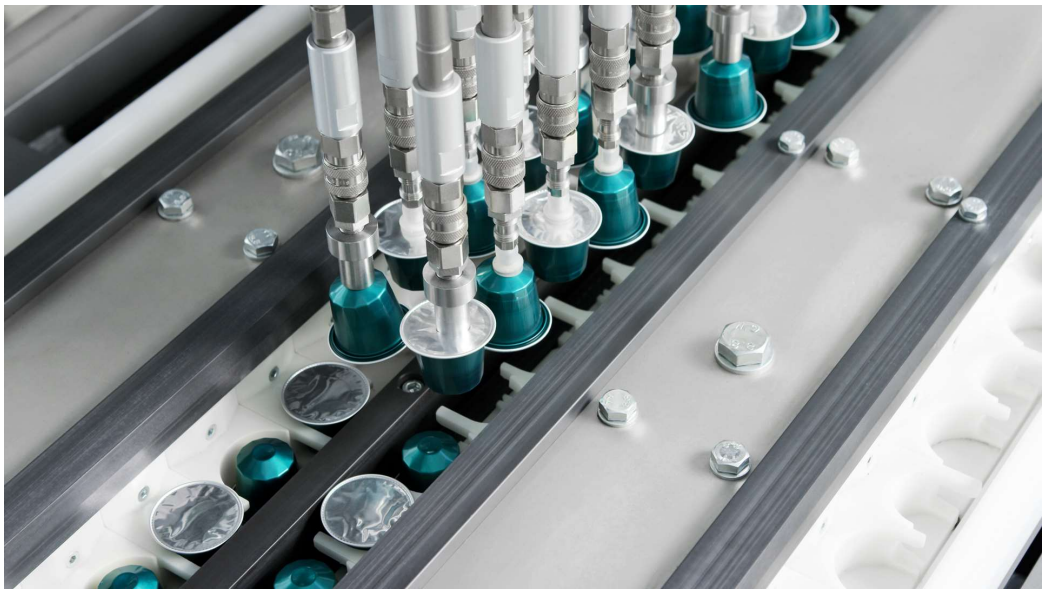
INVOLVED PARTNERS

GCL International | CINECA | INFN



Anche importante *riduzione difettosità e scarti*

con vincoli difficili e challenging su *qualità di servizio e latenza*



Testbed #5

Camp Nou

sport facility management and maintenance

TESTBED #5 CAMP NOU SPORT FACILITY MANAGEMENT AND MAINTENANCE

facility management

CAMP NOU testbed focuses on the management of facilities involving the flow of large crowds, both during normal operation and during maintenance and construction projects. The digital twin is based on Machine Learning and Agent-Based Modeling for pedestrian simulation. Current crowd management systems are not capable of seizing large parallel computational power, and their usability for rapid question answering is limited. This testbed will be performed during the renovation of Camp Nou, the home stadium of Football Club Barcelona - the largest sport facility in Europe with a capacity of almost 100.000 seats.

FCB will reconvert all the area and facilities into the best sporting and entertainment complex in the world. The renovation plan foresees both the improvement of the football stadium, expanding its capacity, and the opening of all the private areas around the stadium (28.000 m^2) to the public, while integrating it harmoniously with the neighborhood.

This testbed aims to analyze how crowds move both historically and in real-time using a robust IoT and big data infrastructure to collect, transmit and process data in real-time

https://www.youtube.com/watch?v=5kxomB-UWqc (5:05 – 6:50)

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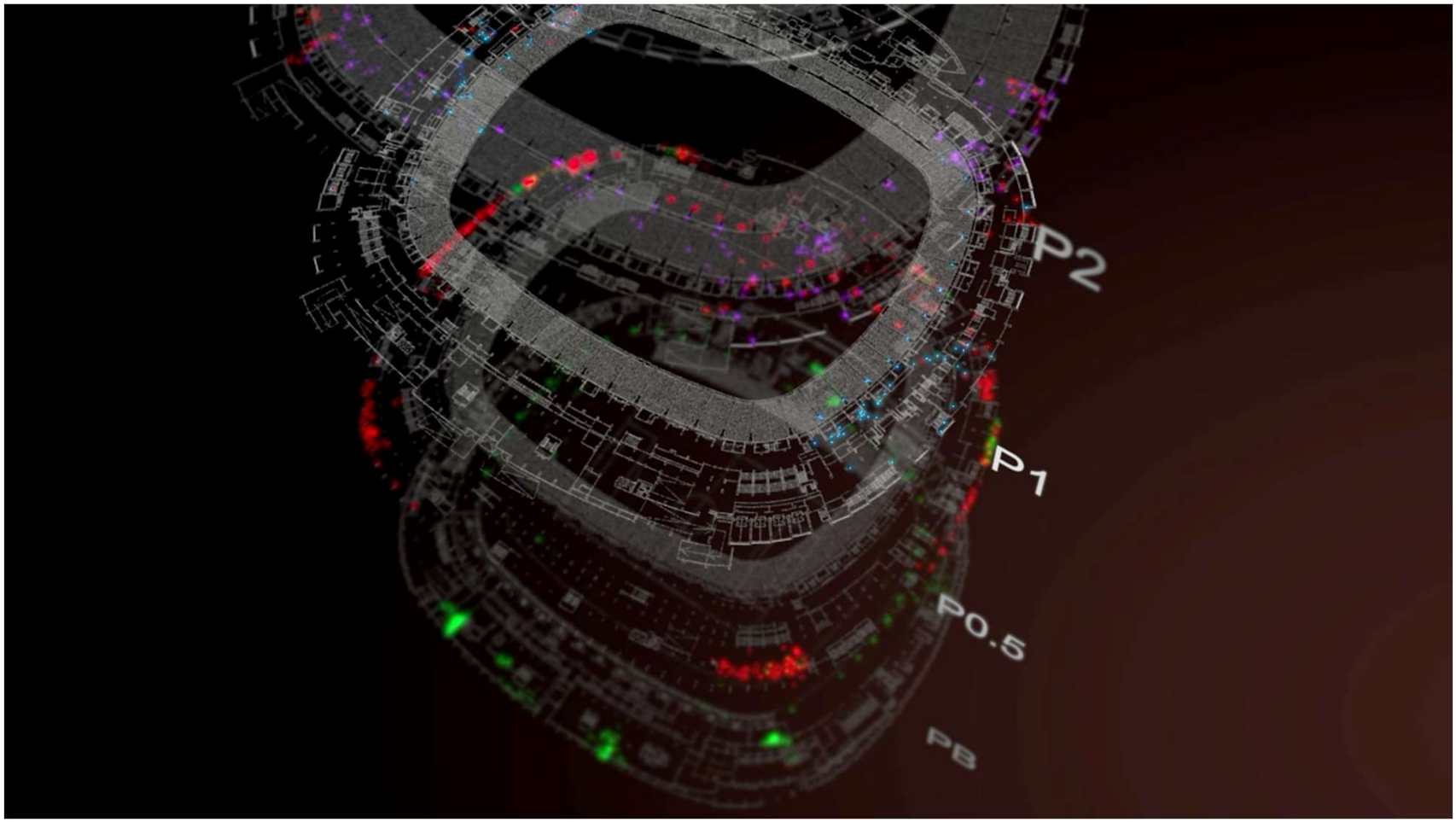
BARÇA INNOVATION HUB | Barcelona Supercomputing Center

The Digital Twin of the Nou Camp Nou Stadium in Barcelona



The Digital Twin of the Nou Camp Nou Stadium in Barcelona

- WiFi data collection being transformed to use Indigo/IoTwins infrastructure in collaboration with INFN (now using an intermediate temporal solution)
- Cameras tested succesfully on a match, but delivery of full order pushed back until march 2022!!!
- Systems tested on stadium during match

Testing videos (phones)

NVIDIA Jetson Xavier NX

Device video (operational)

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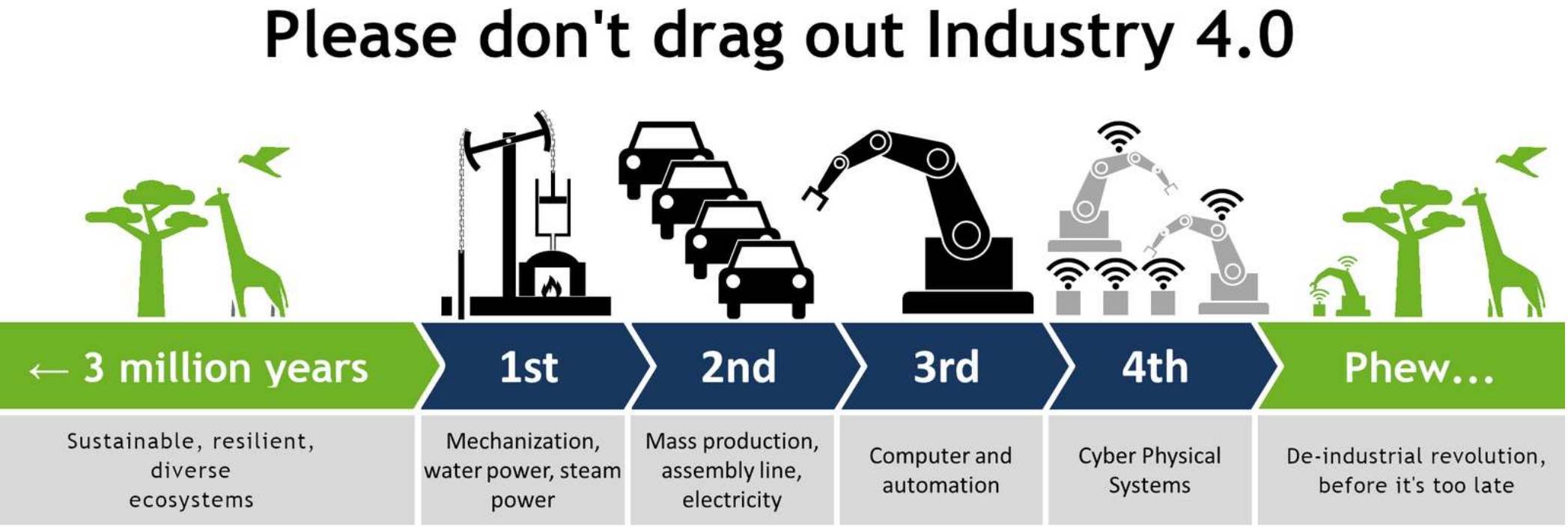
Nugget

IoT and Digital Twins for Industry 5.0

Paolo Bellavista
University of Bologna

Industry 5.0 vs. Industry 4.0



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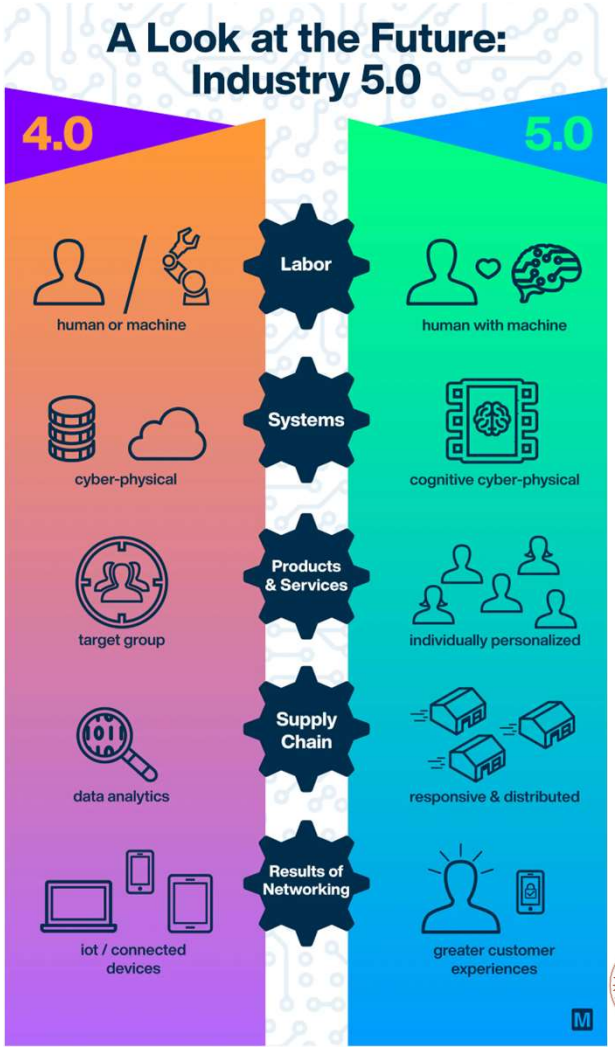
Industry 5.0 vs. Industry 4.0

- Human-centric
- More participative
- More distributed
- Attention to sustainability



Credits to Mouser Electronics, "Industry 5.0 Brings Humans Back Into the Loop"

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Digital Twins: toward a definition

- *Digital counterpart of a physical object*
  - Structure
  - Interaction
  - Global behaviour

- Digital twin requires a ***bidirectional communication flow*** between physical and digital objects

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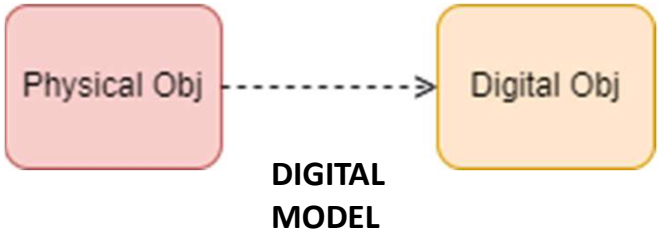
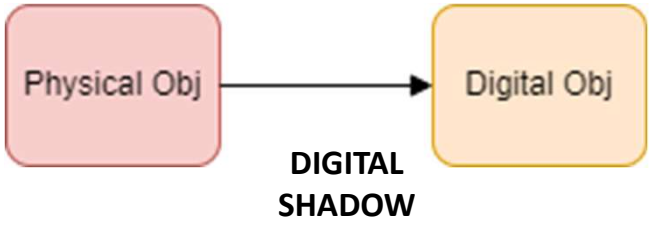
Digital Twins: toward a definition



Digital object is a **static reproduction** of a physical one. Every change to the digital model has to be done manually



Digital object is a **dynamic reproduction**. Autonomous update of the digital model. Data flow just in one direction

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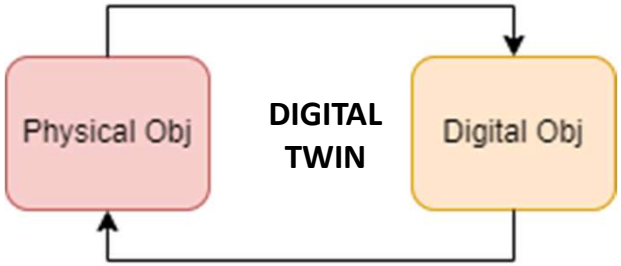
Digital Twins: toward a definition



Digital object is a **dynamic reproduction**

Data flow in both directions

Every change to the digital model has an effect on the physical one

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Digital Twins for Industry 4.0 & 5.0

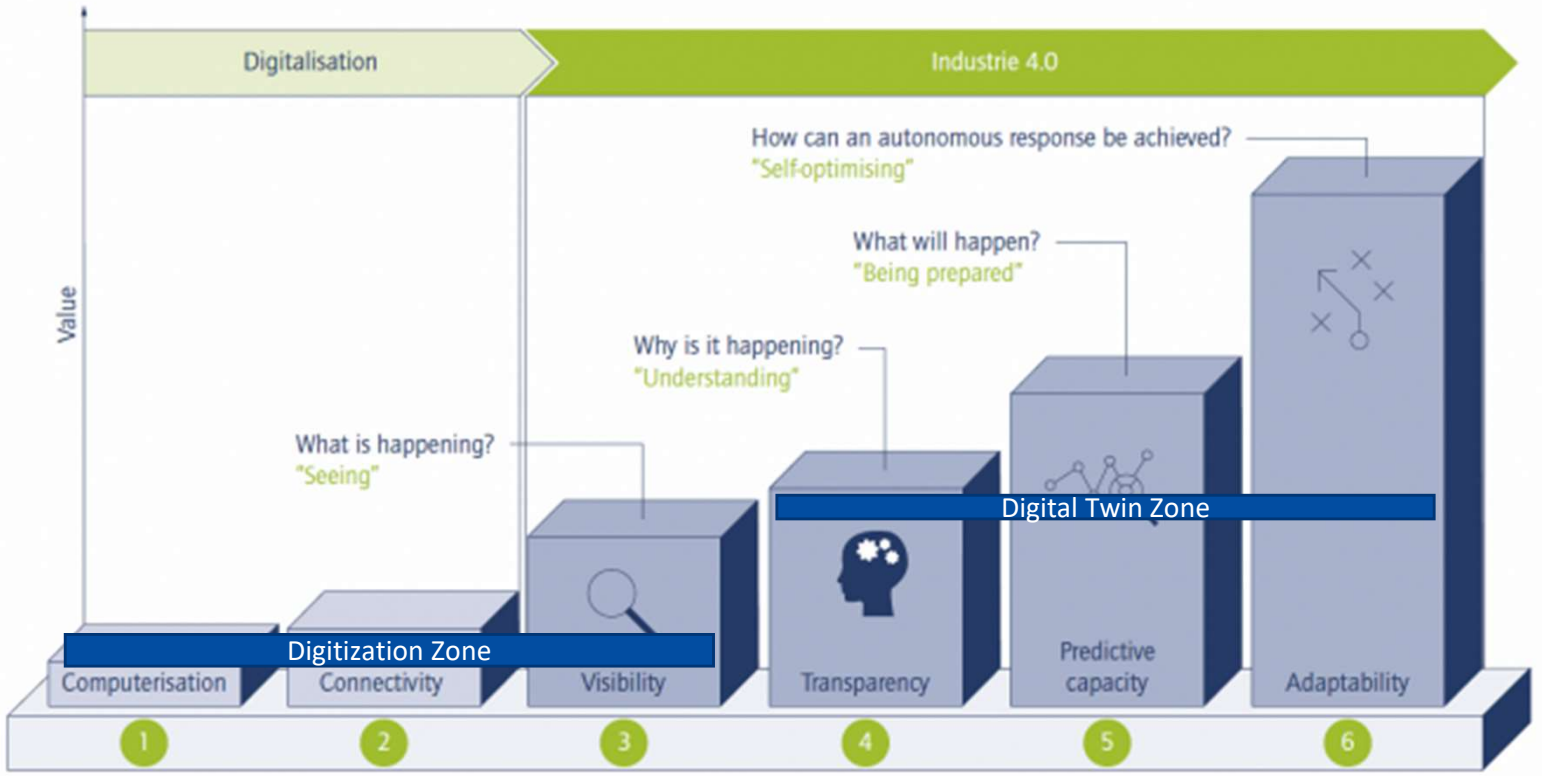

Figure 5: Stages in the Industrie 4.0 development path (source: FIR e. V. at RWTH Aachen University)

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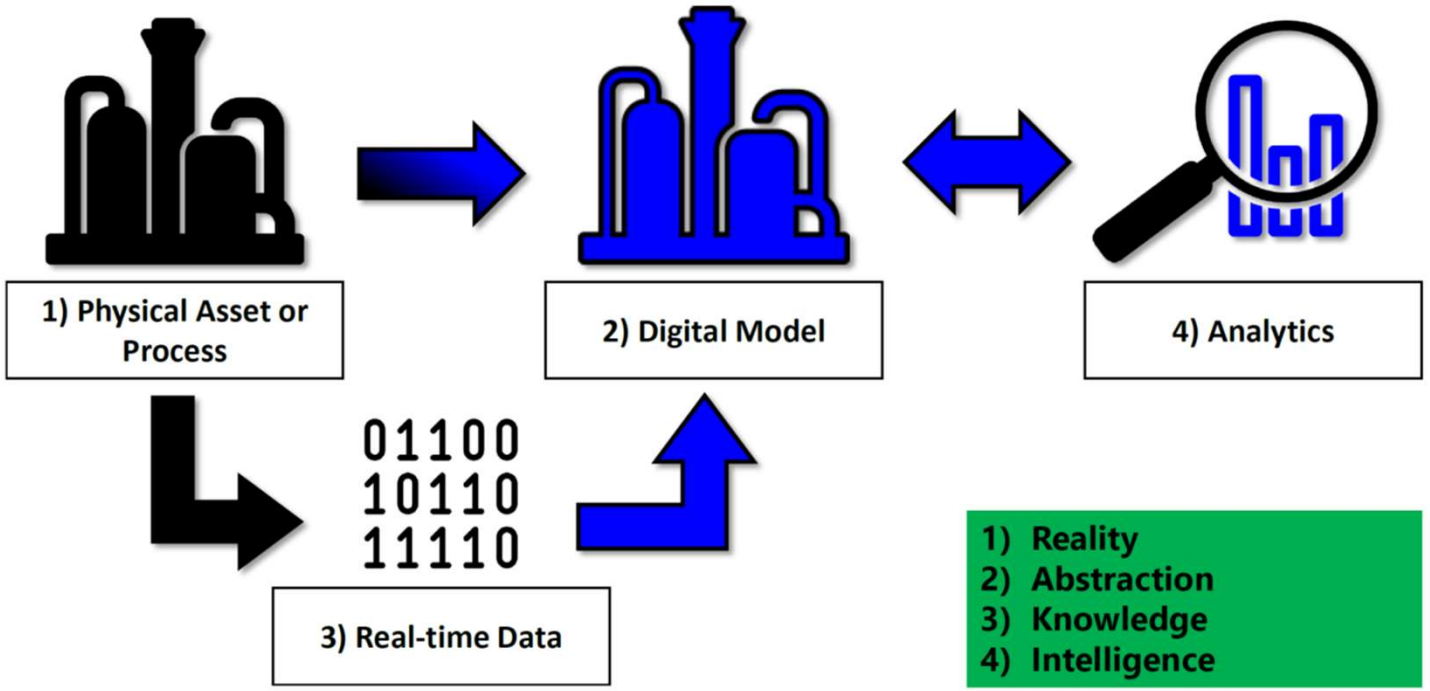
Digital Twins: Model based + Data driven



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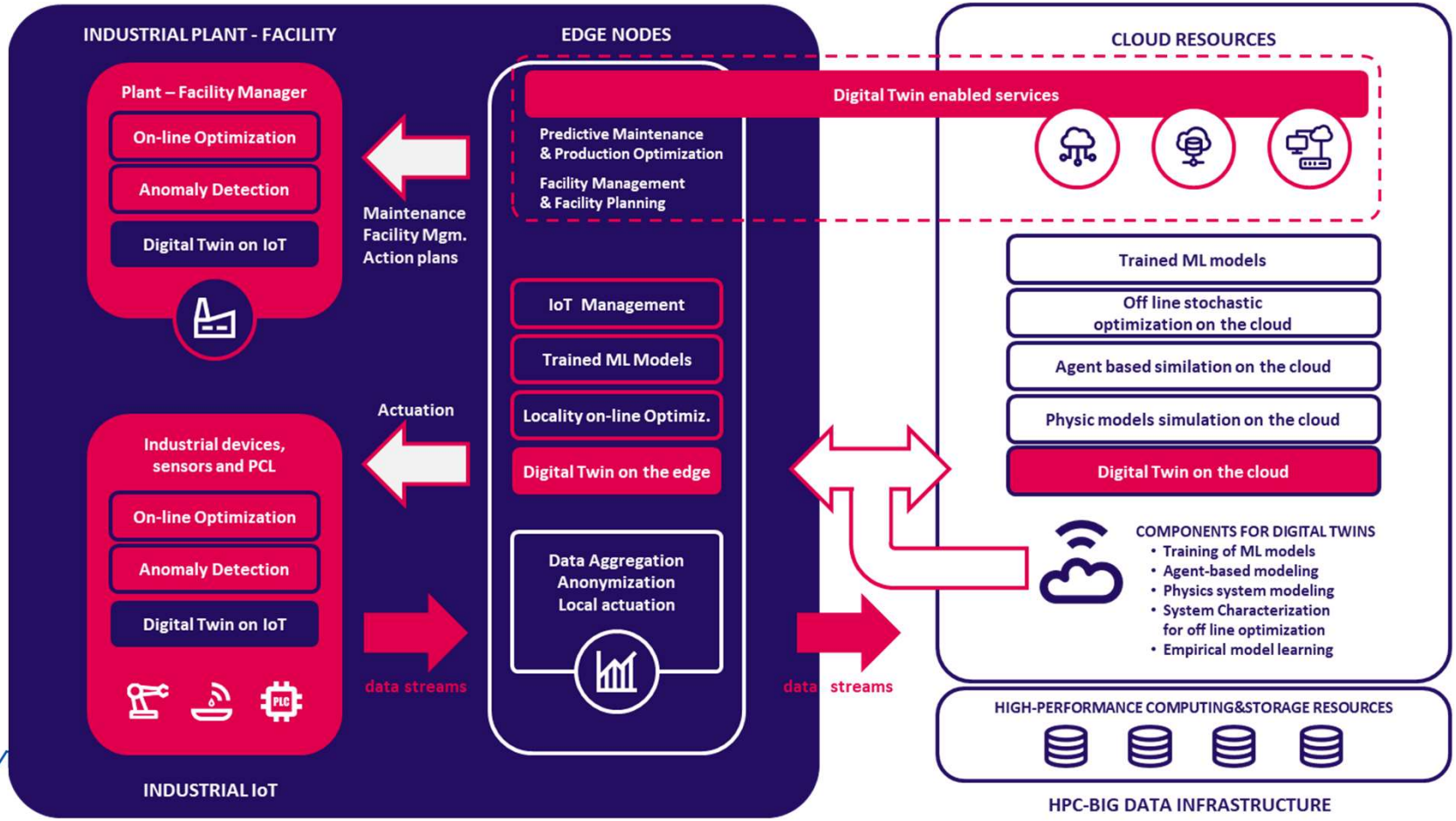
Digital Twins in the Cloud Continuum



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In short…

- Digital twins for Industry 5.0
- Digital twins are model-based AND data-driven
- Cloud Continuum as a crucial enabling technology
- Very promising but attention to complexity and targeted purpose, not a generic silver bullet

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In case of stimulated interest ☺, Further material:

- G.N. Schroeder et al., "*A Methodology for Digital Twin Modeling and Deployment for Industry 4.0*", Proceedings of the IEEE, Vol. 109, No. 4, 2021
- F. Tao, H. Zhang, A. Liu, A.Y.C. Nee, "*Digital Twin in Industry: State-of-the-Art*", IEEE Transactions on Industrial Informatics, Vol. 15, No. 4, 2019
- G. Mylonas et al., "*Digital Twins From Smart Manufacturing to Smart Cities: A Survey*", IEEE Access, Vol. 9, 2021
- P. Bellavista, C. Giannelli, M. Mamei, M. Mendula, M. Picone, "*Application-Driven Network-Aware Digital Twin Management in Industrial Edge Environments*", IEEE Transactions on Industrial Informatics, Vol. 17, No. 11, 2021

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