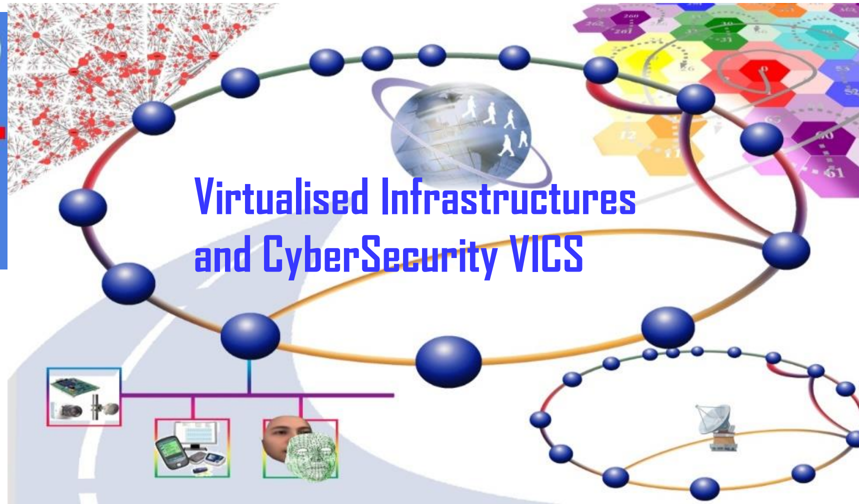

The Industrial Internet Revolution and Digital Transformation Challenges.

HỘI NGHỊ KHOA HỌC QUỐC GIA LẦN THỨ XII
NGHIÊN CỨU CƠ BẢN VÀ ỨNG DỤNG CÔNG NGHỆ THÔNG TIN

Keynote FAIR, Hue, Vietnam 07/06/2019

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VICS
Virtualised Infrastructures
and Cyber Security

OUTLINE

- Introduction
  - The connected world of Internet of Things
  - Industrial Internet: what is it? Why embrace it? why now?
- I4.0 Technologies
  - Address the underpinning technologies that make Industrial Internet possible
- Challenges and Opportunities
  - Where do we go from here?

Moving from Internet of Things to Industry 4.0

The Internet of Things

The IOT addresses networking with everyday objects.

The Internet of Things (IoT) is an information network of IoT objects (sensors, machines, robots, cars, buildings, homes, cities, data, processes, etc.) that integrates and allows interaction and cooperation among them to reach common objectives (e.g., self-driving cars)

IoT Applications and Use Case Scenarios

The IoT application covers "smart" environments/spaces in domains such as: Transportation, Building, City, Lifestyle, Retail, Agriculture, Factory, Supply chain, Emergency, Health care, User interaction, Culture and tourism, Environment and Energy

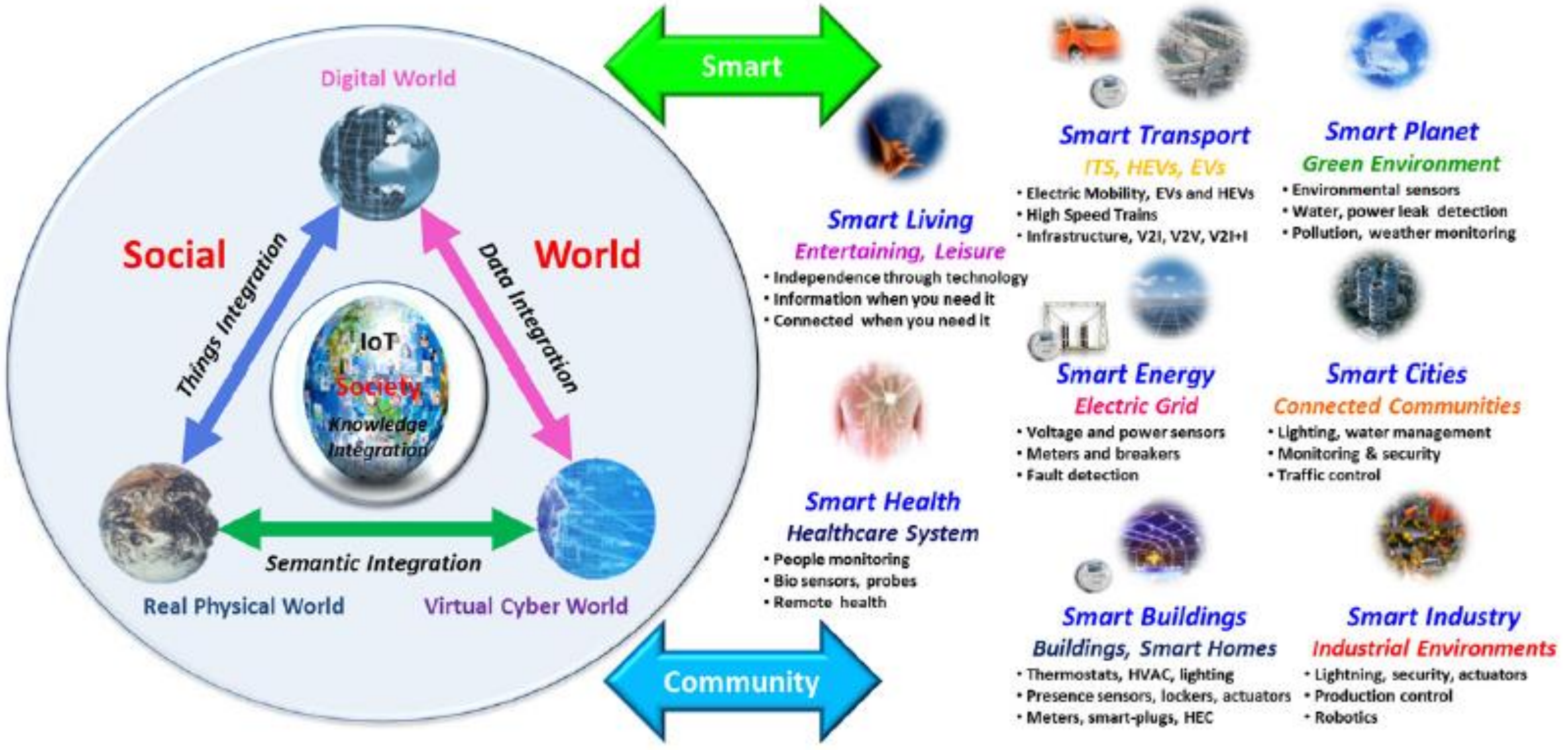
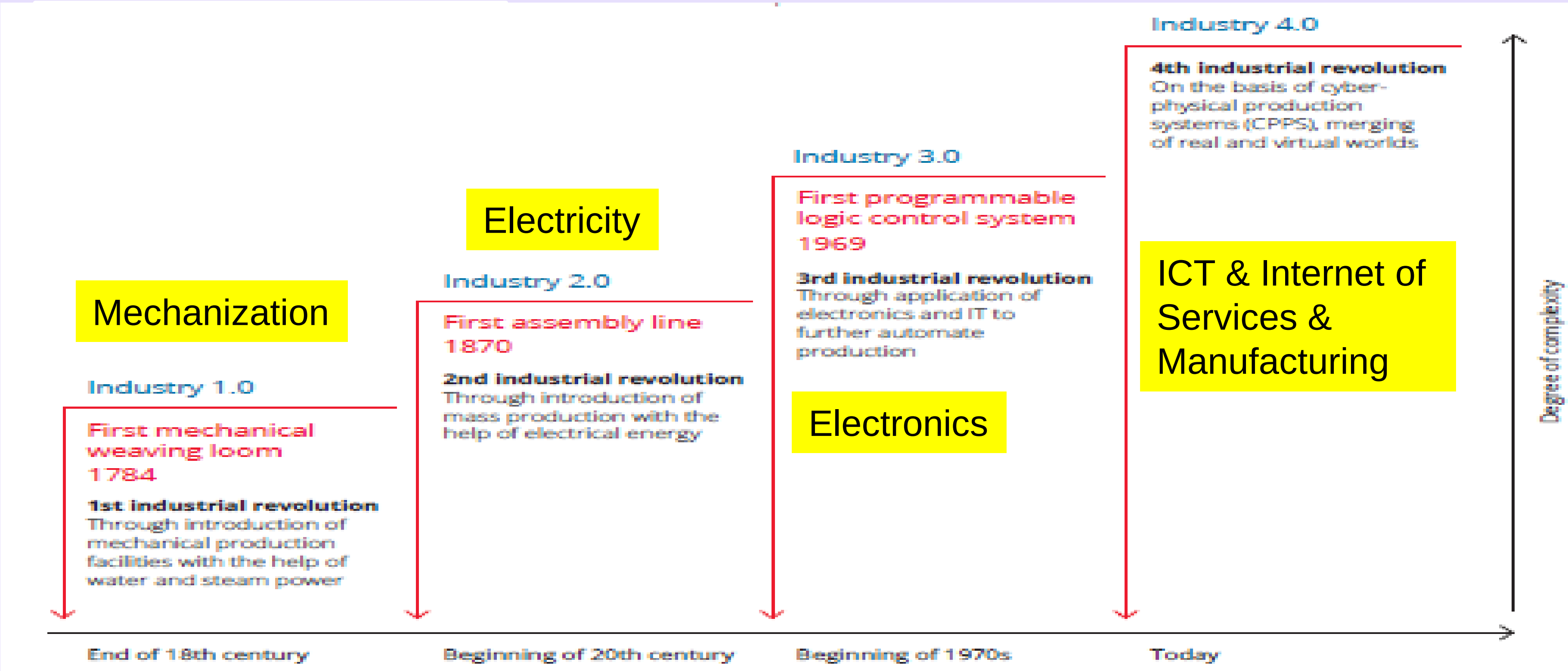


Figure 3.11 Internet of Things in the context of Smart Environments and Applications [84]

Industrial Revolution



1969 Internet – only 50 years ago
2007 First smartphone : iPhone - only 12 years ago
2009 First definition of Cloud computing from UC Berkeley - 10 years ago
2011 Internet of Things
2014 Industrie 4.0 (Germany)

Cyber-Physical Systems for Agricultural and Construction Machinery Current Applications and Future Potential
Georg Jacobs, Felix Schlüter, Jan Schröter, Achim Feldermann

In the same way the Internet created enormous value by interconnecting people, so will the Internet of Things by interconnecting everyday things

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THE POWER of 1%

A modest improvement of 1% would contribute significantly to the return on investment of the capital and operational expenses incurred by deploying the Industrial Internet.

- In aviation, the fuel savings of 1% per annum relates to saving $30 billion.
- Similarly, 1% fuel savings for the gas-fired generators in a power station returns operational savings of $66 billion.
- In the Oil and Gas industry, the reduction of 1% in capital spending on equipment per annum would return around $90 billion.
- The same holds true in the agriculture, transportation, and health care industries.

Alasdair Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress 2016

What is in it for the adopters?

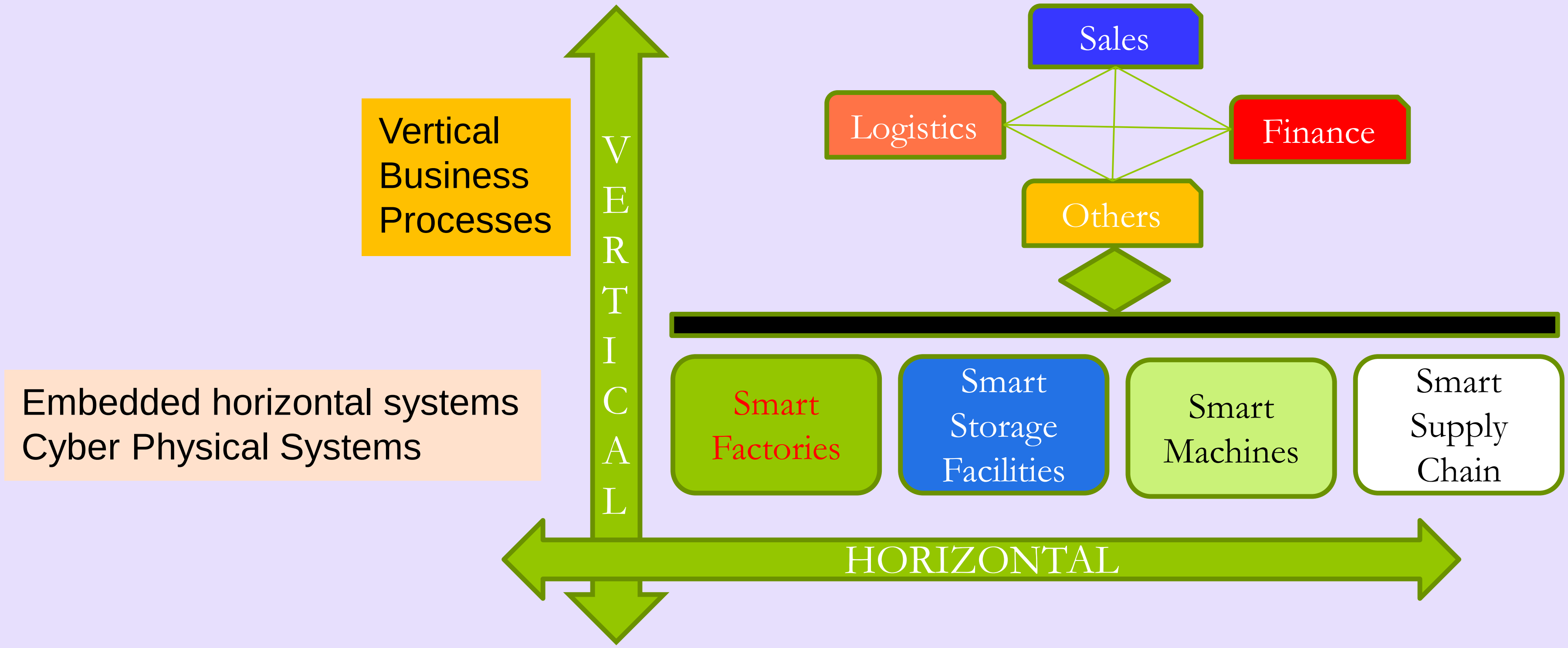
Key benefits adopters want from the Industrial Internet:

1. increased profits,
2. increased revenue flows, and
3. lower operational expenditures.

Some success stories:

- The success experienced by Thames Water, it uses the IIoT for remote asset management and predictive maintenance: anticipate equipment failures and respond quickly to any critical situation.
- Innovative projects from using drones and autonomous vehicles to inspect Oil and Gas lines in inhospitable areas.
- Logistics is the management of the flow of things between the point of origin and the point of consumption in order to meet requirements of customers by using embedded RFID tags.

Industry 4.0



Integration of horizontal cyber physical systems and vertical business processes

- **To align to Industry 4.0. companies must undergo digital transformation: digitalising, automating and connecting all machines, manufacturing and business processes.**

Industrial Systems vs Industrial Internet Systems

- Industrial systems combine a mixture of sensors, actuators, logic and computing components, and networks to allow them to interconnect and function.

- Industrial systems become Industrial Internet systems when they become connected to the Internet and integrate with enterprise systems, for improving business.

Initiatives around the world

- Germany – Industrie 4.0
- USA – Industrial Internet Consortium, Advanced Engineering Partnership
- UK – Catapults, UK Digital Strategy, Made Smarter review
- France – La Nouvelle France Industrielle
- Japan – Industrial Value Chain Initiative, New Robot Strategy, RRI
- **China – Made in China 2025**
- Netherland – Smart Industry
- Belgium – Made Difference
- Spain – Industrie Conectada
- Italy – Fabbrica Intelligence
- Russia – National Technology Initiative
- Australia – Industry 4.0 TestLabs

Bring back manufacturing from “low-wage” countries back to “high-wage countries

Initiatives around the world

Bring back manufacturing from "low-wage" countries back to "high-wage countries

Profound implication

Food for thought: what would be the best strategy for decision makers of "low-wage" countries?

VICS Virtualised Infrastructures and Cyber Security

What Is the Industrial Internet?

- ***The Industrial Internet* provides**
  - a way to get better visibility and insight into the company's operations and assets through integration of advanced technologies.
  - a method of transforming business operational processes by using as feedback the results gained from interrogating large data sets through advanced analytics.
- **The business gains are achieved through**
  - operational efficiency gains and accelerated productivity,
  - results in reduced unplanned downtime and optimized efficiency, and profits.

Intelligent Manufactoring Technologies

Cloud Computing

Advanced Data Analytics

Why Industry 4.0 now?

The complexity of industrial systems has outpaced the human operator's ability

Enabling technologies are maturing and widely available.

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What is the name!

Industrial Internet concentrates on manufacturing, transportation, public sector, and related industrial systems such as

- Agriculture, Aviation, Energy production, Health care,
- Manufacturing, Logistics, Transportation, and others

Industry 4.0 or I4.0 is the fourth industrial revolution: the Industrial Internet with focusing more on the manufacturing environment.

- GE (General Electric) coined the name "Industrial Internet" as their Industrial IoTs (IIoTs)
- Cisco termed it the Internet of Everything (IoE)
- Others called it Internet 4.0 or other variants.

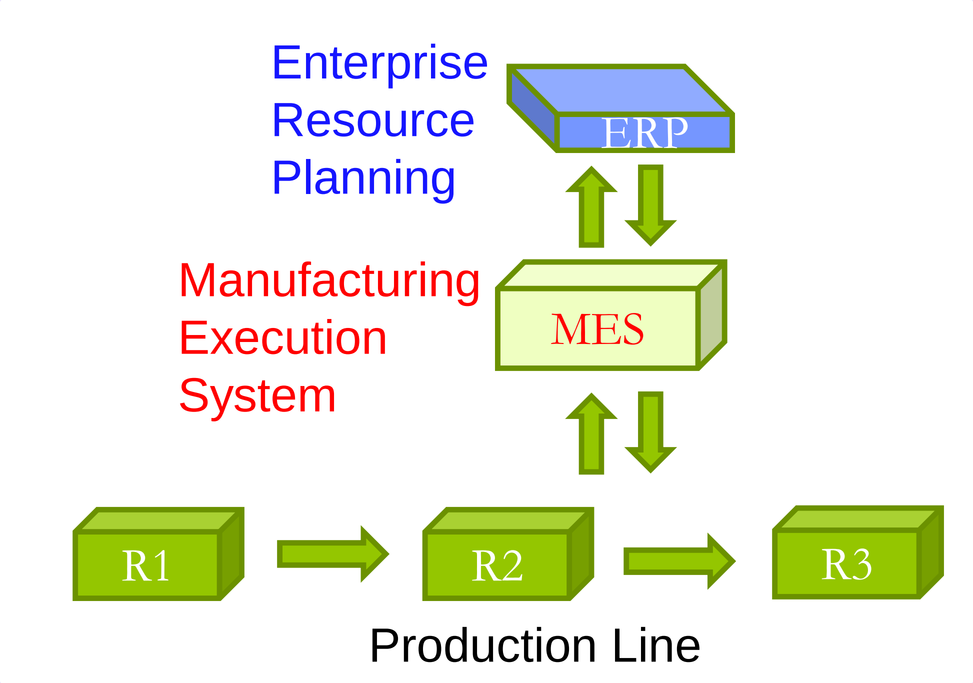
Usage: Industrial Internet of Things (IIoT) = *Industrial* Internet = Industry 4.0 = I4.0

Moving on to
Industry 4.0 manufacturing

-A Factory-
A production line with different lines of shampoo

Scenario - A smart machine fills each bottle with the same base ingredients. Each variant of the brand may have different colour additives of perfume as required for an intended market.

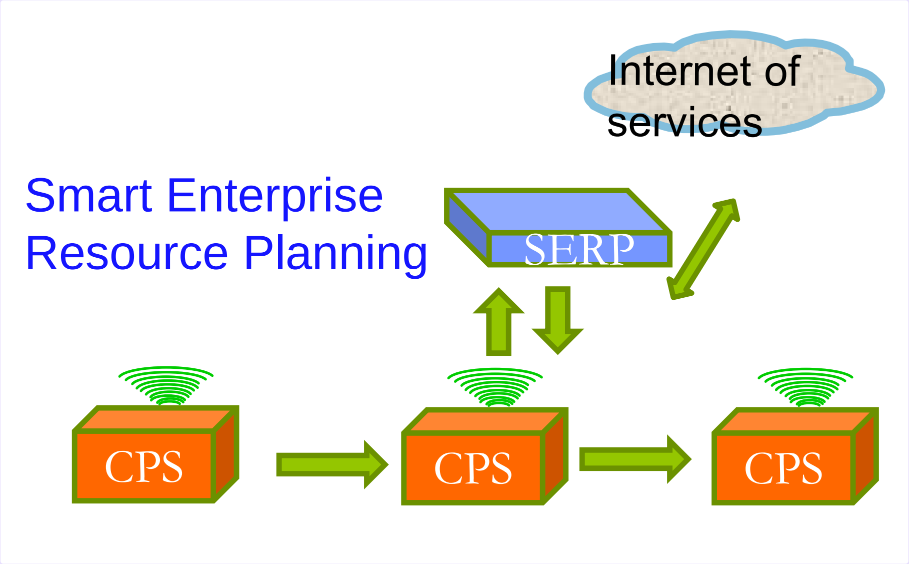
In traditional manufacturing: a production line is required for each individual product:
A dispenser machine would fill the bottle with the required mixture of ingredients as required.



-Smart Factory- A production line with Cyber Physical Systems

Design a production line to produce all products even though they differ in label, colour, and perfume.

Products on the production line are identified together with their status, their history, and what stage of production they must next pass through.



Production Line

The machine must be able to identify each product traversing the production line and what to do with the product.

Each product has its own ID and relevant data stored in RFID tags.

Industry 4.0 manufacturing

- An intelligent, self-regulating, automated manufacturing process on cyber-physical production systems,
- It can produce one or more products simultaneously.
- Products navigate themselves through the product lifecycle via the cyber-physical production systems CPS without direct human intervention.

- Decentralised information
- Self-organisation
- Communication and cooperation among modules

Industrial Internet – underpin technologies

- Advanced Sensing Technology: Wireless and Sensor Miniaturization
- Ubiquitous Networking Technologies: Software Defined networking and Network Function Virtualization
- Intelligent Manufacturing Technologies: Platform, System, Product Life Cycle
- Digital Twins and Simulation
- Fog/Edge and Cloud Computing
- Big Data and Analytics
- Robots
- Additive Manufacturing (3D printing)

Sensor Technology innovation

- Miniaturization of sensors and components
  - Sensors can be reduced to the size of a grain of sand, can now be embedded anywhere and in anything: our bodies, our clothes, food packages.
- Widespread use of multi-sensor systems
  - In smartphones, systems-on-a-board, and even systems-on-a-chip (SoC): Apple iPhone, Raspberry Pi, Arduino for sensing and influence their environment.
- Availability of autonomous and mobile sensors

Intelligent devices. Any device with some intelligent capability for gathering information we wish to harvest, for example, sensors, actuators, engines, machines, components, even the human body, etc.

Cyber Physical Systems

- A cyber-physical systems (CPS) is a system that that integrates all three features: computation, networking, and physical processes.
  - Integrate with their environment
  - Embedded computers and networks monitor and control the physical processes via feedback loops.
  - CPPSs exchange of information over the entire lifecycle of a product, as data transfers seamlessly from system to system.
  - Machines monitor one another and make decentralised decisions about production and maintenance.

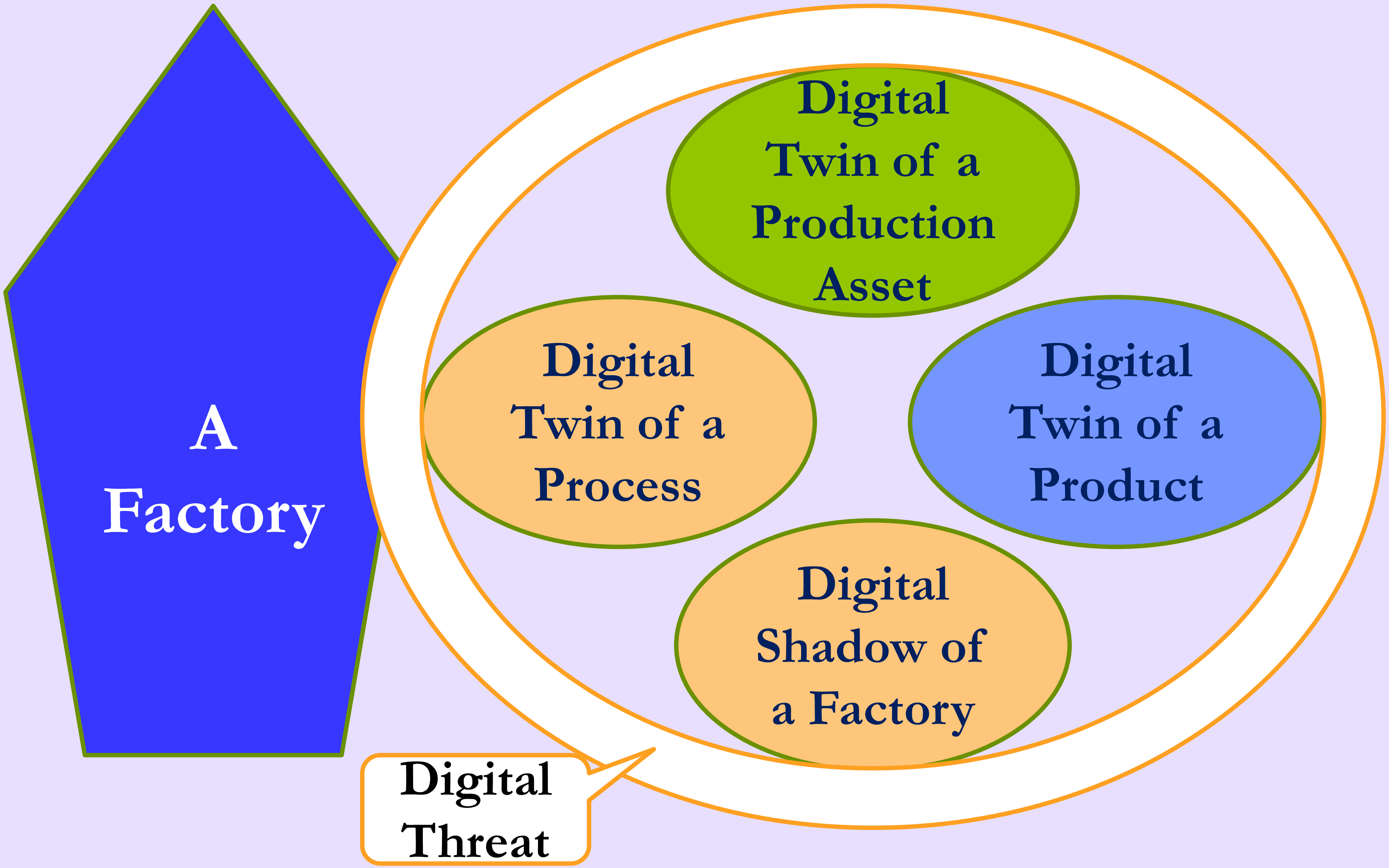
Examples: Human operators, Smart factories, Smart phones, Robots, Intelligent Manufacturing Lines

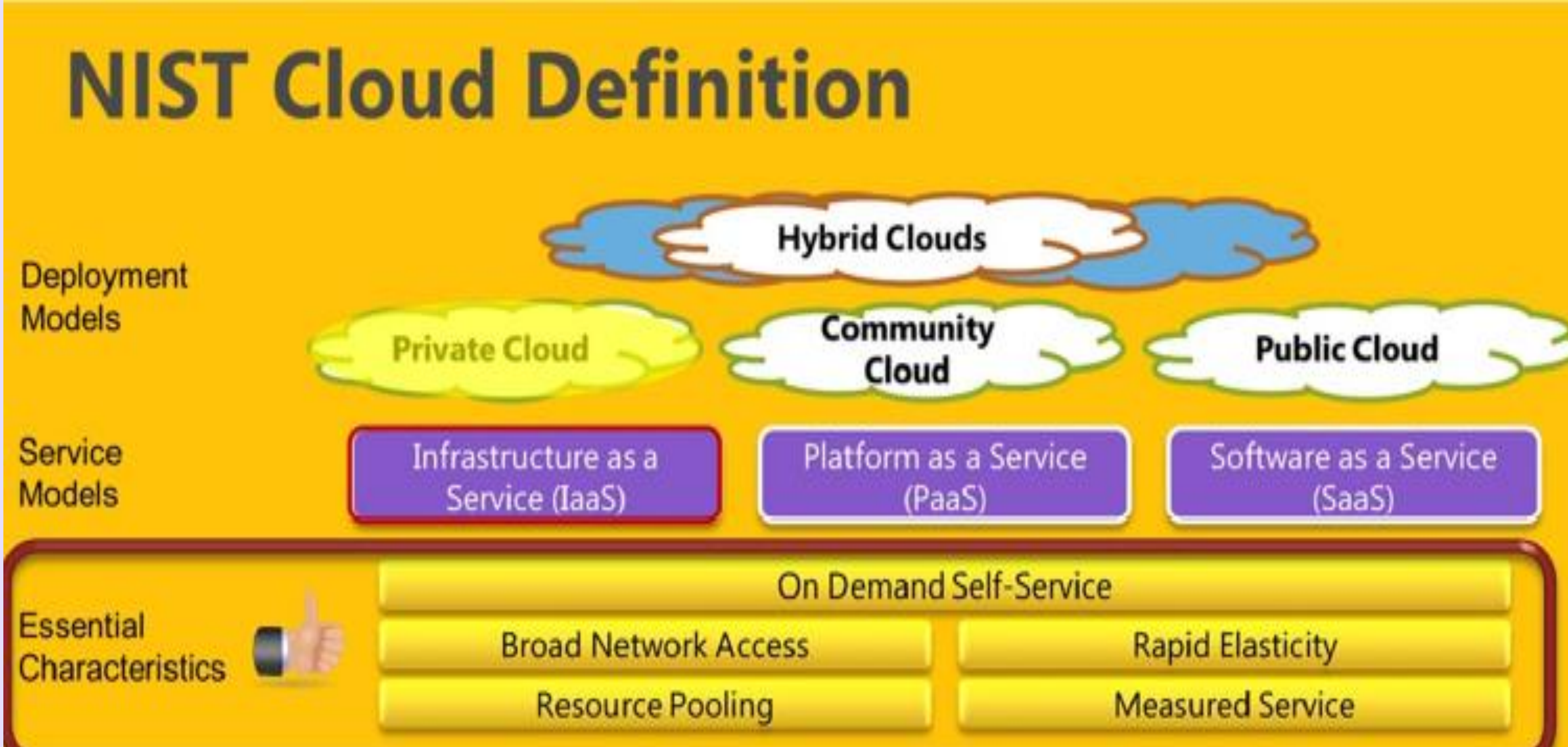
Digital twin

- Digital twin: a digital version of a physical thing
- Digital twin of a product or process: The digital twin refers to a digital model of a particular product or process that includes
  - design specifications and
  - engineering models describing its geometry, materials, components, assembly and behaviour, and
  - the as-built and operational data unique to the specific physical asset which it represents.

Creating machine understandable virtual image of an entity -> entering the virtual world

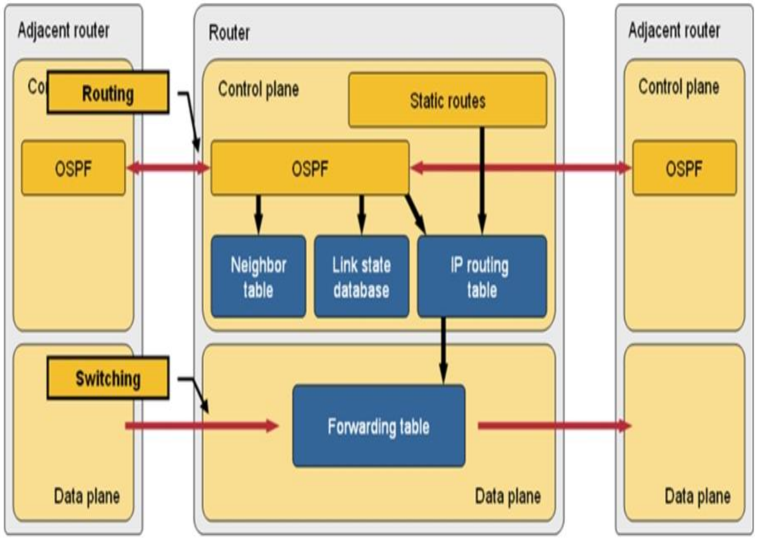
Digital Twins





- **NIST**: CLOUD computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction

Software-Defined Networking Paradigm



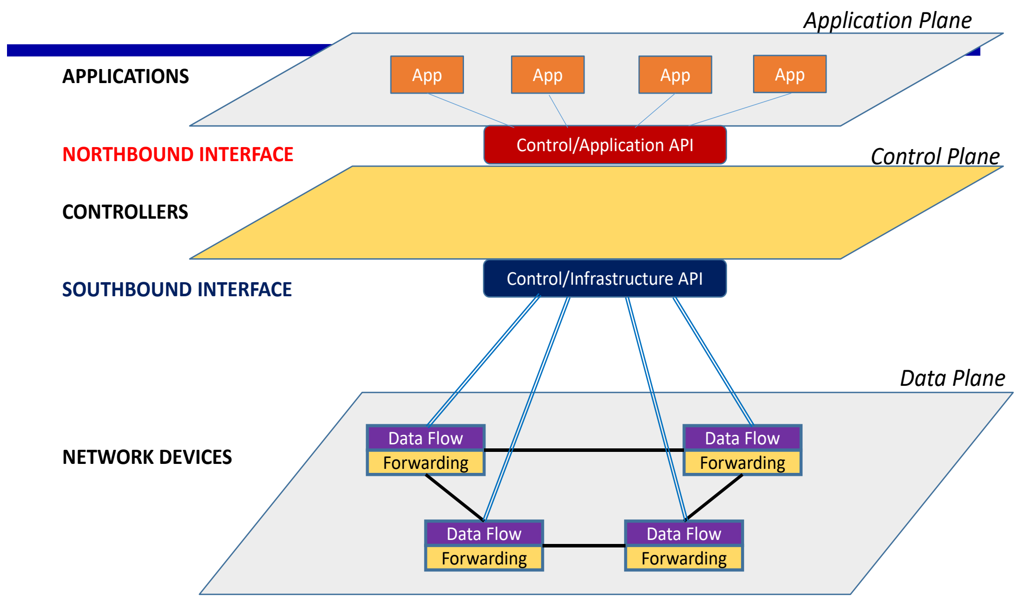


Figure 1 - Software-Defined Networking – A high level architecture

Implications:

- Centralized control
- Programmability
- Embrace Network Function Virtualization
- Virtualization
- Autonomous devices management

Virtual Networks are created just like the way Virtual Machines are created

Network Function Virtualization (NFV)

NFV is the method and technology that enables one to replace physical network devices performing specific network functions with one or more software programs executing the same network functions while running on commodity hardware.

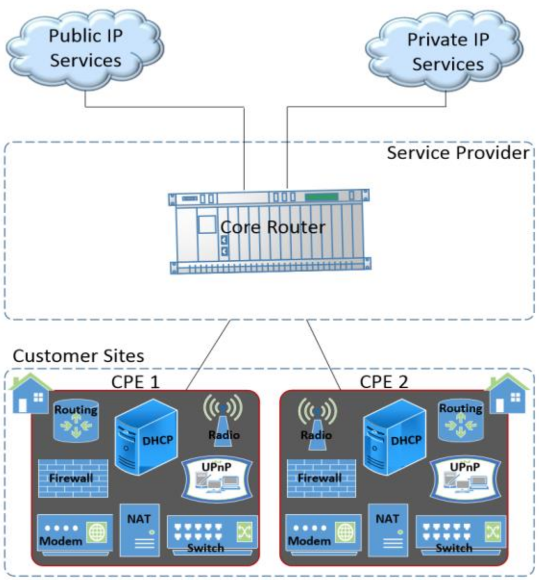


Fig. 1. Traditional CPE Implementations

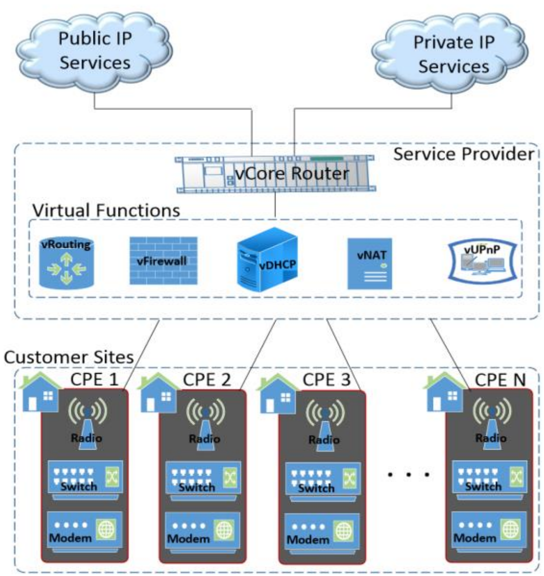


Fig. 2. Possible CPE Implementation with NFV

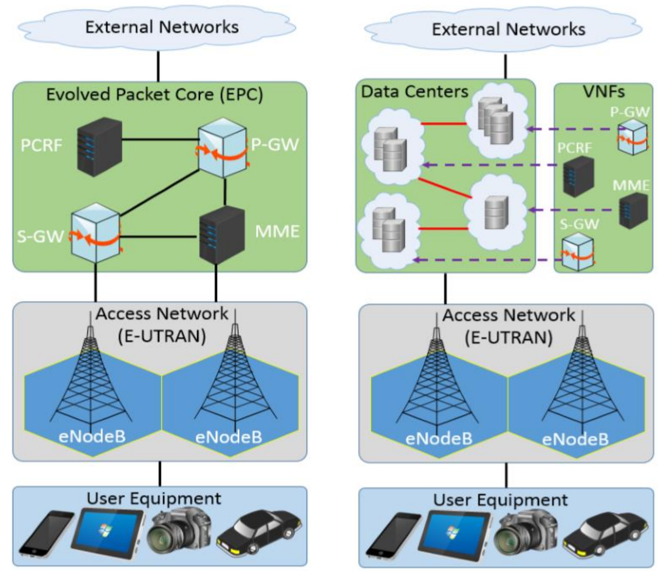


Fig. 3. Virtualization of the EPC

Big Data: Definitions

Big data refers to datasets whose size is beyond the ability of typical database software tools to capture, store manage, and analyse. This definition is intentionally subjective.

- One query search in Google results in over 1M of web pointers.
- Everyday, 2.5 quintillion (or Exa = 10^{18}) bytes of data are created and 90% of the data in the world today were produced within the last two years.
- Flickr, a public picture sharing site, which received 3.6 million of pictures per day on average. This is equivalent to 7.2 terabytes storage every single day.

Business Data => Big Data

Production Line => Big Data

Health Records => Big Data

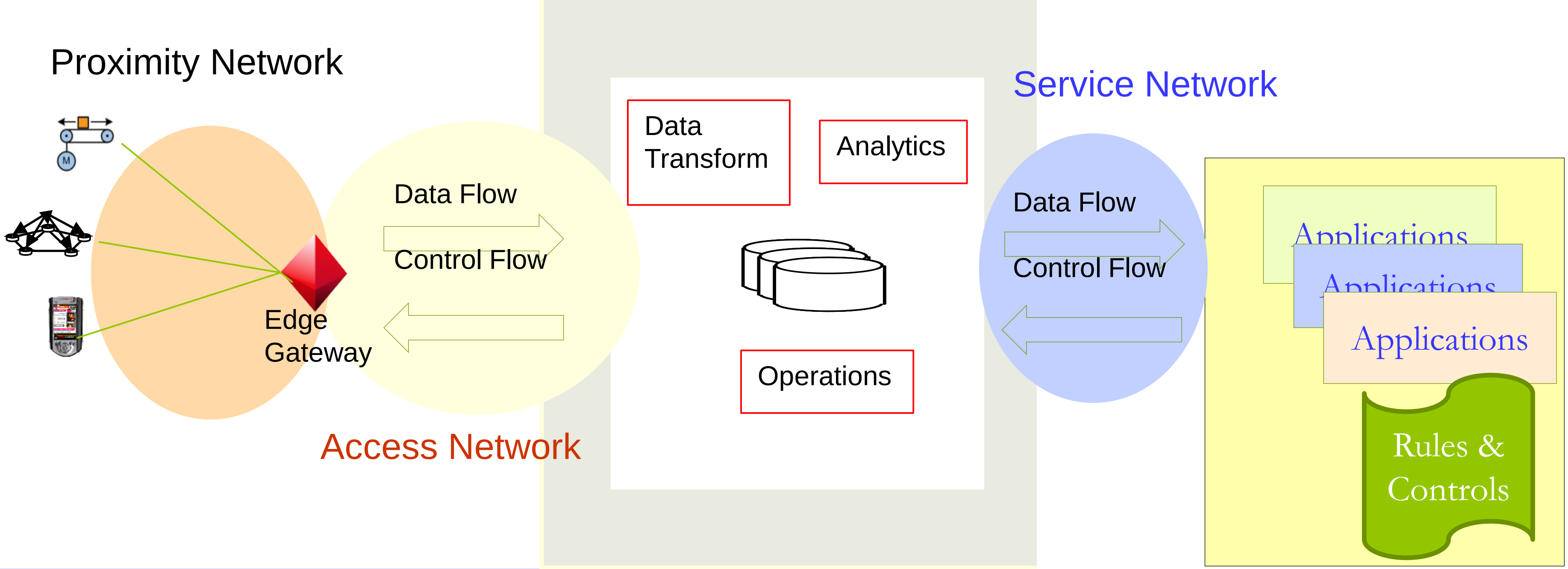
Smart City Data => Big Data

Big Data is characterized by

- Volume,
- Velocity
- Variety

The overall Industrial Internet Scenari0

IIRA ref model: 3 tier architecture



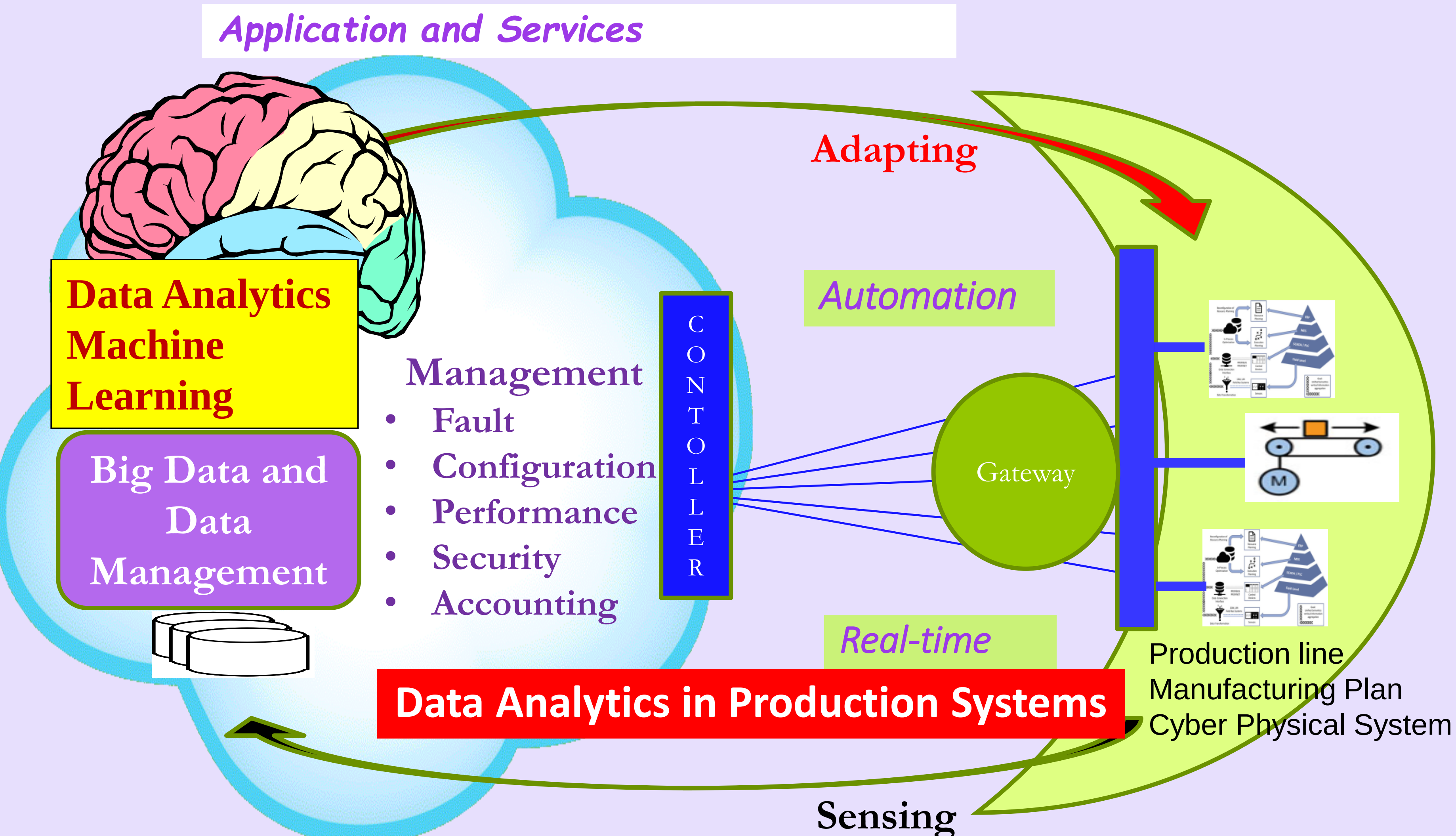
The edge tier is where data from all the endpoints is collected, and transmitted Over the proximity network to a border gateway

The platform tier receives data from the edge tier over the access network
Responsible for data transformation and processing
Also for managing control data flowing in the other direction

The enterprise tier implements the application and business logic for decision support
And end-user interfaces.
Host most of the application and business functions

Main points so far

WHERE DO WE GO FROM HERE?



Data Lifecycle = data gathered by the device ==> data store ==> analytic systems ==> data scientists ==> process ==> the device iNEXT

Huge data from the environment IoTs or networks

NFV: Software Entities/Functions/Services

- Virtual resources generated on-demand
- Deployed anytime, anywhere, anyplace
- Generate data
- Execute actions

SDN

Creating dynamic connectivity infrastructure
Logically centralized control
Programmability
Automated configuration and management

Cloud Computing

- Resources virtualization and provision
- Repository for big data
- Computing power for data processing and value extraction

AI
Machine Learning and
Data Analytics
for generating value services

Data Analytics - Questions

What is the best action?

What if?

Prescriptive

What should we do?

What will happen next?

What is the pattern?

Predictive

What will happen?

Where to look?

Why did it happen?

Diagnostic

Why it happened?

When, where?

What happened?

Descriptive

What happened?

Data Analytics - Science

- Data Analytics is the science of examining raw data with the purpose of drawing conclusions about that information (uncovering patterns, correlations, and other features)

- Data science (combination of statistics, mathematics, programming, problem-solving, and data management) is more about exploring unknowns, while data analytics emphasizes on discovering answers to questions being asked.

Algorithm

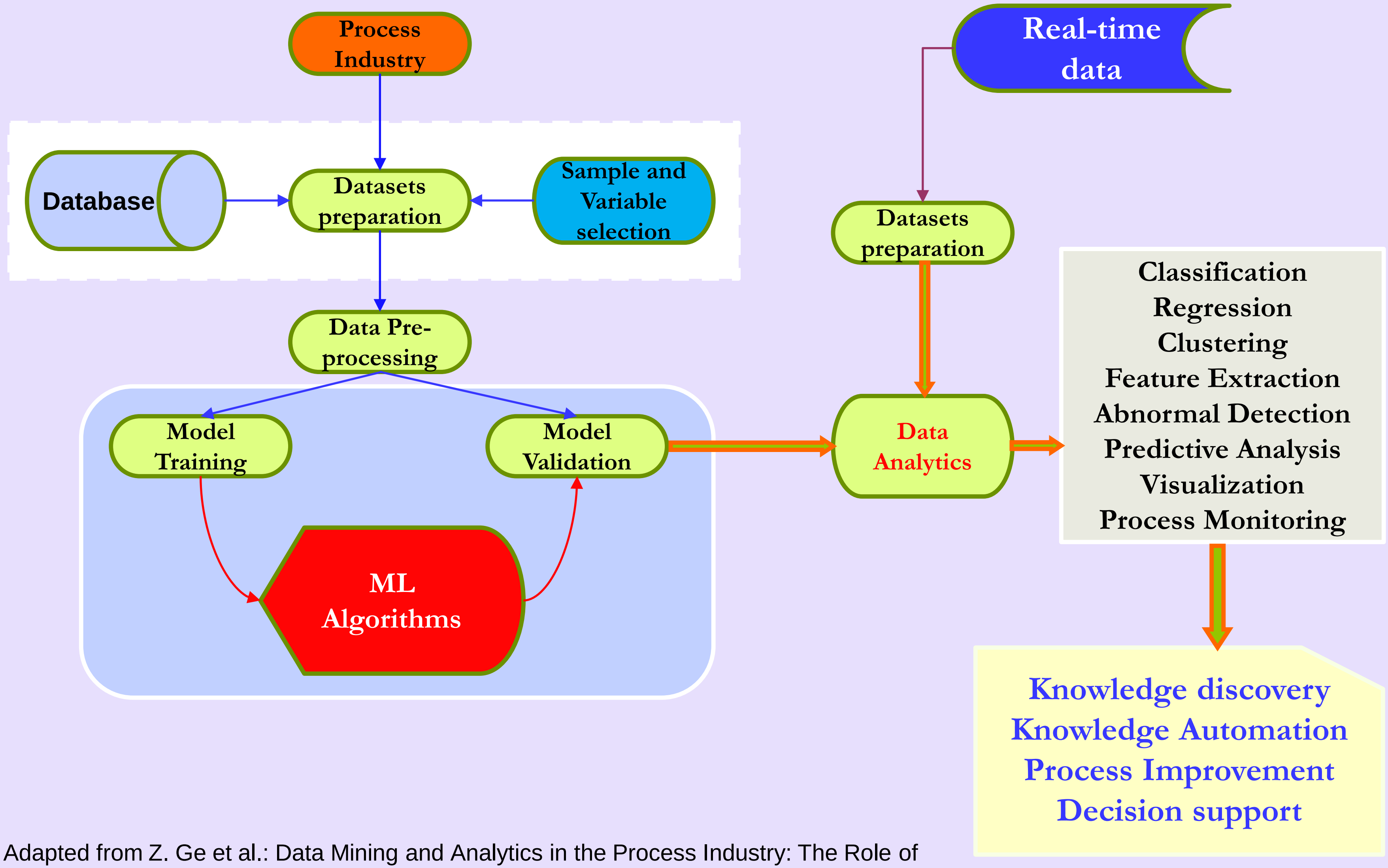
- To solve a problem on a computer, we need an algorithm. An algorithm is a sequence of instructions that should be carried out to transform the input to output. For example, one can devise an algorithm for sorting.

- For some tasks, however, we do not have an algorithm. E.g., Telling spam emails from legitimate ones. We know what the input is an email document. We know what the output should be: a yes/no output. But we do not know how to transform the input to the output.

Machine Learning – Algorithm when we do not have algorithm

- We do not have an algorithm but have lots of data, what we want is to "learn" what constitutes spam from the data.
- Machine learning is to extract automatically the algorithm for the task that we do not have an algorithm.
- Machine learning algorithms build a mathematical model based on sample data to make predictions or decisions without being explicitly programmed to perform the task

Machine Learning and Data Analytics Process

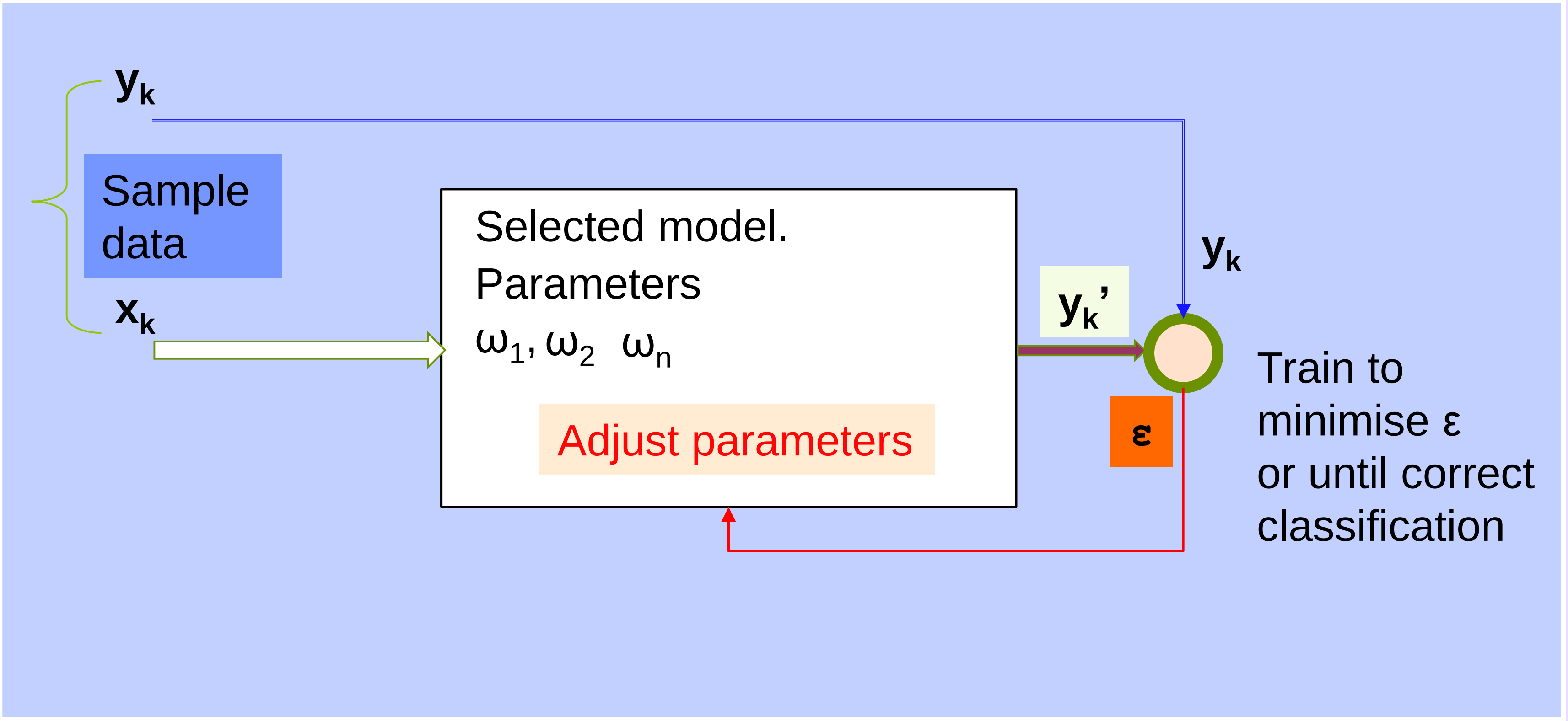


Adapted from Z. Ge et al.: Data Mining and Analytics in the Process Industry: The Role of Machine Learning, IEEE Access, 2017

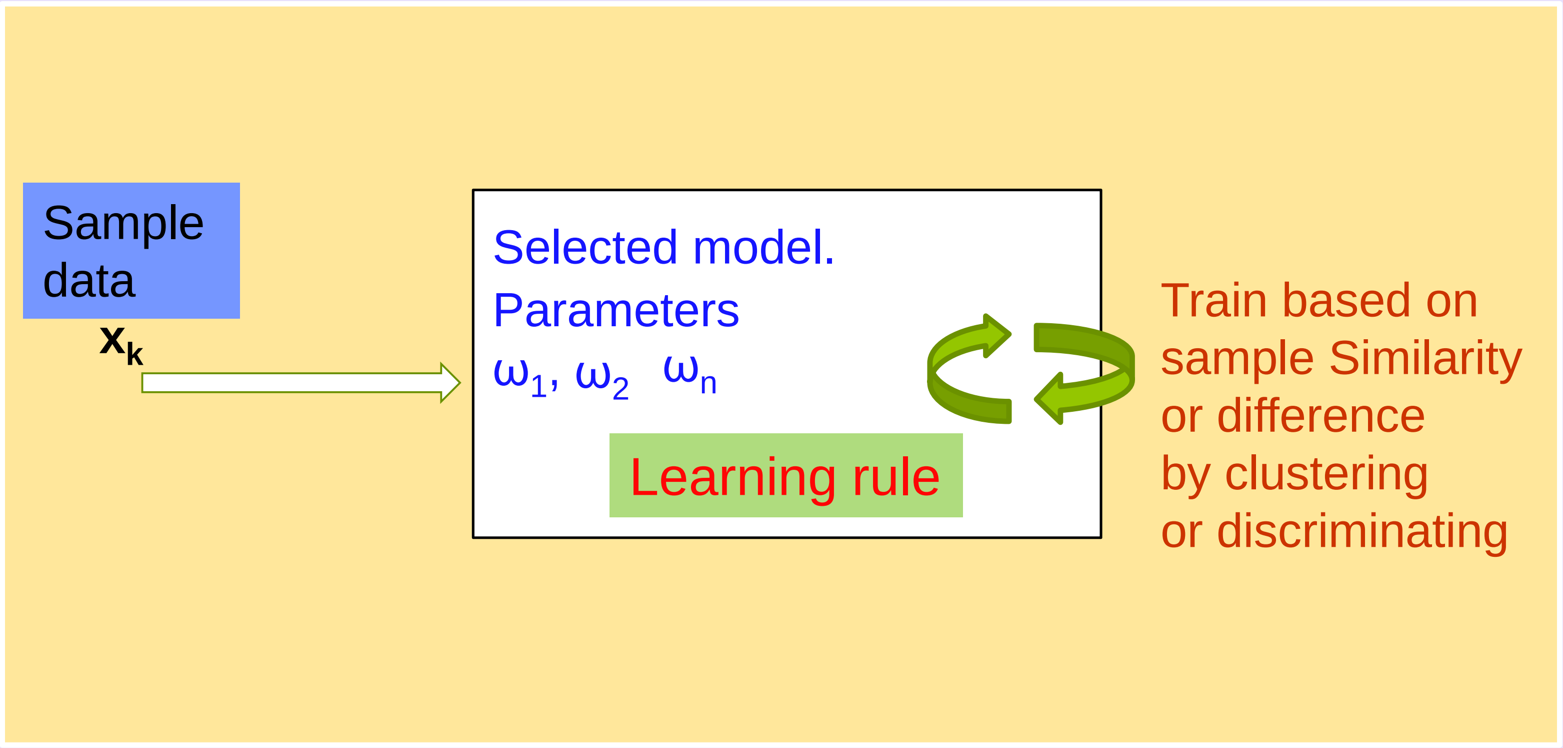
Machine Learning

Machine Learning. A specific subset of AI that trains a machine how to learn, makes it possible to quickly and automatically produce models that can analyze bigger, more complex data and deliver faster, more accurate results.

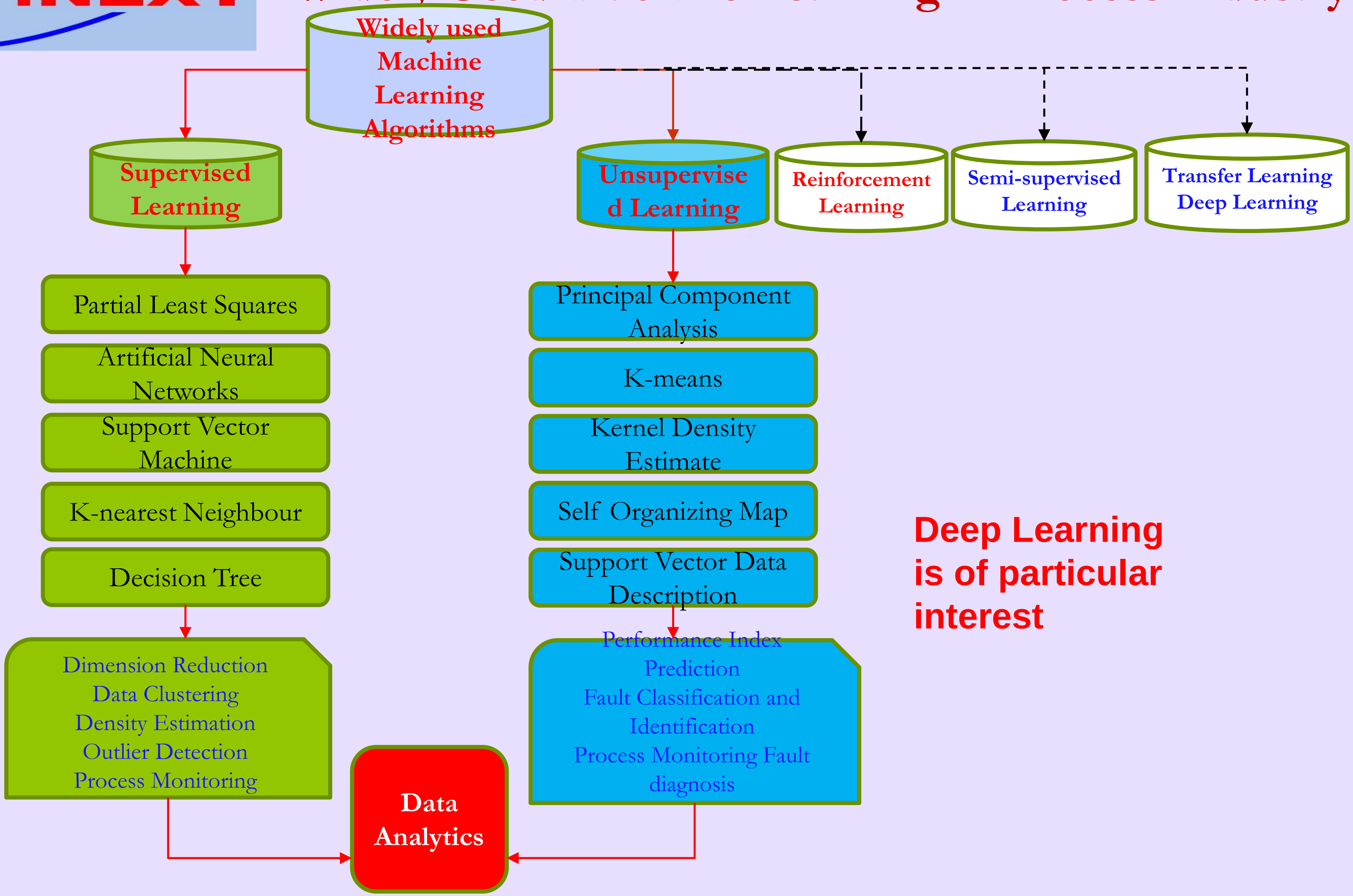
Learning in Machine Learning: Supervised Learning



Learning in Machine Learning: Unsupervised Learning



Widely Used Machine Learning in Process Industry



Deep Learning is of particular interest

Z. Ge et al.: Data Mining and Analytics in the Process Industry: The Role of Machine Learning, IEEE Access, 2017

Frequently used ML algorithms

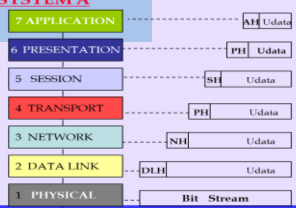
K-Nearest Neighbors	Classification	S
Naive Bayes	Classification	S*
Support Vector Machine	Classification	S
Linear Regression	Regression	S
Support Vector Regression	Regression	S
Classification and Regression Trees	Classification/Regression	S*
Random Forests	Classification/Regression/	S*
Bagging	Classification/Regressions	S*
K-Means	Clustering	U
Density-Based Spatial Clustering 0f Applications with Noise	Clustering	U*
Principal Component Analysis	Feature extraction	U
Canonical Correlation Analysis	Feature extraction	U
Feed Forward Neural Network	Regression/Classification/ Clustering/Feature extraction	S
One-class Support Vector Machines	Anomaly detection	SS

Adapted from Z. Ge et al.: Data Mining and Analytics in the Process Industry: The Role of Machine Learning, IEEE Access, 2017

A road block:
Cybersecurity
Safety, Security and Privacy

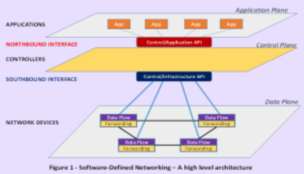
Cybersecurity and Risk Assessment

1.Network



So many issues at each layer and so many security experts at each layer

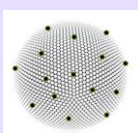
2. Infrastructure



- Cloud security: a complex multi-facet problem.
- SDN issues: controller security issues, flooding flo[illegible] switches, insecure interfaces (North, South, Ea[illegible]
- Secure billion of IoT devices.

3. Reality

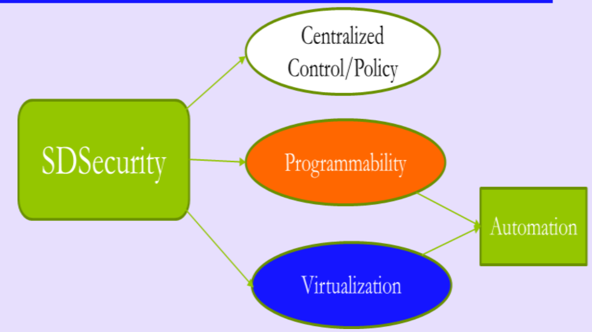
Holes to be plugged every[illegible]



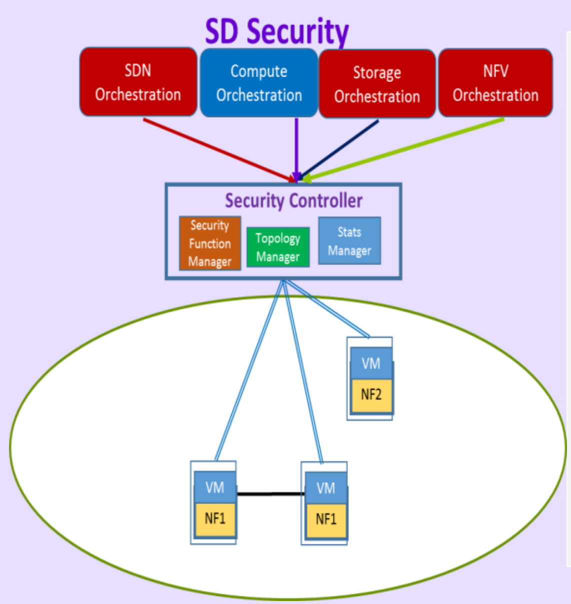
Ad hoc & Fragmented

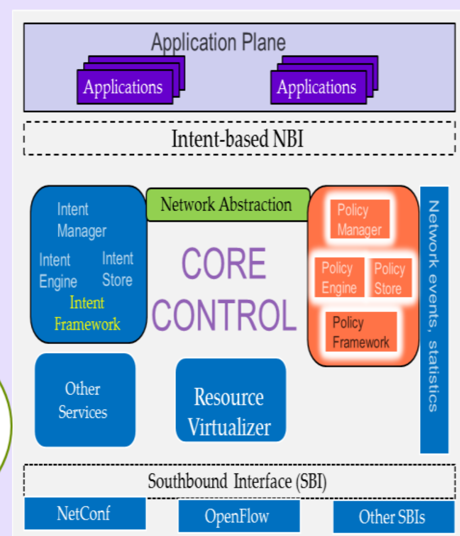
- Security holes everywher[illegible] Old (wherever we turn our attention there will b[illegible]y holes to be plugged.)
- Expertise on specific concern[illegible] per network layer experts, per specific sub-syst, experts, per application experts, per security issue experts, etc.)
- Lack global view and assurance. No overall model that can give assurance. Sum of assurance of component concerns do not provide assurance of the overall system.
- No information sharing or bridging across concerns to build models and standards.

Software-defined Security



Software Defined Security Architecture and Implementation



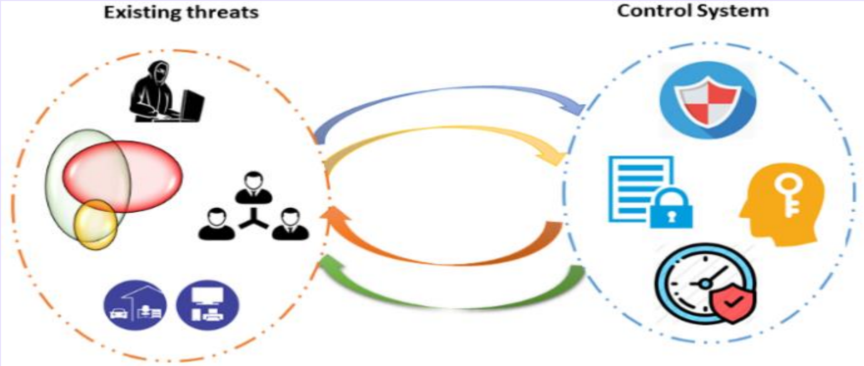


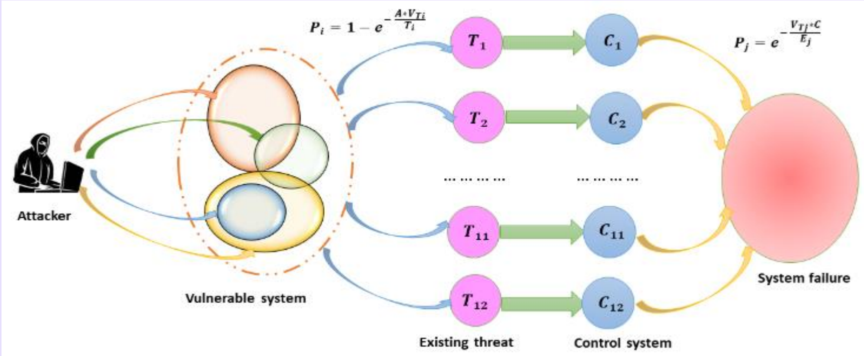
Risk Analysis

A risk is in essence the product of threats, vulnerabilities, and the consequences of the exploitation of vulnerabilities by the threats (i.e., the impact of threat)

Three questions are answered during a quantitative risk analysis:

- A scenario s, (i.e., what can go wrong?)
- The probability p_i, of s_i, (the probability that the scenario is realized)
- The consequence of x_i of s_i,





But that is not enough!
When an incident occurs we want to know
Where it hurts and
By how much

- **Challenges and Opportunities**

  ML Intelligence

  Cyber Physical System

  Cybersecurity

  Direction and Action

ML Challenges

How to put intelligence into a ML algorithm?

- What are the challenges in all ML algorithms?
  - Is there enough data to learn what we expect or desire?
  - Given the data, does the chosen model have adequate dimensions or parameters to discover all that is contained in the data?
  - Which ML algorithm is most suitable for a given set of big data?
  - Which learning method is suitable for a particular task relative to the selected data.

ML has become just a tool, more can be done on it

Challenges in Data Intelligence

- What value do we want to extract?
- What value we would like to extract from the data?
- What data should be collected

Assessment Strategy

We can not detect unknown (if we do not know what we look for)

So how do we detect unknown features?

Self-organization, self-clustering methods? BUT HOW?

New projection from existing data – How about a new dimension?

Introducing random events to find unknowns

On Cyber Physical Systems

Automation & Real-time

Security implication on all products and services

Question?

Bring back manufacturing from “low-wage” countries back to “high-wage countries?

What types of human resources are needed for I4.0? And how do we prepare for the need?

1. Data Managers: managing data and data framework
2. Security experts: protection of assets
3. Data Scientists who understand business to extract value from data
4. IT experts (network, database, application): integrated knowledge for overall system
5. Business analysis – creating businesses

Question?

What would be the best strategy for decision makers of "low-wage" countries?

Observation & Conclusion

- I4.0 is here to stay – Best option : Implement and deploy best I4.0 to support the economy
- Data Analytics is absolutely essential: Need top researchers/experts to extract value from data for business
- Building blocks: Invest in building smart factories, supply chains, and logistics
- Security and Privacy: Built in for the whole lifecycle of any product or service
- **Invest in people wisely for the future – Education**

Reference

A. Gilchrist, Industry 4.0: The Industrial Internet of Things, Apress 2016

Thank You