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MIND COURSE SUPPORT

LECTURE 3
Internet of Things, Digitalization Industry 4.0, Cyber Physical Systems and Mechatronic

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Part 1 – Internet of Things

Content

1 Introduction 79

1.1 Objectives of lecture 79

2 Internet of Things 79

2.1 Definition 79

2.2 Characteristics 80

2.2.1 Smartness in IoT 81

2.2.2 IoT architecture 84

2.2.3 Standardization and regulatory limitations 87

3 History of the Internet of Things 88

3.1 Basic terms and conditions of usage 90

3.1.1 RFID - Radio Frequency Identification 90

3.1.2 NFC - Near Field Communication 90

3.1.3 M2M - Machine to machine 91

3.1.4 Big Data - Very large data sets that can be analyzed to reveal insights and trends 91

3.1.5 IIOT - Industrial Internet of Things 91

4 Present and future of IoT 92

4.1 Internet of Things (IOT) Sectors 93

4.1.1 Smart city 94

4.1.2 Internet of Things in business: the Internet of Everything (IoE) 96

4.1.3 The Consumer Internet of Things (CIoT) 97

4.1.4 Industrial Internet of things (IIoT) 99

4.1.5 Internet of Robotic Things (IoRT) 102

5 Internet of things in manufactoring 102

5.1 IoT use cases in manufacturing: opportunities and context 103

5.1.1 Manufacturing operations 105

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5.1.2 Production asset management and maintenance 105
5.1.3 Field service 106
5.1.4 Other manufacturing IoT use cases 106
6 Security and standardization 109
7. References 111

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1 Introduction

1.1 Objectives of lecture

This course aims to develop the general and specific skills of the students within the MIND project consortium. This course has only theoretical objectives. The theoretical objectives are addressing the challenge of understanding of the principles and practical use of the Internet of think (IoT) as base technology for Industry 4.0.

General objectives:

- IoT definition, architecture and characteristics,
- basic term and conditions,
- history of IoT,
- present and estimated future of IoT,
- projects based on IoT examples (smart city, ect.),
- IoT in industry.

2 Internet of Thinks

1.2 Definition

There is no unique definition for Internet of things accepted by the world community of users. But many different groups of researchers, innovators, developers and academicians have defined the term as „An open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face of situations and changes in the environment".

You can find many definitions, what is Internet of Things. Generally, it is the way how people can connect to digital network and internet with big variety of devices like computers, smartphones, tablets etc. Nowadays devices like cars, lights, thermostats, TVs and lots of more are made „smart" by connectivity to networks and internet. They are not able to send data to the internet, but they can be controlled by internet. This devices are called „Things" on the „Internet of things"

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Another sources says, that Internet of Things (IoT) is „the network of physical devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data.“

It is almost 15 years, when the internet entered to our homes. Nowadays, we do not consider the internet as luxury. For a first time the internet was used on computer. Later with better technology on smartphones. But with IoT technology we can integrate the internet to every aspect of our offices, factories, shops, even our houses.

Internet of things become most hyped concept in the IT world. Last few years attracted attention by global infrastructure of networked physical objects, enabling anytime, anyplace connectivity for anything and not only for anyone. Global network, which can be the Internet of Things considered, allows communication between things to things, things to human and human to human with providing unique identity for every object. IoT talks about world, where anything can communicate and can be connected in a intelligent form as never before. Actuators and sensors embedded into physical objects are linked to wireless and wired networks. These networks usually have same IP address and send huge amount of data to computers of analysis. When object can sense both communicate and environment, it becomes tool for understanding complexity and responds to it swiftly. Revolutionary thing is, that some of these physical information systems can work almost without human intervention.

1.3 Characteristics

General characteristics are:

- **Interconnectivity** – any device can be interconnected with communication and global information infrastructure.
- **Heterogenity** – devices interact with other service platforms or devices through different networks.
- **Things-related services** – the IoT is able of providing thing-relating services without constrains of things. For example, privacy protection or semantic consistency between virtual things and physical things.

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- **Dynamic changes** – State of devices is changing dynamically. For example, sleeping and waking up, connecting or/and disconnecting. Also, number of devices can be changed dynamically.

3 Smartness in IoT

Another characteristic of IoT is „smartness“. It distinguishes IoT from similar concepts like sensor networks, and it can be categorized into „network smartness“ and „object smartness“. Smart network is a communication infrastructure with the following functionalities:

- Multifunctionality (network made for one application would be available for another purposes) and object addressability (direct IP address)
- Openness and standardization of used communication standards, from layer interfacing with the physical world (sensors and tags) to the communication layers between internet and the nodes

IoT is an umbrella term with many cases of usage, technologies, applications and standards. Data and the things are essence and starting point of what IoT means and enables. IoT devices and assets are equipped with electronics, like actuators and sensors, software to capture, communication/connectivity electronics, filter and exchange data about themselves, their environment and their state.

There is a big range of things from customer-oriented devices like wearable devices, solutions for smart home (Consumer IoT) to industrial equipment like robots, machines or operators in industrial facilities and smart factories (essential component of Industry 4.0, Industrial IoT) and connected devices in enterprise (Enterprise IoT). Main question is not what can we connect but why would we. It is because of purpose and outcomes. There are lot of goals which determinate what devices we want to connect and capture data from them (send from, between, or/and to them). That is why we can see distancing between Customer IoT, Industrial IoT etc.

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Usage and connection of IoT „things“ of IoT data enable various innovations and improvements in business, mobility, healthcare, lives of customers, society and cities. Potential goals of IoT are segmented into cases of usage – reasons for which is IoT used. Examples: asset tracking, environmental and health monitoring, home automation and predictive maintenance.

There is a lot of IoT use cases, depending on industry or/and type of application. There is some cases of use across industries but others are more vertical. Examples: tracking of asset is a universal use case. It could mean tracking containers on cargo ships or consumer application for locate our car or pet.

IoT is next logical step in evolution of the internet and follows up to M2M (machine to machine) technologies and networks, building upon and extending technologies in M2M, RFID mobile technologies and more.

The internet of things connects business areas with industries, unite Operational Technology and Information Technology (OT and IT) and helps to Industrial transformation (Industry 4.0) and a lot of use cases in Industrial IIoT or IoT. The Main area of IoT investments (use cases and industries) include operations, manufacturing, transportation, smart buildings, smart grid technologies, retail and smart home automation.

Connection of physical devices with communication possibilities and embedded sensing, including actuators and sensors, is not new technology and has long history in the sense of M2M networks. In IoT, physical endpoints are connected via uniquely identifiable IP (Internet protocol) address; where data can be aggregated, gathered, communicated and analyzed via embedded software and electronics, IoT gateways and nodes, the cloud and additional connectivity technologies, IoT platforms with growing integration of AI and networks, IoT and other technologies like blockchain.

IoT is an additional layer of interaction, information, action and transaction, which is added to the internet by devices, equipped with data sensing, communication and analysis capabilities, using internet technologies. Internet of Things connect physical and digital realities and powers information driven improvements and automation on the level of people´s lives, society and business.

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Captured and analyzed data are used in several cases like maintenance, autonomous and semi-autonomous decisions (where dataflow do not just come from IoT enabled devices, but they are also exchanged between devices, occur with them or they are sent to devices in form of instructions), real time monitoring, scientific research, new business models, data exchange and lot of more.

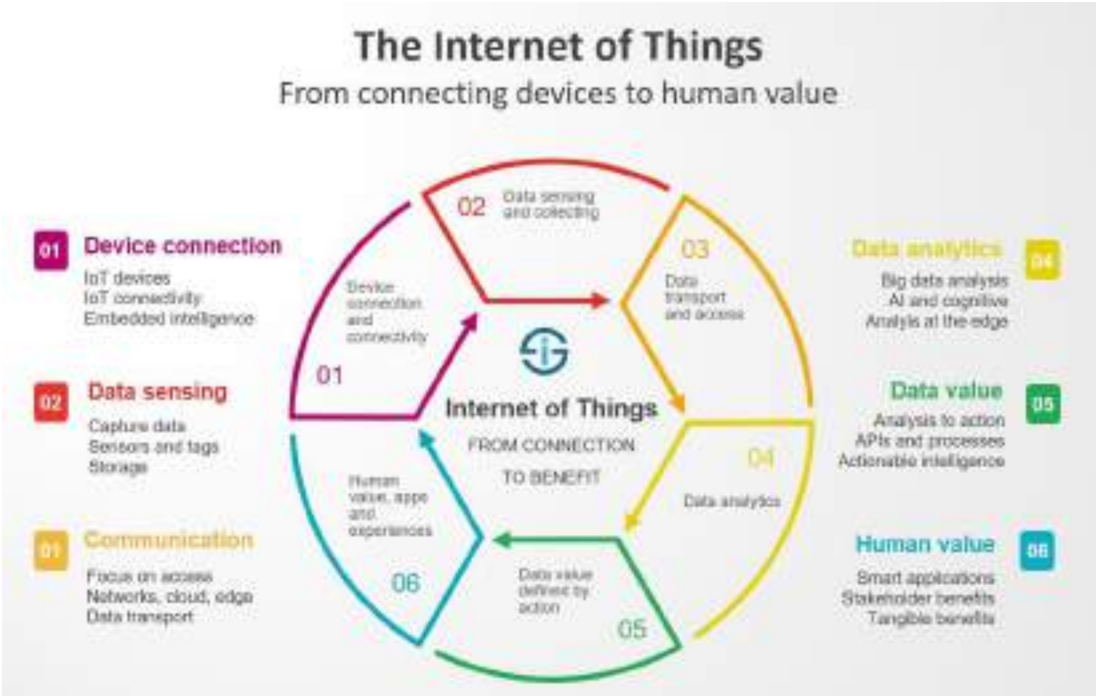

Figure 1. The internet of things

All the networks we mentioned are connected to a network with clout (service for online storage), gateway and value created for it. Infrastructure and communication play a big role for creating this value.

IoT uses devices with sensors which detect environment changes. Sensors are also able to measure physical changings. Examples: Change of light, height, temperature, pressure...

Good sensor should have these three features:

- Sensor should be sensitive to attribute that it measures.
- Sensor should not be sensitive to other attributes.

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- Sensor should not modify measured attributes during process of measuring.

4 IoT architecture

Building blocks of IoT are remote service invocation, sensory devices, communication networks and context-aware processing of events. IoT tries to present us unified network of smart objects where human is responsible for their operations (if needed), which are able to mutual communication with each other. Interconnectivity among entities is a critical requirement. Whole architecture of IoT needs to guarantee flawless operations of its components (we consider reliability as the most important factor in IoT) and virtual realms together. To achieve this, we need to design failure scalability and recovery. Since dynamic and mobility of location become integral part of IoT, wide spreading use of smartphones, state of the art architectures needs to have definite level of adaptability to correctly handle dynamic interactions with the whole ecosystem.

Several research groups designed architectures for IoT. The IoT-A project focuses on the validation and development of integrated supporting building blocks and IoT network architecture, with the objective to be „the European Lighthouse Integrated Project addressing the Internet of things Architecture“. IoT-i project focuses on promotion of IoT solutions, catching interests and requirements. Aim of IoT-i is to achieve strategic objectives like: creating a joint between technical and strategic visions for the IoT in Europe that contain currently fragmented sectors of IoT domain holistically and contributing to the creation of an economically sustainable and socially acceptable environment in Europe for IoT technologies and respective R&D activities.

The aspect of integration and hyper-connectivity often lacks. Where people, devices, information and process are more interconnected than ever before. A key element of hyper-connectivity in the IoT sphere is ongoing bridging of physical and digital environments together with human environments, data and process to create value when they are properly used for connected purposes.

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There is a lot of terms to describe, what is the essential part of network of things. Some use word like intelligent or smart to devices. We can say that they contain technology that gives another ability to „do something“. It could be moisture or temperature levels, sensing movements, capturing location data or any other form of action that can be captured and transformed into a data. IoT needs to be managed. Management of IoT enables overall management of IoT devices, configuration and onboarding. Management can be simple (in consumer applications) and can be done with help of cloud platforms with IoT device management proprietary vendor solutions or another features. It can be also complex. IoT platform become more important, so IoT device management needs to be on same level because it is one of key component like platform. Other components of IoT platform include access control, data management and application enablement.

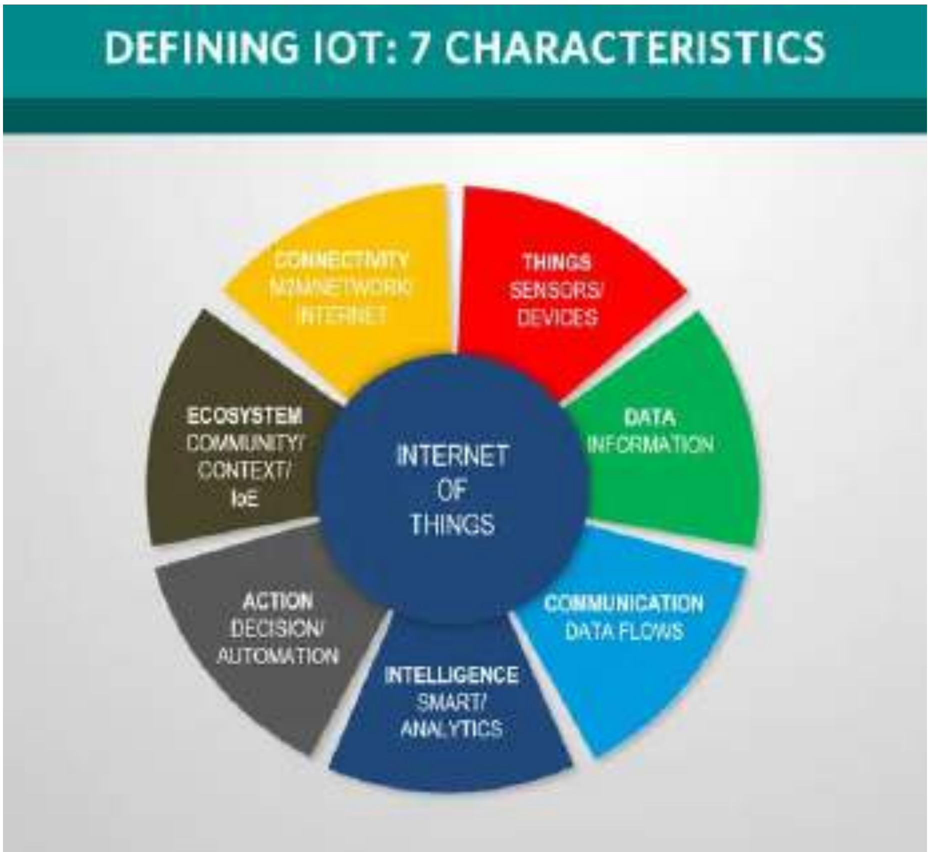

Figure 2. Defining IOT: 7 characteristics

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The number of connected devices to internet increasing rapidly. Approximately each hour is made million connections. Cisco expected that there will be 20 billion devices connected in Internet of Things, by 2020. Examinations for 2030 raised to 50 billion devices. Some predictions are more bullish, in 2025 there will be 100 billion devices connected in Internet of Things.

Gartner company estimated that by 2020 we would live in a world with more than 26 billion connected devices.

Today, IoT is effectively hyped. Gartner's Hype cycle for emerging technologies says, that IoT is at the peak of fulfilled expectations.

There are lot of reasons why IoT is getting bigger attention. Some of them are decreasing cost of storage, material and processing or the third platform with the cloud, smart devices/technologies, big data, etc. There is also people/societal dimension with strong consumer element.

Factor, that also contributed to rise od IoT, certainly in context of industrial IoT and smart buildings is convergence of OT (Operational technology) and IT, where actuators and sensors remove barriers between traditionally disconnected worlds.

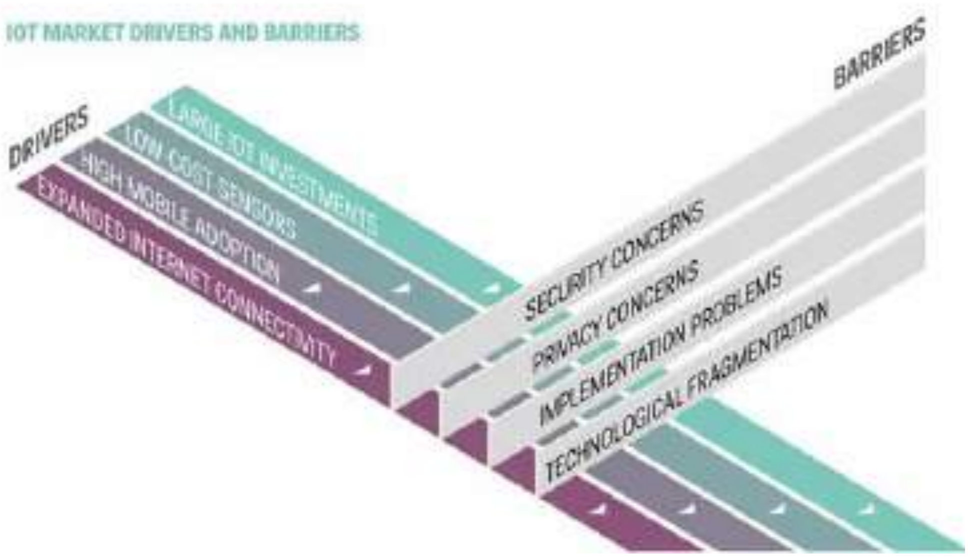

Figure 3. IOT Market drivers and barriers

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5 Standardization and regulatory limitations

The limitation and standardization caused by regulatory policies have challenged the adoption and growth rate of IoT and can be potential barriers in embracing the technology. Broadcasting and defining standards will ease the burden of joining IoT environments for new providers and users. Additionally, interoperability among different service providers, components and users will be greatly influenced in a positive way, if pervasive standards are employed and introduced in IoT.

Even though more industries and organizations make themselves ready to incorporate and embrace IoT, increase in IoT growth rate will cause difficulties for standardization. Strict regulations about accessing radio frequency levels, creating a sufficient level of interoperability among different communication protocols, authorization, identification, authentication, devices and are all open challenges facing IoT standardization.

6 History of the Internet of Things

The Idea of IoT begin at the end of previous millennium, when RFID was a key development towards IoT and the term Internet of Things was created in a RFID context (and NFC). We used RFID to track items in logistics or for various operations in supply chain management.

Origin and the roots of IoT go beyond just RFID. For example, machines with M2M solutions like ATM (cash machines or automated teller machines) existed for a long time before just like RFID. These earlier connected devices, data and networks is where IoT comes from. Nowadays we do not consider this as IoT.

One of the first appliance connected to internet was Coke machine at Crnegie Mellon University in 1982. Programmers wrote a server program that measured how long it has been since last filling of machine and if the slot in machine is full or empty. They want to avoid situation when they come 3 floors down for a drink and vending machine was empty or drinks were not cold enough because maintenance just filled machine with drinks.

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Although the world „Internet of Things“ evolution was set back in 1980s with coffee vending machine, original term is created by Kevin Auston, the Executive Director of Auto-ID Labs in MIT in 1999.

In Auto-ID center in 2003 was the concept of IoT very popular and also in related market analyst’s publications. From the beginning of IoT evolution, there were many objects and things connected to internet for different applications across different technologies depending on type for highest comfortability of human.

In 1999 mobile networks did not have yet the full IP-based configuration and Wi-Fi technology was in crawl stage. It was impossible in those times to think about IoT, where all devices have their own IP address. Producers did not invest in IoT technology until cloud technologies were developed.

In 2000s makes this possible because several key factors happened. Since 2000s, network area starts to expand. With this expansion the internet become more accessible than before. After that, wide range of data analysis tools was introduced and offers ability to interpret and manage data from IoT devices more easily. Perhaps more then anything else the most important part of modern IoT is development of the cloud. It is because of needs to be always connected to the internet and place where storage collect information.

After development of Cloud technology IoT devices start to spread rapidly. The result was that new concept appeared in foreground – the Big Data.

7 RFID - Radio Frequency Identification

RFID device was first used during World War 2 in Britain. It was used for identifying foes or friends in 1948. In the 90s, technologies like sensors, RFID and a few wireless innovations led to couple of applications in connecting of „things“ and devices.

The most implementations of RFID embedded in real life in those days was in general in warehouses, logistics and supply chain.

Step by step, the usage of RFID (and several NFC wireless technologies), become very popular in other areas than supply chain management and logistics. For example: public

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transport, electronic toll collection, identification, access authentication and control, traffic monitoring, retail etc. That growing usage was driven by increasing standardization, decreasing cost of RFID and NFC.

This technology plays an important role for solving identification issues in IoT. RFID technology is classified into 3 categories based on the method of power supply provision in Tags:

- Active RFID
- Semi Passive RFID
- Passive RFID

Main components of RFID are server, software, access controller, antenna, reader and tag. It has an extensive range of wireless applications like military apps, patient monitoring, tracing, distribution etc.

8 NFC - Near Field Communication

Near-Field Communication (NFC) is set of very short-range radio trans-mission standard. It provides data exchange among electronic devices in a short range (as much as 4cm). Transmission of data can be performed by contacting them physically or close enough. Communication can be performed between NFC device and unpowered NFC chip. It works at 13.56MHz frequency (unlicensed band).

9 M2M - Machine to machine

Machine to machine is a communication technology where large number of intelligent devices can autonomously communicate with each other and make decisions together without human intervention. This way we can achieve better time management and cost efficiency.

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Origin of M2M communication are the supervisory control and data acquisition (SCADA) systems. Sensors and other devices are connected via radiofrequency or wired networks. They are used with computers to control and monitor industrial processes.

10 Big Data - Very large data sets that can be analyzed to reveal insights and trends

With increasing internet usage and social media, accumulating data are growing to very high levels on the cloud. These data are called „Information garbage“. R&D companies filter useful data (based on manipulation and advertising) from information garbage. This filtered meaningful data are called „Big Data“.

11 IIOT - Industrial Internet of Things

Industrial Internet of Things is application of IoT in manufacturing industry. It requires communicable and intelligent machines or devices in manufacturing setup.

Specific features of IIoT in process of manufacturing are:

- Capture all sensor data from facilities, machines, machine to machine communication.
- Include machine learning, data analytics and big data analysis technology.
- Philosophy of driving IIoT is that smart (communicable and intelligent) devices/machines along with human intelligence are better for consistent and accurate data capturing and subsequent dispatch.
- Captured data from analyses enable companies to identify inefficiency and invisible problems faster. It saves time, money, and support business intelligence in manufacturing process.
- It has great potential of traceability, maintenance, operational efficiency, supply chain efficiency, sustainable practices and quality control

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12 Present and future of IoT

Today, everybody has a lot of electronic devices in their homes. Apart from the computers and telephone, what kind of possibilities do we have when we connect our electronic devices like light bulb, coffee machine, television, or air conditioner to the internet? If we give an example of the use of IoT, it would be good to make the situation more concrete, but it should not be forgotten that these examples are only about smart cities.

When we go out from the office and go to the house, the IoT devices recognize that our car is moving and coming home, with the help of GPS and opening heaters or air conditioners early, so when we come home, the house temperature will be at our desired level.

Through the garbage cans in our city are empty or full, garbage trucks are coming to them. This is causing wasting both the fuel and the time. The smart garbage cans, only send signals when they are full. The IoT device, located in the garbage truck finds the optimum way in the direction of the signals coming to it and tells the driver. This saves both money and time. While we are out of town, when a thief trying to enter our house, a warning message comes in our phone and instantly notifies the police department. IoT is a must for the factories that take the instant measures themselves if the worse is a flood or a fire.

Ultimately it all boils down to digitization, optimization, visibility of the factory and manufacturing environment and its components in relationship with enhanced services towards customers in the broadest sense.

- Industrial IoT use case segments
- Digital/connected factory
- Facility management
- Asset management
- Safety/security and operations
- Logistics and ecosystems
- Customer preference and behavior
- Services and predictive maintenance
- Quality control

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- Packaging and shipping preparation
- Production flow monitoring
- Condition-based alerts

1.4 Internet of Things (IOT) Sectors

The IOT will affect many areas of day-to-day life. Some of the main sectors are:

Industry/Area	**Use**
Home	Control of heating,lights,door locks etc
Health medical	Remote Patient Monitoring etc
Fitness and wellness	Tacking heart rate and Training plans
Factory and Industry	Production line control ,asset tracking etc
Agriculture	Automatic watering,soil monitoring etc
Cars and Roads	Connected cars, parking spaces,
Smart Cities	Traffic management, parking space tracking and availability

People use IoT all around the world in variety and different sectors. The IoT is used for almost all smart things. For example, in smart cities and in smart homes (reducing costs implementations, home security), in smart agriculture, in smart manufacturing (dark factories), in wearable technology (smartwatch), in the automotive sector (autonomous cars), in healthcare technologies, etc.

Examples of IoT:

- Xiaomi Mi Smart Home Products
- Automatic Car Tracking Adapter
- Scanomat Topbrewer
- Petnet Smart Pet Feeder

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- Philips Hue Smart Bulbs
- Nest

13 Smart city

The potential of IoT offer many possible applications. Some of these applications are shown in figure below. Only some of them are currently completely deployed and in the future, there will be more intelligent applications for factories, enterprises and smarter cities. Smart city applications are developed not only to allow a real time response to challenges but also improve the management of urban flows. Especially in this century, many emerging environmental, economic and technological changes have generated interest in smart cities. These changes include pressures on public finances, ageing populations, economic restructuring and climate change. A smart city can be considered as the general application category in which other domains such a smart grid, smart home, smart automotive and traffic management are included.

Smart home can be considered as a subcategory of smart cities. In this subcategory a residence appliance, air conditioning and heating systems, lighting, audio and video streaming devices and security systems are capable of communicating with each other or through a central control unit in order to bring security, comfort and energy efficiency for homeowners.

The research works on smart cities took a lot of attentions in the last decade. From market's point of view, the smart home is expanding rapidly and is expected to reach more than 100 billion dollars by 2022. In this application family and personal security is a key adoption motivation for the major consumers. Survey shows that 90% of people agree that security is one the most important reasons to purchase for a smart home system. The next motivation is costs saving as the exciting reason for the consumers to use smart home. It has been predicted that a typical family home may contain more than 500 smart devices in 2022, while currently for the most consumers, smart home is not a necessary demand.

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In European countries, since EU Parliament published a directive in 2002 to use the methodologies for increasing the energy efficiency in buildings, a lot of international research projects have established to use energy management system to reduce buildings energy consumption. Some of these projects are:

- **SEEMPubS** (Smart Energy Efficient Middleware for Public Spaces) - is one of the EU founded projects in which the main attention has given to development of an energy system for historical buildings and public.
- **DIMMER** (District Information Modeling and Management for Energy Reduction)
- **AIM** (A novel architecture for modeling, virtualizing and managing the energy consumption of household appliances)
- **IntUBE** (Intelligent Use of Buildings' Energy Information)
- **DEHEMS** (Digital Environment Home Energy Management System)

Europe's historic buildings have visitors from all around the world every day. It can be struggled to provide energy efficient buildings without significant construction works. In SEEMPUBS project we were involved in developing an ICT-based energy management control system cope with avoiding possible damages caused by important building interventions due to energy management hardware installation. In this project a new computer-based system controls heaters, air conditioners and lighting and other environmental units in large buildings. The SEEMPUBS technology provides a central control system at software level which is connected wirelessly to energy structures placed in number of buildings or different parts of a building. Beyond the hardware, the most significant results have been on elaboration of an energy-efficient model for existing buildings and public spaces. This model can be applied to many different historic buildings to avoid disruption, construction work and possible damage, even with deploying new emerging technologies. As a user application, the Heating, Ventilation and Air Conditioning (HVAC) control applications include products, services and systems that target control strategies to save energy. HVAC systems use IoT hardware and software infrastructures to achieve their objectives. Another subcategory application for IoT in a smart city is where the automotive industry offers smart cars. From engine to headlights

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all systems in between request a range of innovative technologies in modern cars. IoT will provide web-connected vehicles to implement predictive maintenance, telemetry, car to user and car to car connections. It is mostly desired to replace wire with wireless communications in a smart car while maintaining a safe and comfortable driving.

The breadth and complexity of manufacturing shows lot of IoT use cases in manufacturing. 76% of early-movers in manufacturing says IoT is increasing insight into customer behaviors and preferences.

Part of them are in the context of connected/digital factory, other refer to asset management and facility. Another group to components like security or safety and logistics, operations and ecosystems.

14 Internet of Things in business: the Internet of Everything (IoE)

Internet of things use devices like actuators and sensors, but the term Internet of Everything (IoE), which is used by Cisco, is broader and contains data, devices, process and people.

Devices like sensors send data. This data will be processed and used by machines or by people to control the devices or another devices.

Example: Temperature sensor sends data to a process, which determinates that the temperature in room is high or low and send signal to turn on or turn of air conditioning.

Even terms IoT and IoE refer to two different things, people tend to represent it as a same thing. Same for web and Internet.

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15 The Consumer Internet of Things (CIoT)

Few years ago, consumers rarely saw what IoT mean to their private lives. Today, they increasingly do. Not because they are interested in technology, but it is because a range of new connected devices and applications hit the market.

These possibilities and devices are getting major attention on virtually every website and news that covers technology.

Although there is some technology fatigue appearing, combination of applications in technology fascination and a consumer context undoubtedly plays a role in the growing attention for IoT. Consumer fascination aspect comes on top of all the real-life possibilities as they start getting implemented and the technological and contextual realities, making IoT one of many pervasive technological umbrella terms. CIoT market is not just driven by new technology fascination. Manufacturers push the market heavily as adoption means news business possibilities with a key role for data.

Here are some consumer electronics challenges to solve first:

- **Smarter devices** - Consumers are waiting for smarter generations of wearables and IoT products, which are able to fulfil more functions without being too dependent from smartphones, as is the case with many of today devices (the first generations of smartwatches, which need a smartphone).
- **Security** - Consumers do not trust IoT yet, further strengthened by breaches and the coverage of these breaches. It is not just about the security of the devices but also about the security of low data communication protocols (and Internet of Things operating systems). An example: home automation standard Zigbee was proven easy to crack in November 2016.
- **Data and privacy** - On top of security concerns, there are also concerns regarding privacy and data usage. The lack of trust in regards with privacy, data and security was already an issue before these breaches of the consumer electronics market evolutions.

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- **A "compelling reason to buy"** - current devices which are categorized as CIoT appliances are still relatively expensive, "stupid" and hard to use. They also often lack a unique benefit that makes consumers massively buy them.

While the focus of the Industrial Internet of Things is more on the benefits of applications, CIoT is more about immersive customer-centric and new experiences.

As mentioned, the CIoT is typically about smart home appliances and smart wearables but also about drones for consumer applications, smart televisions and a broad range of gadgets with IoT connectivity.

It's important to note that de facto the CIoT overlaps with the use of the Internet of Things across several industries.

On top of examples such as smart meters, it is clear that the CIoT offers manufacturers of applications and devices important opportunities to leverage data to build new revenue streams and new ecosystems and partnerships to leverage this data in various ways. Security and data privacy will remain a challenge for several years to come but at the same time new generations of devices with clear benefits and a focus on the consumer experience will boost the market.

16 Industrial Internet of things (IIoT)

There are numerous IoT definitions of relevance to industrial application make explicit the kinds of smart components that get embedded into ordinary objects so that objects can count as IoT devices, and form constituents of cyber-physical systems (CPS).

Three relevant definitions are:

- "group of infrastructures, interconnecting connected objects and allowing their management, data mining and the access to data they generate" where connected objects are "sensor(s) and/or actuator(s) carrying out a specific function that are able to communicate with other equipment".

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- “The terms ‘Internet of Things’ and “IoT” refer broadly to the extension of network connectivity and computing capability to objects, devices, sensors, and items not ordinarily considered to be computers. These “smart objects” require minimal human intervention to generate, exchange, and consume data; they often feature connectivity to remote data collection, analysis, and management capabilities“
- “The IoT represents a scenario in which every object or ‘thing’ is embedded with a sensor and is capable of automatically communicating its state with other objects and automated systems within the environment. Each object represents a node in a virtual network, continuously transmitting a large volume of data about itself and its surroundings…”.

Based on them, an initial definition of IIoT can be: the use of certain IoT technologies (certain kinds of smart objects within cyberphysical systems) in an industrial setting, for the promotion of goals distinctive to industry.

Simple similar definitions are for example:

- “The Industrial Internet of Things (IIoT) is the use of Internet of Things (IoT) technologies in manufacturing”
- “Industrial Internet: A short-hand for the industrial applications of IoT, also known as the Industrial Internet of Things, or IIoT”

The simple conception does provide a template for a definition of IIoT, for it correctly attempts to define IIoT by appeal to two basic features:

- the kinds of technologies that are used in an IIoT setting
- the distinctive aims and purposes to which those technologies are put.

Next bottleneck to avoid when attempting to arrive at a definition of IIoT is defining IIoT in terms of some other notion, which is not obviously different from the notion of IIoT itself. This would render the definition uninformatively circular. That sort of problem is exemplified in the industry-driven literature by, for example: “The IIoT vision of the world is one where smart connected assets (the things) operate as part of a larger system or systems of systems

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that make up the smart manufacturing enterprise”.A definition that improves incrementally over the simple definition is: “Industrial Internet or Industrial Internet of Things (IIoT) is built for bigger ‘things’ than smartphones and wireless devices. It aims at connecting industrial assets, like engines, power grids and sensor to cloud over a network”.

The central advantage of this still admittedly vague definition is that it makes it clear what the function of IIoT devices is: to monitor, collect, exchange, and analyze information so as to enable them to change their own behavior, or else instruct other devices to do so, without human intervention.

Several researchers writing in German, offer a cluster of definitions of IIoT that share a focus on the kinds of technologies which are put into operation in IIoT settings, and the ways they are put to use in those settings. It is suggested that a central element of IIoT is its reliance, in an industrial setting, on objects, systems and machinery which has been upgraded to the status of a CPS, so that products and services can be guided through the supply and value chains in an autonomous manner. Another perspective is that IIoT relies not just on CPS, but also on embedded systems, cloud computing, edge computing, the generic technologies associated with the smart factory, and associated software. A further insight relates to the aims and purposes of IIoT technologies, suggesting that they should not merely function to enable autonomous production, but enable real-time information to users, consumers and other processes. The definition of Industry 4.0 in Section 2.1 sheds light on the kinds of technological processes utilized as part of IIoT, and how those processes are applied in promoting the values of the relevant industries whilst also making it explicit how IIoT technologies are connected to other features of the industrial technological landscape, such as Smart Factories and the Internet of Services.

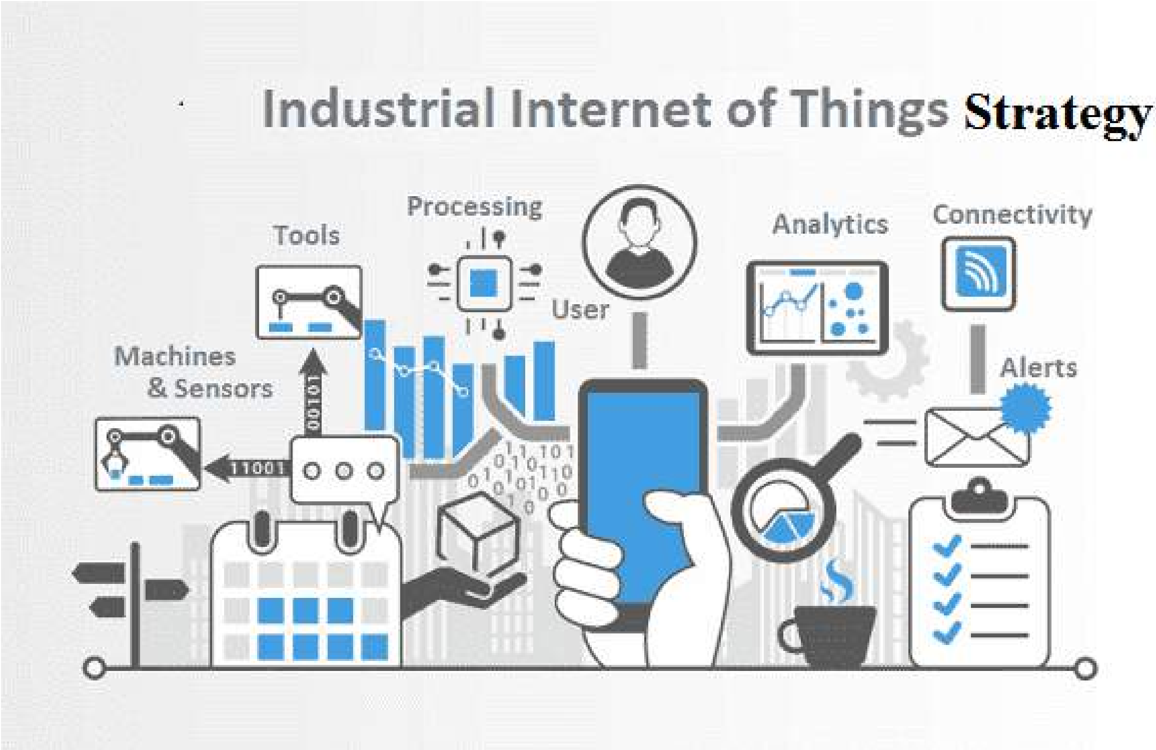

Figure 4. Industrial Internet of Things Strategy

The IIoT is related with Industry 4.0. All IoT applications in Industry 4.0 are forms of IIoT but not all IIoT use cases are about the industries which are categorized as Industry 4.0.

Typical use cases of the IIoT include smart traffic solutions in smart cities, smart lightning and intelligent machine applications, factory floor use cases , industrial control applications, condition monitoring, smart grid applications, use cases in agriculture and oil refinery applications.

Even if the term is not so much an umbrella term as IOT is, it still covers many potential use cases and applications.

17 Internet of Robotic Things (IoRT)

One of the major characteristics of the IoT is that it enables to build far stronger bridges between digital (cyber) and physical worlds. We can see it in all of IoT use case and in the IIoT in what's called the Cyber Physical Systems.

In most case, the focus is mostly on the 'cyber' part whereby data from sensors basically are leveraged to achieve a particular outcome with a focus on data analytics and 'cyber' platforms and human interference. ABI Research, who came up with the IoRT concept puts it is that basically many businesses and applications models are built upon passive interaction.

By adding robotics to turning devices (robots) and the equation in intelligent devices with the ability to add sensor data from other sources, embedded monitoring capabilities, distributed and local intelligence and the fusion of data and intelligence in order to allow these devices determine actions to take and have them take these actions, within a pre-defined scope, you have a device that can manipulate/ control objects in the physical world.
Examples: warehouse automation (Amazon Robotics), in the field of Industry 4.0 (with collaborative industrial robots) and even personal robots for cleaning and so forth make it more tangible. It's still early days for the IoRT but realizations and the projects in this next stage are real. IoRT is not tied to the consumer and industrial IoT distinction.

18 Internet of things in manufactoring

US manufacturers were using IoT Technology in the manufacturing plant (approx.. 32%), followed by the extended supply chain, the warehouse and the customer environment.
When looking at the usage of manufacturing and IIoT, also note the importance of cyber-physical systems (sometimes used interchangeably with IIoT, which is not correct) and the reality/ notion of digital twins in the Industrial Internet and Industry 4.0.

Internet of Things in manufacturing: use cases

The graphic from Verizon's "State of the Market: Internet of Things 2016", below shows benefits and some data across several use cases.

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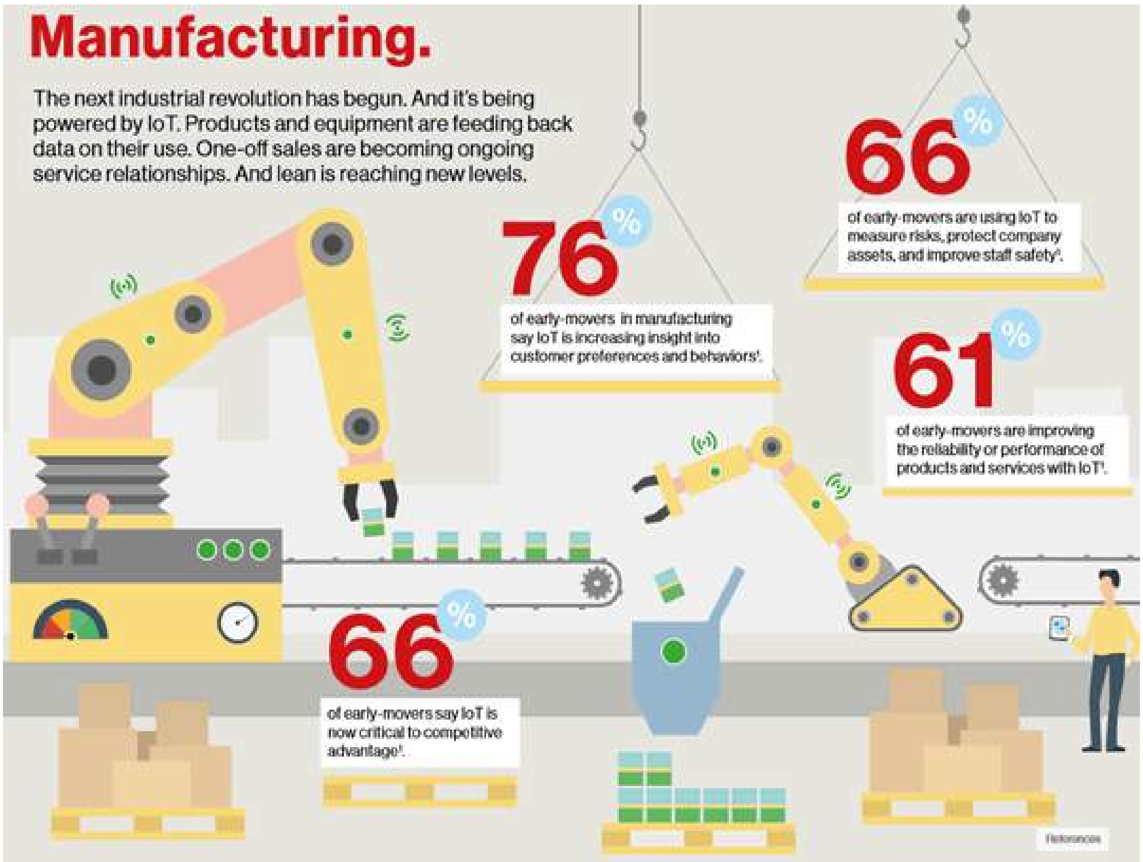

Figure 5. State of the Market: Internet of Things 2016

In the age of Industry 4.0 and the digital transformation of manufacturing, the manufacturing industry is the market where most IIoT projects are realized and by far the market where most IIoT investments are made. IoT is a core component of industrial transformation efforts across the globe, including the Industrial Internet (with the Industrial Internet Consortium) and Industry 4.0.

Manufacturing is not just the clear leader in the Industrial Internet but it tops all industries (including the consumer IoT space) in the broader IoT reality.

Drivers of the IoT manufacturing market are “linking islands of automation” and efficiency optimization. In the APeJ (Asia Pacific, excluding Japan) region, close to one third of all IoT spending (software, hardware, connectivity combined and services) will be for the manufacturing industry in 2020. Also in other regions, manufacturing ranks first but with

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slower market shares of total IoT spending. In the US, for example, IoT spend by the manufacturing industry will account for approximately 15% of total IoT purchases.

The manufacturing industry is leading in the IoT for various reasons: some are related with the so-called next industrial revolution (Industry 4.0), others historical and then there are the many uses cases and actual IoT deployments that offer rapid return and enable manufacturers to realize digital transformations from several perspectives: automation, efficiency, competitive benefits, customer-centricity and the advantages which are offered by using data across the manufacturing value chain and to tap into new revenue sources. This is a key aspect of digital transformation in manufacturing.

1.5 IoT use cases in manufacturing: opportunities and context

Manufacturing operations accounted for a total IoT spend of $102.5 billion in 2016 (on the mentioned total of $178 billion), according to the same IDC 2017 release.

Manufacturing obviously covers many types of operations, products, vast space of activities, processes and components, information systems, machines, partners, people and so forth. It is a long way from raw materials to finished goods and it is inevitably related with logistics, supply chains and transportation as well.

66% of early-movers in manufacturing say IoT is now critical to competitive advange.

It is among others in this sense that the IoT almost by definition is key for the manufacturing industry in an integrated approach, further including technologies such as robotics, cloud, big data analytics and, most importantly perhaps, the integration of OT (Operational Technology) and IT (Information Technology).

In other industries there are so many opportunities to leverage the IoT in connecting digital and physical, making various assets, other production assets, such as machines and the various object in a non-production sense, as well as a variety of manufacturing process and product parameters part of a vast information network. This is an important element as with manufacturing we typically tend to think about products and goods but the bigger opportunity

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for manufacturers lies in a service economy model, cyber-physical systems, and the information opportunity.

19 Manufacturing operations

Manufacturing operations include the several elements which are typical for Manufacturing Operations Management (MOM), such as intelligent manufacturing, asset management, performance monitoring and optimization, human machine interaction, planning, end-to-end operational visibility and these cyber-physical systems as we know them from Industry 4.0. In fact, IoT and cyber-physical systems are twins in Industry 4.0.

IoT spending in this last use case (or set of use cases) is good for over 57% of all IoT manufacturing investments.

20 Production asset management and maintenance

Production asset management and maintenance is the second largest IoT use case in manufacturing and in reality also consists of a range of potential applications. It includes production asset tracking and monitoring, from location to the monitoring of parameters in several areas such as performance, quality, potential damage and breakdowns or bottlenecks, etc. On top of optimization and performance, there is of course also the dimension of proactive maintenance (as a result or/and in a predictive way).

It is clear that asset maintenance and management in a manufacturing industry setting also go beyond pure production assets.

21 Field service

US manufacturers deploy IoT tech in warehouse, the manufacturing plant, extended supply chain and customer (site). Here we leave manufacturing facility or the factory and go directly

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to an important area where manufacturers are service providers. From product-related services to business-related services: the service organizations of manufacturers are important drivers of margin and of growth. Information in the hyper-aware digitized and hyper-connected and IoT-enabled manufacturing ecosystem, along with the tools to plan, pro-actively service and schedule, are important differentiators.

22 Other manufacturing IoT use cases

Although, the 3 mentioned areas account for the large majority of spending, there are several other manufacturing IoT use cases on levels of processes, assets and people. Worker protection (and productivity), security, safety, and the many links between manufacturing in the strictest sense with connected industries/services/operations such as supplier management, transport and so forth all contribute to the vast IoT-related manufacturing solutions.

Connected factory applications, asset and vehicle, staff safety applications, real time health monitoring, air quality management and smart ventilation, smart environmental measurement, access control (security), smart measurement of levels /presence of liquids, gases, dangerous materials (depending on the type of operation), radiation and asset protection, facility management, risk measurement.

Finally there are the several related processes outside and inside the manufacturing facility. Production assets are one thing, activities such as packaging, preparing for shipment and quality control of manufactured goods another.

As you can see it distinguishes between the manufacturing plant, global facility insight, the customer site and global operations with the latter being divided into the benefits and goals for management, field service and R&D.

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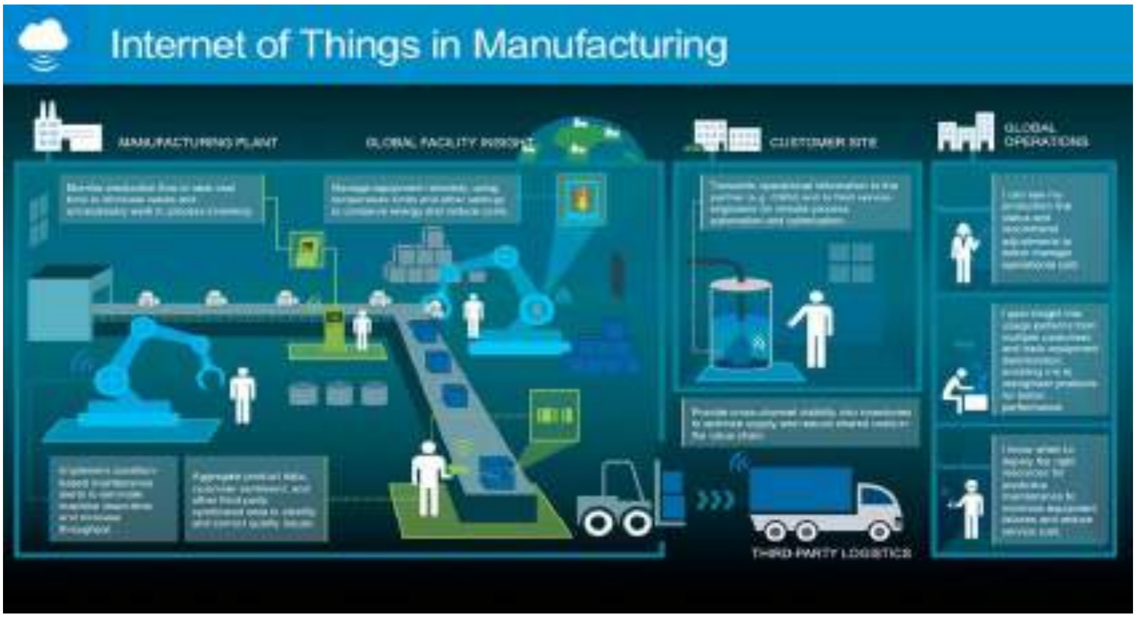

Figure 6. Internet of Things in Manufacturing

It also shows some additional or more detailed use cases and the benefits they offer, including**:**

- **The usage of various data** (customer sentiment, product and more) as a driver of quality monitoring and enhancement in function of outcomes and this aggregated data.
- **Condition-based maintenance alerts**: minimize interruption, increase throughput and optimize machine availability.
- **Remote equipment management**, including setting specific parameters and limits to save cost and energy.
- **Production flow monitoring**: eliminate waste, optimize flow and avoid unnecessary work in process inventory.

Outside of the plant and actual manufacturing environment we see the transmission of operational information for those field service engineers on customer sites, the overall value and supply chain perspective, third-party logistics and the global operations dimension.

Benefits of IoT in manufacturing

Here are some additional data points on that IoT benefit dimension:

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A. The Things – Sensors and Devices

In contrast to tablets and computers which are the main devices currently connected to the Internet. IoT devices will mainly be:

- Examples are Simple sensors – temperature, pressure etc.
- Wireless
- Low cost
- Low Power- Power usage and computational Power.

To turn an everyday object like a car or a house into a smart car or a house a **"**thing**"** will require that the object has:

- A way to connect to a network – Wireless.
- A unique address – IPv6 address

B. IOT Networks And Protocols

The Internet of things will utilize the existing technologies, networking infrastructure and protocols currently used in offices/homes and on the Internet and will introduce many more. Protocols are designed to operate at a particular level in the networking stack. IP/TCP uses a 4-level model and we will discuss IOT networking using this model. However, because of the requirement for low powered end devices there will be major developments in the Wireless connectivity protocols. Bluetooth and Wi-Fi are being actively developed for low powered applications and there are new connection technologies like ZigBee, LPWAN, 6LoWpan and Thread.

At the networking level IPv6 is set to become the standard, but in the intermediate time frame IPv4 will also be used.

At the application level there are lot of new protocols. Some have been available for a long time like MQTT and http, whereas others have been developed especially for the IOT e.g., COAP.

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C. IOT Platforms, Apps and Services

An IOT platform combines several IOT functions in one. It can distribute and collect data, convert data between protocols, analyze and store data. They are available as standalone and cloud-based platforms and are available from many companies both small and large.

Examples:

- IOT and The Cloud
- ThingWrox
- Microsoft Azure
- IBM Watson Bluemix
- Amazon Web services (AWS)

The cloud will have an important role to play in the IOT as it will enable companies to store data, create networks, automate processes without having to build the infrastructure themselves. This will enable IOT services to be developed much quicker, and at lower cost than using traditional in services and house systems.

23 Security and standardization

As adoption of IoT continues to grow, malicious users and attackers and are shifting their target from servers to end devices. There are several reasons for this. First, sensors and smart devices are far less protected than servers and having physical access to a device gives the attackers an advantage to penetrate with less hassle. Second, the number of devices that can be compromised are far more than the number of servers. Since devices are closer to the users, security leads to leaking of valuable information and has catastrophic consequences. However, due to the distributed nature and heterogeneity of IoT, the patching process is more consuming, thus opening the door for attackers.

The physical object-based security architecture for IoT

The physical object-based security architecture for the IoT is constructed according to the objects' status and the IoT's architecture. Physical objects in different stages have different

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characteristics, security and privacy problems. For clarity, physical objects are analyzed from the three stages respectively.

Security and privacy issues of physical objects in pre-working

In the initialization state, physical objects are usually pre-loaded with some security parameters or/and work in a security and trusted environment, so privacy-preserving requirements and the security can be guaranteed. In the connection state, a physical object tries to access an existing IoT or connect with other physical objects. Since both sides do not know each other in advance, there are many privacy and security problems, such as illegal accessing, data leakage and connecting to a malicious IoT, etc.

Security and privacy issues of physical objects in in-working

In working stage, physical objects at different layers have different tasks and face different security and privacy problems. The same physical object may undertake different tasks in different spatiotemporal environment. Accordingly, their privacy and security requirements usually change with the tasks and environments. So, it is wise and necessary to study the physical objects privacy and security problems according to their tasks instead of themselves.

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PART 2 - ROBOTIC SYSTEMS VIRTUALIZATION, A STEP FORWARD TO CYBER-PHYSICAL-SYSTEMS

Contents

1 Objectives of the lecture 114

2 Will Industry 4.0 change Education 4.0? 114

3. Intelligent Manufacturing and Cyber-Physical-Systems.. 119

3.1 Intelligent Manufacturing Systems……………………………………………….................. .... .119

3.2 Cyber-Physical-Systems 125

4 Virtualization of Manufacturing Systems 130

4.1 Characteristics of Manufacturing Systems Virtualization……………………..……130

4.2 Examples of Robotic Systems Virtualization ……………………………..……………133

5 Conclusion……….135

6 References 137

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1. OBJECTIVES OF THE LECTURE

The targeted theoretical skills in this lecture are on:

- Systematization of knowledge notions on Industry 4.0 and its major changes introduced in manufacturing systems,
- Better comprehension of Intelligent Manufacturing Systems (IMS) major characteristics,
- Improving the knowledge of meaning, architecture and scope of Cyber-Physical-Systems,
- Knowing the functions, structure and purpose of IMS virtualization,
- Understanding the new trends in education, changing the students' perception about teacher-student relationship,
- Trying to alter students learning methods and means.

Specific objectives:

- To know the main equipment with which they interact,
- Knowledge the steps required to make virtualization models,
- To create a SCARA robot model and application,
- To know how SCARA robot works,
- To program and visualize a robot online.

2. WILL INDUSTRY 4.0 CHANGE EDUCATION 4.0?

Education 4.0 might mean either a revolution or simple adjustments in education (proposed by Intelitek [Int01]). There must be a reaction in Education System to the changes expected to appear in our lives due to Industry 4.0. The same way the other 3 industrial revolutions (fig. 1) modified the way work-force was prepared for their life, it is expected that Industry 4.0 will modify the education paradigms and future education process.

Education 4.0 defines today's required education for an active member of society and a valuable employee in the industrial workspace. [Int01]

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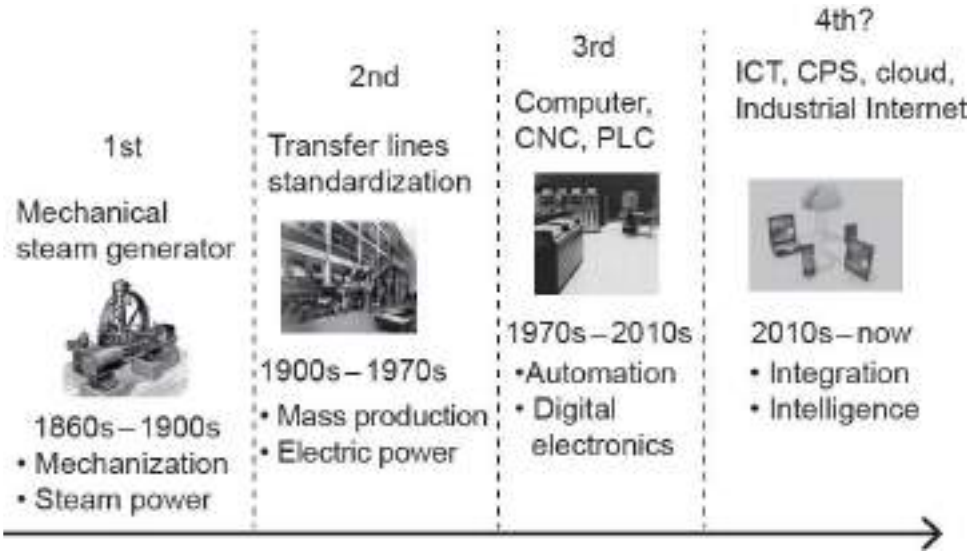

Figure 1. The four Industrial Revolutions [Yub17]

Analyzing the way the fourth industrial revolution will change our life aspects, there are predictions that Industry 4.0 will make possible to alter war's face, by the introduction of cyber war. Countries, enemies or terrorists can now attack and cause a lot of damage from a distant computer, through Internet. These cyber wars can affect any aspect of our life: such as train control, flights, power plants and more. And yet cyber war was science fiction just fifty years ago.

Education followed the changes introduced by industrial revolutions in humanity life, but much slower and with more or less reserve from the teacher's part. A parallel between the manufacturing characteristics in production lines and in education system from the corresponding epoch is presented in fig. 2.

Internet technology allows students to participate in long distance learning and to have access to unlimited sources of information. Nowadays, most of our students still don't know how to handle the huge information volume, to find online similarities/advices for their projects, to distinguish the reliable sources and good quality knowledge. Until the teaching and learning approach are not aligned to the new IT technology, the education paradigms will not be upgraded to the 21st century reality world.

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Figure 2.Parallel between manufacturing requirements and education in 20 century

The Education Paradigms taken in discussion to be changed are:

a) A Requirement for "Basic Knowledge"

Present situation	Must change to..
Students should have basic knowledge from the previous education stage and use it to build new knowledge in the next stage	The basic knowledge definition isn't changed, but its domain has changed

b) Computers Interfere with Thinking

Present situation	Must change to..
Computers interfere with the ability to encourage thinking	Computers are tools for calculus, information search and models visualization Time saved from digital calculus can be better used for practical applications
	Using the computers, one can apply active learning, sharpen one's thinking and acquire skills better suited today

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c) The Empty Container Paradigm

Present situation	Must change to..
Students brain is an empty container and the teacher pours knowledge	Students knowledge process is differently and individually way constructed, and each one have different prior knowledge
	Students construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences
	Students create actively their personal knowledge They need to ask questions, explore, and self-evaluate the existing knowledge
	In the right education environment, students will learn "how to learn"
Students are passive recipients of information, have few logical relations in their knowledge system	Students are active participants in the learning process
Students construct their knowledge mechanically, memorising knowledge on short terms	Students construct actively their knowledge

d) Learning Occurs Individually

Present situation	Must change to..
Students are required to sit quietly in class, have no interaction with their	Students require collaboration with peers, guests, teacher... Education environments must foster discussion and teamwork.

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colleagues and listen to the single source of knowledge – the teacher	

As Industry 4.0 has a target to become customer oriented and the production must respond rapidly to buyer requirements, the Education 4.0 can be modeled to be individual student oriented, to shape undergraduate's knowledge to the real world requirements. In fig. 3 there is represented a parallel between flexible manufacturing line characteristics and education nowadays demands.

The proposed, by Intelitek, Education 4.0 paradigms are:

a. "The learning path is tailor made" means:

- Personal learning path that suits each student's strengths and interests
- Build knowledge based on individual previous knowledge
- Experience and acceptance of the new information by students
- Not to force all students to learn the same thing at the same time and at the same pace
- Formative assessment is focused on helping the student accept and learn the new information
- Formative assessment does not classify students based on exams results.

b. Teachers become mentors, this imply:

- To offer their students an individual curriculum and a personal journey
- That teachers are expected not to lead, but to support learning
- The need to assist students during their education personal journey
- Teacher role is to become student's mentor.

c. Divergence and pluralism means:

- Students identify the field in which they are suited and teacher help them to excel at it
- Finding the area of aptitude gives the student a better chance to serve his society as adult

- Students possess multiple Intelligences and can use any of these to actively acquire knowledge.

d. Knowledge Acquisition Does Not Define Education

- Education as opposed to knowledge transfer
- Essential facts in education are the universal values of doing good, accepting others, collaborating with them and executing your jobs/tasks the best you can.

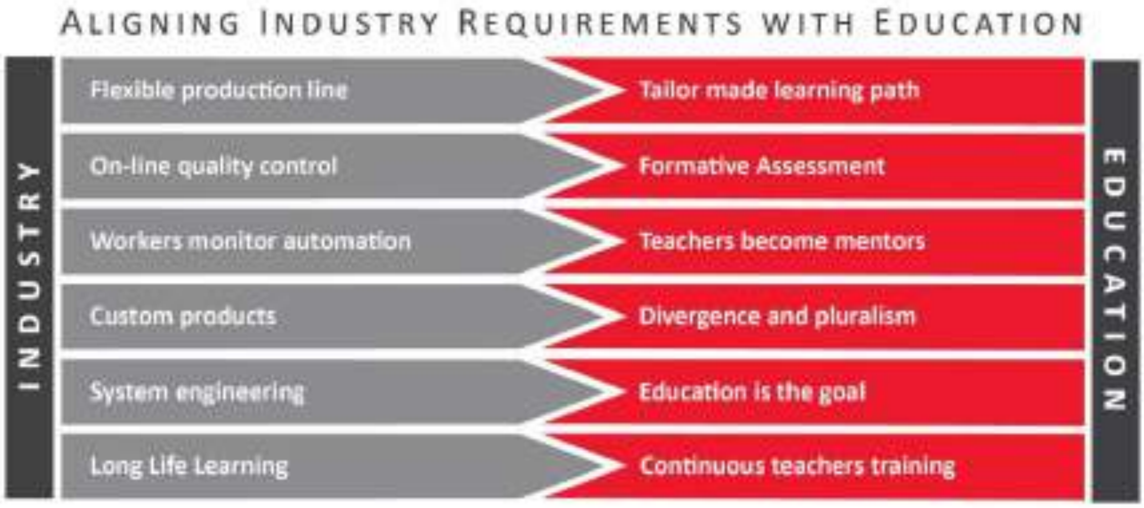

Figure 3. Education of 21st century aligned to industry requirements

The answer for the paragraph title question is: Education System (teachers and students) must adapt itself to society changes; otherwise there will be a growing gap between society requirements and education output, this fact will slow down our society progress.

3. INTELLIGENT MANUFACTURING AND CYBER-PHYSICAL-SYSTEMS

3.1 Intelligent Manufacturing Systems

New generation intelligent manufacturing, which serves as the core technology of Industry 4.0 Revolution, incorporates major and profound changes in the development philosophy, manufacturing modes and other aspects of the manufacturing industry.

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For decades, the degree of manufacturing intelligence grew due to capabilities that involved many different paradigms, such as: lean production[1], flexible manufacturing, concurrent engineering[2], agile manufacturing[3], digital manufacturing, computer-integrated manufacturing (CIM)[4], networked manufacturing, cloud manufacturing[5], intelligent manufacturing and more.

Taking into account various intelligent manufacturing-related paradigms, considering the information technology integration characteristics, analyzing the manufacturing industry through different stages, it is possible to generalize three basic paradigms of intelligent manufacturing: digital manufacturing, digital-networked manufacturing and new-generation intelligent manufacturing [Zho18].

The key features of **digital manufacturing** are as follows:

① Digital technology is widely used in products, forming a ‘‘digital generation” of innovative products (fig. 4);

Figure 4. The next generation of CNC five-axis machine tool [4]

[1] **Lean manufacturing** is a methodology that focuses on minimizing waste within **manufacturing** systems while simultaneously maximizing productivity.

[2] **Concurrent engineering**, also known as simultaneous **engineering**, is a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively.

[3] **Agile manufacturing** is a term applied to an organization that has created the processes, tools, and training to enable it to respond quickly to customer needs and market changes while still controlling costs and quality. It's mostly related to lean **manufacturing**.

[4] **CIM** is the technique of using **computers** to control an entire **production** process. It's commonly **used** by factories to automate functions such as analysis, cost accounting, design, distribution, inventory control, planning and purchasing.

[5] **Cloud manufacturing** is a new manufacturing paradigm developed from existing advanced manufacturing models and enterprise information technologies under the support of cloud computing, Internet of Things (IoT), virtualization and service-oriented technologies, and advanced computing technologies

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② Digital design, modeling and simulations, and digital equipment information management are widely applied (fig. 5 represents an example of new digital file for AutoCAD);

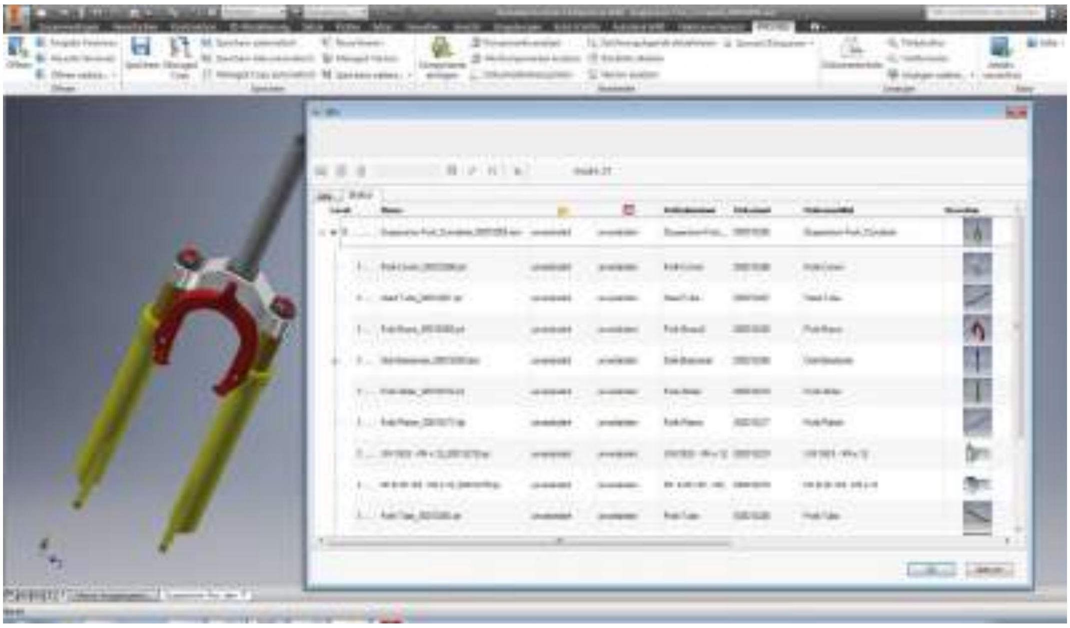

Figure 5. The PRO.FILE product data and document management system [5]

③ Production process integration and optimization are achieved.

Digital manufacturing is present now in all aspects of industrial domain [6]:

- **Product Life Cycle.** Digital manufacturing affects every activity from design and engineering through manufacturing and product servicing. Data is kept throughout each step and the impact of these changes is reflected on product life cycle.
- **Smart Factory.** Digital manufacturing helps connecting operators with smart machines, sensors and tools while gathering data from technology and sharing it with IT systems. This allows a better analysis of overall production data, improving on the performance of smart machines.

- **Value Chain Management[6].** Digital manufacturing improves value chain management by minimizing resources and inventories while producing better quality products and increasing customer satisfaction.

Digital-networked manufacturing is the second basic paradigm of intelligent manufacturing; it may also be referred to as ‘‘Internet + manufacturing” or as second-generation intelligent manufacturing systems. The main characteristics of digital-networked manufacturing are as follows (fig. 6. is an example of furniture plant on its way to Industry 4.0):

- o At the *product level*, digital technology and network technology are widely applied. Products are connected through the network, while collaborative, shared design and R&D are achieved.
- o At the *manufacturing level*, horizontal integration[7], vertical integration[8], and end-to-end integration[9] are completed, thereby connecting the data and information flows as an entire.
- o At the *service level*, enterprises and users connect and interact through the network platforms, while enterprises begin to transform from product-centered production to user-centered production.

Both Germany’s Industry 4.0 report and General Electric’s Industrial Internet report present very informative and well-structured descriptions of the digital-networked manufacturing.

[6] **Value Chain Management** is the process of organizing the connected group of activities that create **value** by producing goods or services from basic raw materials for purchase by a consumer.

[7] **Horizontal integration** occurs when a company is closely integrated with its suppliers and partners.

[8] **Vertical integration** addresses the issue of seamless connectivity among all the elements that are included in the product life cycle within an organization.

[9] **End-to-end integration**: Firstly, on the factory floor, machine to-machine integration is provided so that machines are truly an integral part of the manufacturing system. Secondly, it is now feasible to integrate customers into the manufacturing system, thus allowing engineers to obtain feedback from customers easily and in a timely manner. Thirdly, product-to-service integration is feasible, allowing the condition of the product in use to be directly monitored by the manufacturer [Yub17].

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Figure 6. Intelligent furniture plant with integrated information flow [7]

Intelligent manufacturing is now reshaping the development paths, technical systems and industrial forms and is thereby pushing the global manufacturing industry into a new stage of development.

Digital-networked-intelligent manufacturing is the third basic paradigm of intelligent manufacturing; it may also be referred to as new-generation intelligent manufacturing.

Jointly driven by a strong demand for economic and social development, the penetration of the Internet, the emergence of **cloud computing and big data, the development of Internet of Things (IoT)**, and rapid changes in the information environment, there has been an accelerating development of strategic breakthroughs in new-generation **AI technologies.**

New-generation intelligent manufacturing will modify all design and manufacturing processes, production management and services. Soon the emergence of new technologies, new products, new business forms and new models will become a reality. The I2M (intelligence and integration manufacturing) systems implementation demand new technics, structures, models, products in industry, but also will influence lifestyles and thinking models of humankind. It will ultimately result in a great improvement of social productive forces. At present, all world manufacturing enterprises need urgently to improve quality, rise efficiency, lower cost and speed market responses.

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New-generation Artificial Intelligence (AI)[10] has become the core technology of a new science and technology revolution. Most of the major countries in the world have made developing new-generation AI into a top priority. New-generation AI possesses new features such as **deep learning**, **crossover collaboration**, **human-machine hybrid-augmented intelligence** and **crowd intelligence**.

The new generation AI, with increasing *cognitive and learning capabilities*, provides:

- different ways of human thinking,
- assists humans to understand complex systems,
- can generate general knowledge and its better use,
- decreases abruptly the needed of physical power and offer analyzed, complex information in intuitive ways,
- greatly speeds up the pace of innovation,
- makes new applications more present in industrial world,
- better, deep understanding of new technology,
- more efficient industrial knowledge generation and its utilization,
- increases the capability to reconstruct both nature and society.

The mutually heuristic growth of human intelligence and machine intelligence will shift knowledge-based work in the manufacturing industry toward the direction of *autonomous intelligence* and then solve the bottlenecks and difficulties that hinder the current development of the manufacturing industry. At the same time, production processes feature high quality, flexibility, high efficiency, and environmental friendliness.

New-generation intelligent manufacturing will bring revolutionary changes to human society. On the one hand, the boundary between humans and machines will shift dramatically, with intelligent machines taking over a huge amount of manual labor and a considerable amount of brainwork from humans. This shift will *leave humans to be more engaged in creative work*. On the other hand, our working and living environments and modes will become more *people-centered*. Meanwhile, new-generation intelligent manufacturing will

[10] AI techniques are important tools in managing IMS information, but are beyond the scope of this lecture.

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effectively reduce the consumption and waste of resources and energy while continuously promoting the green and harmonious development of the manufacturing industry.

3.2 Cyber-Physical-Systems (CPS)

Definitions of terms: **Cyber** (according to Merriam Webster Dictionary) means: of, relating to, or involving computers or computer networks (such as the Internet).

Cyber Technology is computer **technology** that involves the internet or cyberspace. Because the internet plays such a huge role in our lives today, it's easier to point to **what is cyber technology**. Even the car you drive today is part of **cyber technology** because it has access to the internet.

A **cyber-physical system** [8] is a system in which a mechanism is controlled or monitored by computer-based algorithms. In cyber-physical systems, physical and software components are deeply intertwined, able to operate on different spatial and temporal scales, exhibit multiple and distinct behavioral modalities, and interact with each other in ways that change with context.

Examples of CPS: autonomous automobile systems, medical monitoring, industrial control sy s-tems, robotic systems, and automatic pilot avionics.

CPS involves transdisciplinary approaches, merging theory of cybernetics, mechatronics, design and process science. The process control is often referred to as embedded systems. In embedded systems, the emphasis tends to be more on the computational elements, and less on an intense link between the computational and physical elements. CPS is also similar to the Internet of Things (IoT), sharing the same basic architecture; nevertheless, CPS presents a higher combination and coordination between physical and computational elements.

The most fundamental and essential technology is the concept of the **digital twin**, as perfect mapping and in-depth integration of cyber systems with physical systems.

A cyber system might replace humans in order to complete some of the brainwork. These, along with machines and other components integrate human cyber physical systems (HCPS).

A considerable portion of humans' sensing, analysis, and decision-making functions are reproduced and migrated to the cyber system.

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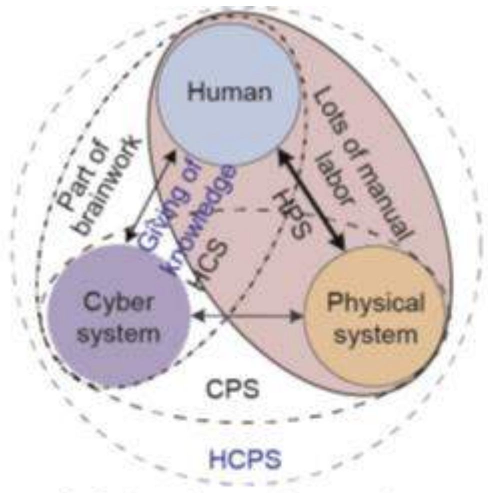
The physical systems are controlled through the cyber system in order to replace humans and complete more manual labor.



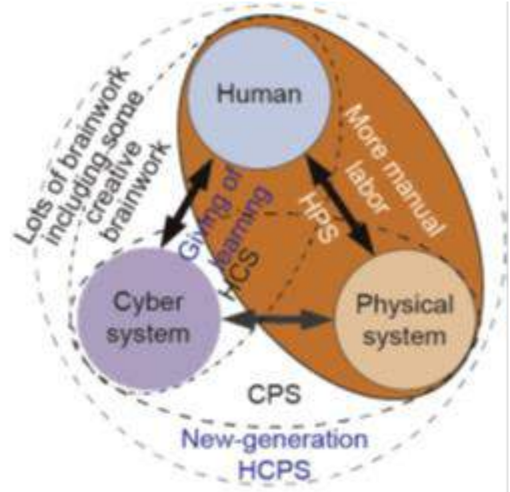
In first- and second-generation intelligent manufacturing systems

First- and second-generation intelligent manufacturing systems acquire great capability enhancement, especially in computing analysis, precision control, and sensing capabilities.

It improves: the work efficiency, product quality, stability of the physical systems. The efficiency of human knowledge management, transfer, and application is growing [Zho18].

The new-generation HCPS will change:

(1) Humans will transfer some of their cognitive and learning brainwork to the cyber system, enabling the cyber system to ‘‘cognize and learn” and obtain its own knowledge.



In new-generation intelligent manufacturing systems

(2) Through the hybrid-augmented intelligence of ‘‘humans in the loop,” in-depth human-machine integration will fundamentally improve the capability of manufacturing systems to handle complex and uncertain problems, and will greatly optimize the performance of manufacturing systems.

New-generation intelligent manufacturing further highlights the central position of humans. It will bring quality and efficiency in the manufacturing industry to a higher level, and strengthen the foundation of human civilization. It will free humankind from intensive and tiring manual labor and low-level thinking, thus enabling humans to engage in more creative work. With new-generation intelligent manufacturing, human society will authentically enter the ‘‘age of intelligence”.

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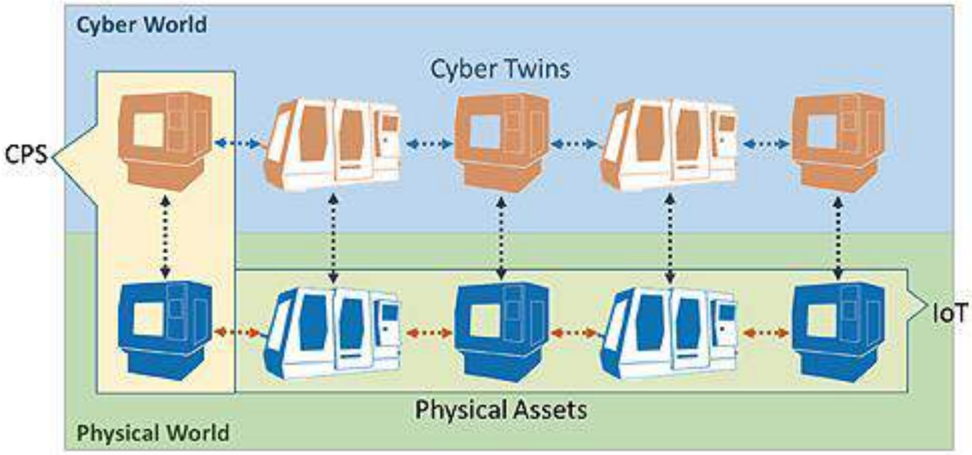

Figure 7. CPS model for CNC Machines [9]

The architecture of CPS

Since CPS is in the initial stage of development, it is essential to clearly define the structure and methodology of CPS as guidelines for its implementation in industry. It was taken into account perception, analysis, decision and control as main features of CPS in manufacturing. In general, a CPS consists of two main functional components:

- **The advanced connectivity** that ensures real-time data acquisition from the physical world and information feedback from the cyber space;
- **Intelligent data management**, analytics and computational capability that constructs the cyber space.

The proposed architecture of CPS in [Lee15], fig. 8, has five levels:

1. **SMART CONNECTION LEVEL:** First step of implementing CPS is acquiring accurate and reliable data from machines and their components. The data might be directly measured by sensors or obtained from controller or enterprise manufacturing systems. For instance, at the level of components of the today's factories, sensors have implemented the technology of smart sensors and fault detection; in 4.0 Industry perspectives these will have attributes of self-aware and self-predict with the technology of degradation monitoring and remaining useful life prediction.

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2. **DATA-TO-INFORMATON CONVERTION LEVEL:** At the second level of CPS architecture brings self-awareness to machines, based on data acquired, analyzed and transformed in information for men/machines.
3. **CYBER LEVEL**: The third level, Cyber acts as central information hub in this architecture. Information is being pushed to it from every connected machine to form the machines network. Having massive information gathered, specific analytics have to be used to extract additional information that provides better insight over the status of individual machines among the fleet. These analytics provide machines with self-comparison ability, where the performance of a single machine can be compared with and rated among the fleet. On the other hand, similarities between machine performance and previous assets (historical information) can be measured to predict the future behavior of the machinery.
4. **COGNITION LEVEL:** Implementing CPS upon Cognition Level generates a thorough knowledge of the monitored system. Proper presentation of the acquired knowledge to human expert users supports the correct decision to be taken. Since comparative information, also individual machine status are available, decision on priority of tasks can be made, to optimize the maintaining process. For this level, proper info-graphics are necessary to completely transfer acquired knowledge to the users.
5. **CONFIGURATION LEVEL** is the feedback from cyber space to physical space and acts as supervisory control to make machines self-configure, self-adaptive and supply chain will be automatically coordinated. This stage acts as resilience control system to apply the corrective and preventive decisions, which has been made in cognition level, to the monitored system.

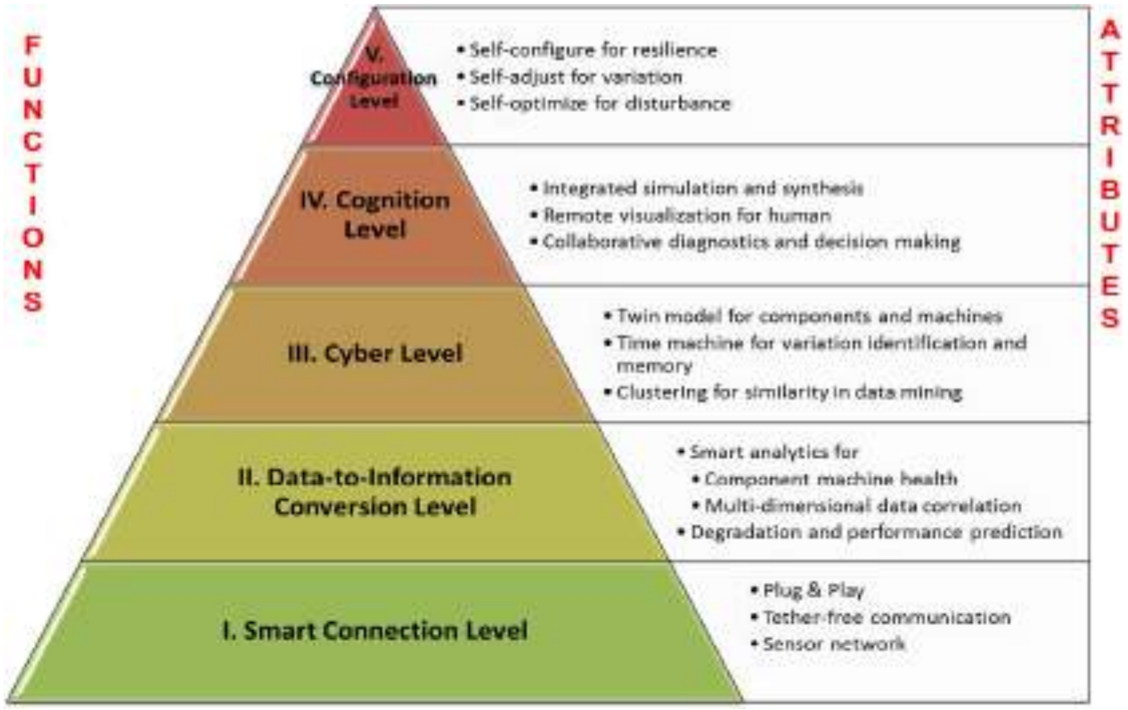

Figure 8. Cyber-Physical-System Architecture [Lee15]

Example of CPS for CNC Machines

Fig. 9 represents the intelligent data management function of CNC machines. The tables and graphics are the result of data collection from machines, analyzing and calculus of data and they are a useful tool for human decisions at the fourth level's CPS architecture.

4. VIRTUALIZATION OF MANUFACTURING SYSTEMS

4.1 Characteristics of Manufacturing Systems Virtualization

The virtualization might simply mean that a set of technical data is gathered and made available to the virtual world. For complex manufacturing systems, the results of complex simulators, allowing an interconnected twin between physically, on one hand and computationally and graphically on the other hand, are available in higher level of industrial system.

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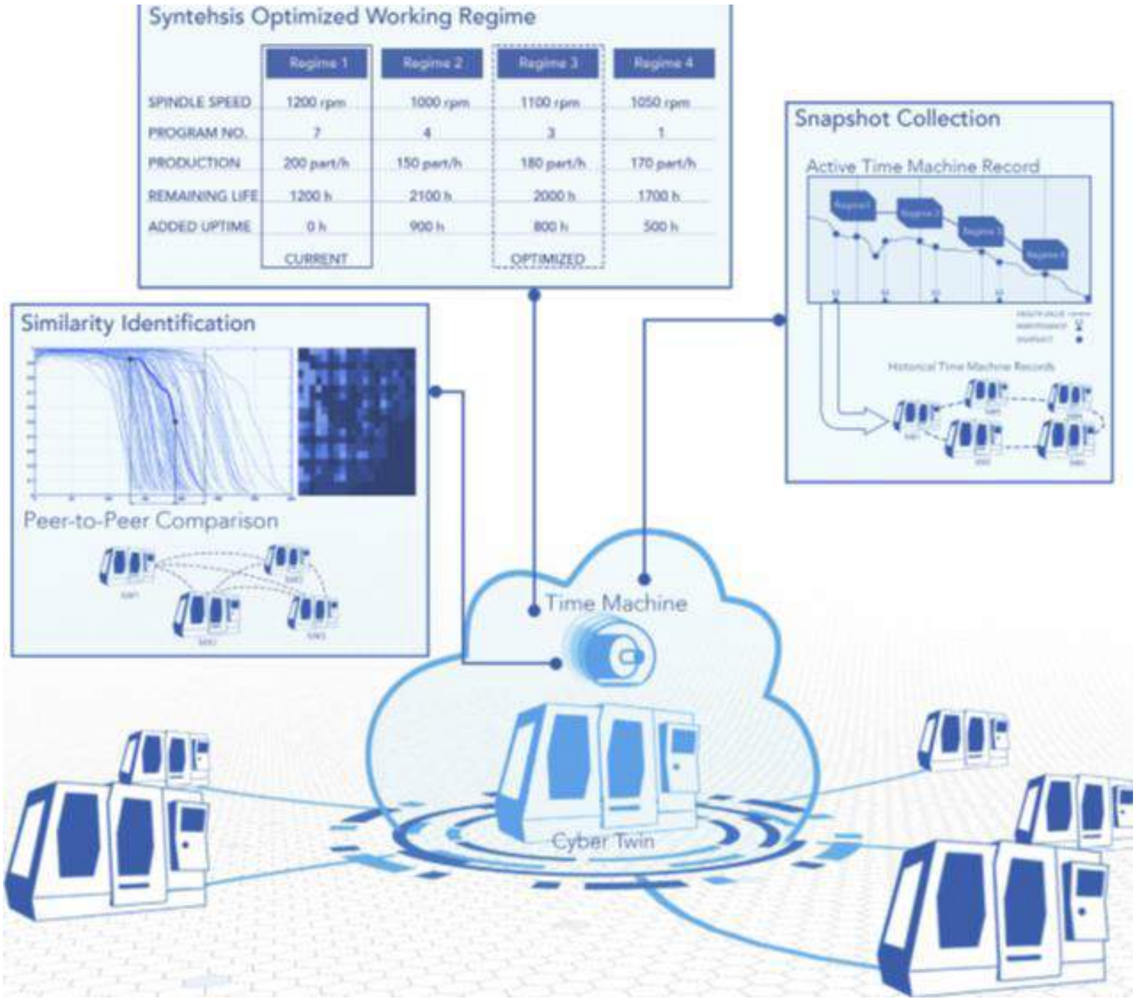

Figure 9. Global scheme illustrating the CPS for machine fleet [Lee15]

The main difference between virtualization and CPS is that mainly, the virtualization does not allow the manufacturing system control, permits only online visual supervision of the physical system. In current Covid-16 pandemic situation, this might be an effective tool in education activities.

Virtualization allows:

- reducing times for system design, for equipment update or for its replacement within the manufacturing system,
- testing realistic what-if scenarios of I2M configurations,
- planning and scheduling production system,
- monitoring equipment activities and their operating state.

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There are two main problems in manufacturing system virtualization: *communication* and *graphical simulation*.

Whatever complexity manufacturing applications, data structure and communication layer standardization is paramount. OPC (Open Platform Communication) UA (Unified Architecture) is emerging as a viable solution, almost *a de facto* standard, due to its structured, secure and open platform approach. These characteristics are also important in existing industries, where legacy equipment dominates. Often, the introduction of relatively simple sensors and/or automation, together with the structured approach on data collection and communication brought by protocols such as OPC UA, allows the connection to the digital world of older (but still highly productive) industrial devices. In what concerns the use of OPC UA, it was created an information model and a prototype OPC UA Server using it for data acquisition, event generation and remote control of a machine tending industrial robot. [Mar19].

On the matter of graphical simulation, in next table there is presented a comparative analysis between the most known simulation and online robot programming software.

Software Platform	Firm	Characteristics
Gazebo	Gazebo opensource	o mostly for mobile robotics
Process Simulate -Tecnomatix	Siemens	✓ does not have a true physics engine ✓ plug-and-play to Siemens brand PLCs ✓ the simulations less realistic
V-REP	Coppelia Robotics	▪ includes more industrial robotic arms related scenarios ▪ it does not support using vendors specific programming languages ▪ the robotic arm programs are more limited

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Software Platform	Firm	Characteristics
Visual Components	KUKA	o provides for a generic simulation environment, with an easy learning curve o does not include physics simulation capabilities o no true physics engine o the simulations less realistic, includes converters for vendors specific languages, but only for a small set of instruction
Robot Studio	ABB	➢ specific for ABB robots ➢ provides a simulation environment ➢ it is capable of simulating many components by importing their 3D models ➢ adding a dynamic and responsive behaviour ➢ it allows for the complete set of RAPID (ABB robots programming language) instructions to be programmed and tested.

4.2 Examples of Robotic Systems Virtualization

I. [Bla18] paper presents a case study for distributing castings application, using a Stäubli Robot.

The process begins when a customer, who is finalizing online order and selects the desired piece. The customer has already sent the characteristics of the parts desired. The task is fully automated with a real-time response of picking the selected parts. In addition, all available information related to the piece itself is also transmitted as well as the process activities like piece characteristics verification, for instance weight, the times of use, unscheduled stops and maintenance, etc.

The production process involves three agents for improving product supply chain performance:

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—Firstly, there are the two aspects of the robot manipulator: the actual robot and the simulated robot (CPS). The real and/or virtual robot manipulator is transparently and remotely controlled in real time and is integrated into the manufacturing process tasks.

- The second agent is the interconnection network that links each part of the smart factory, bi-directionally and univocally. Examples of smart factory functions are: Customer Relationship Management (CRM), Enterprise Resource Planning (ERP), Manufacturing Resource Planning (MRP), databases.

- The third agent is decentralized decision-making. Intelligent Manufacturing Core (IMC), applying algorithms for artificial intelligence and machine learning, can make autonomous decisions based on the information it has from all the agents associated with the business process, including the robot.

II. In [JIA16] it was designed a Personalized Customization Manufacturing System (PCMS) with the ability of mobile services.

This PCMS adopts a cloud platform as an information processing mean to form a flexible production mechanism. Today's smart mobile phones are adopted as a mobile terminal through which consumers can connect to the cloud platform. It was implemented a PCMS in this example by a customizable candy production system. A part if PCMS is presented in fig.10.

The PCMS can provide consumers with a mobile terminal APP, which in turn enables order customization and information inquiries. In the manufacturing system, the cloud platform is used for data processing, and the communication technology is used for purposes of information exchange and production coordination. The PCMS system can adopt big data technology as means to process massive data for information extraction and application modeling. Big data technology can be used for massive data analysis of IoT, and the results obtained during information extraction can be applied in industrial production and management. A cloud platform service mode can read an industrial production model for reference, thus enabling the production model to be flexibly customized. The information flow can be uploaded to the cloud via network technology. By combining the cloud service model and the adjustment measures of enterprise managers, the processed information will be automatically delivered to the factory, so as to achieve the goal of intelligent production.

Figure 10. PCMS Processing scenes

5. Conclusion

Taking into account the notions presented above, especially the proposed architecture of CPS, virtualization is really an up step towards the realization of a cyber-system for I2M and virtualization stage corresponds to level 1 and 2 of the cyber structure development.

The advantages of implementing the virtualization of educational equipment are obvious, these allowing students to access it remotely, experiment with its operation and programming, towards a better understanding of the problems of automated systems.

The key issues are:

- the simulation or virtual reality software is appropriate for the robot or machine, whose operation is digitized,
- the communication of the equipment with the server is real-time,
- data structure is as complete and well-structured to the intended purpose.

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